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Platinum: a sustainable solution for the energy transition

Summary

With an increasing focus on the materials requirements of the energy transition, this paper examines platinum as a critical material for fuel cell vehicles (FCEVs) and other technologies, such as fuel cell stationary power systems and electrolytic hydrogen generation, used in the hydrogen economy.

Platinum is a well-supplied metal, with a regulated and resilient mining base and a highly effective recycling network already in place. We review platinum's current applications to show that FCEVs and hydrogen applications will act as natural replacement for older, declining markets with the phase-out of fossil fuels. While other energy transition metals such as lithium and copper face a widening and concerning supply-demand gap, the dynamics of the platinum market support mass production of FCEVs within its existing supply base.

If demand for FCEVs and other energy transition applications grows to outstrip current platinum supplies, it benefits from substantial above-ground stocks that have accumulated over decades and can supplement availability. Once these stocks are absorbed, platinum mining could be expanded with relative geological and operational ease, given sufficient investment.

Even if its price increases, the low – and falling – intensity of platinum use means that it is unlikely to negatively impact the viability of FCEVs and other platinum-using technologies. In fact, its value drives recycling and circularity, as is typical for the platinum group metals (PGMs), and its cost should be viewed by its users as an investment rather than an expense.

The mineral efficiency with which renewable electricity is generated and used does not receive enough attention – a significant oversight in a mineral-constrained world. Much commentary on the 'competition' between BEVs and FCEVs focuses on energy efficiency. But this misses the crucial benefit that PGM-catalysed PEM technologies have to offer: their relatively low mineral intensity. With these two technologies in the mix, we can more easily navigate the transition to a net-zero world within our finite mineral resources.

Platinum therefore presents a valuable opportunity for the energy transition, which must be seized. With unique insight into the PGMs, Johnson Matthey describes the benefits of platinum to support its uptake and address concerns its stakeholders might have. Our aim is to ensure that this opportunity is fully exploited to help decarbonise global energy use.

Introduction

As the energy transition accelerates away from fossil-fuels and towards renewable energy, there will be an unprecedented demand for many metals and materials. Several of these are classed as critical raw materials, and they are now receiving increasing attention. At the moment, concerns are primarily focused on battery vehicles and their metal requirements:

- Can metal supply be scaled up sufficiently?
- Can circularity be established so the metals can be recycled into new products?
- Can the metals be extracted and processed in a safe, sustainable, and ethical way?

Regulators across the world now recognise how crucial clean hydrogen will be for the energy transition, particularly for sectors that are more difficult to decarbonise such as heavy goods vehicles, steelmaking and other heavy industries, shipping, and aviation. Hydrogen will power these sectors through fuel cells and gas turbines, while also being a feedstock to make other sustainable fuels. So the same questions must be addressed for the metals needed to enable this fast-growing hydrogen economy.

Platinum is one of these critical materials and is essential to the technology that produces clean hydrogen through proton exchange membrane (PEM) electrolysers, and the PEM technology used in fuel cell electric vehicles (FCEVs). Therefore, specifically for platinum, concerns about whether there will be enough metal available to enable scale in these technologies need to be addressed, along with how circularity of PGMs works, the potential cost, and environmental, sustainability and governance (ESG) implications.

Johnson Matthey is at the intersection of platinum group metals and hydrogen technologies, so we're in a unique position to address these questions. Our expertise in PGMs integrates leading PGM market knowledge, securing metal supply sustainably, recycling (as the world's largest secondary PGM refiner by volume), and manufacturing a broad range of PGM products. With almost 30 years of experience developing fuel cell technology, we're established in catalyst-coated membranes (CCMs) for PEM fuel cells and PEM electrolysers, and have a unique position in the value chain to develop both the catalyst layers and membrane and optimise the way these systems work together. With our continual R&D investment, we're at the forefront of these technologies.

Where is platinum used in technologies for hydrogen production and consumption?

At the centre of PEM electrolysers and fuel cells are membranes that require catalysts on both the cathode and the anode sides. Only with these catalysts can the electrochemical reactions occur; in electrolysers they split water into hydrogen and oxygen, and in fuel cells they combine hydrogen and oxygen to produce power, with water and heat being formed as by-products.

PEM electrolyser and fuel cell stacks, consisting of hundreds of catalyst coated membranes (CCMs), are harsh acidic and oxidising environments, requiring catalysts that can withstand the conditions and deliver sustained high performance over the stack lifetime. PGMs (platinum and iridium) are irreplaceable in these technologies, thanks to their unique combination of catalytic activity and durability.

Either side of the membrane electrode assembly (MEA) are two bipolar plates, which transport water, hydrogen and oxygen to and from the membrane, as well as conducting electricity and circulating coolants. Platinum plating is vital to protect the MEA against the acidic conditions; this minimises contact resistance by preventing oxidation of the bipolar plates and porous transport layers, ultimately reducing degradation whilst maintaining conductivity.

When assembled into the stack, separator plates sit in between each MEA to carry the electricity flow. These need a conductive surface, for which platinum and gold are typically used, again using the stability and conductivity of these precious metals.

Most of the hydrogen and fuel cell markets are still nascent and can often use a mix of technologies, so projections of how much platinum they will use is uncertain. Our current forecasts indicate that platinum consumption in FCEVs (which rely on PEM fuel cells) will far outweigh combined demand from renewable electrolytic (green) hydrogen and fuel cells in applications other than road vehicles. But these applications are still likely to be material, accounting for around 20–30% of platinum consumption in hydrogen applications by the mid-2030s (the remaining 70-80% being used in FCEVs).

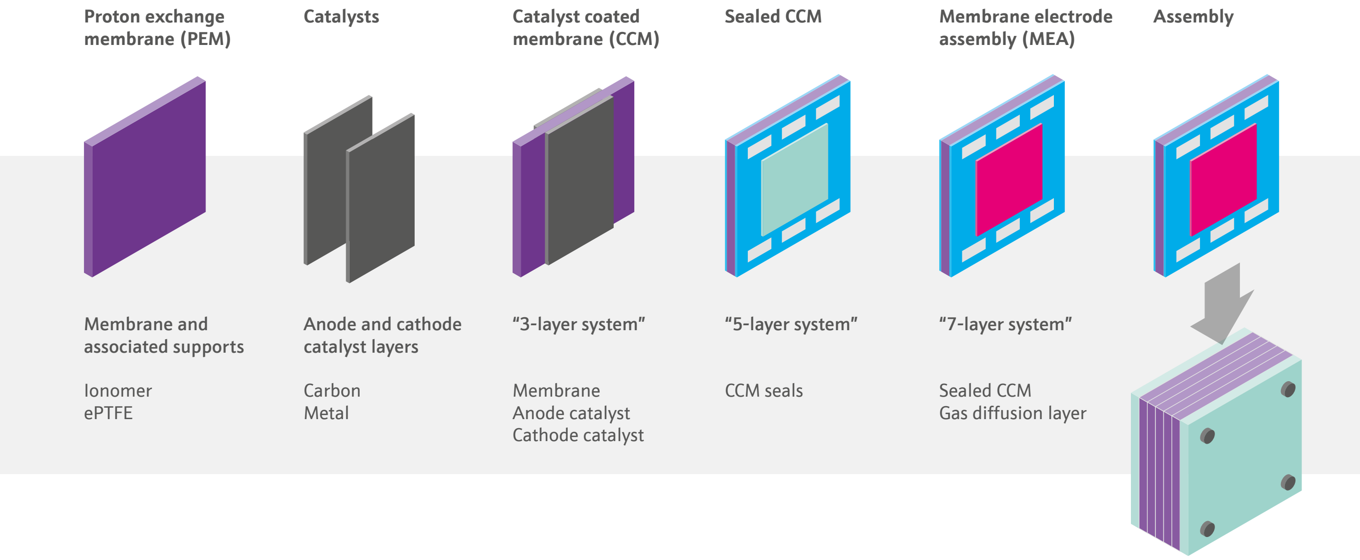

Figure 1 PEM stack components and assembly

Platinum supplies

The platinum market benefits from two well-established sources of supply.

Its primary supply from mines has a long history, since extensive deposits were discovered in South Africa in the early 20th century, becoming increasingly important as platinum found widespread industrial use from the 1950s onwards. Its secondary supply is recycled metal from various forms of scrap, processed by specialist refiners such as Johnson Matthey and others.

Crucially, the long history of platinum being mined and recycled means that the amount of platinum that is potentially available to the market is broader than just its primary and secondary supply. It also encompasses stocks of platinum that have built up in various forms and locations over the decades but have not yet been sold back to the market.

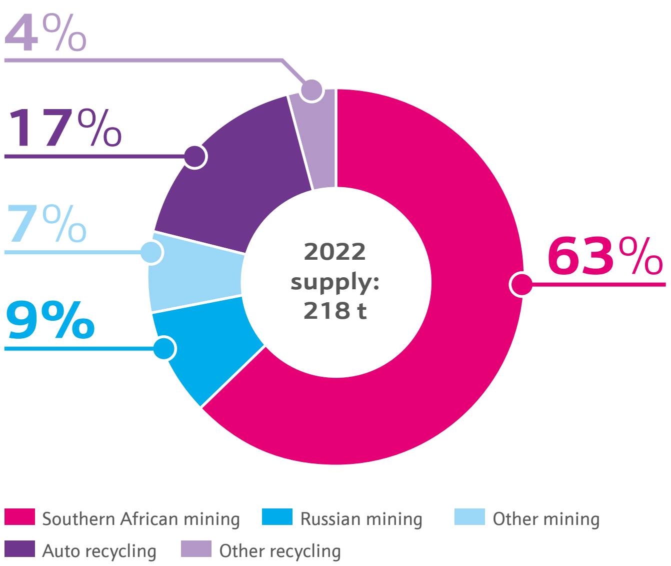

Figure 2 Platinum supply in 2022

Platinum supply: mining

Platinum mining is heavily concentrated in southern Africa, where the most extensive known PGM reserves on Earth are located[1]. Smaller amounts of platinum are also produced as a by-product of palladium mining in North America, and of nickel-copper mining in Canada, Russia and elsewhere. But southern Africa will continue to be the most abundant and important source of platinum for many decades.[2]

This heavy reliance on one region presents a potential geopolitical risk, but there are several reasons why this is unlikely to affect platinum supplies. Taking politics first, the governments of South Africa and Zimbabwe both recognise the critical economic benefit of PGM mining operations and the sale of the metal, but they directly control neither. PGM mining and refining is complex and technically challenging, with a very high barrier to entry, so in southern Africa it is undertaken almost exclusively by large, multinational, publicly quoted mining companies who serve their shareholders and other stakeholders, and typically sell their metal through long-term contracts internationally.

The operational risks in this region are of more concern: South Africa faces a difficult situation in power supply, which is heavily reliant on coal and suffers frequent outages ('load-shedding') that impact both citizens and businesses. Industry is prioritised for electricity supply and, so far, has been protected from the worst impacts of load-shedding: we estimate that at most 1% of PGM production was foregone in South Africa in 2022 due to these electricity outages. But there is no doubt that unstable electricity supply is an ongoing challenge for the PGM mining companies.

That said, these companies have an established track-record in managing both operational challenges. This is shown by the remarkable resilience of PGM output from operations in South Africa and Zimbabwe over the last two decades, during periods of turmoil in the wider operating environment (see Figure 3), including the unusually prolonged strike action in 2014 and the downturn during Covid in 2020.

The environmental, social and governance (ESG) aspects of PGM mining in southern Africa are also more reassuring than is generally understood. All the major platinum mining companies are investing heavily to meet their own ambitious targets to decarbonise their processes. By using renewable power generation and other initiatives to make their operations more resilient and cleaner, they'll be less heavily reliant on coal-fired power. The carbon footprint of platinum mining is therefore set to shrink[3-6].

From a social perspective, there is negligible 'artisanal' PGM mining, so this is not a concern in PGM supply chains. The South African mining companies are highly regulated and operate with stringent mining and environmental, health and safety practices.

While hard-rock mining at depth carries inevitable hazards, and these should not be downplayed, the mines are subject to regular safety inspections, reflecting the South African government's strong commitment to mine safety. Both the companies themselves as well as external inspectors have the power to stop operations if there are safety concerns and these must be investigated. Health and safety are given prominence at all South African PGM mining operations, and employees benefit from free, comprehensive healthcare for themselves and their families, provided by the mining companies through fully equipped clinics and hospitals.

Considering the broader aspect of mining, PGM mining in southern Africa does more than merely mitigating a negative social impact; it demonstrably supports several of the UN's Sustainable Development Goals as it works towards a social good.

The economic benefit of PGM mining translates into a social benefit for the local communities in South Africa, through the mandated 2018 Mining Charter[7] for all mining companies. To be able to mine, they must maintain extensive social and labour plans, including developing and implementing comprehensive human resources, mine community projects, housing and living conditions, and employment equity. This is intended to promote employment and advance the social and economic development of all South Africans, while ensuring economic growth.

High ESG standards are also a feature of PGM mining in Zimbabwe; the mining companies understand that engaging the local people is crucial in underpinning the sustainability of these operations. Investing in local communities, developing local enterprise as part of supply chains, and creating employment directly and indirectly are all explicit targets of the Zimbabwean PGM mining projects.

There is, however, one risk to PGM mining in southern Africa that needs to be more widely understood: it is costly. Ongoing capital investment is needed to access new areas of ore as older shafts reach the end of their lives, and to maintain the extensive processing infrastructure that takes platinum from parts-per-million concentrations in hard rock through to 'pure' useable form. It takes many years for new shafts to start producing, so mining investment looks to the longer-term future.

As the conventional automotive market for platinum (and its mining co-products palladium and rhodium) will decline with the internal combustion engine (ICE) being phased out, the prospective use of platinum in hydrogen fuel cells and electrolysers is therefore a critical incentive for continued investment in southern African PGM mining. This in turn will secure the future of iridium[8], which is a minor by-product of platinum mining and is critical to PEM electrolysis: southern Africa is the source of over 90% of the iridium mined every year.

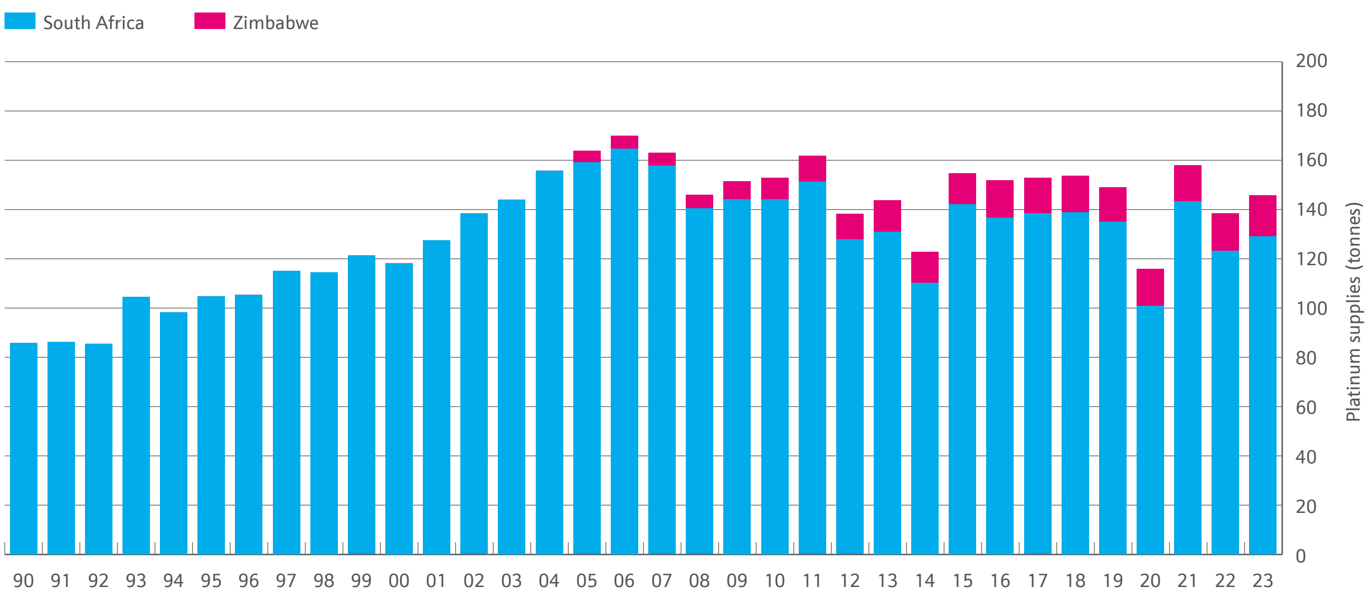

Figure 3 Resilient platinum mine supplies from southern Africa since 1990[9]

Platinum supply: recycling

Platinum (and all PGM) maintains the same properties when it is recycled compared to when it is first mined, so primary and secondary platinum are completely interchangeable, and it can be reused over and over again. This is not always the case for other metals: for example, nickel recovered from end-of-life process catalysts is currently not suitable for reuse in replacement process catalysts, and must instead be directed to alternative applications, such as bulk steels.

In theory, the recyclability of platinum is very high: if it is effectively recovered from the application, nearly all the metal can be reused, but in practice, collection and handling losses mean recovery is usually less than what is technically feasible. It is important to emphasise that, while recovery and recycling can be boosted by mandates, platinum recycling is usually driven by the value of the metal. As a result, platinum already benefits from a well-established global recycling network and significant existing recycling capacity: several large refineries across the globe (including JM's operations in the US, UK and China) process platinum sourced from all over the world for reuse by customers or for sale to the market.

Around 20-25% of platinum currently supplied to the market is from recycled sources, benefiting from significantly lower CO_2 emissions and lower cost of production compared to primary mining today. Most of this secondary supply is currently recovered from catalytic converters in scrapped vehicles, which will continue to be a significant source of platinum for decades to come. Even when sales of fossil-fuelled ICE vehicles end, they typically have a lifetime of ten to twenty years on the road, meaning autocatalyst scrap recovery will continue into the 2050s and beyond.

Platinum is also recovered from automotive sensors, electronic scrap, and used jewellery. Significant quantities of old platinum jewellery are recycled every year in Japan and China, and many tonnes of platinum jewellery still sit in consumer hands in these regions.

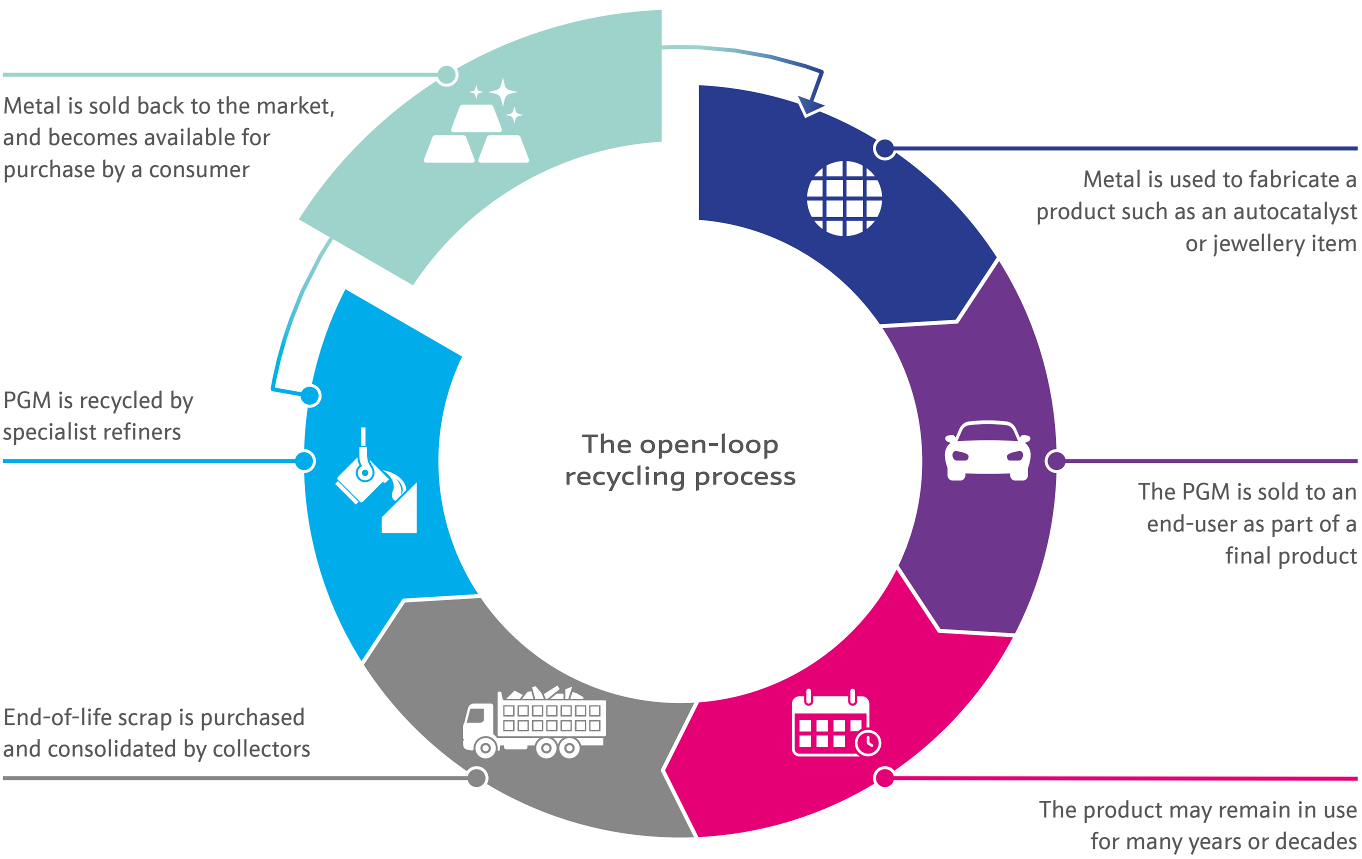

Figure 4 Open-loop recycling of PGM: the source of secondary supply

But this is far from all the platinum recycling that takes place. Unseen by the market, substantial quantities of platinum circulate constantly in 'closed loop' – meaning that when the product reaches the end of its life, the metal is owned by the same user during the refining process and then returned to them for reuse within the same application (see Figure 5). This routinely happens in many industrial applications, including fuel, chemical and pharmaceutical manufacturing processes using platinum catalysts, as well as in glass manufacturing equipment using platinum alloys. These applications benefit from an inventory of recycled platinum, retaining the metal as an asset that can be repeatedly reused and therefore dramatically reducing ongoing demand for 'new' metal. The existence of this closed loop means the total amount of platinum recycled every year is much higher than the reported secondary metal supplies to the market.

There is thus no doubt that circularity for platinum (and other PGMs) in fuel cell and electrolyser technologies will be established, leveraging the recycling network that already exists and incentivised by the value of the metal and lower carbon intensity compared to primary metal. The remaining challenge will be ensuring collection and refining processes are optimised for these new materials to maximise metal recovery - a challenge that is being actively addressed by the industry.

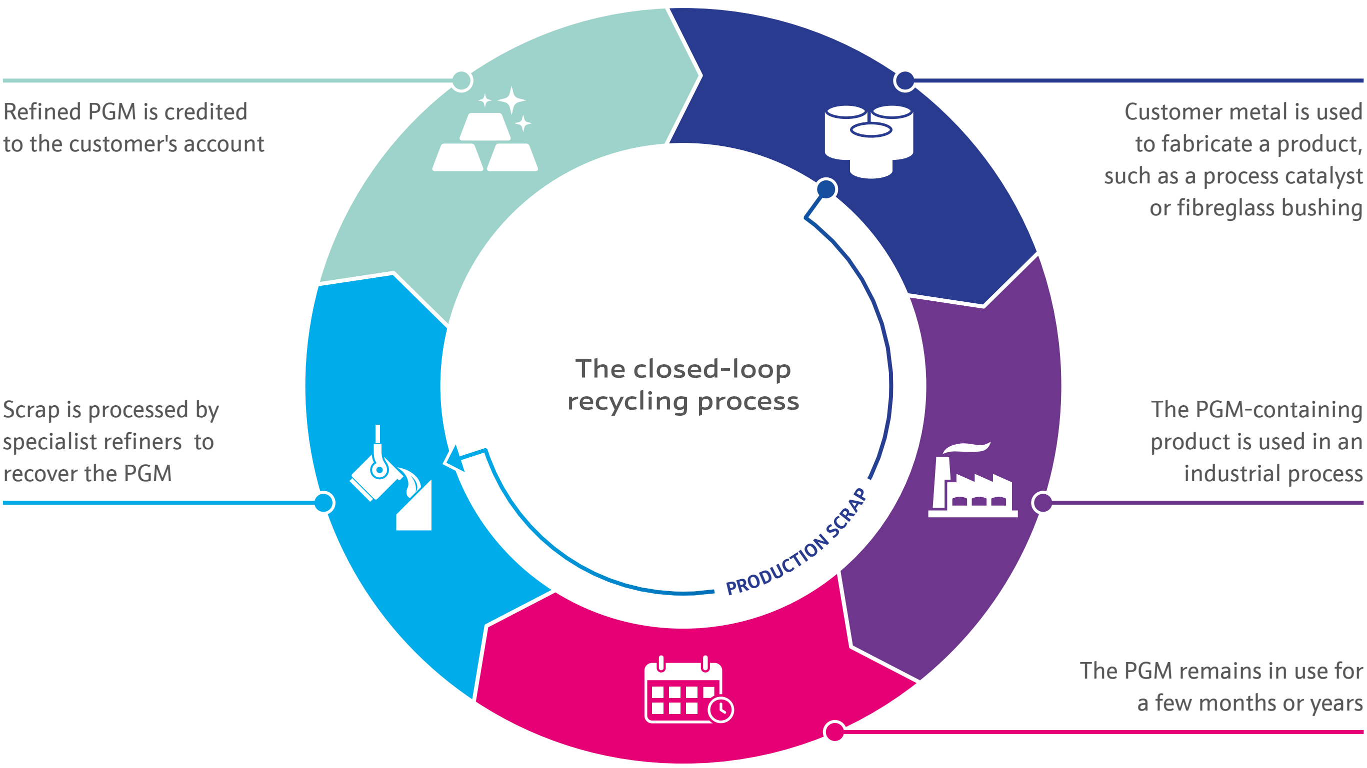

Figure 5 Closed-loop recycling of PGM: retaining metal within an application

Platinum's supply and demand balance

Platinum availability

Platinum availability for future applications is more than the annual supply and demand profile indicates. There are substantial above-ground stocks around the world and, in southern Africa, extensive below-ground deposits of platinum that could increase primary supply with sufficient capital investment.

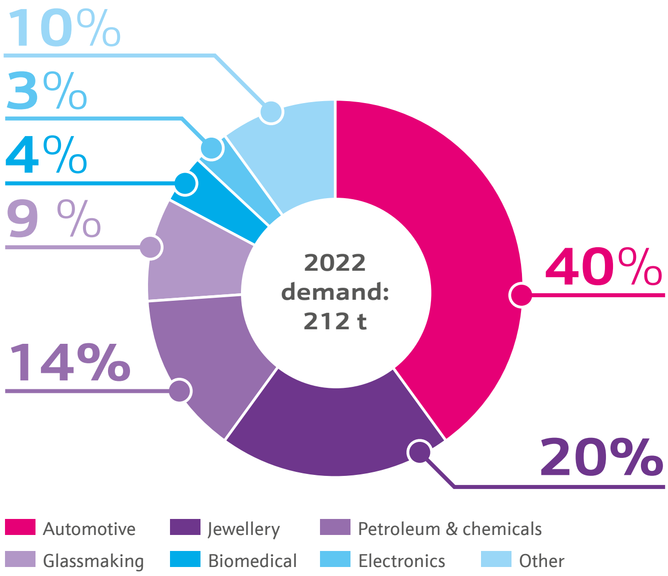

Figure 6 Platinum demand in 2022

Commentary around platinum requirements for fuel cell vehicles frequently expresses concern that platinum availability will act as a constraint or bottleneck in the large-scale deployment of this technology. But platinum is a well-supplied metal, technically in oversupply: in four of the last six years, more platinum has been placed on the market than has been required by its various users. Such an imbalance is often seen for PGMs, where a simplistic law of supply and demand does not apply.

In terms of primary supply, this is mainly because platinum is never mined in isolation: the southern African platinum mines are more correctly referred to as PGM mines, since the ores in this region contain all the PGMs together (along with other metals as well). Mining companies are constrained by geology, so the PGM output can't be optimised to perfectly meet demand for each individual metal. For example, palladium and rhodium in particular are currently in high demand for catalytic converters, making them valuable co-products of platinum mining and impacting the overall output from the PGM mines.

Despite being in surplus, it doesn't make sense to reduce the secondary platinum supply from scrap sources, since its value drives its recycling, and a backlog of metal in scrap has negative cashflow implications for the supply chain. Any excess refined metal is held as stocks in various banks and depositories around the world – a typical situation for precious metals[10].

Looking ahead, platinum is ready for a large new market, and that market is fuel cells. Platinum's largest application at present is automotive emissions control for ICE vehicles (i.e. catalytic converters). While this is currently a robust market due to tightening pollutant regulations around the world, using nearly 85 tonnes of platinum in 2022, it will inevitably decline as we transition to a zero emissions world.

Added to that, its second-largest market – platinum jewellery – is not expected to grow in line with global GDP. Asia dominates platinum jewellery demand; demographic trends in Japan are not supportive of growth there, while changing consumer tastes and spending patterns have caused platinum jewellery fabrication in China to decline for nine consecutive years. While platinum jewellery has established a niche in the Indian market, gold remains overwhelmingly favoured.

FCEVs as replacement demand for platinum

Assuming platinum supplies remain constant, how much scale could that metal support in the hydrogen economy, specifically for fuel cell electric vehicles (FCEVs)?

Although thousands of FCEVs are already being produced annually, for simplicity let's assume FCEV production starts in 2023. As a starting point, we can reasonably assume that 45 tonnes of platinum are available to FCEVs in 2023, as this is a fraction of the platinum thought to be held in relatively liquid stocks today.

In our model, we then project annual availability will grow at a straight-line rate to 130 tonnes per annum (tpa) by 2040 – this figure comes from simply adding jewellery demand (42 tonnes) and automotive demand (86 tonnes) in 2022 and assuming a small amount (2 tonnes) of additional availability from stocks. So the implicit assumption here is that combined demand in these two markets declines at a steady rate from 2023 onwards, reaching zero in 2040, and that platinum availability for FCEVs from 2040 onwards remains at 130 tpa (i.e. it assumes everything else remains constant).

This is not a forecast, or a definitive statement on availability, but is intended to illustrate how FCEV mass production might be accommodated within the existing supply base.

Platinum loadings on FCEVs have already decreased by over 90% since the early 1990s. We project a further reduction in platinum loadings as the efficiency with which the metal is used in PEM fuel cells continues to improve through R&D – this is very typical in PGM applications. Average FCEV loadings are around 45g per vehicle today (a weighted average across all passenger and commercial vehicle classes) and we model both a two-fold and three-fold improvement in metal intensity per vehicle by 2050 (i.e. a 50% thrift to 23g/vehicle on average and a 67% thrift to 15g/vehicle).

With decades of experience of optimising PGM technologies, we believe that improvements on this scale over the next 25–30 years are a reasonable expectation. For example, per kilogram of vehicle weight, catalytic converters on gasoline-fuelled cars in Europe in 2016 contained the same amount of PGM on average as cars in 1992 (themselves already much more efficient than earlier generations of catalytic converters). But they emitted around 70% less exhaust pollution, because continued R&D over the years delivered more effective PGM emissions catalysts[11].

Our projection also shows the effect of reusing platinum from end-of-life FCEVs, on the assumption of closed-loop recycling where the metal is retained within the application. Recycling end-of-life FCEVs is a certainty and has already been proven by Johnson Matthey and others, so must be incorporated into any projections. Here, collection and processing losses of 20% are assumed[12], and an average 12-year vehicle life.

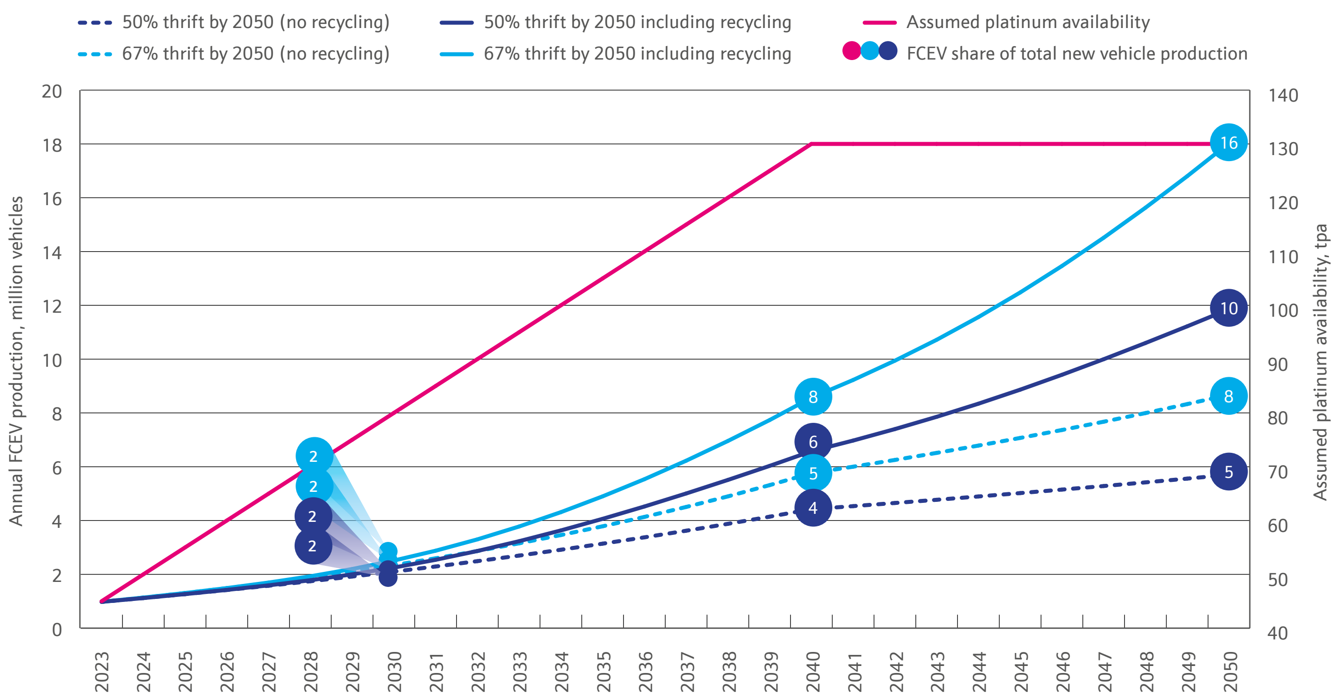

Figure 7 The impact of thrifting and recycling on FCEV production (light and heavy vehicles), based on existing platinum availability

Putting all of this together, how many fuel cell vehicles can then be produced every year?

By 2030, if just 80 tonnes of platinum is available for FCEV, between 2.1 million and 2.5 million FCEVs can be produced in that year, depending on how much thrifting has been achieved. This would account for about 2% of total vehicle production expected in 2030 (across all vehicle classes).

How might this break down between light duty and heavy duty vehicles? There are by far more light vehicles (94% of total anticipated vehicle production in 2030), so a 2% fuel cell market share of overall vehicle production would allow fuel cells to take as much as a quarter to a third share of the heavy duty vehicle market, plus around 1% of light vehicle production[13]. This exceeds industry expectations of FCEV market shares in 2030.

By 2040, with 130 tonnes of annual availability and the added benefit of recycled metal recovered from end-of-life FCEVs, between 6.6 and 8.6 million FCEVs can be produced annually, again depending on the extent of thrifting. This is an overall market share of around 6–8%, again feasibly allowing fuel cell powertrains a dominant share in heavy vehicles and a supporting, but increasingly important, role in light vehicles.

By 2050, and with no assumed improvement in availability beyond the 130 tpa constraint, FCEVs can still account for 10–16% of global vehicle production[14]. This would comfortably allow fuel cells to be used in all commercial vehicles produced in that year, and to also take a material share of the passenger vehicle market (6–12%, depending on the extent of thrifting achieved[15]).

Platinum availability for the hydrogen economy

Our model is not a supply-demand forecast, rather an illustration of why platinum availability should not be viewed as a barrier to the deployment of fuel cell road vehicles. Rather than placing stress on supplies, this new market for platinum will create the replacement demand to incentivise continued investment in mining and refining infrastructure.

Although FCEVs are expected to be the largest new source of platinum demand, due in part to the sheer size of the road vehicle market, there will be other applications within the hydrogen economy. Platinum-catalysed fuel cells are also deployed in other sectors, including stationary installations for power generation, which can harness the by-product heat to produce hot water alongside electricity. They are also used in a number of other transportation modes such as aircraft, ferries, mining vehicles, drones, and warehouse forklift trucks, the latter already well established in the USA.

Platinum will also be used to produce hydrogen: alongside iridium, it is an important catalyst in proton exchange membrane (PEM) electrolysers. Additionally, it is employed in other electrolyser technologies to boost their performance and durability, such as plating salts.

Based on our estimates, we believe platinum availability is sufficient to facilitate growth in these other markets as well as in road vehicles.

In the near term, above-ground stocks can supplement availability. Hundreds of tonnes of platinum ingots and coins are held in bank vaults and depositories around the world, but large quantities of platinum are also ‘held’ in catalyst or alloy form within industrial facilities. Most relevant to this discussion is the petroleum industry: platinum has been used for decades to catalyse the production of high-octane gasoline blendstock as well as a number of petrochemicals, with substantial quantities installed in petroleum refineries and petrochemical plants around the world.

This metal is in use and presently unavailable to the market, and in fact the past few years have seen more platinum use due to improving fuel standards in developing markets and growing global demand for petrochemicals. However, as we transition to net zero, gasoline demand is expected to peak within the foreseeable future before entering a terminal decline[16]. So, in the longer term, we expect to see some platinum (and other PGMs) being released by the petroleum industry[17] and becoming available for use in hydrogen and other energy transition applications. This includes production of sustainable fuels and chemicals, where platinum’s power as a process catalyst will once again be harnessed.

Ultimately, however, platinum mining may well be called on to produce more metal to meet rising demand. Thanks to the size of the deposits in southern Africa, and the vast quantities of platinum (and other PGM) they are estimated to host, we can be confident that the metal exists to be extracted and meet global needs for decades to come. Whether sufficient platinum will be extracted is a question of investment, not of geology, as new shafts will have to be sunk to reach new areas of reef and processing infrastructure such as smelters and refineries will have to be expanded to increase output.

This investment depends on a healthy outlook for platinum demand. Excessive caution about employing platinum in new technologies because of a perceived lack of future availability thus risks becoming a self-fulfilling prophecy. At worst it may shift demand onto other metals for which availability, efficiency and ESG concerns are much more problematic.

The impact of price

In the context of circularity – a given for platinum – its cost should be viewed as an investment. Platinum remains in a recoverable form at the end of the useful life of the fuel cell or electrolyser stack, and the value of the metal helps to incentivise effective recycling. This ensures that the platinum remains an asset to its owners, and is reusable in new stacks.

Along with recycling, the value of the metal also drives efforts to 'thrift' platinum use, so as to minimise the amount that is needed to maintain the same performance. We have already seen a significant drop in the quantities of platinum (and other PGM such as iridium) used to efficiently operate fuel cells and electrolysers, and we expect significant further reductions as optimisation efforts continue and benefit from advancements in materials science.

The effect of a platinum price rise on equipment cost will be mitigated by this thrifting and is limited by the relatively small quantities of platinum employed – a few grams per car and per electrolyser, rather than kilograms. Our current estimates of the PGM cost contribution to overall FCEV or electrolyser cost are less than 5%.

To place this into context: cars on the road today use a few grams of PGM in their catalytic converters, and the fuel cell cars of the future are expected to require comparable quantities of platinum in their stacks – around 10 g per car or less. A logical conclusion is that PGM cost on future fuel cell vehicles will be comparable to PGM cost on conventional vehicles today.

While platinum is a relatively expensive metal compared to other metals on a per-gram or per-ounce basis, the amount used is typically orders-of-magnitude lower than, for example, the amount of base metals used in clean energy technologies such as batteries. Hence, comparisons of cost for energy transition metals on a per-gram base are not valid or helpful: intensity of use and ease of reuse should both be considered.

What is the alternative?

Global transportation must still be decarbonised in a timely fashion. But if concerns about platinum availability and cost persist, regardless of the facts to the contrary, and cause a move away from platinum-catalysed fuel cells and electrolysers, what might be the consequences for the energy transition?

Fuel cells using alternative materials might be developed for use in vehicles, but all evidence to date and fundamental principles suggest that such vehicles will be less fuel-efficient and less durable than those using platinum-based PEM fuel cells – likely prohibitively so.

If fuel cells for vehicles are abandoned altogether, then road vehicles must be decarbonised through a combination of battery-only electric powertrains and the use of sustainable fuels in internal combustion engine vehicles. Sustainable fuels will be a crucial part of the energy transition and are likely to play a useful role in road vehicles[18], but these still emit harmful pollutants, and they will be limited in supply[19] so will be mostly needed in transportation forms where powertrain electrification faces practical limitations: shipping and aviation. The absence of fuel cells in road vehicles would therefore most likely lead to increased reliance on batteries, beyond the heavy reliance faced already.

This would very significantly increase the mineral intensity of zero-emissions road transportation, because battery electric vehicles (BEVs) contain far more critical metals per vehicle than comparable FCEVs (see Figure 8).

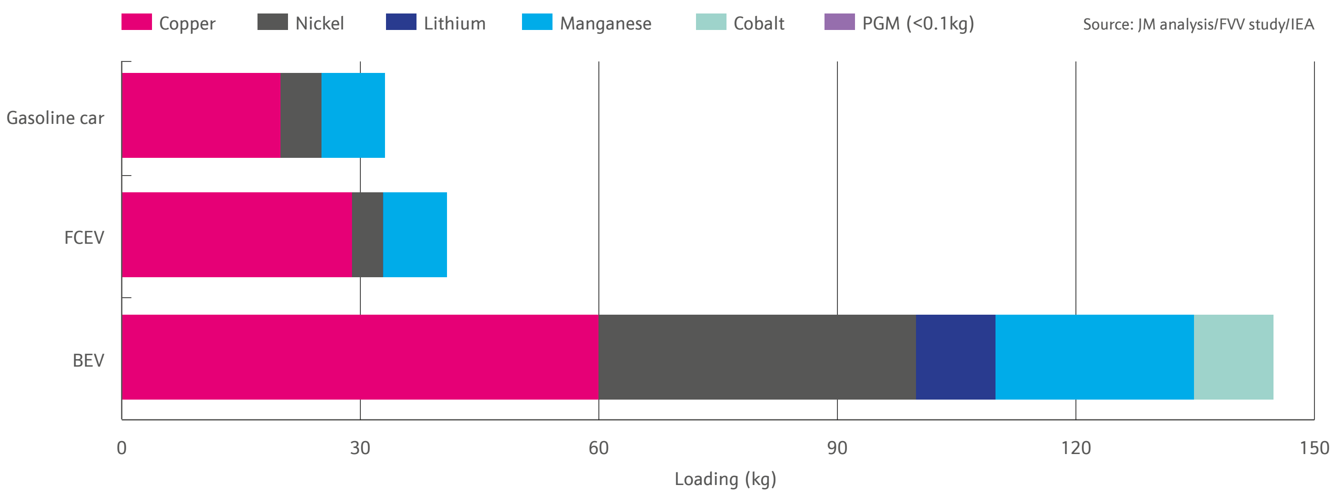

Figure 8 Typical critical metal content per medium passenger car, kg/vehicle

Mineral intensity must be addressed

While an extraordinary and unprecedented increase in mining investment to scale up supplies of copper, lithium, and nickel might allow every vehicle in a future world to be a BEV, the climate and biodiversity impact of this mining can't be ignored, and we face a considerable risk that the gap between supply and demand for these metals cannot be closed[20]. This has been recognised by the World Bank's Climate Smart Mining initiative[21], for example. It would also place further strain on particular critical materials where availability is already a concern, such as copper, which is needed in significant quantities for BEV charging infrastructure and for the vast amounts of cabling necessary to expand electricity generation and consumption.

In contrast, refuelling infrastructure for FCEVs is very similar to today's refuelling for ICE vehicles. And because FCEV refuelling times (around five minutes for a full tank of hydrogen[22]) are much faster than typical BEV charging times each 'charging point' can serve more vehicles, reducing the overall mineral intensity of the refuelling network.

In fact, incorporating hydrogen refuelling alongside BEV charging is likely to lower total infrastructure cost[23]. This counterintuitive result is because fuel cells are used in vehicles that are the most challenging to decarbonise through batteries alone– i.e. larger vehicles or vehicles with high energy usage. These 'hard-to-abate' vehicles disproportionally affect charging infrastructure costs; they need fast-charging and associated grid upgrades to carry the large currents needed, and are much more cheaply served by hydrogen.

"A scenario that excludes FCEVs is not a sensible outcome in a mineral-constrained world."

Using FCEVs alongside BEVs to decarbonise road transportation would not only reduce overall mineral intensity, but will also rebalance and redistribute demand for individual metals, reducing the constraints.

This is extremely important. Renewable energy and electrification will eliminate the need for fossil fuel extraction, and is, in effect, limitless and non-polluting. But mineral extraction, which will enormously increase as a result, is neither. While energy efficiency is often discussed, particularly when comparing BEVs to FCEVs, the question of mineral efficiency is ignored. The efficiency with which the renewable generating infrastructure is used must be included in the calculation, and then the overall efficiency of BEVs and FCEVs is comparable[24]. It is crucial that we maximise the overall efficiency with which we use our finite minerals for decarbonisation. There are numerous reasons to expect that using hydrogen alongside renewable electricity will substantially lower the mineral intensity of the energy transition as a whole – a subject we will explore further in a forthcoming whitepaper.

There are other considerations too. Decarbonisation and environmental management are already significant challenges in mining: how much harder are these challenges when mining is scaling up at a rate never seen before? The PGM mining industry, even if it were to expand in the longer term, would do so at a much more measured pace within established locations of PGM extraction, and the well-established and publicly accountable PGM miners would leverage existing infrastructure and skilled human resources to do so. Environmental stewardship, social responsibility, and decarbonisation are all less challenging in that context.

From a minerals perspective, it is sensible – and will likely prove imperative – to employ platinum-catalysed fuel cell vehicles as a significant part of the solution for decarbonising road transport. A BEV-only transition would be far more difficult to accomplish and would place even greater reliance on a form of electrification that already faces daunting challenges in raw material availability and recyclability.

A scenario that excludes FCEVs would also risk ultimately shuttering a PGM mining industry that does much good in the Global South and would fail to benefit from an existing recycled supply of a very useful metal. This is not a sensible outcome in a mineral-constrained world.

Conclusion

Platinum, almost uniquely among metals, will see rising demand in new applications naturally replacing declining demand in traditional fossil-fuelled applications, and will be much less subject to a widening supply-demand gap than other metals needed for the energy transition. Concerns that platinum will act as a barrier to the deployment of hydrogen technologies are misplaced. While the challenges of scaling up clean energy technologies should not be underplayed, platinum availability presents an opportunity, not a challenge.

By investing in platinum-containing technologies, users will benefit from supply chains that leverage existing infrastructure, in the form of responsible mining operations and an effective global PGM recycling network. They will further benefit from the short-term buffering effect of above-ground stocks and the long-term availability of extensive quantities of platinum hosted in known deposits.

Platinum is a precious metal, and its value – as reflected by its price – drives its efficient use and reuse. Bringing any additional supply to market would require a rising price, necessary to incentivise investment to expand mining operations. Should such a price rise occur, it is highly unlikely to threaten the viability of platinum-based technologies for the hydrogen economy, given the low (and falling) intensity of platinum use in these technologies.

The use of critical metals in the energy transition is coming into increased focus. Constraints on certain metals such as copper are looming and could significantly hamper the shift to a net-zero world. By employing platinum-based PEM technologies alongside batteries and other technologies in key sectors such as transportation and energy storage, the overall mineral intensity of the transition can be moderated, and the overall efficiency of the energy system can be optimised. These are crucially important considerations.

Through its sustainable use in several clean technologies for hydrogen production and consumption as a fuel, platinum is a key enabler for the energy transition.

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11. Based on JM Market Research analysis of average vehicle loadings and EU emissions limits applicable at the time for carbon monoxide, hydrocarbons and nitrogen oxides (NOx). Period chosen excludes the more recent introduction of on-road testing.
12. Losses in PGM recovery from automotive catalytic converters today are typically higher than the 20% assumed here (around 30-40%, mainly from collection losses as well as some processing losses) but take place within an open-loop model; we expect increasing focus on circularity and closed-loop approaches will mean relatively low collection losses in recovery of PGM from FCEV – potentially significantly lower than the 20% assumed here.
13. These market shares imply around 55% to 60% of all FCEVs produced in 2030 would be heavy vehicles. Using the projected weighted average loading, and assuming the light FCEV produced in 2030 have an average loading of 12g/vehicle, the heavy FCEV made in 2030 would then have average loadings of 55 to 60g per vehicle.
14. Depending on the size of the future vehicle market: this projection assumes 115 million vehicles are produced in 2050, up from output of around 90 million this year.
15. For the more ambitious projection of a 67% thrift to an average 15g/vehicle for all FCEVs produced in 2050, if we assume that the light FCEVs produced that year have an average loading of 8.5g/vehicle, this implies an average loading for heavy FCEVs in 2050 of 32g/vehicle – a reasonable allowance, given the larger stacks and tougher durability requirements typical of commercial vehicles.
16. To achieve net zero soon after 2050, in line with the Paris climate agreement, requires that all vehicles burning fossil gasoline must be eliminated from the global road vehicle fleet by that point. As gasoline is mainly used in passenger cars, which are subject to both rapidly improving fuel economy and increasing electrification, gasoline demand is expected to peak ahead of demand for middle distillates (diesel/jet fuel) and well ahead of peak oil demand.
17. Recent years have in fact already seen a wave of closures of older petroleum refineries in the West, as they are outcompeted by newer facilities constructed in the East, and as growth in gasoline fuel demand has abated in these mature markets.
18. To reach net-zero targets, it is increasingly evident that sustainable (or 'climate-neutral') fuels, both advanced biofuels and synthetic/e-fuels will be needed to decarbonise the legacy fleet of ICE vehicles still on the road by 2050, and will play a supporting role in decarbonising hard-to-abate vehicle segments such as freight haulage.
19. To be truly climate neutral, these sustainable fuels must either make use of sustainable biomass, which is limited by what can be harvested without deleterious effects on food supply, biodiversity, or carbon sinks, or must be synthesised from green hydrogen plus carbon or nitrogen sourced from direct air capture.
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