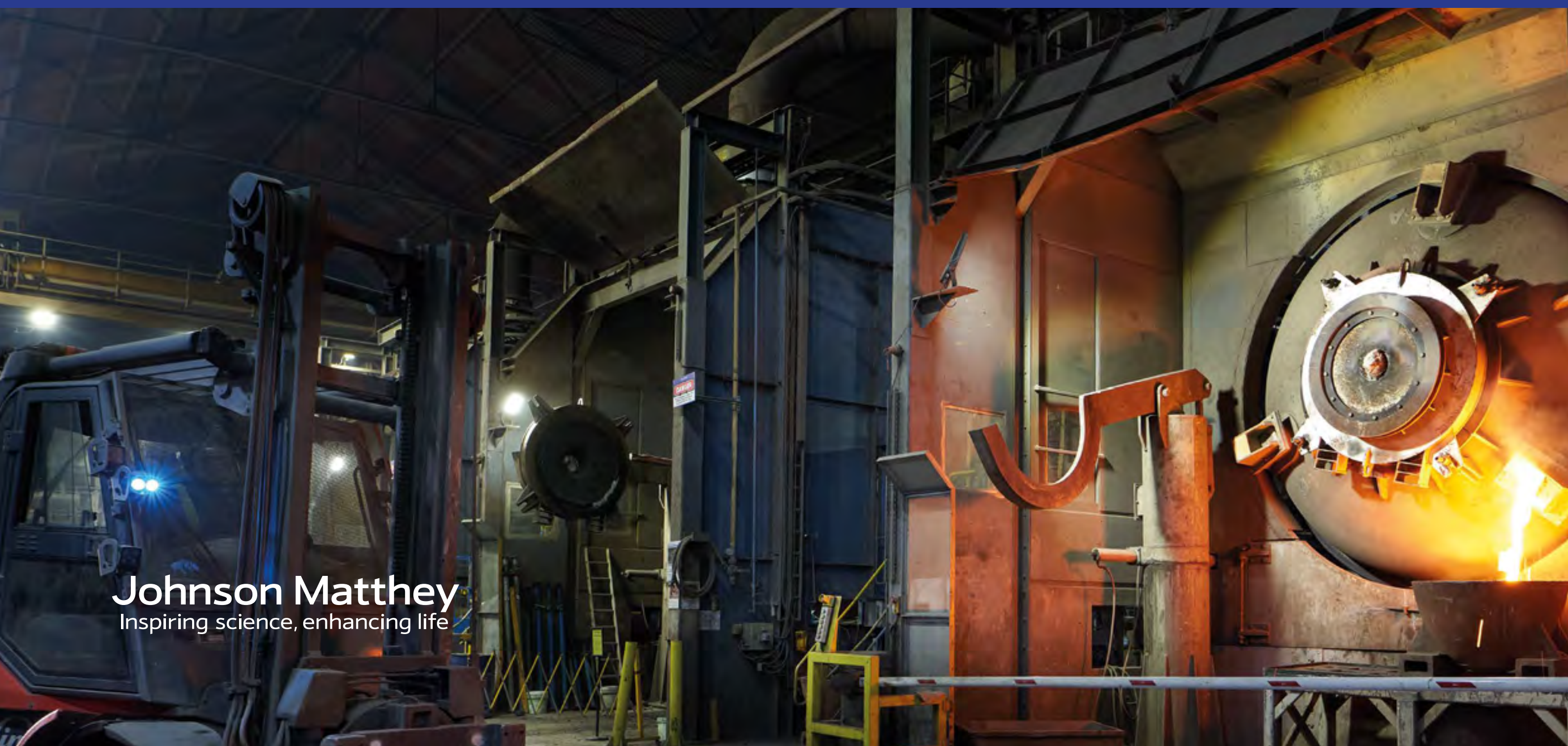
A guide to PGMs

Understanding the fundamentals of platinum group metals



Johnson Matthey
Inspiring science, enhancing life

Platinum group metals (PGMs) are the backbone of JM. We've been working with them for over 200 years, giving us unique expertise in PGM chemistry and catalysis.

We use this knowledge to create specialist products, and as the world's largest recycler of secondary PGMs (by volume) we play an important role in recovering these valuable metals so they can be reused. Together with our global team of PGM experts who source and manage PGMs, and our unique and informed PGM market insights, we secure access to a reliable, sustainable and circular supply of these critical raw materials.

This guide draws upon JM's extensive knowledge to give an overview of PGMs: where they come from, how they are used and why they are important. We use PGM to refer to platinum, palladium, rhodium, ruthenium and iridium – although osmium is also a platinum group metal, its applications are very niche, so we don't cover it here.

Where do PGM supplies come from?

Primary supplies

Primary supply is metal sourced from mines, also called virgin metal. PGMs are mined in a limited number of places and are usually mined in association with each other.

PGM mining is heavily concentrated in southern Africa, targeting igneous deposits in South Africa and Zimbabwe that were formed two billion years ago by huge intrusions of magma from the Earth's mantle, which solidified below the Earth's surface. Most PGM mining occurs in its own right, although some PGM is also extracted as a by-product of mining for other metals.

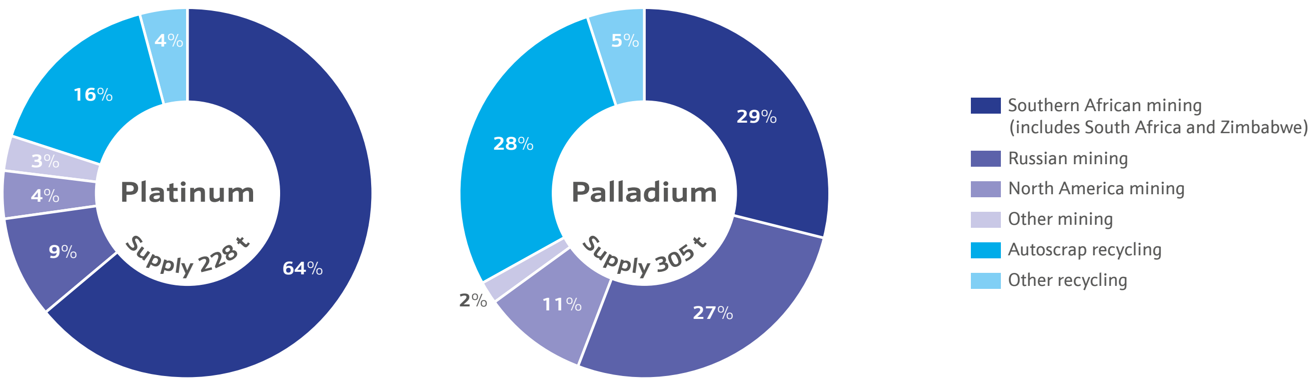
The process of mining and refining PGMs is complex and technically challenging. As a result, the sector is populated by several large, multinational, publicly quoted mining companies who adhere to stringent mining and labour regulation. Despite concerns in other mining industries that can be more 'artisanal', the well-established and reputable South African PGM mining companies maintain high environmental, social and governance (ESG) standards to ensure the metal is sourced responsibly; this is reported annually alongside their production.

Platinum is the main product of southern African PGM mining, and this region provides about 80% of global mine supplies of the metal. The remainder is produced as a by-product of either base metals or palladium mining in other regions.

Palladium has a more diverse supply profile: about 40% of palladium mined every year comes from Russia and a similar amount from southern Africa, with the remainder mainly coming from North America. In Russia it is a by-product of base metals mining and in Southern Africa it is mined with platinum. In North America, some production is from mines where palladium is the main product, and the rest comes from base metals mining. So, the amount of palladium mined in Southern Africa or Russia is largely dictated by how much of the primary products (platinum or nickel) are produced.

This is also true for **rhodium, ruthenium and iridium**, which are all entirely extracted as by-products, mainly from platinum mining in Southern Africa. Because they are all produced in relatively small concentrations compared to platinum and palladium, they are collectively referred to as the "minor metals".

PGM market supply from primary and secondary (open loop, see page 5) sources in 2023



Secondary supplies and the importance of recycling

PGMs are valuable because of their unique properties and their relative rarity in the Earth's crust. With total mined (primary) supply of the five PGMs amounting to around 450 tonnes per year, but demand of around 600 tonnes per year, it is clear that recycled metal (known as 'secondary' supply) plays a crucial role to meet this demand.

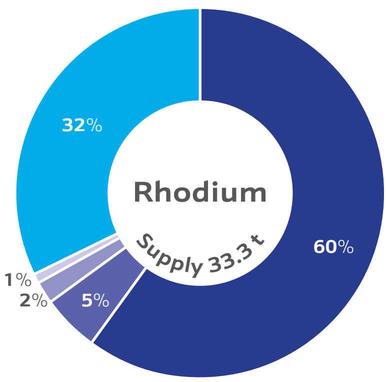
The high value of the PGMs means that recycling is widely undertaken; depending on the application, most PGMs are recoverable throughout the product lifecycle, from production scrap through to end-of-life materials. Once recycled, secondary PGMs have exactly the same properties as primary PGMs, so most of the PGM mined to date is still either in use or in a useable form.

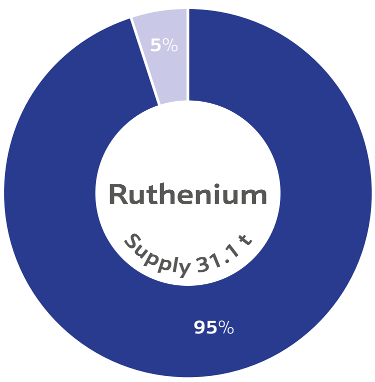
PGMs are recycled in two ways:

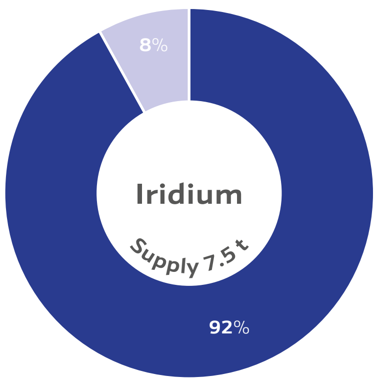
1. **Open-loop recycling** occurs where the original purchaser does not retain control of the PGM, and the metal is available to the market again once recovered. It contributes to market supply and helps to bridge the gap between supply and demand. The main source of open-loop metal is automotive catalytic converters, which are widely recovered from scrapped vehicles and recycled to recover the platinum, palladium and rhodium that they contain. Outside of the autocatalyst, jewellery and electronics markets, open-loop recycling is negligible.
2. **Closed-loop recycling** is where the owner of the metal retains it within the application. An example would be recovering the metal from used chemical process catalysts and using it to make fresh catalyst to replace the spent charge. This metal is recycled by PGM refiners and an equivalent amount is returned to the original owner, who retains the metal value throughout the process. Because the net amount of metal in use has not changed, this 'returned' metal does not count as market supply. However, by keeping metal in use, closed-loop recycling reduces net demand, i.e. the need for fresh metal, and therefore makes demand more sustainable. This is particularly important for ruthenium and iridium; while substantial quantities of these PGMs are recycled annually, the vast majority takes place in a closed loop and it is therefore 'invisible' to the market.

Total recycling of PGMs is the sum of open- and closed-loop recycling. When quoting recycling rates for PGMs it is not valid to only consider open-loop recycling. (However, figures for closed loop recycling are not published: see page 15, "working with JM's supply and demand figures".)

Total market supplies of PGMs are the sum of mined (primary) supplies plus secondary supplies from open-loop recycling only, as shown in the charts below.







Geological PGM deposits[1]

There are a limited number of places on Earth where PGMs occur in mineable quantities, with little prospect of significant production elsewhere. Primary PGM supplies will remain reliant on these known deposits, most notably those in southern Africa; fortunately they are extensive and can meet our needs for a long time to come.

PGM deposits are classed as mineral 'reserves' or 'resources', and reporting of either must meet rigorous international standards. According to most definitions used in the PGM mining industry, a mineral 'reserve' is an ore body for which adequate information exists to be confident that economic extraction is possible. Mining companies typically plan their exploration and evaluation strategies so that they have several years of ore in this category. A mineral 'resource' is an ore body for which there are reasonable and realistic prospects for eventual extraction. Mining companies might aim to have a further ten years of ore in this category.

There are known to be substantial and extensive PGM deposits beyond what has already been evaluated as reserves and resources, sufficient to sustain PGM mining for many decades into the future. The major deposits are summarised below. These are all likely to be far more economically viable than unconventional sources of PGMs, such as deep-sea or meteor mining, would ever be.

The Bushveld Complex

The largest deposit of PGMs in the world occurs in the Bushveld Complex in South Africa, mainly formed of two PGM-rich layers called the Merensky Reef and the UG2 Reef. There are enough PGM deposits in the Bushveld Complex to last for many decades using current mining techniques. Geological evidence shows that these deposits continue far beyond the reserves and resources already reported. Taking just platinum, for each 1 km of depth into the Earth in the Bushveld Complex there is around 350 million ounces of platinum, compared to its current annual production of around 6 million ounces.

Other significant deposits

Although the Merensky and UG2 Reefs are the largest, there are other significant deposits of PGMs, notably:

- The Platreef, which is a northern outcrop of the Bushveld Complex in South Africa and is currently being mined by the open-cast or open-pit method. Indications are that the Platreef continues to dip to at least 2 km depth, so significant quantities of PGM may be accessed in future if suitable underground mining methods for this reef are developed.
- The Great Dyke, which is a large PGM deposit being mined in Zimbabwe and is similar to the Merensky Reef, but with a much smaller area of intrusion.
- The Stillwater Complex in Montana, USA, which is much smaller than the Bushveld Complex or Great Dyke, but contains PGMs at significantly higher concentration within the ore. However, the PGM-containing zones are patchily concentrated and steeply dipping, reducing the volumes of ore that can be extracted.
- The Norilsk-Talnakh nickel-copper deposits in northern Siberia, which contain significant quantities of nickel by-product PGMs, with combined reserves and resources exceeding 500 million ounces of PGM total.

[1] Cawthorn, 2010

PGMs in use

Because the PGMs are highly recyclable and retain the same properties once recycled, the 'urban mine' of metal currently in use will continue to be a valuable source of these metals for many decades. In fact, with regulatory support to ensure PGMs in end-of-life equipment are collected as efficiently as possible, even more could be recovered in future.

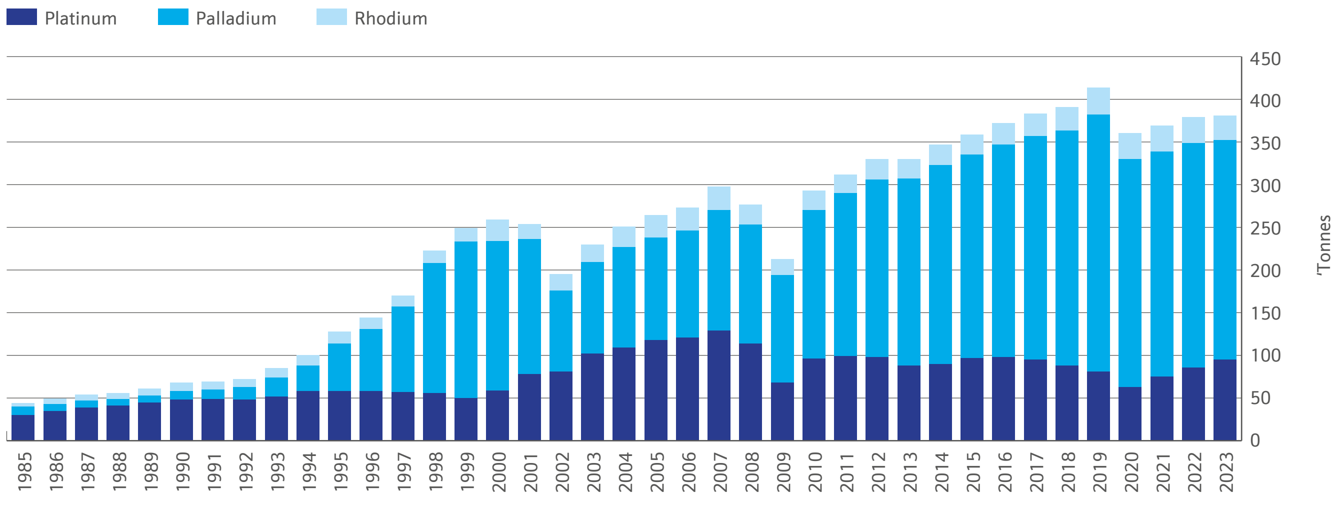
The largest source of secondary supply today is catalytic converters and this is currently a robust market for platinum, palladium, and rhodium. With internal combustion engine (ICE) vehicles typically remaining on the road for fifteen to twenty years (and sometimes for even longer), this will be a source of PGM for a long time to come.

In jewellery applications, stocks exist mainly of platinum and are held by consumers. In Western regions, there is minimal recycling of old jewellery, whereas in China and Japan this happens more routinely.

Substantial quantities of platinum jewellery are still held by consumers: much of it is unlikely to ever find its way back to market, but it's possible that a future platinum deficit and higher price could incentivise consumers to sell some of this jewellery.

PGM in service in industrial applications are another form of stocks, and these are currently circulating in a closed loop. Because this PGM has been purchased for its particular use, it is unavailable for the duration of that use. However, if the application is no longer required in future due to new technologies or changes in product demand, the metal can be recovered and becomes available for other uses. Substantial quantities of PGMs have accumulated in some applications over years or even decades, for example in petroleum refineries and petrochemical plants, so should not be overlooked as a potential source of future availability for new applications.

PGM used on Internal Combustion Engine (ICE) vehicles since 1985



PGM availability

In any given year, total demand for a PGM can be different from total market supply (from primary metal and open-loop recycling). In fact, it is quite usual for the PGM markets to see annual surpluses or deficits, with stocks playing a balancing role.

Availability of PGM at any point is distinct from just supply, as there is often (but not always) metal held in stock, or metal held by users that could be released to the market. These above-ground stocks can make up for a shortfall in market supply.

PGM stocks held by miners ('producer stocks') or those held by fabricators, dealers, banks and depositories around the world ('market stocks') are relatively liquid; they are readily available to the market as the metal has either not yet been purchased, not yet been put into industrial use, or has been bought purely for investment purposes. These stocks have accumulated over time from periods of excess production.

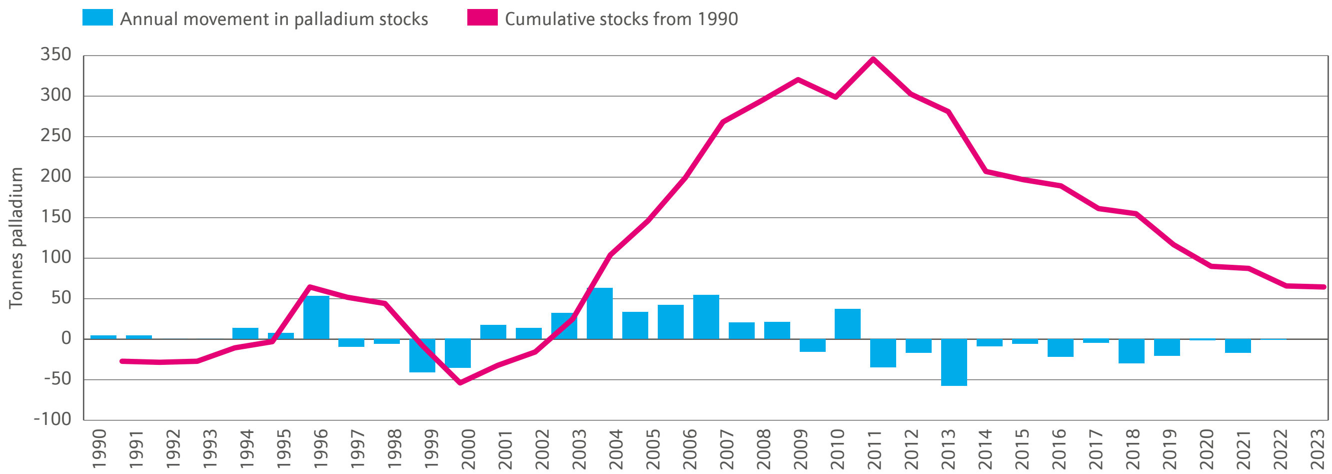
Producer stocks only count as supply to the market when they are sold by the miners. Market stocks, on the other hand, have already been counted as supply to the market, so any movement of such stocks are not counted as fresh supply.

Traditionally, producer and market stocks of platinum and palladium have been held in ingot form in either London or Zurich, due to their pivotal role as 'clearing locations' for the 'over-the-counter' (OTC) precious metals markets.

While the precise amount of such stocks is unknown, it is possible to track the flow of platinum and palladium into and out of these locations. Trade data for recent years suggests a significant drawdown in palladium stocks, which broadly coincides with a deficit period in annual palladium supply, implying that these above-ground stocks have been used to compensate for supply shortfalls. A similar outflow of platinum in recent years partly reflects rapidly growing demand in China.

There are fewer liquid stocks of rhodium, ruthenium and iridium, which are more likely to sit in producer vaults.

Palladium market stocks since 1990



The global PGM network

PGMs are constantly moving around the world in different forms, within a truly global network. Metal that is first sold in a particular region is not necessarily used, recovered, processed or resold in that region.

PGMs are only mined or recycled in a few locations across the world. Meanwhile, PGM-containing products are manufactured by specialist fabricators, with those products then being sold into many different end-markets globally. When it reaches its end-of-life, there is PGM material all over the world that must reach specialist PGM refiners to be effectively recovered and recycled. The PGMs are highly valuable commodities, which means that buying, selling and shipping these metals is not straightforward: it is necessary to consider security, financing arrangements, liquidity, quality verification and proper handling and storage.

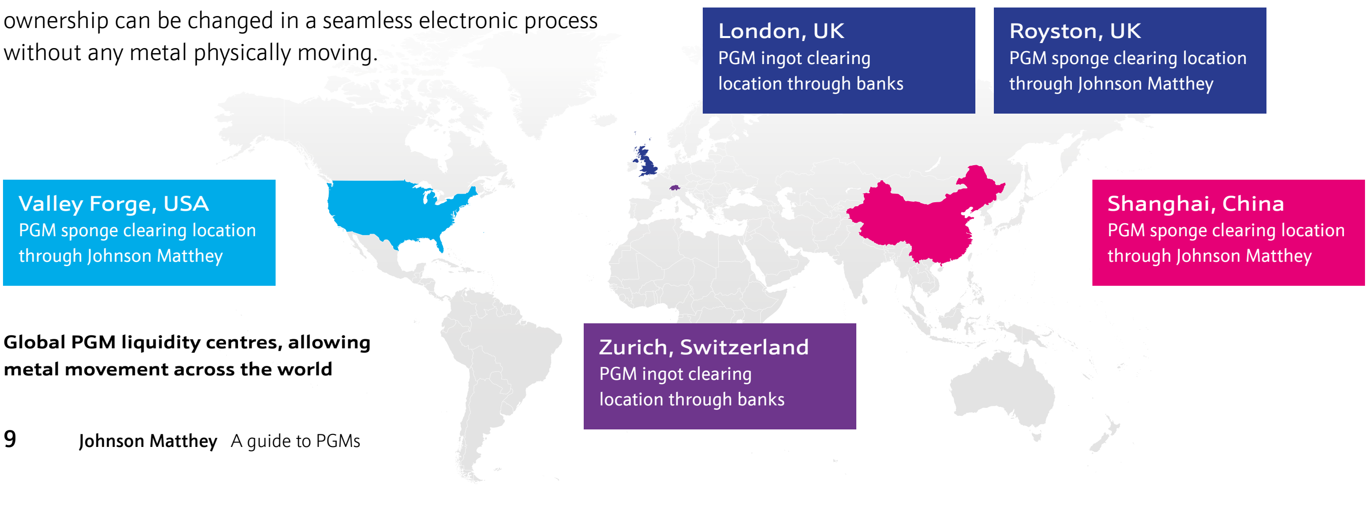
Movement in PGM supply

Starting with the supply side, primary metal from South Africa, Russia, or North America will move via air transport to refineries and customer accounts worldwide (although current restrictions on Russian entities such as sanctions and import penalties limit exports). In most cases it is delivered to refiners and fabricators who process or use the metal for precursors or products, which are then used to make final products elsewhere. The refiners and fabricators frequently process metal on behalf of their customers and do not own the metal themselves. Quite often, the physical location of metal differs from the location of the owner, and ownership can be changed in a seamless electronic process without any metal physically moving.

These metal movements between regions are facilitated by companies that handle relatively large quantities of PGMs through refineries and liquidity hubs around the world, such as Johnson Matthey and others. Two hubs exist (outside of China) for 'good delivery' metal sponge – a 'pure' powdered form of PGM often used to make chemicals and catalysts – one in the UK and one in the US. These hubs handle verification and secure storage and shipping, while also facilitating trading in sponge.

Ingots that have been certified to meet London Platinum & Palladium Market (LPPM) 'good delivery' standards may also be delivered into bank depositories at the London or Zurich ingot hubs for trading purposes, instead of being used in industrial applications. It is important to note that 'good delivery' metal held in Western vaults is interchangeable and can move around from location to location to satisfy contractual obligations without ever being used for a manufactured product.

These four hubs or 'clearing locations' therefore expedite PGM trade between regions, allowing metal users to buy and sell metal with confidence. This supports the industrial use of the PGMs: a company that wants to use PGM in its products does not need to physically handle the metal itself. It can buy metal from a supplier and 'send' it to a fabricator to manufacture its products without needing to deal with shipment, security, or verification, and remove delays between purchase and delivery.



Global PGM liquidity centres, allowing metal movement across the world

Movement in PGM demand

On the demand side, PGMs move across borders in a vast range of different parts and products and the metals may not appear explicitly in trade data. For example, automotive emissions control catalysts containing PGM may be produced in one region, shipped to another region for canning, then to another for fitment onto new vehicles, and then these vehicles can be exported to yet another region for sale; none of this will be captured as an obvious PGM movement in trade data.

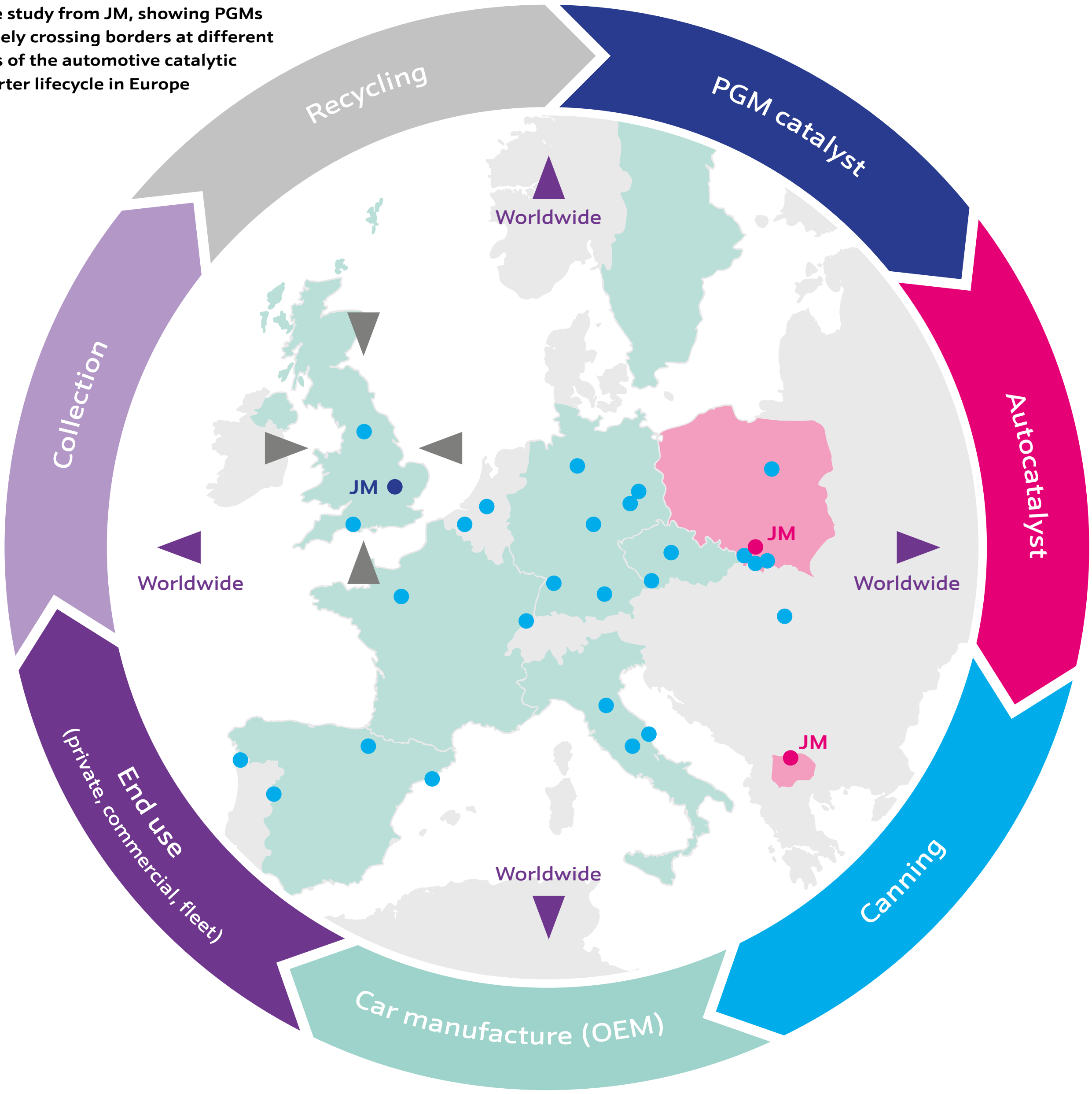
When it then comes to recycling PGM at the end of product life, additional cross-border movements routinely occur to allow effective recovery. Because these forms of spent metal are less easily monetised, they tend to move over conventional land and sea freight routes rather than by armoured carrier or flights. There are a wide variety of different forms of spent material, and over time the major recyclers have designed their processes to maximise efficiencies and economies of scale when handling different PGM materials, some of which may be hazardous or pose other handling or processing challenges. As a result, global recycling of PGMs is much more optimised and cost-effective than it would be if numerous recyclers were to process small volumes of all the different types of material within their domestic markets.

Once PGMs have been recycled, the secondary refiner (recycler) will often not buy or use the recovered metal itself, so it needs to be shipped again (in sponge or ingot form) to settle contracts, and this is once again facilitated by the hubs.

Outside the Western markets, trade and export barriers exist that restrict metal movement, which are particularly important to consider for countries such as China, India and Russia. For the rest of the world, however, cross-border movements of PGM ingot, sponge, product, and end-of-life material are a normal and an important part of the functioning PGM supply chains.

PGMs routinely move across borders, which is often unseen in trade data.

A case study from JM, showing PGMs routinely crossing borders at different stages of the automotive catalytic converter lifecycle in Europe



What are PGMs used for?

PGMs are used to make products that enhance our daily lives, but you may not even notice the breadth and scale with which they are needed. Platinum, palladium, rhodium, ruthenium and iridium have a unique combination of very useful properties that are unmatched by other materials, often making them irreplaceable in a multitude of applications.

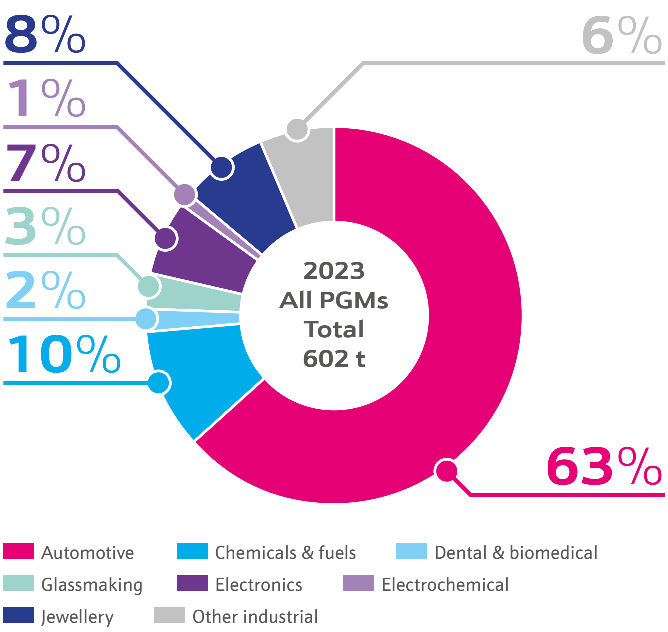
These include high thermal stability, corrosion and oxidation resistance, and the ability to catalyse a broad range of chemical reactions. This makes them indispensable in an almost endless list of processes; from removing pollutants from cars and turning petroleum into fuels and chemical feedstocks, through to synthesising life changing pharmaceuticals and making parts that connect phones to mobile data networks. They are also found in a diverse range of products such as hard disk drives in computers, airbags in cars or the jet engine in aeroplanes.

The PGMs are also critical and strategic metals for the future, given their broad range of applications in the energy transition. For example, they are essential in technologies for the hydrogen economy, as well as making and using sustainable fuels.

Apart from these and other industrial uses, discussed in more detail below, platinum and palladium in particular have also found favour in both the jewellery and investment markets. Platinum has for many years been marketed as a premium jewellery metal, rarer even than gold, while palladium is often used as an alloying element or 'whitener' in white gold.

The charts in this section show the net PGM demand (excluding investment demand) in each application, after accounting for closed-loop recycling – i.e. the inflow of 'new' metal into each use annually. Many applications have very substantial amounts of metal installed and in use, which circulates through closed-loop recycling, but that in-use metal is 'invisible' in net demand estimates.

Net demand for all five PGMs by application



Platinum

Platinum is used in a wide variety of applications. Currently, its largest applications are automotive emissions aftertreatment (catalytic converters), followed by jewellery, but it also has a diversity of other uses.

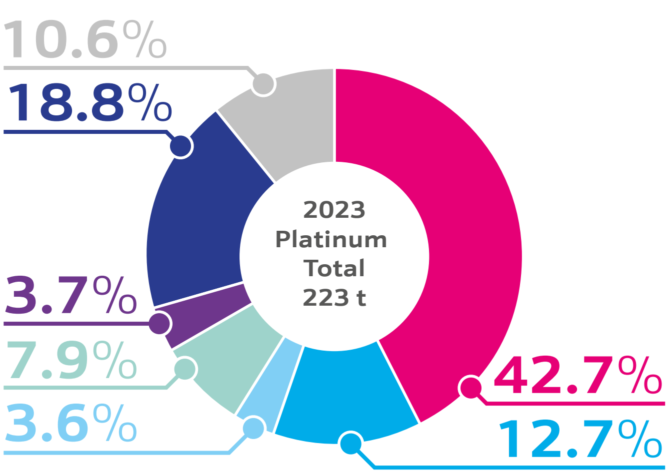
Diesel-fuelled vehicle exhausts and gasoline-fuelled vehicle exhausts contain different mixes of gases and pollutants. Both require PGM-based catalysts emissions control but with differing quantities of platinum, palladium and rhodium. Platinum is particularly important for controlling emissions from diesel-fuelled vehicles, whether cars, vans, trucks or buses, and there are no substitutes for platinum in this application (although palladium can be used as a partial substitute).

Platinum is used as a catalyst to produce fuels and chemicals, where again it is unrivalled in its ability to catalyse a number of processes that are central to our global economy. These range from reforming naphtha and creating high-octane gasoline blendstock and chemicals, to producing nitric acid for fertilisers and medical-grade silicones.

In medical applications, platinum is used in chemotherapy to treat a range of cancers, as well as being used as an alloy to make dental materials and biomedical devices such as stents and pacemakers.

In the glass industry, platinum-rhodium alloys are used to coat and protect glassmaking equipment against highly corrosive molten glass, particularly to produce fibreglass and high quality flat glass for TVs and phone screens.

Platinum is also essential for two major types of fuel cell technology: proton exchange membrane (PEM) fuel cells and phosphoric acid fuel cells (PAFC). PAFC have been used for decades for back-up power supply and are now being used in Korea to supply power to the grid. PEM is the only fuel cell technology suited to the demands of vehicle applications. As the world moves towards net zero carbon emissions, growth in fuel cell vehicles is expected to lead to significant platinum demand in this application.

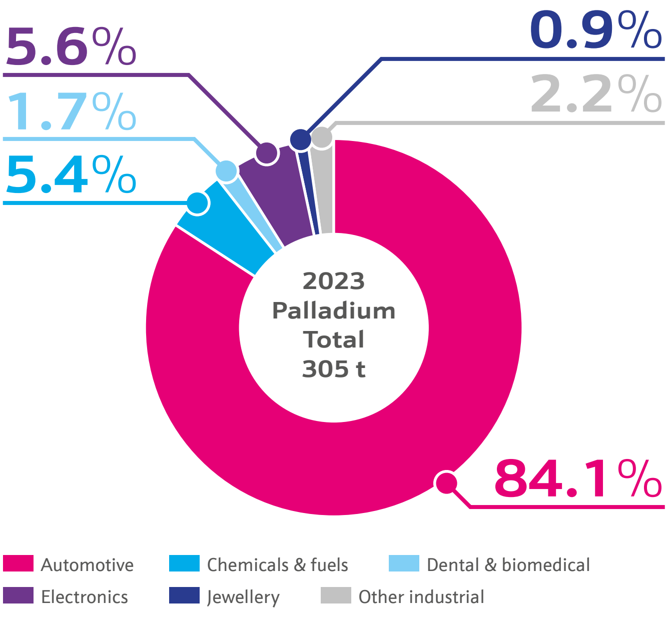


Automotive · Chemicals & fuels · Dental & biomedical · Glassmaking · Electronics · Jewellery · Other industrial

Palladium

In contrast to platinum, demand for palladium is heavily dominated by its use in automotive emissions control, and in palladium's case it is mainly used in gasoline-fuelled vehicles.

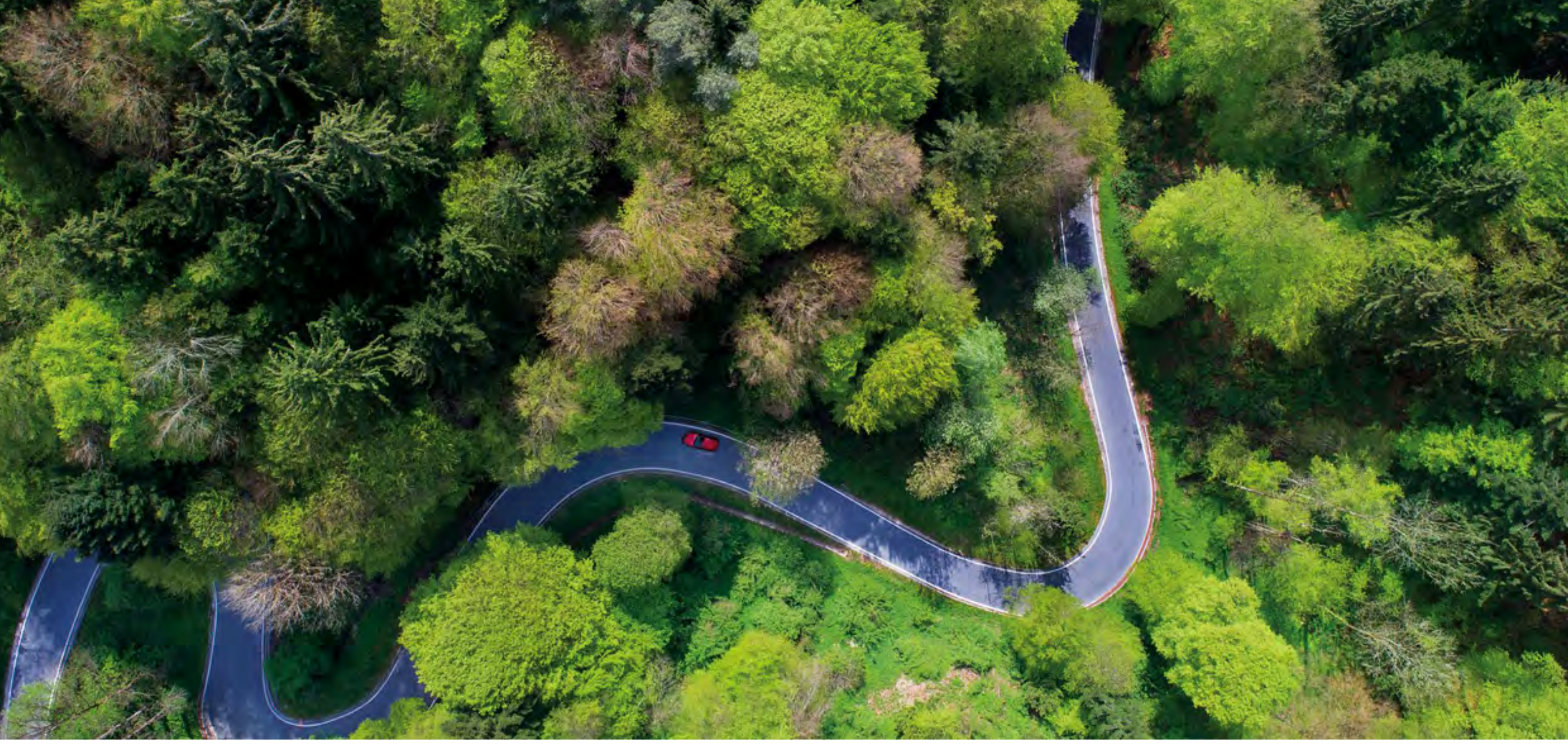
The only metal that can compete with palladium in gasoline vehicle catalytic converters is platinum, but palladium has been more widely used because it offers higher durability and had a lower price. Palladium has more recently been more expensive than platinum, so platinum is being increasingly used again in gasoline vehicles, although palladium remains favoured by a long history of development and optimisation for this application.



Palladium's use in the electronics industry is predominantly as a plating component for printed circuit boards (PCBs), lead frames and connectors, and as a paste product in components such as capacitors, actuators, resistors and thermistors. Over the past decades, palladium's use in chip components has declined substantially, instead using base metal alternatives such as nickel. Palladium, typically in combination with silver, is used mainly in medical, military and aerospace chip applications. In plating applications, it is prized for its excellent combination of conductivity, corrosion resistance and hardness (wear resistance) and is often used in combination with nickel and gold.

Palladium is a vital catalyst for the production of a variety of bulk and specialty chemicals, including several key intermediates for plastics manufacturing, hydrogen peroxide, nitric acid and a huge range of pharmaceutical compounds. In these processes it offers optimal activity, stability and selectivity, meaning it minimises unwanted by-products and makes best use of the raw starting materials, with the added benefit of being highly recyclable.

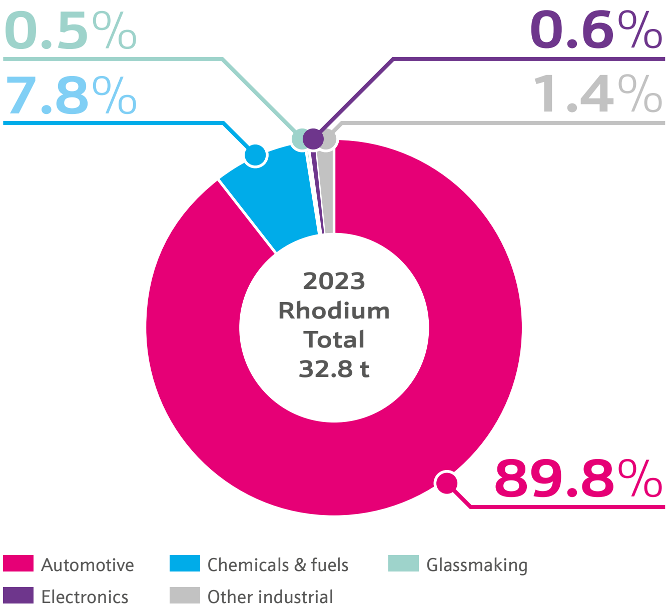
In other applications, palladium is used as an alloying component in white gold and platinum jewellery. It is also used for dental alloys, where its good solubility with other metals allows it to add strength by alloying, while its biocompatibility and tarnish/corrosion resistance make it suitable for use in the mouth. Palladium alloys are used in several dental reconstruction procedures such as crowns and bridges, although in recent years ceramic materials have taken share from palladium-based alloys in these applications.



Rhodium

As with palladium, by far the largest use of rhodium is in automotive emissions control. Rhodium's selectivity and activity for nitrogen oxides (NOx) abatement in gasoline-fuelled vehicles, and tolerance to poisons in the exhaust stream, is unrivalled by any other metal.

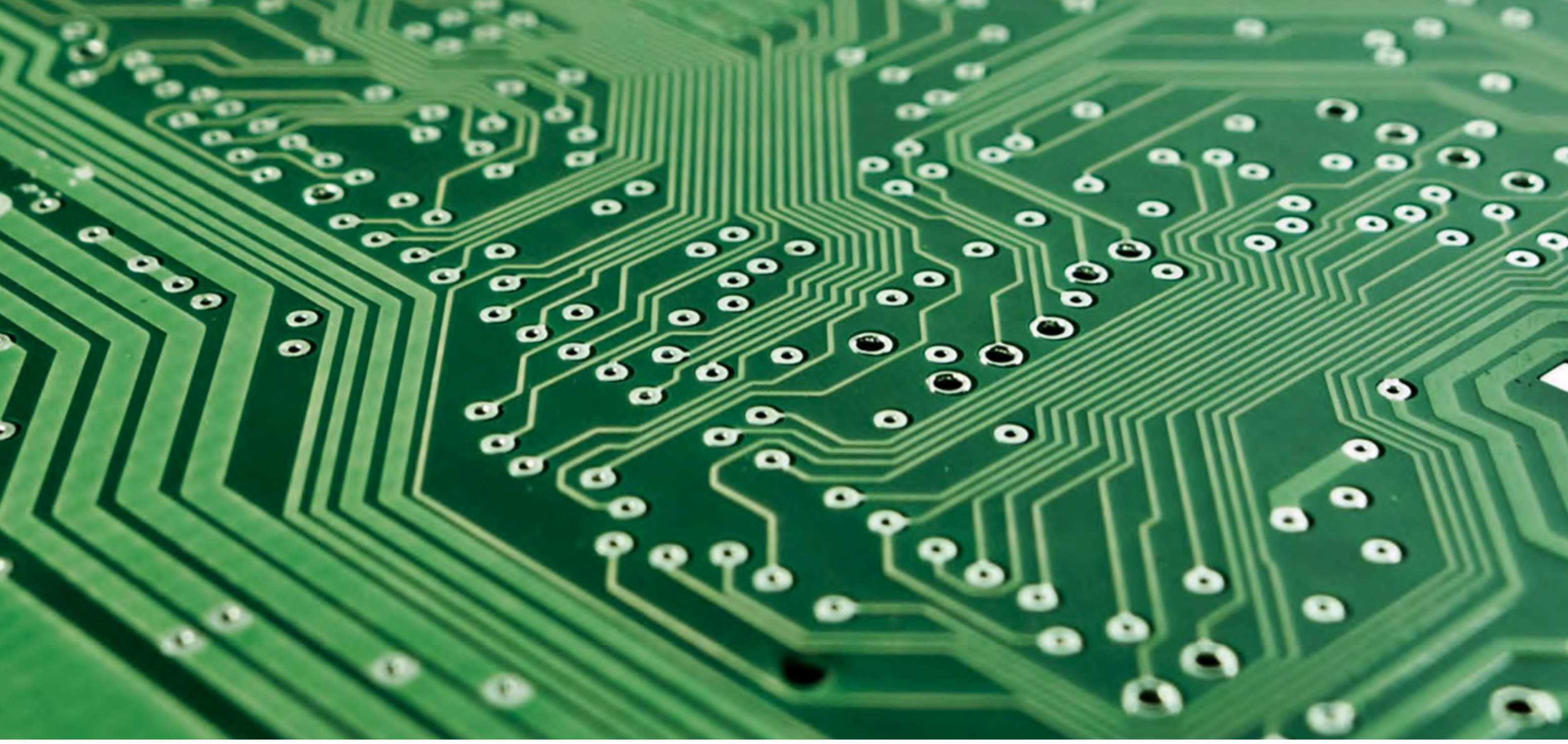
Palladium has some NOx abatement capability, but atom-for-atom is much less effective than rhodium. So every catalytic converter fitted to a gasoline vehicle that is subject to NOx emission limits must contain some rhodium. (Diesel vehicles typically do not require rhodium; the composition of diesel exhaust gas allows for other methods of controlling NOx).



Outside of the automotive industry, industrial rhodium demand is dominated by the chemical and glassmaking industries, with other applications relatively niche in comparison.

Because of rhodium's high melting point, it is used in platinum-rhodium alloys to increase durability in glassmaking. Alloys used in fibreglass manufacturing have traditionally contained between 10% and 20% rhodium; higher rhodium content allows the equipment to better withstand the extremely high temperatures involved in fibreglass production, allowing for longer lifetimes. However, at high rhodium prices it can make sense for glassmakers to reduce the rhodium content of their alloys, potentially even below 10%, and this has been seen recently.

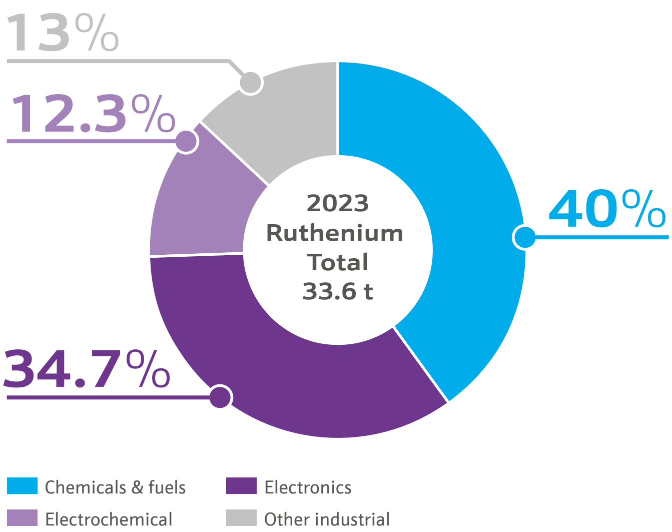
In the chemical industry, rhodium is mainly used as a catalyst to produce acetic acid (via the Monsanto process) and oxo-alcohol products. Acetic acid is a bulk commodity chemical used in numerous downstream products, while oxo-alcohols are often used as plasticisers – for example to increase the strength and rigidity of PVC.



Ruthenium

Ruthenium has no application in automotive emissions control; however, it has a range of unique properties that make it extremely useful industrially.

Its use as an underlayer (to the platinum-containing storage layer) in hard disk-based computer memory has allowed the data storage density of hard disk drives to greatly increase. The other key application for ruthenium in electronics is in resistor components, which are present in almost every electronic device as chip components, arrays and hybrid integrated circuits. Here, a ruthenium-oxide-based ceramic paste is used as the resistive element.



Ruthenium is widely used as a catalyst coating on electrodes in electrochemical reactions. Applications for this include chloro-alkali production, salt-water chlorination of swimming pools, and the electrochemical treatment of shipping ballast water to kill invasive species. While often used with iridium in electrolysis, ruthenium also has the potential to substitute iridium in some cases if its stability can be addressed.

In the chemical industry, ruthenium is used to produce acetic acid, treating industrial waste water through catalytic wet air oxidation, and as a catalyst in the Chinese caprolactam industry. Caprolactam is the starting material for nylon production, but outside of China the process typically uses alternative, non-PGM routes.

Ruthenium is also used in a range of alloys, including extremely hard tungsten carbide alloys used in the machine tool industry, and corrosion-resistant alloys for the oil, gas and chemicals industries.

There is increasing interest in ruthenium for energy-transition applications, particularly in the hydrogen economy.

Iridium

Similar to ruthenium, iridium finds application in a range of specialist industrial uses, where its unique high-temperature, strength and corrosion-resistance properties are critical.

Iridium is very useful electrochemically, often being used with ruthenium in electrodes for chloro-alkali production and ship ballast water treatment. In addition, it is used in anodes to form thin, uniform copper foils by electrodeposition; these foils are used in circuit boards and lithium-ion batteries in battery electric vehicles (BEVs).

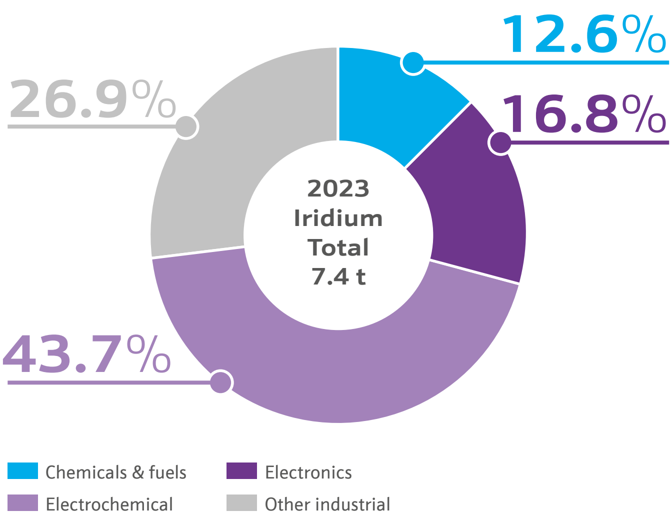
In another electrochemical application, demand is growing for electrolytic ('green') hydrogen production by proton exchange membrane (PEM) electrolysis of water. A PEM electrolyser cell is a harsh environment for materials and the only effective catalysts for the anode reactions under these conditions are PGMs, either iridium or ruthenium. Of the two, iridium is the most stable under high-voltage and commercial PEM electrolysers today rely on iridium, alongside platinum on the PEM cathode.

Electronics demand for iridium is dominated by iridium crucibles, used to produce single crystals of various metal oxides by 'crystal pulling' (the Czochralski process). Iridium is used only in the highest-temperature applications – for crystals that are produced at around 1,600˚C and higher. A major use of these crystals is in surface acoustic wave (SAW) filters for mobile phones and other wireless communication technology.

One of the fastest growing electronics applications in recent years has been the use of speciality iridium chemicals for organic light emitting diode (OLED) displays. OLEDs are made from materials that emit light when an electric current is applied to them and are very energy efficient.

Iridium is also widely used as an alloy material in the tips of premium spark plugs in gasoline-fuelled vehicles and in aerospace, giving much longer plug life and improving ignitability for better mileage compared to base metal tips.

Demand for iridium process catalysts for chemicals production is predominately in the Cativa acetic acid process, although iridium is also used in some speciality chemical reactions, particularly in the pharmaceutical industry.



Working with Johnson Matthey's supply and demand figures

Each May, Johnson Matthey (JM) publishes a PGM Market Report. It's free and publicly available, giving insight into the supply and demand developments in the PGM markets. This section gives more detail as to how we report the data in our report.

Supply

Primary supply: this is mined (primary) metal supply sold by the miners each year. Since this is sales, it can differ from underlying mined production in any given year; producers can sell PGM from existing inventory, counting as supply, or put it into stock. Supply is allocated to the region where the mining took place.

Secondary supply: open-loop recycling only – in other words, secondary metal supplied to the market each year. Closed-loop recycling is not included in our supply figures, as it does not provide new metal to the market. JM does not publish closed-loop recycling figures.

Combined primary and secondary supply: is the total supply, reflecting all of the metal placed on the market in the year. Because primary and secondary PGM have identical properties, it is not correct to only count primary supplies of PGM.

Demand

Net demand is the annual requirement for 'new' metal in each application, once closed-loop recycling has been subtracted. In other words, it is net of closed-loop recycling.

Gross demand includes metal returned to its owner in closed-loop recycling, which is reused on new products. So the total requirement for metal on these products is partially served by that closed loop. By keeping metal in use, closed-loop recycling therefore makes PGM use more sustainable and reduces the need for primary supply. But importantly to note, closed-loop recycling does not appear in reported figures, since it does not affect the balance of metal in the market.

Reported demand therefore refers to net demand, accounting for the physical inflow of metal to all automotive, jewellery and industrial applications. On occasion, some industrial users may sell some of their PGM inventory – this is captured as negative demand (not supply) in JM's numbers.

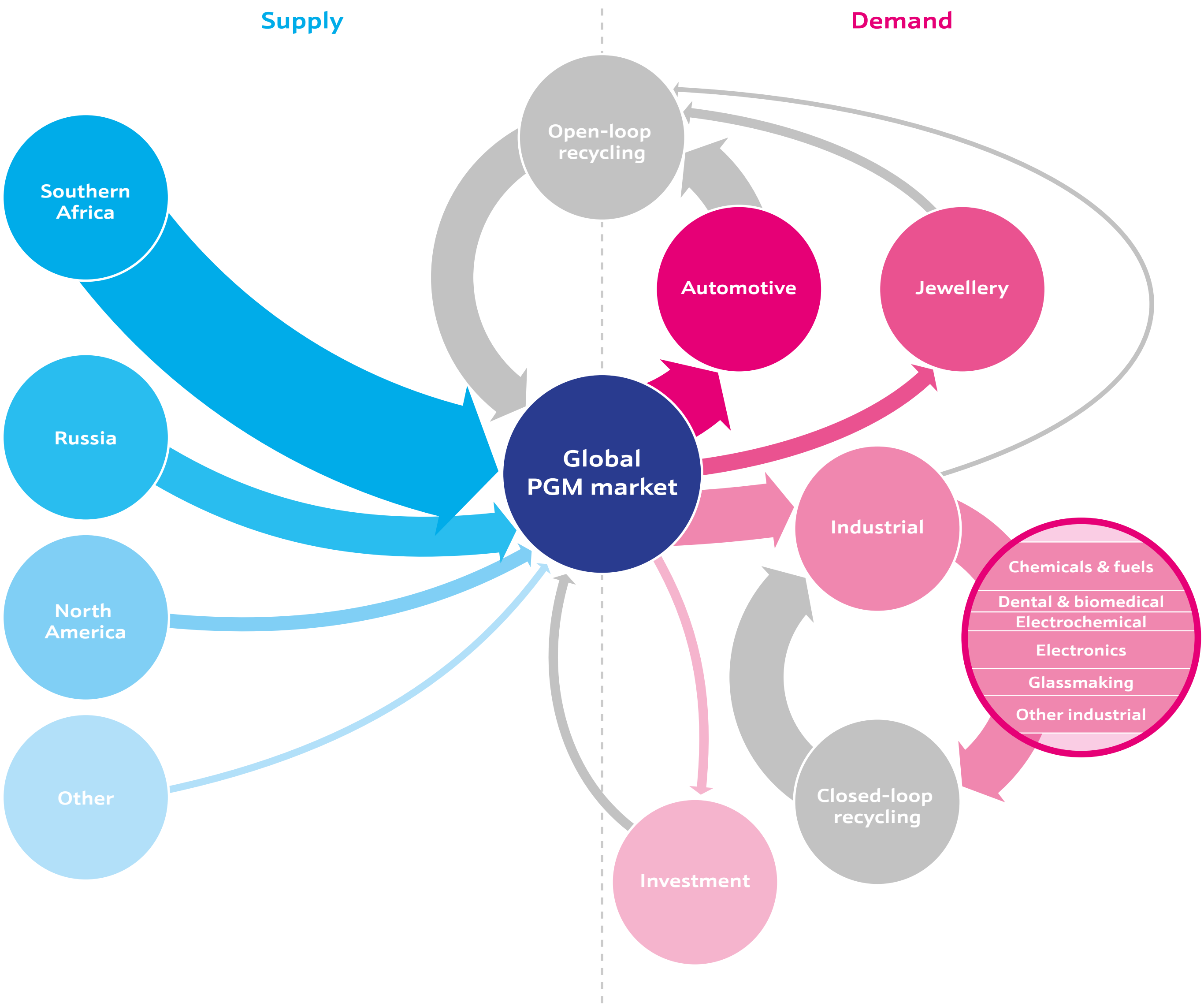
Demand also includes PGM investment in physically-backed and identifiable forms, predominantly exchange-traded funds (ETFs), which are backed by physical metal held in a vault, or platinum bars and coins. There are other ways to gain investment exposure to PGMs, particularly platinum, and these can have an impact on price. However, JM only counts measurable, physical investment flows in its numbers. Net investment in any year can be negative, reflecting a physical outflow from investment holdings back to the market.

Working with the figures in our tables:

Subtracting net demand from total supply gives the supply-demand balance, which indicates the extent of market stocks that must be mobilised to balance the market each year.

In any year where JM's numbers show excess supply (a surplus) this is assumed to reflect a flow into market stocks. Where there is a shortfall in supply (a deficit), this is assumed to reflect a draw-down of market stocks.

PGM ecosystem



For more information on PGMs and our market research, visit
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