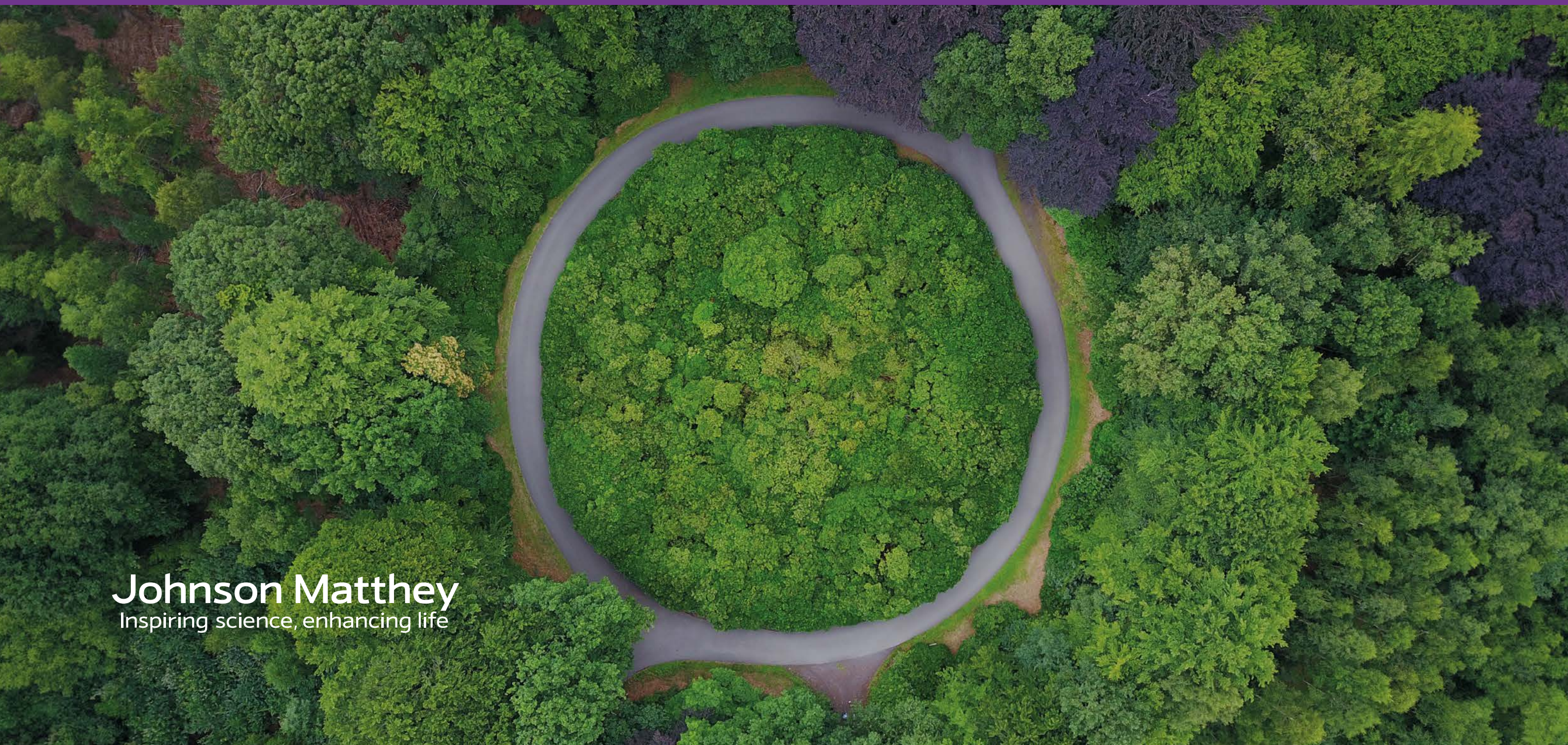
# Reclaiming the future: PGM insights for a circular economy



Johnson Matthey
Inspiring science, enhancing life

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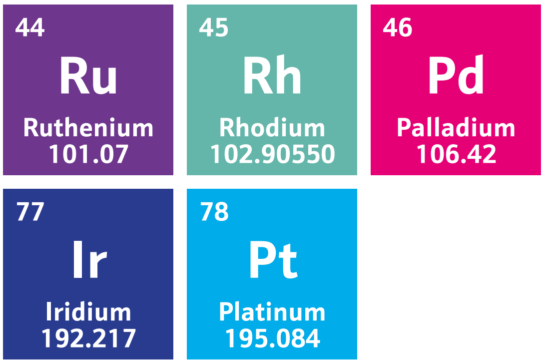
## The platinum group metals: unique metals with unique advantages



# Executive Summary

Automotive and industrial use of the platinum group metals (PGMs) has grown dramatically over the past 50 years. Recycling of the PGMs has not been incidental to this: indeed, meeting this rising demand would not have been possible without circularity. Today, the PGMs are among the most highly recycled materials in the world, with recycling rates in some applications exceeding 95%. The story behind this success is not well known but deserves attention.

As the world's largest refiner of secondary (recycled) PGMs, a central player in global PGM supply chains and trade, and a leading provider of PGM market intelligence, **Johnson Matthey has unparalleled insight into how PGM circularity works in practice**. We have produced this white paper to offer that knowledge to policymakers and other stakeholders working to create a circular economy in all metals and materials critical to our sustainable future.

In this paper, we for the first time reveal the full scale of PGM recycling by publishing an estimate of the size of the closed loop. Open loop recycling of PGM returns metal to the market and is a well-quantified figure. Closed loop recycling however remains more enigmatic to the wider world. By retaining metal ownership, it enables reuse within the application. Unlike open loop recycling, it is not reported and is often overlooked. Yet **the closed loop is far from minor: it is in fact several times larger than the open loop**.

> "Almost 60% of the PGM used on new products every year is now recycled metal, showing the importance of circularity in securing metal availability"

As a result, with the closed loop accounted for, we estimate that **almost 60% of PGM used on new products every year is now recycled metal**, from both the open and closed loops. This has importance for the sustainability of PGM use beyond boosting availability: the global warming potential of recycled PGM is about 97% lower than that of newly mined metal[1].

This shows that, even as consumption grows, a focus on circularity can ensure that 'urban mines' become a reality in serving the needs of the industrial economy. The true scale of PGM recycling also underscores that **circularity is not merely an adjunct to mining, but an equally important consideration in securing future metal availability**. This is particularly true as we look ahead to the growing need for industrial metals through the energy transition, which cannot be sustainably met through mining alone.

However, achieving success in circularity is at least as complex and challenging as it is in mining, and **regulatory approaches require careful consideration to avoid unintended consequences**. PGM circularity is based on a market-driven, global ecosystem that took decades to evolve to its present form. Our intention in this paper is to provide the necessary insight to ensure further regulation builds on, and does not hamper, that maturity.

We provide our recommendations to regulators, summarised in Figure 1 and discussed in more detail at the end of this paper, but we also caution against a 'one size fits all' approach to policymaking in this space. While there are learnings to be taken from PGM circularity, our overarching recommendation to policymakers is this: **the best regulatory measures are informed by industrial experience**. We urge regulators to work closely with the respective industries in question to achieve regulatory success in stimulating market-driven circularity for critical and industrial metals where it is currently nascent.

### Recommendation 1:
### Create a framework for industry-led approaches

- Regulation should be informed by industry consultation
- Avoid blanket or 'one size fits all' regulatory approaches

### Recommendation 2:
### Use regulatory instruments to mimic the advantages of closed loops

- Implement producer responsibility where practical
- Enable market-led (rather than regulatory) tracking of materials
- But avoid enforcing re-use within the same application

### Recommendation 3:
### Support innovation to embed systemic circularity

- Incentivise ‘design for recycle’
- Fund innovation in product and process design

### Recommendation 4:
### Form strategic international collaborations in circularity

- Collaborate with like-minded partners to enable economies of scope and scale
- Align domestic policy to facilitate cross-border movements

### Recommendation 5:
### Recognise metals circularity as a horizontal enabler of industrial strategy

- Identify metals processing as a cross-sector enabler
- Identity the needs and opportunities of the metals sector to unlock economic potential

### Recommendation 6:
### Widen focus beyond supply criticality

- Supplement critical materials strategy with strategic materials assessments
- Ensure the needs of all sectors are addressed, not just those at 'supply risk'
- Place urban mining on an equal footing with primary mining

**Figure 1** Johnson Matthey’s recommendations for measures to enhance the recycling of metals such as the PGMs

> “While there are learnings to be taken from PGM circularity, our overarching recommendation to policymakers is this: the best regulatory measures are informed by industrial experience”

# Introduction

## Critical metals and the case for circularity

Modern industrial civilisation has been built on a linear model of consumption: resources are extracted to produce goods that are used and then disposed of at the end of their lives as waste. This is fundamentally unsustainable: resources are not infinite, nor is the capacity of the biosphere to absorb waste. A shift from a linear to a circular model of consumption is not optional.

This is reason enough for recycling to be an important topic. But two other factors are driving the focus on circularity:

### 1. The energy transition

While this may shift society away from linear consumption of fossil fuels towards renewable energy resources, it will not free us from resource consumption. Many clean energy solutions, including wind turbines and solar panels, electric cabling, and battery technologies, rely on intensive use of a finite pool of critical metals that must be extracted from the earth. Demand for these metals will increase dramatically[2], to an extent that in some cases could be impossible to meet. Key examples are the rare earth elements (REEs) and lithium, with REE consumption projected to nearly double by 2040 and that of lithium growing by eight times[3].

Meeting demands for these critical metals will be much harder if they are not efficiently recovered from end-of-life products. But the recycling rates for a number of these critical metals are still under 50%, sometimes even below 1%[4].

### 2. Geopolitics and supply chain resilience

Geopolitical tensions and the surging demand for raw materials driven by the clean energy transition are driving nations to prioritise domestic supply chain resilience and self-sufficiency. Those that are not rich in critical metals, yet face growing domestic demand, are increasingly concerned about their exposure to foreign supply chains. For such nations, recycling of metals used domestically is particularly crucial to mitigate their exposure.

These considerations are driving rapid evolution in the global regulatory landscape: notable examples are the EU's Critical Raw Materials Act, which sets benchmarks for recycling rates[5], and the Strategic Framework on Circularity for Secure and Sustainable Products and Materials being developed by the US Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE).[6]

> "Critical metals underpin the energy transition. Failure to embed circularity principles at the heart of these supply chains risks undersupply of essential materials, ultimately impacting our climate goals"

**1.**
**Extraction**
EU extraction capacity of at least 10% of the EU's annual consumption of strategic raw materials.

**2.**
**Processing**
EU processing capacity of at least 40% of the EU's annual consumption of strategic raw materials.

**3.**
**Recycling**
EU recycling capacity of at least 25% of the EU's annual consumption of strategic raw materials.

**4.**
**External sources**
Not more than 65% of the EU's annual consumption of each strategic raw material relies on a single third country for any relevant stage of the value chain.

**Figure 2** The four benchmarks set by the EU Critical Raw Materials Act

## Platinum Group Metals: leading the way in circularity

**The PGMs' unique catalytic properties, high melting points, and resistance to corrosion make them crucial to a long list of industrial and everyday applications. These applications are supported by routine PGM recycling, whether of production scrap or end-of-life materials, or typically both.**

**Against this backdrop, the high recycling rates of PGMs provide a prominent example of getting it right. Like many other critical metals under scrutiny, PGMs are not geologically abundant. Yet, for decades these metals have supported large industrial applications with sufficient availability to meet growing consumption. This has only been possible because they are recycled at high rates.**

### PGM applications today and into the future

The extensive use of these metals often goes unnoticed, with many unaware of just how integral PGMs are to countless technologies and processes that power modern life. Such applications include:

### Reducing pollution from fossil fuel use

PGM catalysts are used to produce high-octane gasoline, helping to eliminate the use of leaded fuel and make vehicles more fuel-efficient. They are also fundamental to catalytic converters that remove the vast majority of pollutants like carbon monoxide and nitrogen oxides from vehicle exhaust before it is emitted.

### Enabling modern healthcare

PGMs are used in biomedical devices such as cardiac catheters and pacemakers, in mammography to scan for breast cancer, in core anti-cancer treatments, and to make many pharmaceuticals.

### Underpinning the digital economy

PGMs are ubiquitous within modern electronic circuitry and are also needed to make certain electronic components, such as the frequency filters used in mobile phones. PGMs enable cloud data storage, as data centres rely on hard disks and PGMs are needed for data storage within hard disks.

### Making aviation viable

Jet engines used in today's large aircraft operate at high temperatures. They could not work without PGMs providing thermal protection to key components. PGM catalysts are also used to produce advanced sustainable aviation fuels that will reduce fossil fuel carbon emissions in the future.

### Powering the hydrogen economy

Among other hydrogen-related applications, PGM catalysts sit at the heart of proton-exchange membrane (PEM) technology, used in both fuel cell vehicles and in electrolysers that produce hydrogen by splitting water.

### Unlocking clean energy

As well as their key roles in sustainable aviation fuels and clean hydrogen, PGM-protected equipment is necessary to make the fibreglass for wind turbine blades, and the copper foil that goes into lithium-ion batteries in electric vehicles.

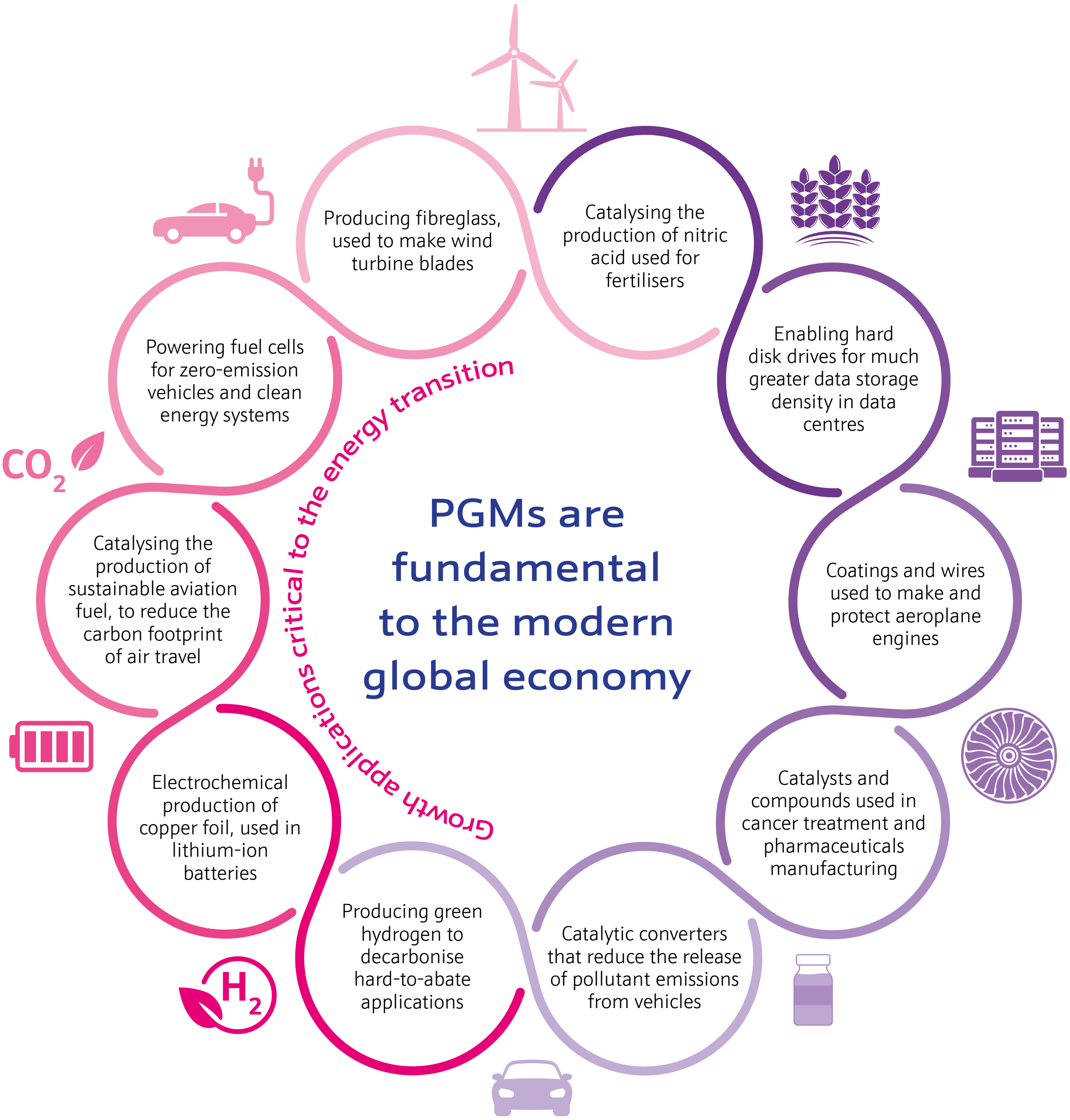


**Figure 3** PGMs are widely used throughout the modern industrial economy and in clean energy[7]

# How PGM recycling works today

**Routine PGM recycling has been enabled not just by the value of these metals, but also because recycled PGM is physically indistinguishable from 'virgin' metal – but with a carbon footprint that is two orders of magnitude lower[1]. Two distinct PGM recycling pathways exist, one of which returns metal to the market, and the other allowing for reuse of metal by the owner.**

## PGM recycling drivers

The high level of circularity in PGMs is driven by their financial and industrial value and shows that critical resources are much less likely to become 'waste' when they are appropriately valued. PGMs can be recycled many times over and remain in use indefinitely. Because recycling does not change the physical properties or how the PGM can be used, there is a level playing field for primary (mined) and secondary (recycled) PGMs in the market. Indeed, quite often some final refining of primary PGM takes place in a refinery that also processes recycled metal, and then a mass-balance approach must be used to distinguish primary and secondary metal output.

Recycled PGMs have about 97% lower global warming potential ('carbon footprint') than newly mined metal[1]. This enhances the overall sustainability of PGM use, and for this reason PGM purchasers may wish to buy metal that is specified as sourced from recycling (validated by certification)[8].

## PGM recycling pathways

Recycling supports PGM availability in two ways: through **open loop** and **closed loop recycling**. Both open and closed loop recycling pathways operate well for PGMs and are essential components of the market. Whether a closed or open loop is implemented depends on various factors: the nature of the application or market the PGM is being used in, financial considerations, regulatory requirements, and logistical challenges.

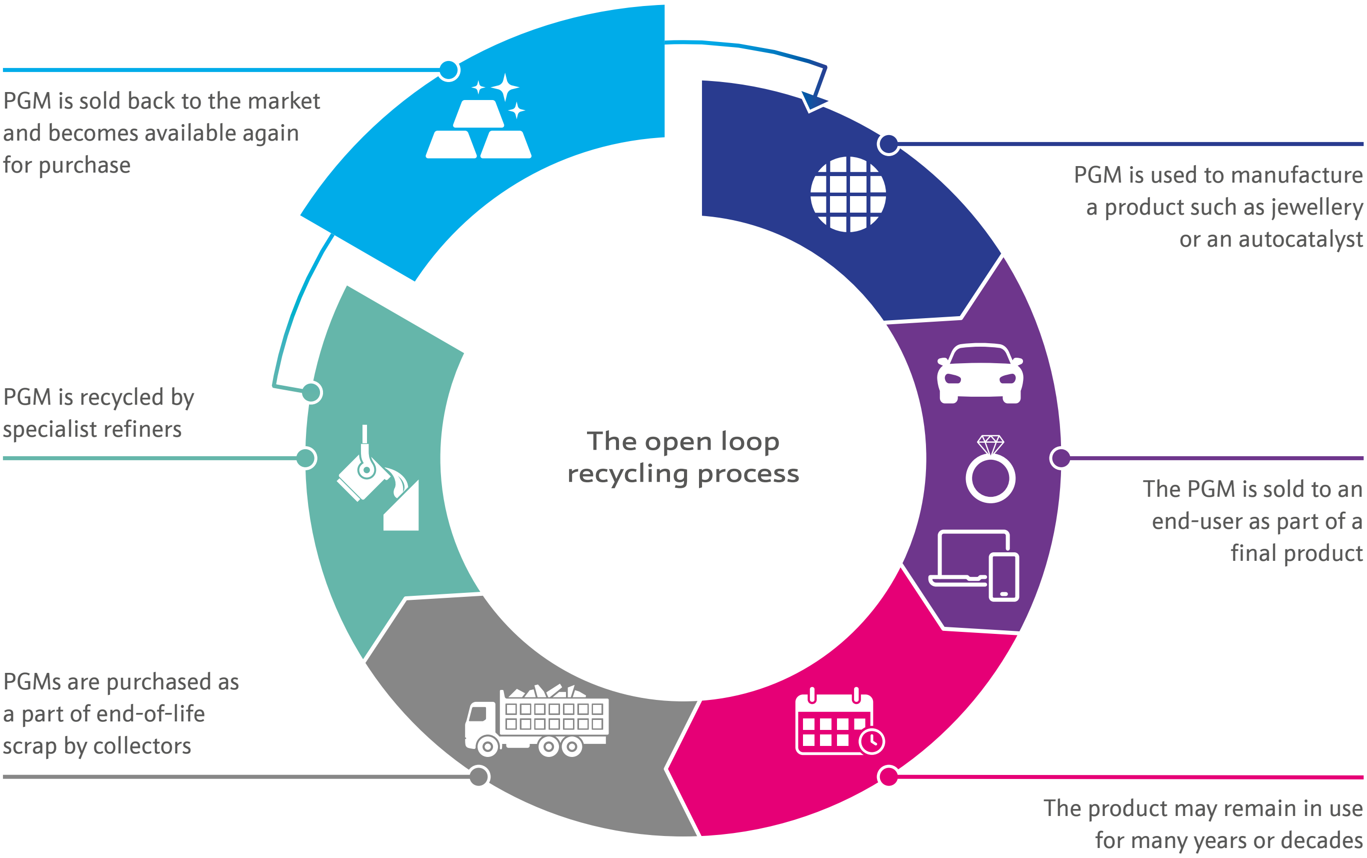
### What is open loop recycling?

Open loop recycling typically occurs in consumer markets, with the main source being the automotive industry, where palladium, platinum, and rhodium are recovered from scrapped catalytic converters. Smaller amounts of platinum and palladium are also recycled in an open loop from electronics scrap and old jewellery.

Features and characteristics of open loop recycling are:

- Metal ownership is not retained by the original purchaser (usually the original equipment manufacturer, OEM) and can change throughout the PGM-containing product's lifecycle.
- Once recovered from the end-of-life product, the recycled metal then becomes available to the market as new supply and can be reused in any application.
- PGM recovered in this way is reported as 'secondary supply' in PGM market data[9]. It acts to increase total supply to the market, supplementing newly mined metal.

> "Because closed loop recycling does not return metal to the market, it does not count as secondary supply. Instead, it reduces market demand and the need for fresh metal, sustaining overall PGM use"



PGM is used to manufacture a product such as jewellery or an autocatalyst

The PGM is sold to an end-user as part of a final product

The product may remain in use for many years or decades

PGMs are purchased as a part of end-of-life scrap by collectors

PGM is recycled by specialist refiners

PGM is sold back to the market and becomes available again for purchase

**Figure 4** The open loop recycling process, showing typical stages of metal ownership

### What is closed loop recycling?

Closed loop recycling typically occurs within markets such as chemicals, fuels and pharmaceutical industries alongside production scrap across all PGM applications.

Distinct features of closed loop recycling are:

- The original purchaser of the metal retains ownership throughout the product lifecycle and recovers it from the spent product to reuse it within the same application.
- It reduces the amount of new PGM that the user must buy each time, although small losses through the lifecycle mean that there is usually some purchase of 'top up' metal.
- Because closed loop recycling does not return metal to the market, it does not count as secondary supply. Instead, it reduces market demand and the need for fresh metal, sustaining overall PGM use. PGM demand data reported by Johnson Matthey and others does not include closed loop recycling, so this recycling loop is 'invisible' to the market data. This means it is often overlooked when assessing recycling rates.

Typical examples are process catalysts in the chemicals industry that contain PGM as the active component, and PGM used for specialist manufacturing equipment like fibreglass extrusion. In both cases, the catalyst or equipment has a finite life and must be regularly renewed, and the recovered PGM is retained for this purpose.

It is important to note that this is only notionally the same metal. In practice, PGMs are recycled in facilities that process material from various sources, and refined PGM is fully fungible (interchangeable) and not differentiated by source. An equivalent amount of metal is credited back to the owner to allow the owner to 'reuse' it, but the 'reused' metal in the new catalyst/equipment is not physically the same metal that was recovered from the end-of-life catalyst/equipment.

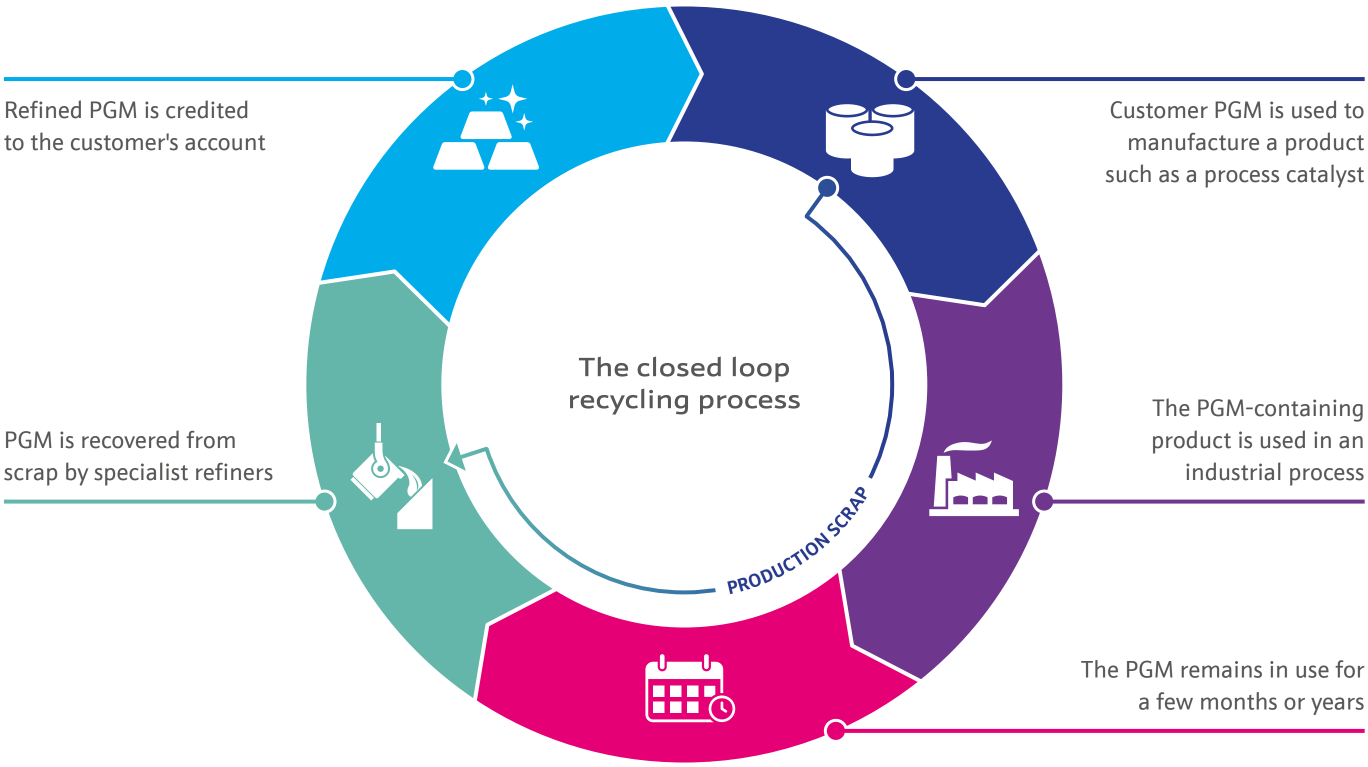


**Figure 5** Closed loop recycling process, with ownership of PGMs typically retained throughout

## Quantifying the impact of PGM recycling today

**Today, almost 60% of the PGM used on new and replacement products every year is recycled metal, with primary mining now acting as a supplement to the urban PGM mine.**

To truly grasp the pivotal role recycling plays in the dynamics of the PGM market, we must explore three fundamental questions:

### Question 1: To what extent does recycled metal from open loop systems increase overall supply?

Reported figures[8] show that currently about 20% of platinum and around 30% of both palladium and rhodium supplied annually for purchase is secondary metal from open loop recycling. Ruthenium and iridium lack consistent sources of secondary supply as they are typically recycled in closed loop.

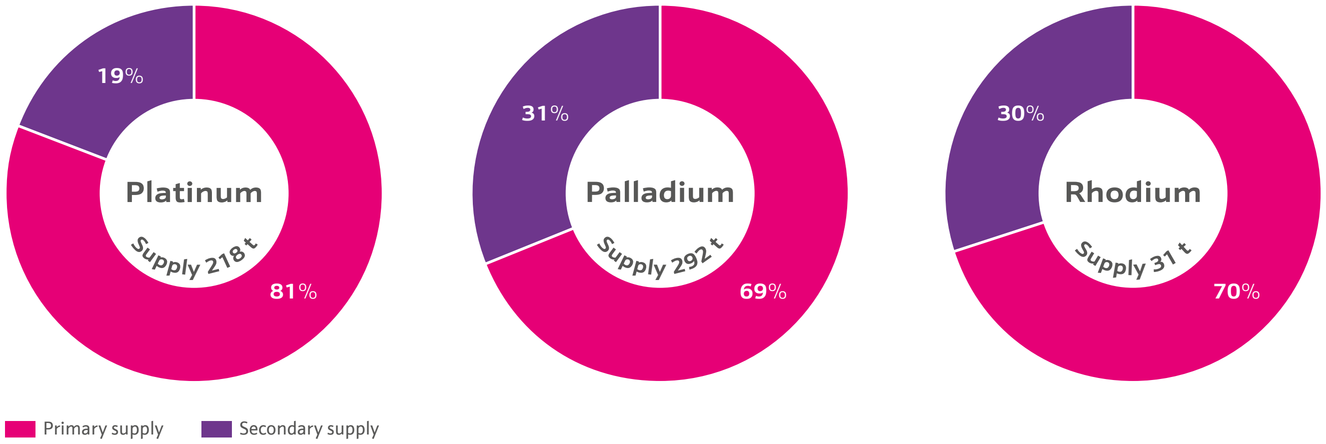


**Figure 6** Market supply of platinum, palladium and rhodium showing the contribution of open loop recycling (preliminary figures for 2024 calendar year)

**Total supply**
(Amount available to the market)

**Primary supply**
(Metal sold by miners)

**Secondary supply from open loop recycling**
(Increases total supply)

**Gross demand**
(Total metal required across all applications)

**Net demand**
(Annual requirement for new metal, after subtraction of closed loop recycling)

Metal recovered and reused from **closed loop recycling**

**Figure 7** Breakdown of the components of supply and demand

### Question 2: By how much does recycling in closed loop systems decrease demand for 'new' metal?

The impact of closed loop recycling remains more challenging to quantify due to the lack of routinely published data on the closed loop and total annual PGM usage on new products. This challenge arises partly because it is difficult to accurately measure the size of the closed loop across the various industries. There is added complexity to this assessment since in many cases inventories have built up with industrial growth and equipment/catalyst lifetimes are variable.

Nevertheless, here for the first time Johnson Matthey unveils the full size of the closed loop. We estimate total (or gross) PGM demand (excluding physical investment) to be around 1,100 tonnes (35.4 million troy ounces) in 2024, with net demand (i.e. the requirement for new metal) >40% lower due to the metal re-circulating in closed loop (~490 tonnes or 15.7 million troy ounces). This unique insight provides a clearer picture of the impact closed loop recycling has on the market.

| Tonnes | Pt | Pd | Rh | Ru | Ir | Total |
|---|---|---|---|---|---|---|
| Reported net market demand[8] | 233 | 302 | 33 | 34 | 7 | **610** |
| Estimated re-circulation in closed loop | 313 | 93 | 28 | 42 | 14 | **490** |
| **Resulting estimate for gross demand** | **546** | **395** | **61** | **76** | **21** | **1100** |

**Table 1** The difference between net and gross PGM demand. Note: Preliminary figures for 2024 calendar year. Market demand excluding investment. Closed loop figures are approximate

### Question 3: How much gross PGM demand is estimated to have been met by total recycling?

To address this question, we must now add closed loop recycling to the contribution of open loop recycling across the five PGMs:

| Tonnes | Pt | Pd | Rh | Ru | Ir | Total |
|---|---|---|---|---|---|---|
| Secondary supply (from open loop recycling)[8] | 42 | 91 | 9 | 0 | 0 | **141** |
| Estimated PGM recirculation in closed loop (as above) | 313 | 93 | 28 | 42 | 14 | **490** |
| **Estimated total recycling (open loop + closed loop)** | **355** | **184** | **37** | **42** | **14** | **631** |
| Primary supply[8] | 177 | 201 | 22 | 32 | 8 | **439** |
| Shortfall vs gross demand (met by market stocks) | 15 | 10 | 2 | 2 | 0 | **29** |
| **Proportion of gross demand met by recycling (%)** | **65** | **47** | **61** | **55** | **66** | **57** |

**Table 2** Contribution of recycling to gross consumption of PGMs. Note: Preliminary figures for 2024 calendar year. Market demand excludes investment. Closed loop figures are approximate

NB: Percentage is not an end-of-life recycling rate since it is being compared to current demand, not to original metal input, and only recycling undertaken within this annual period has been considered.

**We can therefore conclude that in 2024, most PGM demand on a gross basis was met by recycled metal, accounting for ~57% of the total metal used on new and replacement products (631 tonnes of recycled metal versus 1,100 tonnes of gross demand).**

The remainder was mainly met by primary supply from the mines, and some draw-down of market stocks to meet a small shortfall. It is usual for annual supply and demand in PGMs not to match exactly, so market stocks are built up during years when there is excess supply to the market and then are used in years where there is more demand than supply (thus PGM market stocks also comprise a proportion of recycled metal/secondary supply, but this is not quantifiable).

## The role of collection practices

**Open and closed loop systems vary distinctly not just in terms of metal ownership, but also in collection practices and recycling efficiencies. This is mainly because the closed loop benefits from better tracking of metals and owners who wish to maximise the benefit of their investment in metal.**

As a rule, collection efficiency in closed loop is likely to be higher than in open loop. Although collection efficiency alone will not determine the resulting recycling rates within an application, because in-use losses and processing efficiency must also be factored in, it has a crucial impact. This can be seen in the open loop recycling of end-of-life catalytic converters today.

### Open loop collection efficiencies

Open loop recycling typically targets metal that has been highly dispersed via product sales, with market forces governing whether collectors see enough value in the recoverable metal to make the effort of going after it worthwhile.

The automotive industry is the largest user of PGMs as well as the largest 'supplier' of secondary metal to the market via open loop recycling (in the form of metal recovered from scrapped catalytic converters). This is supported by mature global recycling networks and specialist collectors who profit from selling the metal recovered from auto scrap operations in numerous locations. And yet, we estimate that over 30% of the PGM used in catalytic converters on new vehicles is not recovered. Most of this loss derives from the fact that not all spent catalytic converters are collected: many are discarded as waste or left on scrapped vehicles, particularly in smaller or less developed markets where accessing global PGM recycling infrastructure is harder.

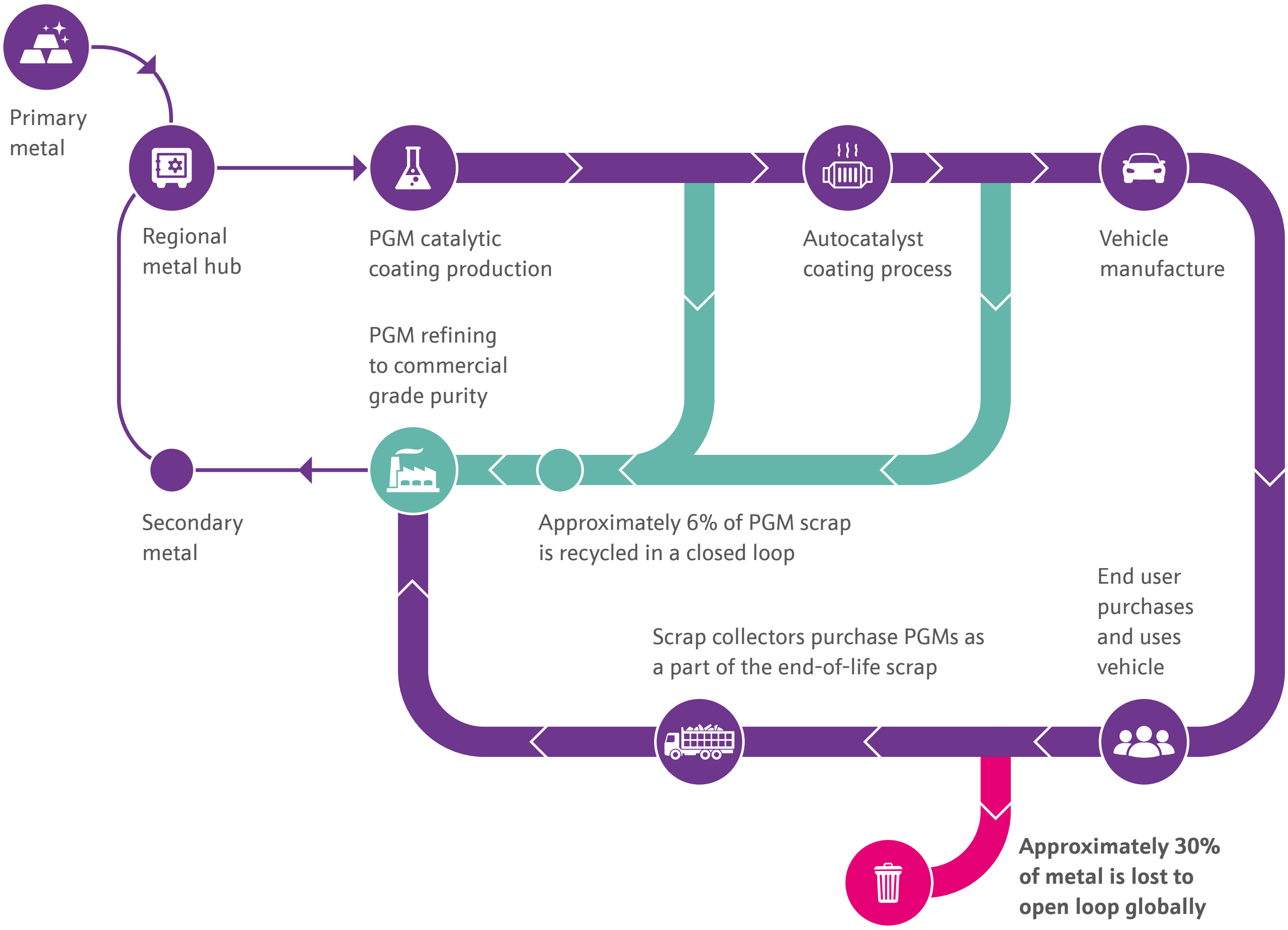


**Figure 8** PGM recycling from auto catalytic converter manufacturing and use

### Closed loop collection efficiencies

By contrast, closed loop PGM recycling rates within certain applications can exceed 95%, because the metal owner ensures the spent product reaches an appropriate processor or refiner for the PGM to be effectively recovered. That said, certain applications have high in-use losses due to harsh process conditions that even PGMs cannot withstand forever. As a general rule, in those instances where recycling rates are low within a closed loop, high in-use losses are the culprit, with the lost metal being dispersed in an unrecoverable form.

| Parameter | Open loop | Closed loop |
|---|---|---|
| **Impact on market** | Increases supply | Reduces demand |
| **Routine for which PGMs today?** | Pt, Pd, Rh | Pt, Pd, Rh, Ru, Ir |
| **Visible in reported market data?** | Yes | No |
| **Original purchaser retains ownership?** | No | Yes |
| **Driver** | Recovered metal is sold for profit | Recovered metal is retained asset |
| **Initiated by** | Specialist collectors | Original metal purchaser |
| **Collection efficiency** | Tends to be lower | Tends to be higher |
| **Typical recycling rate** | Dependent on region and market, typically < 70% | Dependent on metal and application, can exceed 95% |
| **Example applications** | Catalytic converters, electronics, jewellery | Production scrap across all PGM applications. Spent catalysts from fuels, chemicals & pharma production, glassmaking, electronics industry, etc. |

**Table 3** Comparison of the characteristics of the open and closed PGM recycling loops

# The role of processors

**Processors play a crucial role in enabling market-driven circularity, by making recycling economically feasible as well as technically possible. The global PGM industry has evolved to allow processors to specialise in treating certain types of material at sufficient volume to allow economies of scope and scale.**

### The impact of processing costs

Once collected, spent material or equipment must be processed to separate the contained PGM. Several stages of processing may be necessary, including disassembly and pre-processing, which are often overlooked but are key to enabling effective final processing of material. Final processing of PGM-containing material often (but not always) involves refining, which itself may require both pyrometallurgical and hydrometallurgical processes.

The crucial consideration throughout is that the cost of processing must not exceed the value of the recovered metal. PGM recycling has not historically been mandated and has been driven by market forces, thus there are cases of PGMs not being recovered at end of life because the relative cost of doing so is too high.

For example, a decade ago the price of ruthenium was much lower than it is today[10]. As a result, some users of ruthenium-containing catalysts in the chemicals industry did not recycle their end-of-life catalyst, as buying replacement ruthenium was cheaper than processing the old catalyst to recover the ruthenium. But the spent catalyst was not discarded: instead, it was stockpiled until the ruthenium price rose sufficiently to make recycling cost-effective. As such, effective collection still took place, even if processing was delayed, and this ultimately enabled recycling. Most of this stockpiled catalyst has since been refined, putting the ruthenium back into use.

In other areas, innovative approaches have been adopted to lower overall processing cost. For example, where the PGM remains in metallic form and is not contaminated, it may simply be melted down before being reused in an alloy again. For example, gauze catalysts (made from knitted PGM wire) are used in making nitric acid for fertiliser production, and they can often be recycled without going through the full refining process. Nitric acid producers globally benefit from this more cost-effective recycling approach[11].

PGM processors and refiners thus have invested significant effort in innovation over decades, not just to develop effective recycling technology but also to reduce processing costs as far as possible. This is not straightforward, as PGMs are used in a great diversity of materials and products that were often designed with no thought to eventual recyclability.

### Partnership and collaboration

The diversity of materials that must be treated is both a technical problem and an economic one, since it makes economies of scale in each type of processing harder to achieve. Partnerships between processors help to address this.

For example, a refiner may partner with a pre-processor to ensure the refinery intake material is optimally geared for its process, or refiners may contract out the processing of certain side-streams. No one company tries to do it all.

This is why **PGM recycling takes place in an international network: major players in PGM recycling have adopted a degree of specialism coupled to scale to make recycling as cost-effective as possible**. This is particularly evident in the global secondary refining companies, who operate large refineries in Europe, the US, Japan and elsewhere that process material from all over the world.

These PGM refiners may purchase the recovered metal, but often they process it as a service to the owner, whether that is the open loop collector or the original owner in the closed loop; this is known as 'toll-refining'. This means that certain countries are in effect providing PGM recycling services to other countries, to the mutual benefit of both. It also means that metal can often be found in a different country from its owner for purposes of processing. This is quite normal in the PGM industry.

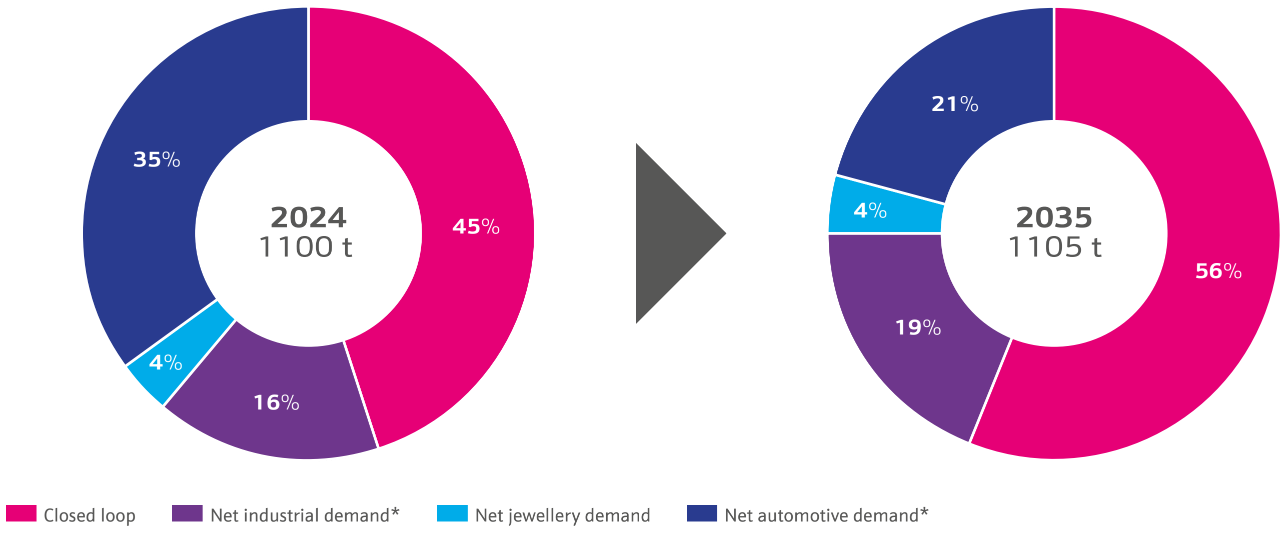
## PGM recycling for the future

**Many PGM applications today are largely sustained by their retained metal inventory, which circulates through closed loop recycling, with metal only being purchased to 'top-up' any losses or when capacity expands. Recycling will play a similarly important role in future applications.**

As the use of PGMs in catalytic converters declines in the longer term with the move away from internal combustion engines, demand in industrial and energy transition applications such as hydrogen will grow. If these applications practice a form of closed loop recycling, and ensure efficient collection and recovery, then recycling will become an increasingly important aspect of securing PGMs for the energy transition.

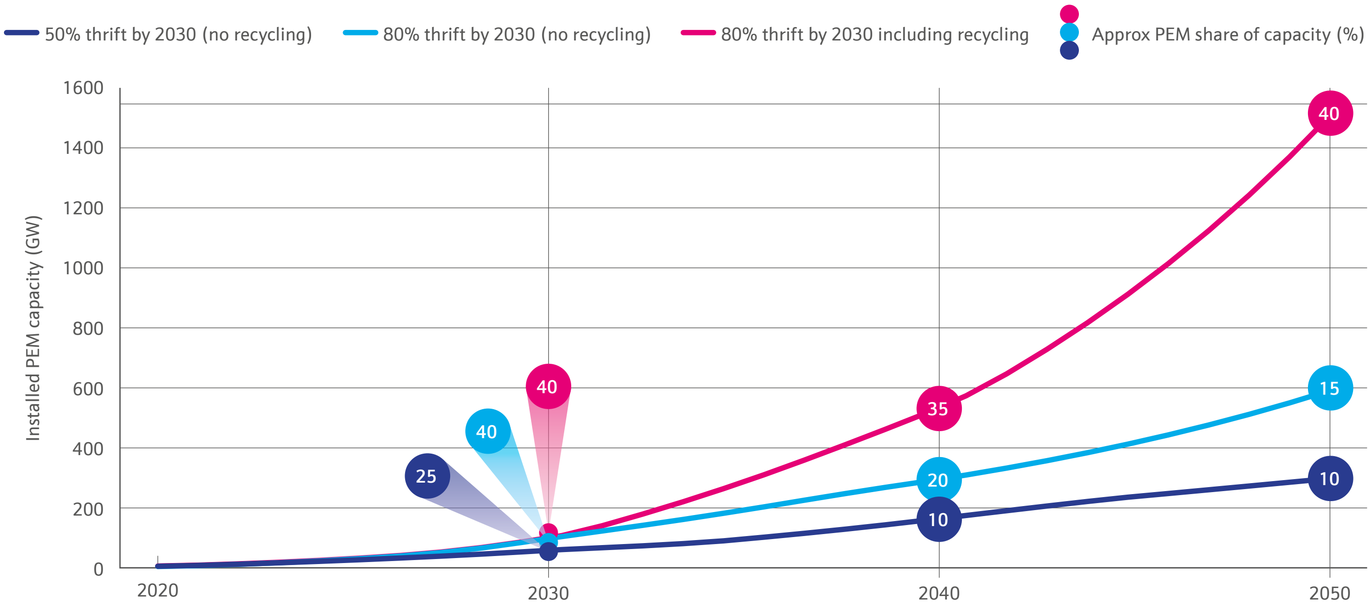
For example, Johnson Matthey has demonstrated how iridium recycling, coupled with increasingly efficient metal use through innovation (a standard concept in the PGM industry, termed 'thrifting'), will enable clean hydrogen. Our projections in Figure 10 show that installed capacity of proton exchange membrane (PEM) electrolysis – the preferred technology for coupling to variable renewable power – can grow to play a much larger role in this market than would be the case if iridium were not recycled and reused. As such, the demand for newly mined iridium for green hydrogen will be much lower than is often projected[12,13].

> "PGM recycling takes place in an international network: major players in PGM recycling have adopted a degree of specialism coupled to scale to make recycling as cost-effective as possible"



*Projected automotive demand includes fuel cell vehicles, and other energy transition applications are included in projected industrial demand

**Figure 9** Estimated gross PGM demand in 2024 and projection for 2035, assuming metal is retained in closed loop recycling within industrial and energy transition applications. 2035 projection is for currently known and commercially implemented applications only, no additional new applications included



Source: Hydrogen Council, JM analysis

**Figure 10** The impact of thrifting and recycling on proton exchange membrane (PEM) capacity, based on 1.5 tonnes p.a. iridium supply (Source: Johnson Matthey white paper (2022) "Two key focus areas will ensure iridium availability does not stall electrolyser growth")

## Leveraging existing PGM recycling infrastructure for hydrogen

The use of PGMs in fuel cells and electrolysers is relatively novel, and these markets are still nascent, but recycling of PGMs from fuel cells and electrolysers is already happening every day at high efficiency. This is because pre-existing PGM collection networks and recycling infrastructure are being used to recycle materials from their production and from early deployments of these technologies that have now reached the end of their lives.

Some adaptations have been necessary, but recycling of these materials to recover platinum, iridium and ruthenium is otherwise routine. That said, the PGM industry is aware that volumes of this type of material are expected to grow significantly and is therefore innovating to optimise its processes to maximise the efficiency and sustainability of this circularity.

For example, proton exchange membrane (PEM) technology (used for both fuel cells and electrolysers) requires the polymer membrane onto which the PGM catalyst has been coated to be burnt off, before the PGMs can be refined. The membrane acts as the electrolyte and consists of an advanced ionomer. Combustion completely destroys this ionomer, ensuring that no harmful substances escape into the environment and rendering the PGMs recoverable in existing processes.

However, it would be much better to omit the combustion step and recover the valuable ionomer along with the PGMs, and innovation is already well advanced towards that goal[14].

These novel processes will be implemented as a new step within existing networks and infrastructure to maximise efficiency and minimise cost as volumes scale up. PGM circularity is thus ready and waiting to serve the energy transition and other future technology needs.

# Recommendations to embed metal circularity

Regulators and others are making strides in implementing a circular economy for critical metals. We offer the following recommendations to further enhance the circularity of the PGMs and other metals.

### Recommendation 1:
### Create a framework for industry-led approaches

- Regulation should be informed by industry consultation
- Avoid blanket or 'one size fits all' regulatory approaches

### Recommendation 2:
### Use regulatory instruments to mimic the advantages of closed loops

- Implement producer responsibility where practical
- Enable market-led (rather than regulatory) tracking of materials
- But avoid enforcing re-use within the same application

### Recommendation 3:
### Support innovation to embed systemic circularity

- Incentivise ‘design for recycle’
- Fund innovation in product and process design

### Recommendation 4:
### Form strategic international collaborations in circularity

- Collaborate with like-minded partners to enable economies of scope and scale
- Align domestic policy to facilitate cross-border movements

### Recommendation 5:
### Recognise metals circularity as a horizontal enabler of industrial strategy

- Identify metals processing as a cross-sector enabler
- Identity the needs and opportunities of the metals sector to unlock economic potential

### Recommendation 6:
### Widen focus beyond supply criticality

- Supplement critical materials strategy with strategic materials assessments
- Ensure the needs of all sectors are addressed, not just those at 'supply risk'
- Place urban mining on an equal footing with primary mining

**Figure 11** Recommendations to progress metal circularity.

## Recommendation 1: Create a framework for industry-led approaches

- **Regulation should be informed by industry consultation.**
- **Avoid blanket or 'one size fits all' regulatory approaches.**

Metals supply chains are complex and end-of-life materials are diverse, raising the risk that new regulation intended to drive circularity will be ineffective or even have unintended negative consequences. In our experience, it is difficult for outside observers to gain a clear or comprehensive view of the challenges and opportunities pertaining to PGMs, even when good data is available. (Part of the problem is that such analyses tend to view the PGMs as individual metals, missing the co-dependencies within the PGM 'basket' that are fundamental to the functioning of their markets and infrastructure.) We see a risk that regulation based entirely on such external analyses will be poorly informed, and this is likely to be true for other metal industries too.

Close consultation with industry will help to avoid this, and while there are learnings to be taken from PGM circularity, we also caution against a blanket approach. The best regulation will be crafted in a way that creates a framework within which more specific measures can be adopted for particular metals, technologies and even regions, to maximise the recycling potential within each.

## Recommendation 2: Use regulatory instruments to mimic the advantages of closed loops

- **Implement producer responsibility.**
- **Enable market-led (rather than regulatory) tracking of materials.**
- **Avoid enforcing reuse within the same application.**

Closed loops enhance PGM recycling rates because the original purchaser of the metal has an interest in recovering and reusing it from end-of-life material. Regulatory instruments can incentivise this, even in the case of an open loop where the original purchaser of the metal does not retain ownership.

### Case study: Producer responsibility in practice

The EU's End-of-Life Vehicles (ELV) Directive sets targets to create a circular economy in the automotive sector[16]. OEMs are responsible for meeting recovery and recycling targets for the vehicles that they manufacture when they are scrapped.

From 2015, a target was set that at least 85% of the average weight of ELVs must be recycled. This stimulated effective recycling of bulk metals, primarily steel. However, recycling of materials that contribute less to overall weight – such as plastics and critical raw materials (CRMs), including PGMs – remains sub-optimal.

This is illustrated by iridium, which is widely used in the ignition tips of long-life spark plugs on gasoline vehicles. It is typically not recovered from ELV spark plugs, despite iridium being among the most important CRMs for the energy transition because of its use in PEM electrolysers to produce green hydrogen and in the production of copper foils for electric vehicle batteries. While the amount of iridium per plug is small, globally over a tonne of iridium is used in new spark plugs every year; as total mined supplies of iridium are just 7.5 tonnes a year, this is a valuable source of recycled iridium that is currently not exploited.

In July 2023, the European Commission issued a Proposal to revise the ELV Directive into a Regulation, with the aim of enhancing circularity practice for materials used in ELVs. It introduces specific targets for use of recycled materials on new vehicles; in the first instance, 25% of the plastic used in new vehicles must be recycled, of which 25% must be from ELVs (i.e. a mandated closed loop), with the aim of introducing additional specific targets for use of recycled steel, CRMs, and aluminium[17].

This Proposal further aims to increase 'design for recycle' and the reuse and recycling of materials from ELVs by directing that "**valuable parts and materials should be removed from ELVs before shredding and the treatment of waste should be improved to allow high quality recycling**"[14].

This would surely apply to iridium-tipped spark plugs. But mandating a truly closed loop may not be helpful, given that the recovered iridium could instead be used in energy transition applications rather than new spark plugs. **In this instance, therefore, we believe the focus should be on ensuring high-quality recovery, with the market governing where the recycled material is best reused**.

This is the case today with the existing recycling of platinum, palladium, and rhodium from catalytic converters: the recovered PGM is returned to the market for potential reuse in a wide variety of applications. However, here too, mandated recovery of end-of-life catalytic converters (wherever they end up being located) could be successful in driving up collection and therefore the overall recycling rates of PGMs from end-of-life catalytic converters.

We strongly support measures such as producer responsibility, which mandate that the OEM has responsibility for ensuring the recovery and reuse of specified materials at the end of equipment life. However, we do not believe that it is necessary or even helpful for regulation to specify that the recovered metal must be reused in exactly the same application (see case study below). Mandated producer responsibility would further incentivise a market-led approach to tracking important materials as they move around the world and change hands through their lifecycle.

**Regulatory monitoring is not recommended** – indeed it is virtually impossible to track cross-border PGM movements in their various forms and products through trade data, and attempting to do so publicly would add prohibitive levels of friction to supply chains, rendering them less effective, less competitive and probably less innovative. This tracking is better left to the market.

## Recommendation 3: Support innovation to embed systemic circularity

- **Incentivise 'design for recycle'.**
- **Fund innovation in product and process design.**

For a truly circular economy, the end-of-life solution should be built into the product and its supporting supply chain from the start. Producer responsibility should help to incentivise a 'design for recycle' mindset at the start of the product life, but this can also be explicitly incentivised.

This is likely to reduce in-use losses and future recycling costs and support the emergence of effective end-of-life collection networks through market forces. It would also stimulate greater collaboration between recyclers and product developers to guide process design and to prepare for new types of end-of-life material before they arise in quantity.

**Policymakers can further support this by providing funding for innovation, whether this is in product design, novel technology to reduce in-use losses of critical metals, novel approaches to disassembly and sorting, or R&D in refining.**

## Recommendation 4: Form strategic international collaborations in circularity

- **Collaborate with like-minded partners to enable economies of scope and scale.**
- **Align domestic policy to facilitate cross-border movements.**

We recommend the active pursuit of an 'open' circular economy with like-minded partners in cases (such as PGMs) where it would enhance domestic resilience.

For circularity to become embedded in the economy it must be cost-effective, and this requires recycling operations to have access to sufficient volumes of relatively consistent material. Processors can then optimise their processes for certain types of material. This is far more efficient than numerous smaller players attempting to make a profit from gathering and processing small volumes of many diverse materials within domestic boundaries.

Efforts towards international partnerships in critical minerals should therefore not just focus on 'resource-rich' nations, but also on nations that have shared interests in recycling infrastructure, as outlined in the Minerals Security Partnership (MSP)[18].

Today, MSP members account for most of the world's PGM recycling and processing capacity, with the UK, US, EU, Japan and Korea all hosting significant PGM operations and leading innovation in PGM-using technologies. For the PGMs, recycling infrastructure in the West is thus mature – and closely interconnected. It therefore makes no sense for the EU, US or UK to go it alone: we strongly recommend a strategic partnership between these entities in PGM recycling and processing.

**Care should then be taken to align domestic policymaking to avoid unintended consequences that add unnecessary drag to cross-border movements of material for recycling**. For example, the way that import taxes are applied by some nations hampers domestic companies who provide 'recycling as a service' (e.g. toll refining) to foreign entities, even as these nations aim to boost their own recycling rates.

### Case study: Tax policy and circularity

Certain countries levy a value-added tax (VAT) on imports. This is usually paid up front but can then be reclaimed if the material is exported again. If a refiner is importing material for recycling on behalf of another entity who is not VAT registered in that country, the refiner would have to pay VAT on the value of the metal contained in that imported material and reclaim it when the refined metal is exported again to be returned to the owner.

This can have significantly negative implications for cashflow and working capital, especially as processing can takes weeks or even months, and yet it is cost-neutral for the government in question. Workarounds may exist but are generally administratively cumbersome and add business risk.

A small amendment to how VAT policy is applied in the case of materials imported for recycling purposes can make all the difference to whether a country hosts a world-leading metals recycling industry or not, without costing its government any money.

## Recommendation 5: Recognise metals circularity as a horizontal enabler of industrial strategy

- **Identify metals processing as a cross-sector enabler.**
- **Identify the needs and opportunities of the metals sector to unlock economic potential.**

National industrial strategies, such as the one recently published by the UK Government[19], aim to support economically important sectors while reducing their supply chain risks. Typically, metals supply and processing are seen as discrete sub-components within the latter category, rather than a distinct sector in itself. Yet metals supply, processing and recycling is an essential, cross-cutting enabler of many of the identified 'growth' sectors – and for some nations, can be a growth sector in itself.

For example, PGMs support clean energy, digital technologies, defence and aerospace, and many life science technologies, with associated metal processing and recycling happening in common facilities. PGM processing and recycling infrastructure presents domestic and export opportunities to the nations that possess it. For the world as a whole, the established circularity in PGMs can be leveraged for the future, as we have shown. And yet, the PGM industry generally sees a lack of supportive policy to capitalise on these opportunities.

**Recognising metals processing as a distinct industry that enables and supports many sectors of the economy and addressing both its needs and its opportunities through tailored policy will help to ensure circularity becomes a practical reality.**

> "PGM processing and recycling infrastructure presents domestic and export opportunities to the nations that possess it"

## Recommendation 6: Widen focus beyond (mined) supply criticality

- **Supplement critical materials strategy with strategic materials assessments.**
- **Ensure the needs of all sectors are addressed, not just those at 'supply risk'.**
- **Place urban mining on an equal footing with primary mining.**

Building on the above, forward-looking reviews to identify metals of strategic economic importance are needed, to sit alongside and complement criticality assessments that tend to be largely based on mined supply risk and current economic needs.

Even where a forward-looking view is formed, as in the case of the EU's list of strategic raw materials, it is still generally predicated on minimising exposure to risk of disruptions in mined supply of specific metals. It is therefore not well structured to address needs and opportunities that lie in metals and sectors that aren't on the list.

In some jurisdictions, this approach is also leading to an overwhelming focus on mining of certain metals, whether that is opening new mines domestically or partnering with other countries to secure their mined supply. Focus on the rest of the value chain, including circularity, is too often coming second to mining, with some countries even overlooking strengths they already possess further up the value chain.

PGMs have shown that it is possible to move away from heavy reliance on extraction towards reliance on urban mining – but the 'urban miners' who make that happen need appropriate support. Yet urban miners are not even formally recognised as suppliers within the structure of most regulation. For example, the EU's CRM Act only counts primary metal as supply. For PGMs, and other widely recycled metals such as copper, this makes no sense: as discussed above, secondary metal accounts for a substantial portion of market supply of the PGMs. If this secondary metal were counted towards supply (as it should be), it would be apparent that the EU's reliance on South Africa for PGM supply has been overstated – and the status of the UK as a PGM supplier to the EU has been missed.

**Furthermore, to progress to a truly circular economy, we recommend more focus on making the fullest use of the urban mines that already exist, and to a large extent that aim is not well captured by current critical raw materials policy. See below case study for an example.**

## Case study: The US palladium opportunity

In the US, platinum and iridium are the only PGMs listed as critical, with emphasis on mitigating mined supply risk and reducing the country's reliance on these metals within the supply chain. Yet the US possesses:

1. An enormous urban mine of hundreds of tonnes of palladium within catalytic converters in its gasoline vehicle fleet (it also has rich mining assets that produce over ten tonnes of primary palladium annually as well as some platinum[20]).
2. The expertise and recycling infrastructure needed to exploit it.

But the opportunity that palladium presents to the US is currently being overlooked in policymaking.

If battery vehicle market share grows with time, consumption of palladium in new catalytic converters will gradually decline. This means availability of recycled palladium will grow for other uses in new technologies. These could be impactful: palladium is a powerful catalytic metal and has other useful and unique properties.

By funding R&D into new palladium uses, the US could develop novel technology exploiting its domestic metal supply – potentially reducing its reliance on imports of other metals such as nickel. However, no such funding has yet been made available. Companies that recycle and mine palladium in the US instead face financial pressure due to declining investor sentiment: investors expect that some palladium supply could be surplus to future needs and are already 'pricing in' the longer-term decline of the internal combustion engine. North American palladium suppliers are thus facing an uncertain future, at a time when domestic resilience in industrial metals has never been more important.

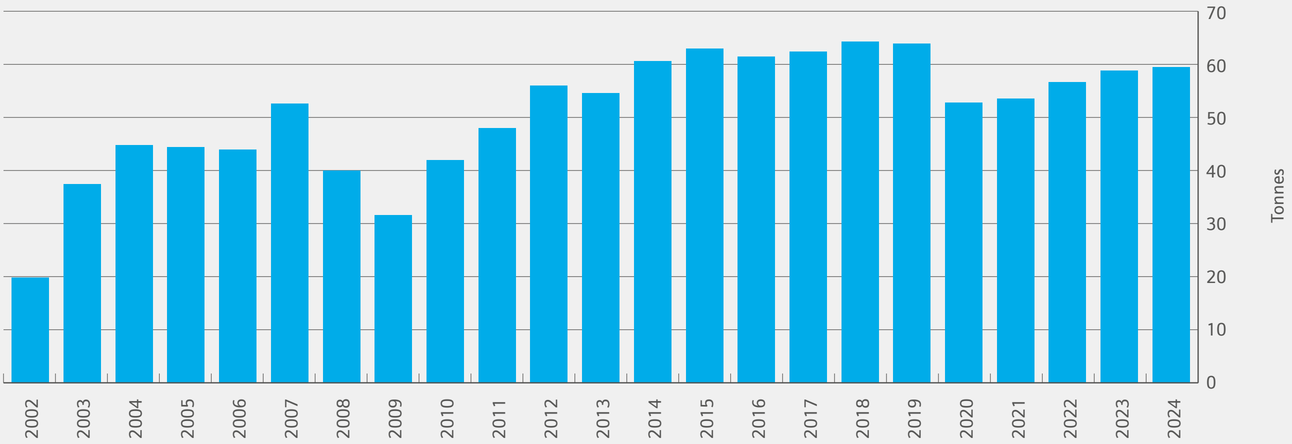


**Figure 12** An urban mine: palladium used annually on new vehicles in the US and Canada every year since 2002 - much of this remains in the vehicle fleet, waiting to be recovered, with new palladium-containing vehicles being added every year

# Learn more about Johnson Matthey's role in PGMs and their circularity

**As a world leader in PGMs we have a long and rich history of working with these precious metals that spans over 200 years. We are widely recognised as a pioneer in enabling a circular PGM economy, supported by our position as the world's largest recycler of PGMs (by volume).**

With refineries in Europe, US and China, and a global network of partners, we provide full geographic coverage and complete refining solutions. Alongside this global ecosystem, we are one of the only companies capable of refining all seven precious metals. With a deep understanding of material and analytical science, pyrometallurgy and chemical separation, we extract and refine these precious metals from even the most complex materials from diverse industries.

PGMs underpin everything we do at JM, supporting our purpose of catalysing the net zero transition. Our expertise spans research and development, supply and price management of PGMs, world-leading market research, innovative product manufacturing, and end-of-life refining. It is through this fully integrated offer that we set the standard for innovation and sustainability in PGMs, playing a vital role in enabling their circular use.

> "It is through this fully integrated offer that we set the standard for innovation and sustainability in PGMs, playing a vital role in enabling their circular use"

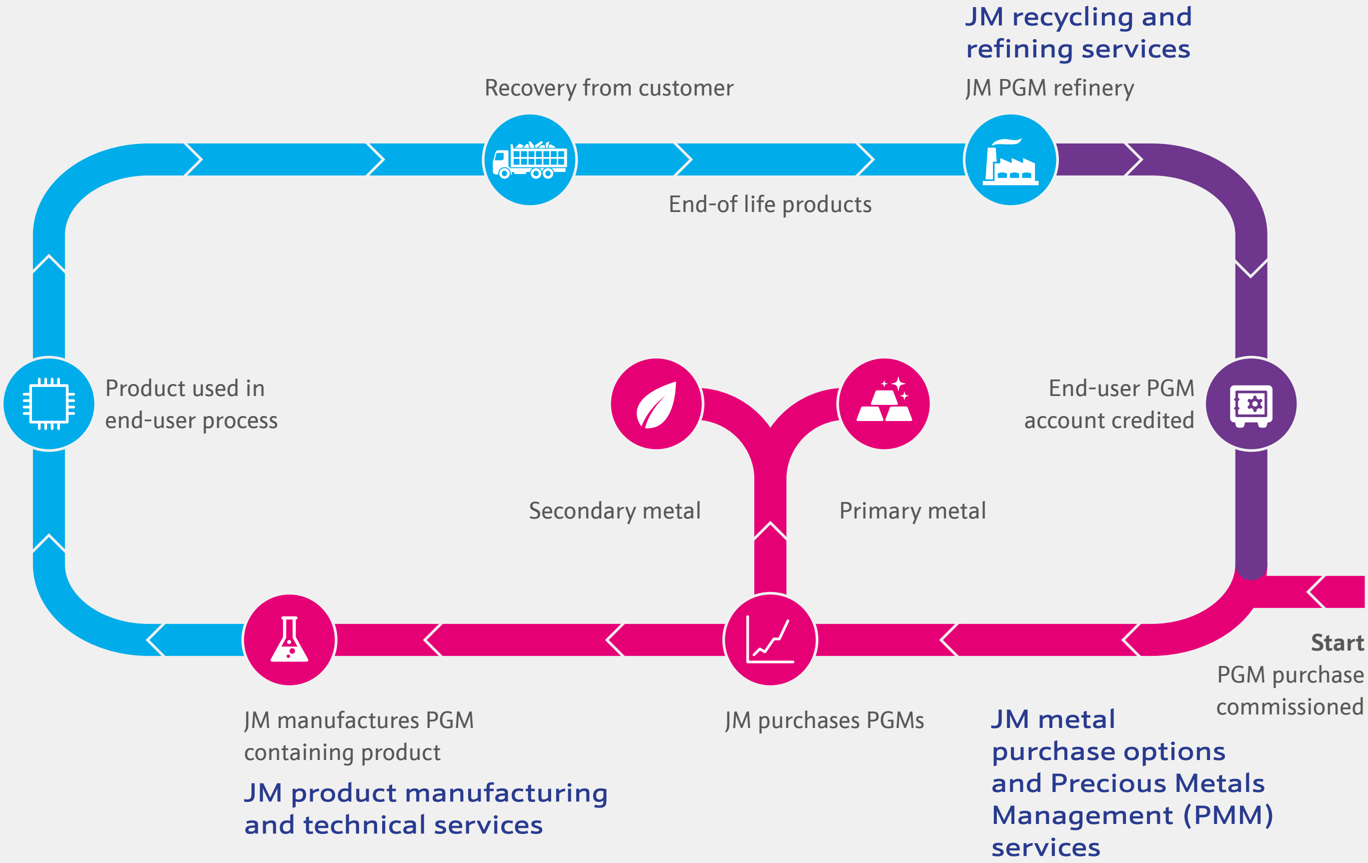
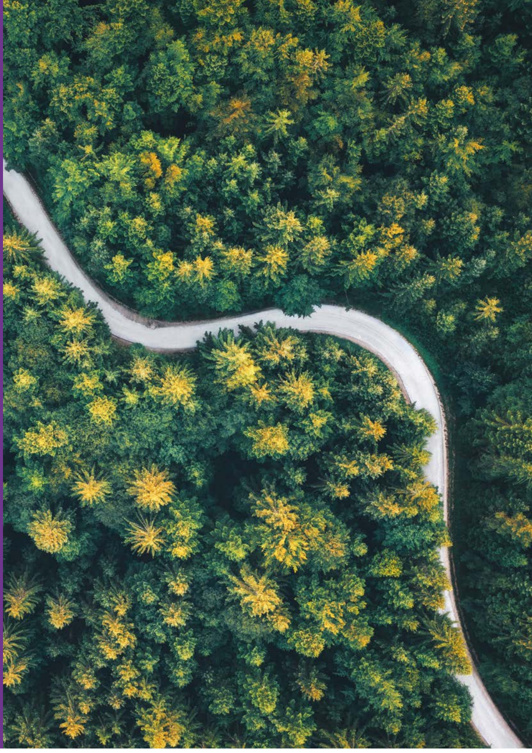


**Figure 13** Johnson Matthey's full-service offer is fully integrated, combining research and development, supply and price management of metals, world-leading market research, manufacturing and end-of-life refining

# References



1 **Johnson Matthey calculation based on IPA data** | Fact sheets – International Platinum Group Metals Association

2 **Johnson Matthey** (2024) | Why critical metals efficiency is essential for the clean energy transition

3 **International Energy Agency** | Critical Minerals Data Explorer – Data Tools

4 **International Energy Agency** (2021) | The role of critical minerals in clean energy transitions

5 **European Commission** | Critical Raw Materials Act

6 **Department of Energy** | U.S. Department of Energy Solicits Feedback on Its Plan To Increase Products and Materials Circularity

7 **Johnson Matthey** (2024) | Platinum group metals: The unsung heroes of our modern world

8 **Johnson Matthey** (2023) | Johnson Matthey offers 100% recycled platinum group metal (PGM) content

9 **Johnson Matthey** | PGM market data

10 **Johnson Matthey** | PGM prices and trading

11 **Johnson Matthey** PGMS Market Research

12 **Johnson Matthey** (2022) | Two key focus areas will ensure iridium availability does not stall electrolyser growth

13 **Catalysis Today** (Aug 2023) | Perspectives on current and future iridium demand and iridium oxide catalysts for PEM water electrolysis

14 **Johnson Matthey** (2023) | Johnson Matthey demonstrates key step towards a circular hydrogen economy

15 **Johnson Matthey** (2024) | Platinum group metal supply chains: mature and global | Johnson Matthey

16 **European Commission** | End-of-Life Vehicles

17 **European Commission** | Questions and Answers: End-of-Life vehicles

18 **United States Department of State** | Minerals Security Partnership

19 **GOV.UK** | Invest 2035: the UK's modern industrial strategy

20 **Sibanye Stillwater** | Stillwater and East Boulder | US PGM Operations

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