JM

The PGM opportunity

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Special feature accompanying JM's 2024 PGM Market Report

PGMs: unique metals with unique advantages

Platinum group metals (PGMs) have unique properties that allow them to fulfill a critical role in a wide range of challenging applications. This is incentivising a renewed drive for innovation and market development to exploit the capabilities, mature supply chains and established circularity of these metals.

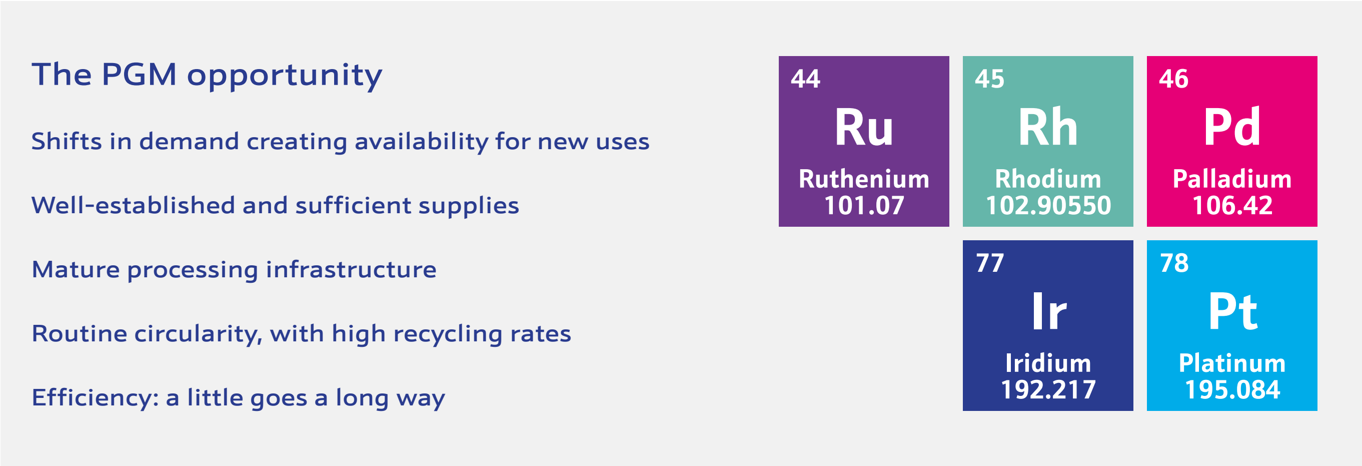
The space for market development is being created by the projected policy-driven decline in internal combustion engine (ICE) vehicle production. With this comes improved availability of platinum, palladium, and rhodium, coupled with a more favourable price for palladium and rhodium than seen in recent years. This gives an opportunity that is unique within ‘critical’ or ‘strategic’ materials: for other critical/strategic metals, such as the base metals used in lithium-ion batteries, demand through the energy transition is growing rapidly and supply shortfalls are likely.

As well as availability, the PGMs have highly developed supply chains and processing infrastructure, which continue to receive investment to improve efficiency and sustainability. Circularity is routine in PGM use, as is ‘metals efficiency’ – a concept that is likely to become more important in future. The PGMs tend to offer superior efficiency wherever they are used, with many PGM-enabled processes also characterised by low energy consumption and waste generation compared to alternatives.

To date, PGM use has always been driven by necessity. They are the only viable option in a number of technologies, because of their performance and durability in extreme environments. But they may now be increasingly chosen over other metals due to the range of relative advantages they offer (Figure 1):

- Good availability, with well-established and sufficient sources of supply.
- A normalising and stabilising price environment.
- Mature circularity, with high recycling rates.
- Ultralow intensity of use.

These characteristics are likely to prove indispensable in a future that is increasingly metals-driven – and one that is likely to be challenged by metal shortages.



The PGM opportunity

Shifts in demand creating availability for new uses

Well-established and sufficient supplies

Mature processing infrastructure

Routine circularity, with high recycling rates

Efficiency: a little goes a long way

Figure 1 The advantages of using PGMs

The critical metals challenge

Critical metal efficiency

'Critical materials' is a term used by policymakers for metals and other materials of economic importance and at risk of short supply or supply disruption. Often the alternative term 'strategic materials' is used to refer specifically to materials that are crucial for the future, used in energy transition, defence, or other key technologies.

What then is meant by 'critical metals efficiency'?

Energy efficiency is a well understood concept, particularly in the context of fossil fuels. Supply of fuel is finite, and consumption impacts the environment; therefore, we should use energy as efficiently as possible.

The same reasoning should be applied to the use of critical metals. Supply is finite and extraction has negative consequences for the environment; therefore, we should use them efficiently. Some energy transition technologies such as batteries are inefficient users of critical metals and require large quantities – they are 'metals intense'.

For the energy transition, critical metals efficiency is as important as energy efficiency. After all, the sun and wind are essentially infinite and non-polluting, but the metals we use to harness them are not and are facing a supply gap.

The dramatic transformation in the energy landscape needed for a carbon-neutral world presents a host of difficulties. It is becoming clear that the metals challenge is perhaps the most concerning of these, with the potential to delay or even derail the energy transition[1]. This arises because clean energy technologies, specifically batteries and electricity infrastructure, rely on intensive use of certain metals, including (but not limited to) copper, nickel and lithium[2].

The intense requirement and the rapid projected rise in demand of these metals will likely result in supply shortfalls, and this is widely acknowledged[3].

Attempts to address these shortfalls are already leading to a growing risk of serious environmental harm, for example with carbon-intensive nickel mining in Indonesia that leads to deforestation and pollution of waterways[4], and the consideration now being given to seafloor mining[5]. Geopolitical tensions add further complexity and risk[6].

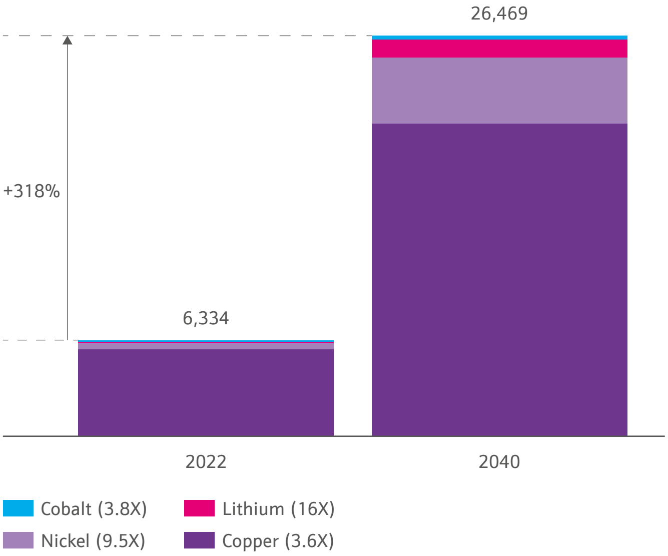


Figure 2a Projected clean technology demand growth by metal (kt)

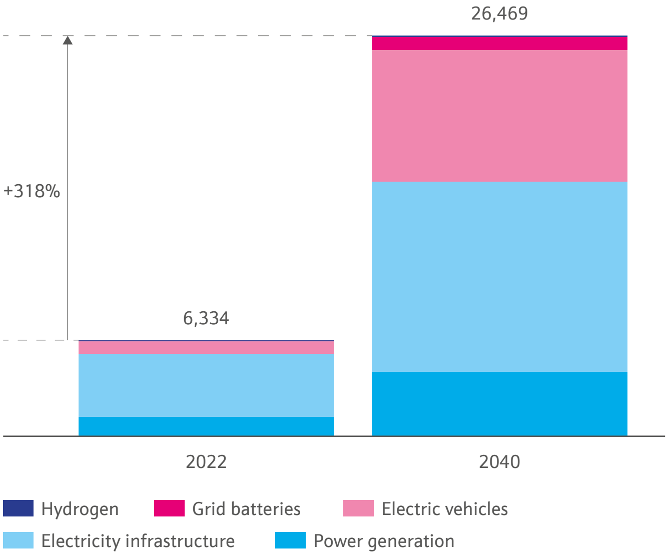


Figure 2b Projected clean technology demand growth by application (kt)

The PGM distinction

The PGM landscape stands in contrast to this. While the PGMs are often included as 'critical metals', this can obscure the fact that they do not face the same challenges, with different and less pressurised supply-demand dynamics.

Demand shifts to new areas

To a large extent, use of these metals in new technologies is replacement demand for older markets (see Figure 9). In some cases, this replacement is a natural transition, such as platinum use in ICE vehicles being replaced by platinum use in fuel cell electric vehicles (FCEVs).

In other cases, such as iridium in electrolytic hydrogen production, growing use in one area will be accommodated by price-driven shifts in other applications. These will include partial substitution by other materials (in the case of iridium, probably by platinum or ruthenium), greater efficiency of use (thrifting), or improved recycling rates – or some combination of the three.

Although adaptations are required, new applications of the PGMs and new users can therefore take advantage of existing supply chains and infrastructure that already serve the global market for these metals.

Supplies remain consistent

Sources of PGM supply are well established and sufficient for the future.

On the primary supply side, where South Africa is dominant, the economic and social importance of PGM mining to that country mean it is well integrated into the international PGM network. PGM production and sales contributed 1.6% to South Africa's GDP in 2023 (compared to 2.5% for the entire agricultural sector) and accounted for almost 10% of the overall value of South African merchandise exports[7]. PGM mining in South Africa also has a relatively benign environmental, social and governance (ESG) profile and widespread adherence to responsible sourcing programmes[8].

The vastness and PGM richness of the Bushveld Igneous Complex (BIC) in South Africa is such[9] that attempts to secure PGMs from 'unconventional' sources, such as the seabed and even asteroids, are neither necessary nor likely to prove competitive. Mining of the BIC will continue to produce the full suite or 'basket' of PGMs, predominantly stimulated by platinum demand in energy transition technologies such as fuel cells, but ensuring continued extraction of palladium, rhodium, ruthenium, and iridium along with it.

Secondary (recycled) supply of platinum, palladium, and rhodium is tapping an 'urban mine' of these metals currently in use on catalytic converters, largely within the Global North. This will be available for decades: even if sales of ICE vehicles cease, as is expected for Europe in 2035, the lifetime of vehicles coupled with the present robust use of PGMs in auto catalysts (Figure 3) mean that secondary PGM supply from this source will persist into the long term.

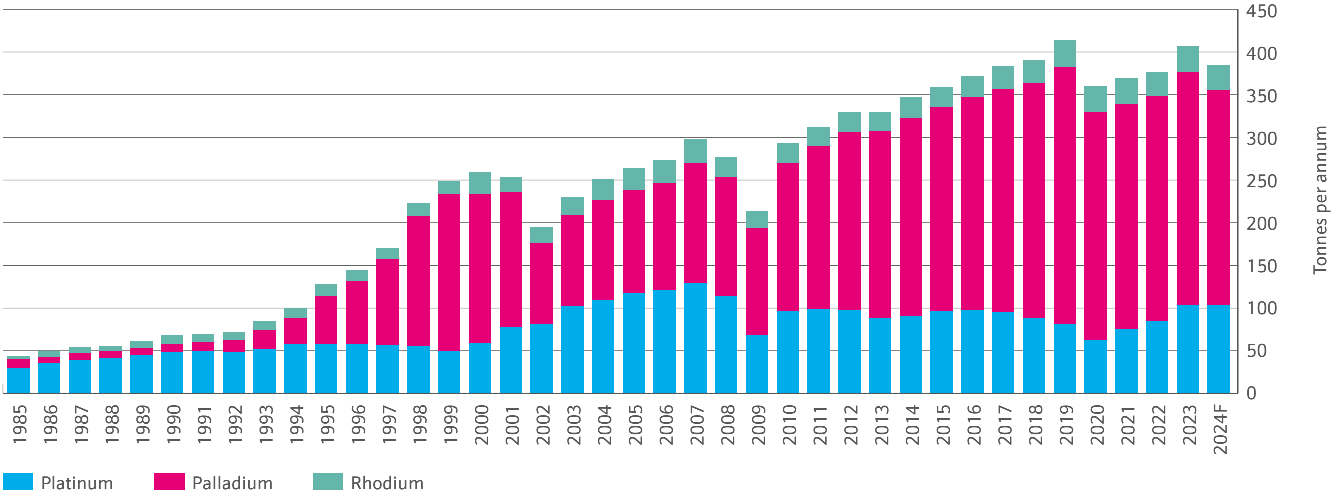


Figure 3 PGM used on auto catalysts since 1985 (Source: JM PGM Market Research)

Circularity is routine

Aside from catalytic converters, other above-ground PGM sources exist. Most of these are circulating through closed-loop recycling, returning the metals to their owner. This is not included in reported recycling figures, but is routine for all PGMs, including iridium and ruthenium.

Effective PGM recovery and recycling from novel materials such as catalyst coated membranes (CCMs) in PEM electrolysers and fuel cells takes place today within existing processes. But PGM refiners innovate to optimise recycling of a particular type of material whenever volumes are expected to be significant, as demonstrated recently through technology development to recover not just the PGMs but also the valuable membrane material (ionomer) from CCMs[10].

New PGM users will therefore discover that circularity is a given, as long as they can ensure that end-of-life material reaches an appropriate secondary refiner.

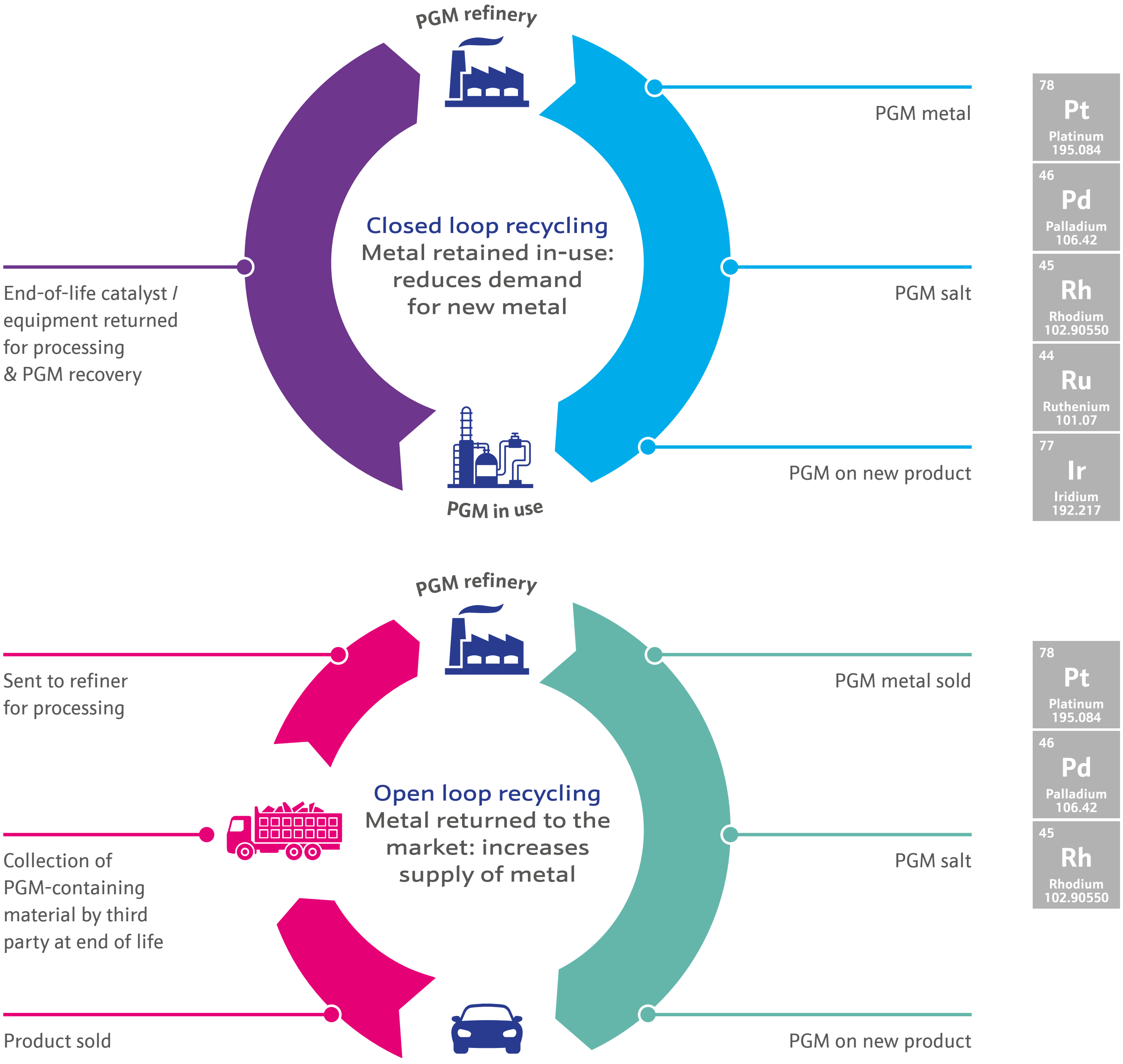


Figure 4 Routine PGM recycling in the two different recycling loops (currently there is little open-loop recycling of iridium and ruthenium)

Low intensity, high efficiency

Conventional thinking for decades has prioritised using 'earth-abundant' transition metals rather than 'rare' metals wherever possible. Such thinking is now challenged by the supply stress that will be created in a number of 'earth-abundant' metals by the sheer scale of energy transition demand, while the PGMs benefit from the more favourable supply-demand dynamics outlined.

The fundamental flaw in focusing on geological abundance is that it neglects the relative intensity of use. The quantity of PGM needed to enable a technology is typically small compared to other metals, and they have always been used as sparingly and as efficiently as possible.

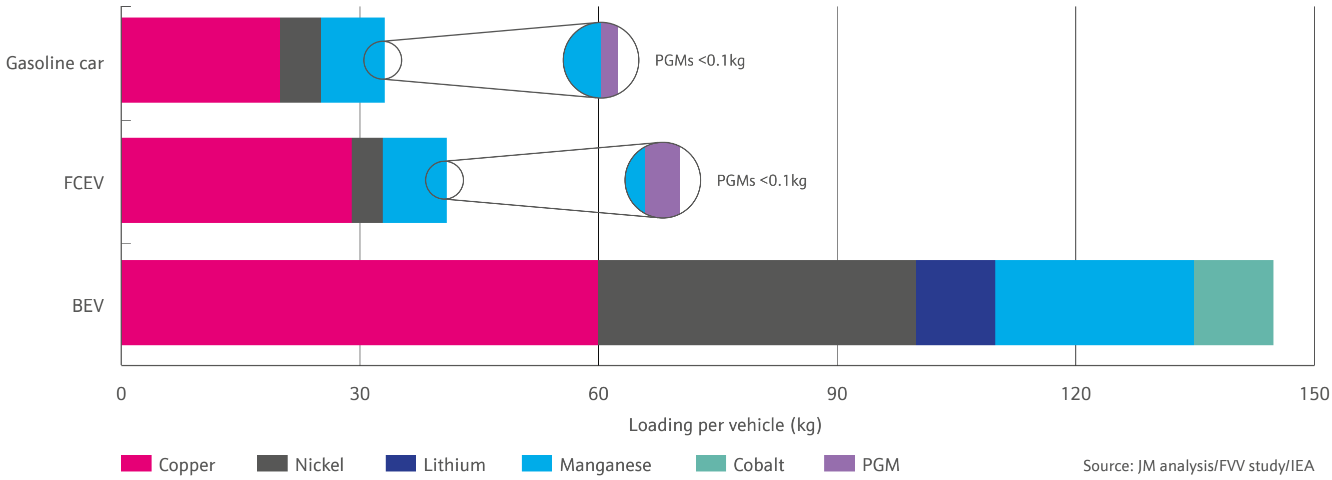
Straightforward comparisons can be made within process catalysis. For example, many processes that are catalysed by nickel can also be catalysed by palladium, but the amount of palladium needed on the catalyst is usually an order of magnitude smaller.

The difference in total quantity required grows with time, because catalysts installed within process plants must be periodically refreshed. Spent nickel catalyst may be sent for recycling but frequently ends up in landfill if that is not economic; if it is recycled, quite often the recovered nickel cannot be reused in fresh catalyst and is only suitable for a lower-specification duty.

Such a situation would not arise for a palladium catalyst, which is widely recycled, producing 'secondary' metal that has the same properties as 'primary' or 'virgin' palladium. For the catalyst owner, this means that palladium purchased upfront will serve multiple catalyst replacements, whereas the nickel may have to be repurchased in full for every catalyst replacement.

This difference in metal efficiency and recyclability is expected to drive more uptake of palladium at nickel's expense. An example of this is being seen today in treatment of pyrolysis gasoline, a low-value byproduct of ethylene production which must be processed to higher-value products. The first step of the process can use either a nickel or a palladium catalyst, but nickel has been historically favoured due to cost. The recent drop in palladium's price is starting to favour it, helped by the fact that nickel pyrolysis catalyst is not recycled, but the palladium catalyst will be – and at efficiencies approaching 100%.

The example of a medium passenger car shown in Figure 5 also illustrates the low intensity of PGM use. Making a zero-emissions battery electric vehicle (BEV) requires well over 100 kg of critical metals, while only 20 grams of platinum is needed for a FCEV (with around 40 kg of critical metals, although this depends on the size of the hybrid battery in the FCEV) – and ongoing development is seeking to further reduce that platinum loading.



Source: JM analysis/FVV study/IEA

Figure 5 Typical powertrain critical metal content per medium passenger car, kg/vehicle

Not all metals are created equal

As illustrated, a gram-for-gram comparison of PGMs and base metals such as nickel is unlikely to be meaningful. It is widely accepted that the PGMs are 'expensive', and certainly a gram of PGM will always cost much more than a gram of base metal, even if palladium prices were to fall much further (and the price of nickel were to rise, as is probable).

But the ultralow intensity (i.e., high efficiency) of PGM use means that this price difference does not translate through to cost of equipment. Using the vehicle example in Figure 5, the cost of platinum on the FCEV is about $600; the total cost of critical metals in the powertrain, including the platinum, is around $1,000. By comparison, the total cost of critical metals in the BEV powertrain is well over $2,000, even though the battery doesn't use 'expensive' PGMs.

The total cost of ownership of PGM reduces over time (and any initial price premium compared to base metal may be eliminated) if it is retained in a closed loop, as per the process catalyst example.

The same principle applies when considering the global warming potential (GWP, i.e. 'carbon footprint'), specifically for primary PGMs[11], which is assessed per unit of weight. The relatively small quantities used, and the fact that they can be recycled indefinitely, are important factors when assessing the true impact of PGMs on equipment carbon footprint.

Small size, big impact

There is nothing new here: even being relatively rare and high value, PGMs have delivered substantial industrial impact through most of the 20th century – not least in automotive emissions control.

Over 300 million ounces (~10,000 tonnes) of PGM have been used on auto catalysts since their inception 50 years ago, preventing the release of untold quantities of pollutants and providing cleaner air for billions of people. Catalytic converters containing PGMs are now fitted to virtually all vehicles produced globally.

The 21st century should see just as impactful use of the PGMs in new technologies.

New markets for the PGMs

Much of this future potential is still nascent, but an overview of some key areas of the energy transition illustrates the enabling role of PGMs.

Clean hydrogen

Clean hydrogen is produced either by splitting water through electrolysis, or by converting methane from fossil fuels and capturing the by-product carbon dioxide. That hydrogen has many end-uses across transportation, industry, and power generation. It does not need to be used directly but can instead be converted to ammonia or other fuels and chemicals.

Proton exchange membrane (PEM) technology relies on PGM catalysts: platinum for PEM fuel cells, platinum, iridium and increasingly ruthenium in PEM electrolysers. Platinum is also used as an anti-corrosion plating on PEM electrolyser components, providing a conductive surface to carry electricity.

PGMs are also used in other fuel cell and electrolyser technologies. For example, older liquid alkaline electrolyser technology may use PGM for performance benefits, and newer anion exchange membrane (AEM) electrolyser technology uses a platinum catalyst.

On the fuel cell side, platinum is necessary for phosphoric acid fuel cells, a mature, durable and reliable technology that has been used for power generation in South Korea, for example[12]. Solid oxide fuel cells (SOFCs) may not require PGMs in the cells themselves but are usually fed from the natural gas grid and PGM catalysts, notably rhodium but also palladium and platinum, are used to process and clean up the fuel. SOFCs are seeing substantial uptake for distributed power applications.

The use of 'hydrogen carriers' – where hydrogen is turned into a different form to make it easier to handle and transport – also creates PGM demand. PGMs (mainly platinum but also ruthenium) frequently catalyse the processes that 'load' and 'unload' hydrogen from liquid organic hydrogen carriers, and ruthenium can be used in both the synthesis of ammonia (from hydrogen and nitrogen) and its decomposition ('cracking') back to hydrogen, although it competes with base metals in these processes.

Before it can be used, hydrogen often needs to be purified. Depending on the setting, this can be done using a platinum catalyst or by filtration through a palladium membrane. Palladium has the unique capacity to selectively adsorb hydrogen, also making it useful in wire form to be used in hydrogen sensing applications.

PGMs – all five of them – are thus enabling the emerging hydrogen economy and supporting the transition to net zero.

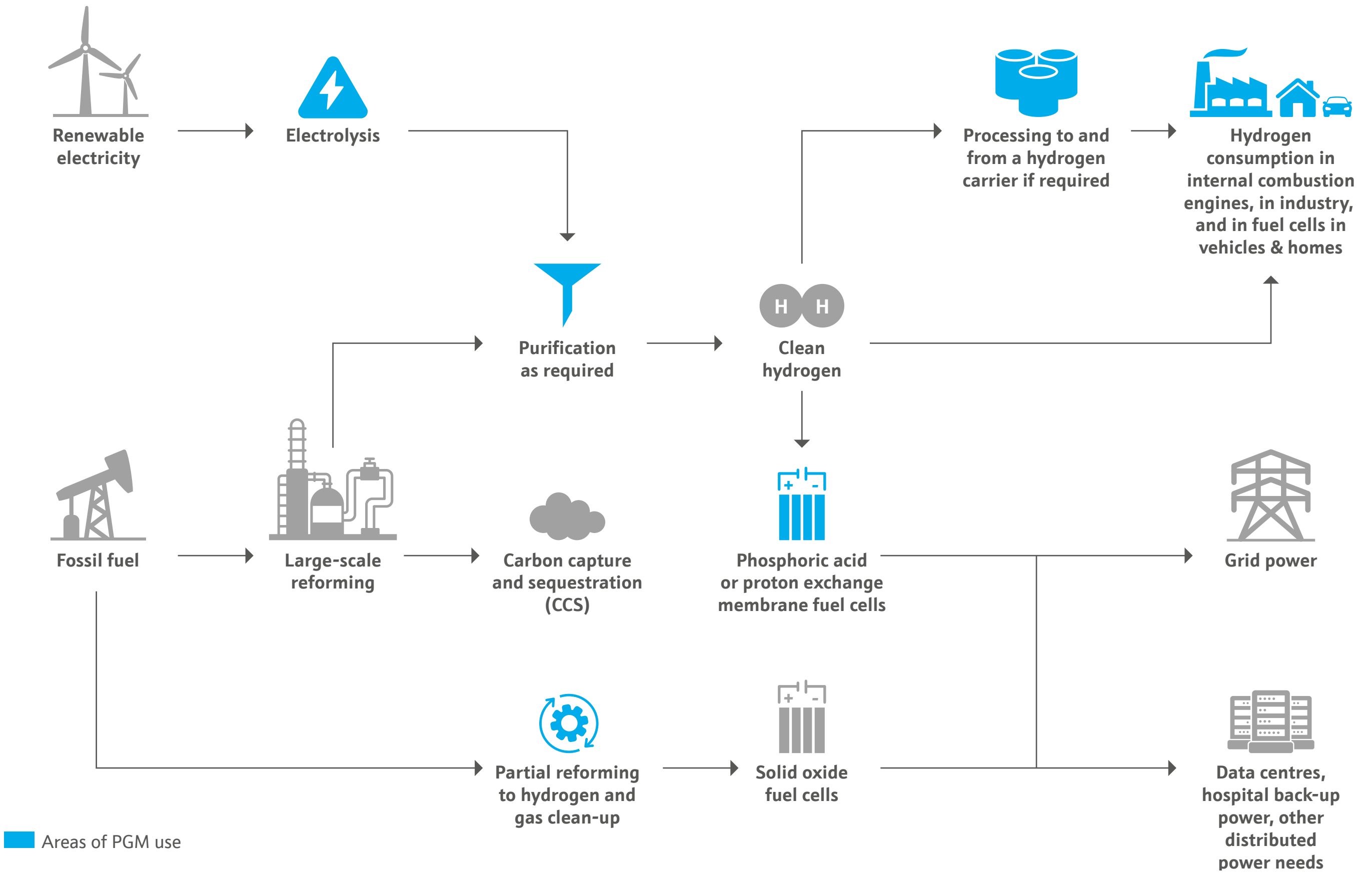


Figure 6 PGM use in the hydrogen ecosystem

Sustainable aviation

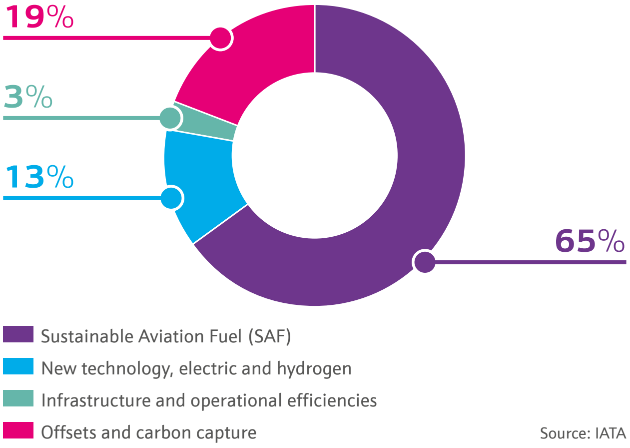
Aviation accounts for 3% of global energy consumption today and this is set to grow. The pathway to net zero for the industry requires different technologies and many of these will need PGMs.

Experimental flights with hydrogen used either in jet engines or in fuel cells are underway and, in the longer term, hydrogen could potentially play a significant role in decarbonising regional or shorter-haul flights.

Long-range flights in large aircraft require a different solution. For these, the industry is working to replace the fossil jet fuel (kerosene) with an alternative that can be used in the same engine. But rather than being derived from crude oil, it instead comes from biomass or is created by combining clean hydrogen with carbon dioxide (CO_2) captured from the air.

This replacement fuel is known as sustainable aviation fuel (SAF), but there are many different forms of SAF and many different processes to make it. This is mostly because no single feedstock is abundant enough to produce the vast quantities of SAF needed, and therefore a combination of diverse feedstocks is needed.

Platinum catalysts are used to produce the most mature form of SAF on the market from vegetable oil (known as HEFA, hydrotreated esters and fatty acids, or hydrotreated vegetable oil, HVO). Demand for this will grow but is ultimately supply limited, with only so much waste vegetable oil available.



Source: IATA

Figure 7 The net zero pathway for aviation outlined by the International Air Transport Association (IATA)

PGM catalysts are also needed in several other processes to make SAF from biomass and waste feedstocks. Together these alternative pathways to SAF could play substantial roles among the patchwork of technologies needed to meet international targets.

Another form of SAF is created by combining carbon from captured CO_2 and clean hydrogen in a process known as Fischer-Tropsch synthesis. If the clean hydrogen is made using electrolysis, then PGMs are used within the electrolysis equipment, and it is likely they will also be used in subsequent purification and processing.

As such, PGMs are relevant across the SAF spectrum.

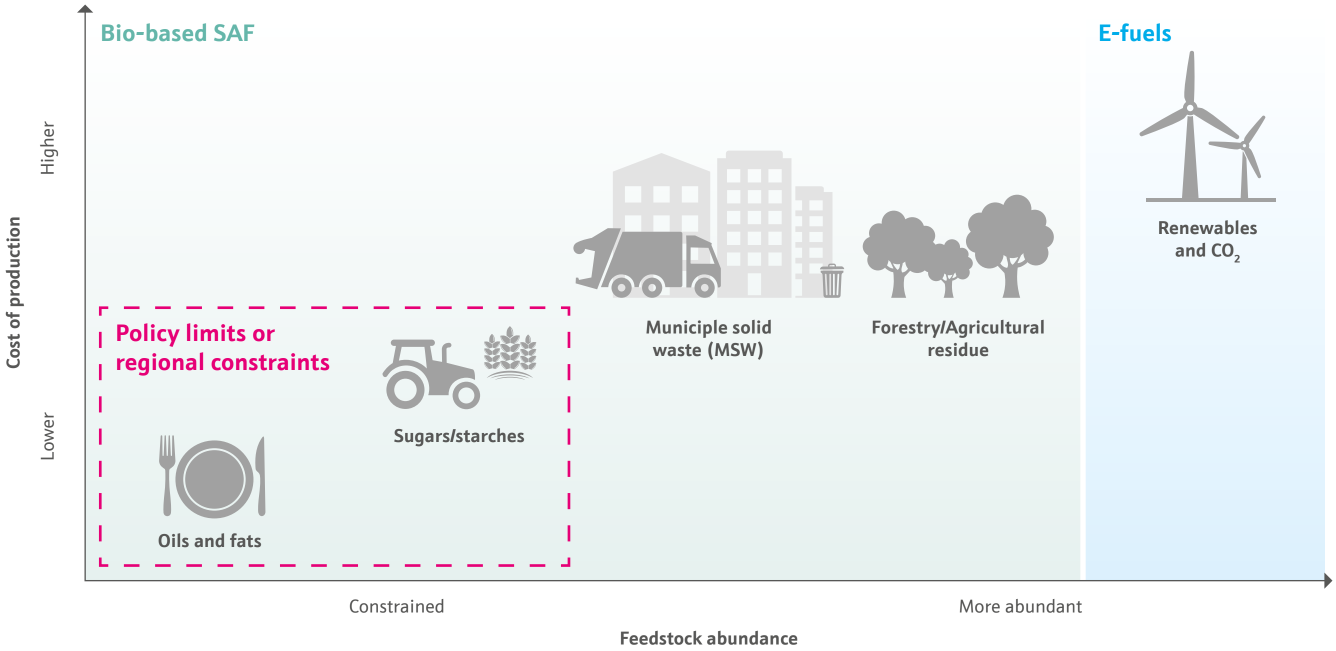


Figure 8 The spectrum of sustainable aviation fuel (SAF) types

Chemicals and materials from biomass

As with aviation fuel, most of the chemicals and textiles in industrial civilisation are derived from fossil fuels. The hydrocarbon chemical building blocks these depend on are still needed, so these industries have the long-term goal of using carbon in a way that does not add CO_2 to the atmosphere.

And here too the catalytic power of the PGMs is proving necessary. For example, platinum-gold, platinum-palladium or platinum-rhodium catalysts are used to modify biomass-derived feedstocks so they can be used in the same way as petrochemical feedstocks. In another example, a platinum process catalyst converts sugars and other biomass into the building blocks for polymers, used to make plastics such as polyester.

PGM process catalysts are used throughout the petrochemical industry today and will be just as necessary in what could be called the future 'bio-chemical industry' too.

Circularity (recycling) must also be implemented in the use of materials such as plastics to reduce waste, and PGM catalysts are seeing interest for processes needed to enable this circularity.

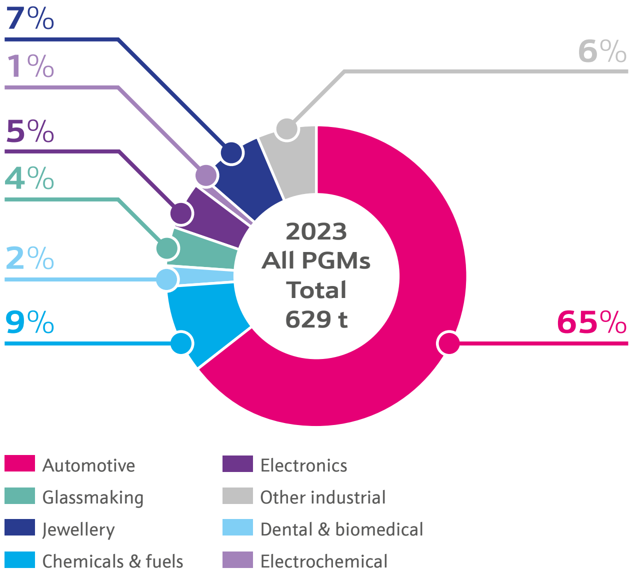


Figure 9 Current net demand for the five PGMs by application (excluding investment)

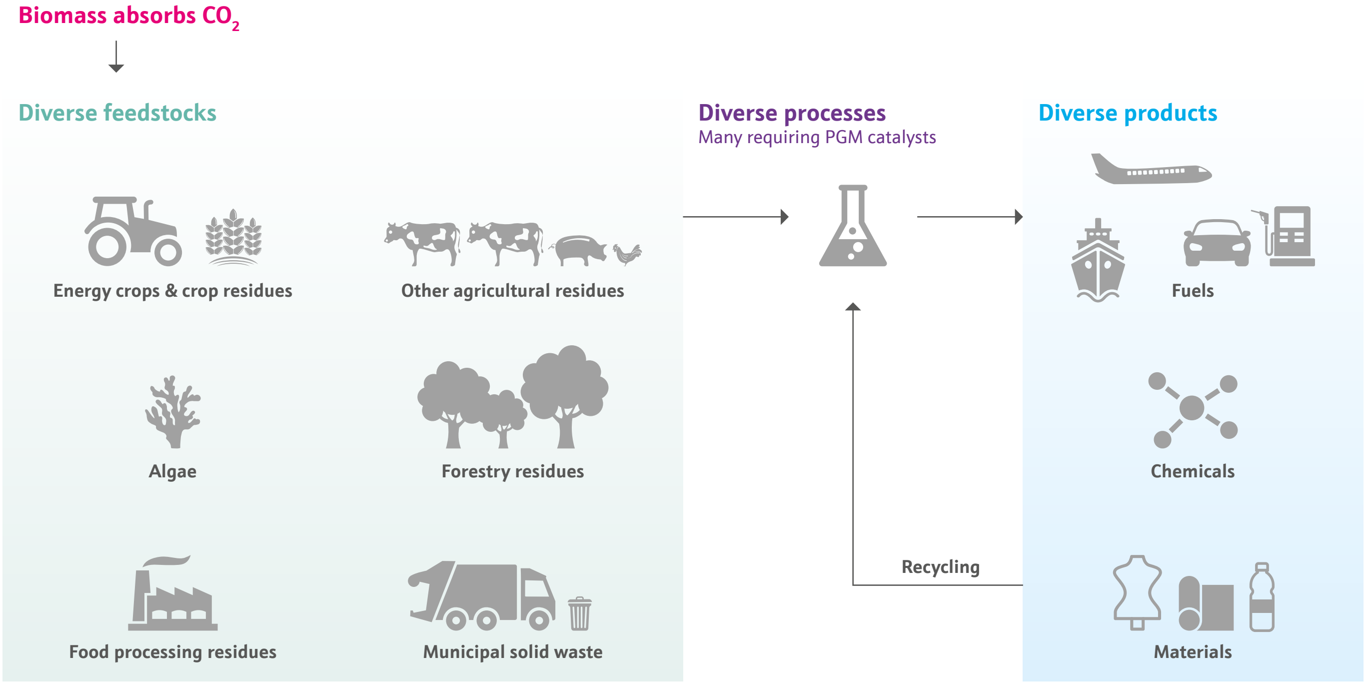


Figure 10 In future, more chemicals and materials will be made from biomass instead of crude oil, and there will be more recycling

PGM-enabled resilience

The PGMs present a valuable opportunity for innovation. Their unique characteristics have always been prized but are now more important – and more accessible – than ever.

It is therefore important that the PGM landscape is truly understood, not least the growing availability of platinum, palladium, and rhodium as the catalytic converter market declines in future. Recent price highs in palladium and rhodium disincentivised R&D in these two metals, but their normalising price environment is removing that constraint.

This should prove a welcome opportunity to innovators looking to exploit their properties. It is also an opportunity for collaboration: the PGM industry has a long history of partnering and supporting PGM market development, and such partnerships should once again prove fruitful in unlocking the potential here.

To mitigate concerns around cost and sourcing, reassurance can be taken from the established nature of PGM supplies and recycling, the maturity of responsible sourcing in the industry, plus the high efficiency with which the metals are used.

The full significance of PGMs to the energy transition is becoming clear, particularly as risks grow of short supply in other critical metals, notably those needed for batteries and electricity infrastructure[1]. Employing clean hydrogen and sustainable bioenergy and harnessing the PGMs to enable these will be crucial for resilient net-zero strategies.

Equally, PGM-based technologies will be needed to address global challenges in environmental stewardship, healthcare provision, and to advance technology in an effective, sustainable way.

The PGMs are ready to help create a resilient, metals-driven future.

Endnotes

1. Why critical metals efficiency is essential for the clean energy transition (https://matthey.com/documents/161599/3147297/JM_Critical_Metals_Efficiency_Whitepaper_v1.pdf/2e5747ae-4acf-771b-fc56-c31db82a3e2f?t=1710172629356)
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5. What We Know About Deep-sea Mining and What We Don't | World Resources Institute (wri.org)
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