



PGMs PLATINUM GROUP METALS

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PLATINUM

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**PGM demand will continuously outstrip
stagnant supply in as little as two to three years**

Research by:

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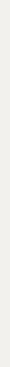
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INTRODUCTION



This review provides an insight into the future supply and demand for platinum, palladium and rhodium (PGMs) in an environment of stringent vehicle emission standards coupled with a stagnant PGM supply and an increase in demand. Under these circumstances and in time, the PGM market balance will inevitably move into a continuous and declining deficit which in turn will put upward pressure on the price, and in particular, the price of platinum.

This upward movement in the price will likely be supported by the combination of a number of market indicators characterised by strong consumer demand and tight physical availability, coupled with a continuous supply and demand market balance deficit. The objective of this review is to provide evidence and timing to support this scenario.

The strong demand for PGMs is inextricably linked to the introduction of vehicle regulation and standards for controlling the tailpipe emission of harmful gases (US Clean Air Act of 1970). Vehicle emission standards have been progressively tightened through regulation worldwide since 1970. In response, vehicle manufacturers have had to increase the content (loading and loading ratios) of palladium, platinum and rhodium (PGMs) in autocatalysts to meet the stricter limits. The auto industry has introduced new in types of drive trains for vehicles being offered for sale. Furthermore, radical shifts in the types of vehicles being offered is becoming a moving target as governments strive to meet zero net emissions by 2050.

The demand for PGMs is set to take a step change upward with the adoption of new mandatory UK and EU CO2 emissions targets which will come into effect from 1 January 2021. The UK, for example, has brought forward the deadline for the ban of sales of new petrol and diesel vehicles to 2030 from 2040. China 6 emission standards also require autocatalyst loadings to increase, particularly in heavy vehicles.

Given the move from IEC to BEVs and HEVs, the industry has attempted to map the global light-duty vehicle sales outlook. This process has proved to be somewhat difficult, as a result numerous maps of sales outlooks have been presented, which in most cases differ from each other. In my view, one key question arises from the scenario described: Has the global light-duty vehicle sales outlook been backed up by matching the quantum of



PGM autocatalyst loadings to synchronises with the sales outlook mix, noting that the autocatalyst loadings are set to increase? In this regard, an estimate of the quantum of PGMs can also be mapped. To date, I have not seen any figures in the public domain regarding this subject. In my view, this calculation is the obvious first step in determining the additional PGM demand required to meet the stricter emission standards

Using Anglo American Platinum's global light-duty vehicle sales outlook, my assessment of the impact of the additional quantum of PGMs required to meet the sales outlook over the period 2019 to 2027 implies that the:

Total PGMs will likely increase autocatalyst demand by c.3.7moz from c.12.3moz in 2019 to c.16mozs, or 30%, from 2019, given a 9.2% increase in LDVs sold between 2019 and 2027, mainly supported by higher PGM loadings in each vehicle.

The additional quantum of PGM autocatalyst loadings is significant as it implies an equivalent increase in PGM supply of 3.7moz would be required to satisfy the supply and demand fundamentals. Should this not be the case, the

market will likely tighten, thereby forcing upward pressure on PGM prices.

In this review, I highlight and quantify a significant and potentially overwhelming demand for platinum, which is now looming at a pace because of the increased demand for hydrogen fuel cells (FCEV) used in the drive trains of heavy-and light-duty vehicles, Furthermore, there are numerous other applications, which include the production of green hydrogen, the use of PGMs in battery electric technology and the conversion of BEV buses and trucks to FCEV in China, among others. It is important to note that my estimates of additional demand are based on published figures "only" and in this regard, represent the lower end of the demand spectrum. Suffice to say that even the lower end of the demand scale will adequately demonstrate the lack of supply to meet the additional demand. Notwithstanding any increase in demand from the industrial, jewellery and investment sectors.

My estimates of the additional platinum demand from FCEV heavy-duty trucks and from the production of green hydrogen are mind boggling:

Approximately c.1,640koz and c.2,200koz of additional platinum may well be required in 2027 and 2030 respectively. This additional platinum supply represents some 27% and 36% of global mine supply in 2027 and 2030. Where will this additional supply come from? Above-ground-stocks?

Clearly, the scenario presented above will likely represent a conundrum for the PGM industry and the environmental emission control regulation authorities.

Strategic and structural change and flexibility within the auto manufacturing industry therefore, in my view, becomes an imperative as PGM supply remains stagnant/diminishes.

It becomes obvious that PGM mine supply, particularly platinum mine supply and secondary recycling supply, will not be able to support current thinking with regard to finding the optimal drive train vehicle mix. Furthermore, this result provides further evidence to support a hike in the platinum price.

Turning to PGM mine supply. The South African PGM mining industry is facing a number of challenges in the long term.

The PGM mining industry has been starved of expansion and ore reserve replacement capital for a number of years. Notwithstanding there have been a number of broken promises regarding the government's Mining Charter, which has created an environment that is not conducive to the investment of large amounts of capital.

In this review, I analyse the life of mine (LOM) supply of three major South African PGM mines: Impala Platinum, Sibanye-Stillwater and Anglo American Platinum, which represent some 68% of global PGM supply. and between 92% and 97% of South African PGM supply. I estimate the LOM PGM supply of two future new mines on the horizon in South Africa: the Waterberg and the Ivanhoe Platreef projects. I have also estimated the LOM PGM supply of the Darwendale project in Zimbabwe, together with Nornickel in Russia's new targets for growth in production of up to 15% for nickel, 20% for copper and between 45% and 50% for PGMs by the early 2030s from the company's 2020 levels.

Under these circumstances Russia could "flood" the market with palladium by 2030, especially when PGM supply from South Africa is also becoming palladium rich. Under these circumstances, I would expect the supply of platinum to

decline further in an environment of an overwhelming and increasing demand for platinum from around 2025.

I note that Impala platinum's PGM LOM production plan implies a decline of roughly c.1.0moz by 2030, from the production levels experienced in 2021. Sibanye-Stillwater SA's production plan shows a continuous decline in PGM production from 2021 to 2040. By 2030 production will likely have declined by around 35% or 4E PGM 550koz. Amplats expects annual production between 2020 to 2030 to remain stable. Amplats' LOM production plan includes the Mogalakwena expansion project, which is expected to increase production by around PGM c.500koz.

It is apparent that significant amounts of capital injection will likely be needed to increase mining development and the replacement of reserves in the South African PGM mining industry, ceteris paribus. In this regard, it is important to also note that it will take at least 5 to 10 years to ramp up additional PGM capacity, given the availability of capital.

The combined South African PGM LOM production profiles studied, including projects, show: A decline in PGM production of c.10% or around 800koz by 2030.

Over this period and beyond, the PGM mining mix ratio will change. This change will result in a continued downward decline in the supply of platinum and rhodium and conversely an upward trend in the supply of palladium. The impact surrounding the change in the PGM mining mix is significant with respect to the expected increase in platinum demand.

The combined South African PGM LOM profiles, including projects in Zimbabwe and Russia, imply that:

PGM mine supply will most likely remain roughly constant with an average of around PGM c.13.mozs, with a recognisable downward trend starting around 2032.but the PGM ratios will change.

The major players in the global LOM production profile imply that the centre of primary PGM production is moving away from South Africa towards Russia and Zimbabwe in the long term, given these circumstances, it follows that the PGM ratios of platinum, palladium and rhodium will change to higher palladium and lower platinum and rhodium supply.



In this review, I have estimated a forward-looking PGM market balance based on Amplats' long-term view of global LDV sales supported by higher PGM loadings per vehicle between 2019 and 2027 (base case). In addition, I have included an estimate of the additional demand for platinum catalyst loadings in heavy-duty trucks together with fuel cell requirements and the requirements to produce green hydrogen. Notwithstanding any increase in demand from the industrial, jewellery and investment sectors.

In my view, PGM demand will continuously outstrip stagnant supply in as little as two to three years.

I am also of the view, that the demand for PGMs and platinum in particular, will inevitably increase at a pace, particularly when a continuous unsustainable palladium and rhodium market balance deficit and high price differentials are considered.

What then is the future of PGMS given the scenario described above? The market balance for palladium has been in deficit for at least nine years and rhodium is about to follow suit. In both cases, the supply imbalance has been the main driver of the sky-rocketing price. In my view, platinum will be next to board the price rocket.

It is also clear that the upward movement in the platinum price will be supported by the combination of a number of market indicators characterised by strong consumer demand and tight physical availability, coupled with a continuous supply and demand market balance deficit going forward.

In this regard, it is not impossible for the platinum price to move upward and reach, and pass, the record price of USD2,080 achieved in early 2008.

AUTOMOTIVE PGM DEMAND

continues to grow

The strong demand for PGMs is inextricably linked to the introduction of vehicle regulation and standards for controlling the tailpipe emission of harmful gases (US Clean Air Act of 1970). Vehicle manufacturers introduced catalytic conversion technology to meet these standards by using platinum, palladium and rhodium (PGMs) in various ratios to catalyse (neutralise) harmful gases such as carbon monoxide and the oxides of nitrogen. Vehicle emission standards have been progressively tightened through regulation worldwide since 1970. In response, vehicle manufacturers have had to increase the content (loading and loading ratios) of palladium, platinum and rhodium (PGMs) in autocatalysts to meet the stricter limits.

As part of the EU's response to the 1997 Kyoto Protocol to reduce greenhouse gas emissions, especially CO₂, the EU published legislation in 2009 stating that it will impose substantial penalties on EU vehicle manufacturers that do not comply with the Euro 6 emission standards, beginning January 2021. In an attempt to mitigate the potential of

huge fines for non-compliance with CO₂ standards, the vehicle industry has strategically shifted significantly to the introduction of electrification, whether it be battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), fuel cell electric vehicles (FCEVs), 48v mild hybrids or full hybrid electric vehicles, 48v mild hybrids or full hybrid electric vehicles (HEVs). Furthermore, radical shifts in the types of vehicles being offered is becoming a moving target as governments strive to meet zero net emissions by 2050. The UK, for example, has brought forward the deadline for the ban on sales of new petrol and diesel vehicles to 2030 from 2040. China 6 emission standards also require autocatalyst loadings to increase, particularly on heavy- vehicles.

Given the move from ICEs to BEVs and HEVs the industry has attempted to map the global light-duty vehicle (LDV) sales outlook. This process has proved to be somewhat difficult, and as a result numerous maps of sales outlook have been presented which in most cases differ from each other. In

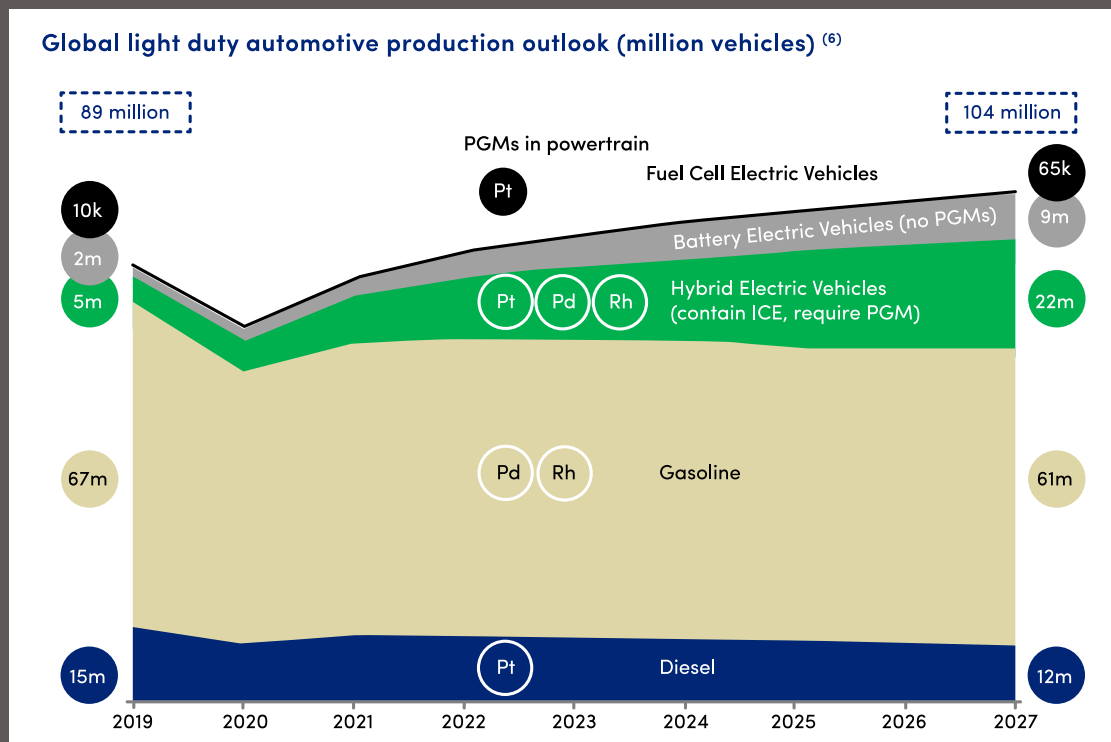
my view, one key question arises from the scenario described: Has the global LDV sales outlook been backed up by matching the quantum of PGMs required for the sales outlook mix, noting that the autocatalyst loadings are set to increase? In this regard, an estimate of the quantum of PGMs can also be mapped. To date, I have not seen any figures in the public domain regarding this subject.

I am of the view that it is important to “assess the impact” and get a “sense” of the quantum of additional supply of PGMs that will likely be required by 2027 to satisfy autocatalyst demand, ceteris paribus. Forecasting the quantum of PGMs associated with autocatalyst demand becomes a “minefield” of “alternative options and possibilities” as the auto industry transition from ICEs to EVs and HEVs gains ground. In this regard, forecasting the quantum of PGM demand comes with assumptions and limitations and should be viewed as such. I note that it

is difficult to project a view this far out.

Some credibility to my forecasts, however, come from Amplats’ presentation in July 2020. In this regard, I was able to use Amplats’ numbers as a “base case” when calculating forward-looking scenarios. This presentation included a map of auto vehicle sales mix over the period 2019 to 2027, Figure 1 below (Amplats reference LMC Automotive).

Figure 1: Long-term automotive production outlook



Source: Amplats July 2020, LMC Automotive



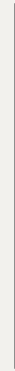
Amplats expects the market share of BEVs and HEVs (ICE) to increase to around 8.6% and 21% respectively by 2027. The market share of petrol ICEs is set to decline from 75% to 59%. Over the same period, the market share of diesel ICEs is set to decline from around 17% to 11.5%.

Amplats also indicated that the long-term view for global automotive PGM demand was robust, mainly supported by higher PGM loadings per vehicle. In this regard, Amplats presented figures which indicate that:

- ICE-based vehicle sales will likely increase by 9% between 2019 and 2027.
- Light-duty petrol PGM loadings between 2015 and 2025 will likely have increased by 40% due to tighter emissions legislation in China and Europe.
- Light duty diesel vehicle PGM loadings between 2015 and 2025 will likely have increased by 10% from already high levels.

I note that Amplats' global LDV sales outlook map (Figure 1) was not backed up by a map matching the PGM outlook, the market is essentially left in the dark about the increased PGM quantum required to support the sales outlook.

MAPPING PGM DEMAND with vehicle sales mix outlook



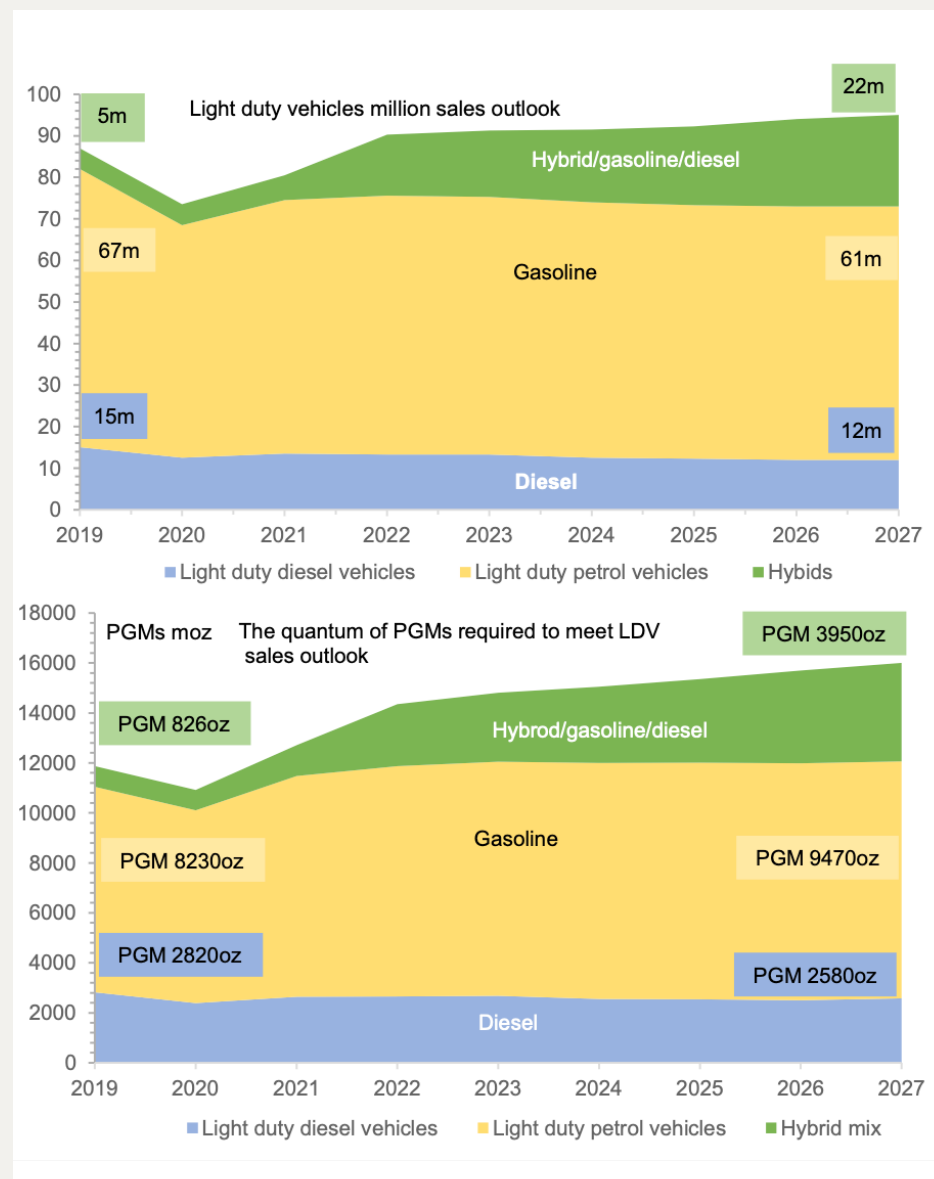
In this discussion, I endeavour to match Amplats' global of LDV map of sales outlook to 2027 to the corresponding PGM increase in demand. I reiterate that forecasting the quantum of PGM demand comes with assumptions and limitations and should be viewed as such.

Given the forward-looking sales mix map and the PGM projected autocatalyst loading for the sales mix respectively, I was able to “assess the impact” and get a “sense” of the quantum of the additional supply of PGMs that will likely be required by 2027 to satisfy autocatalyst demand, ceteris paribus. The results of this exercise are illustrated in Figure 2. The first part of Figure 2 duplicates to a greater extent Amplats’ presentation depicting the global LDV sales outlook map. The second part of Figure 2 illustrates the results of my calculations surrounding the impact of the additional the quantum of PGMs required to meet the sales outlook of global LDVs.

My assessment of the impact of the additional quantum of PGMs to meet the requirements of sales outlook imply that over the period 2019 to 2027 the:

Total PGMs will likely increase autocatalyst demand by c.3.7moz from c.12.3moz in 2019 to c.16moz, or by 30%, from 2019, given a 9.2% increase in LDVs sold between 2019 and 2027, mainly supported by higher PGM loadings per vehicle.

Figure 2: The additional quantum of PGMs to meet the requirements of LDV sales outlook



Source: Amplats July 2020, LMC Automotive, Davis analysis and estimates

- The market share of petrol ICEs is set to decline by around 16%, yet the quantum of PGM loadings will likely increase by around 11%.
- The market share of diesel ICEs is set to decline by around 20%, yet the quantum of PGM loadings will likely fall by around 8% (from already high levels).
- The market share of HEV/petrol/diesel mix set to increase to around 22% yet the quantum of PGM loadings will likely increase by around 4.8x (note, my assumptions regarding HEV/petrol to HEV/diesel sales ratio was set at a 70/30 ratio).

Figure 3 illustrates estimates of the quantum of PGMs required to meet the demand of the sales outlook, as presented by Amplats, together with estimates of PGM autocatalyst demand.

My calculations also imply that:

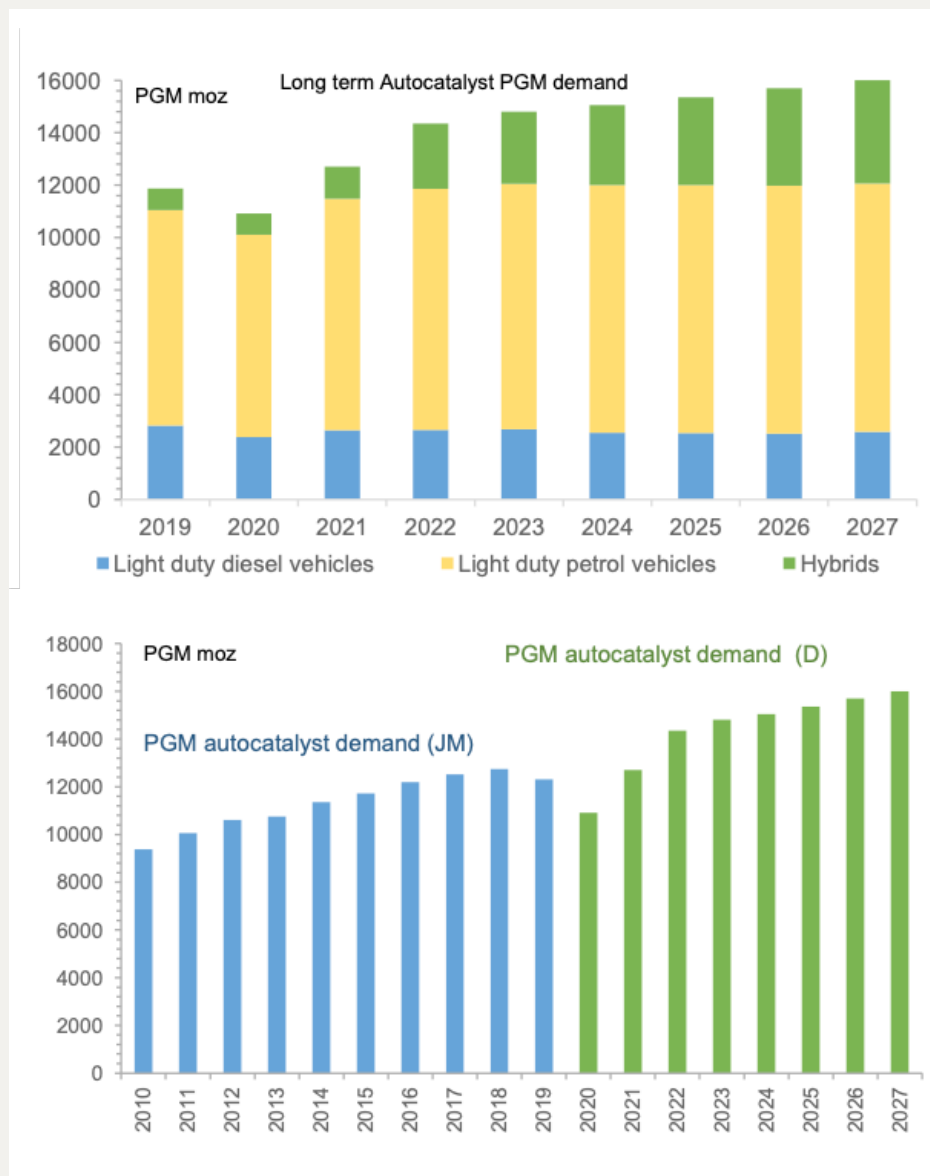


Figure 3: Long term autocatalyst PGM demand estimate for LDV diesel, petrol and hybrid vehicles

Source: Johnson Matthey. Davis analysis and estimates

PGM demand will increasingly outstrip PGM supply, mainly brought about an increase in autocatalyst loadings, which will likely have an impact on physical availability and potentially result in higher PGM prices.

Note that my observations apply before any additional requirements for the use of platinum in FCEVs and in the production of green hydrogen. Furthermore, radical shifts in the types of vehicles being offered are becoming a “moving target” as governments strive to meet zero net emissions by 2050. As mentioned previously, the UK, for example, has brought forward the deadline for the ban on sales of new petrol and diesel vehicles to 2030 from 2040. China 6 emission standards also require autocatalyst loadings to increase, particularly in heavy-duty vehicles.

It is clear, in my view, the LDV map of sales outlook to 2027 goes hand in hand with an assessment of the corresponding PGM autocatalyst demand outlook, as this information may well influence a change in demand fundamentals and the strategic direction of the sales mix outlook.

I am of the view, based on my calculations, that there is little strategic match between Amplats’ presentation of

global LDV sales outlook and PGM demand.

What does this mean? In my view, the industry should not rely solely on the LDV map of sales outlook as an indicator of forward sales but also on the PGM supply-and-demand outlook, which goes hand in hand with the availability of supply.

Strategic and structural change and flexibility within auto manufacturing industry, in my view, becomes an imperative as PGM supply remains stagnant/diminishes.

In my view, this will require an upward step change in the production of BEVs and fast-tracking FCEVs. This evolution has already begun.

I will return to the jigsaw puzzle regarding the scenario and conclusions described above in an attempt to flush out further complexities surrounding supply and demand.



SOUTH AFRICAN LIFE-OF-MINE PRODUCTION





In this conversation, I review the complexities arising from the life of mine (LOM) of PGM production, particularly the LOM of the large South African PGM mines: Impala Platinum, Sibanye-Stillwater and Amplats, which represent some 68% of global PGM supply. and between 92% and 97% of South African PGM supply.

Typically, the LOM plan is represented as a production profile of available reserves which represents planned output and indicates the sequence of anticipated projects. In this regard, the decline in production and end-of-life timeline becomes an important consideration in capital allocation, mine planning and new projects, which are likely to extend and replace production. In this regard, I have used the published LOM data of some of the larger South African PGM mines. It is important to note that “caution” should be exercised when considering the LOM plans as these may vary if assumptions, modifying factors, exchange rates or metal prices change materially.

Note that significant amounts of capital injection will likely be needed to increase mining development and the replacement of reserves, ceteris paribus. In this regard, it is important to also note that it will take at least 5 to 10 years to ramp up additional PGM capacity, given the availability of capital.

Impala Platinum LOM



Figure 4, on the next page, illustrates the LOM (20 year) production plans for Impala Platinum (Implats) as at 30 June 2020. The plans depict LOM of platinum, palladium and 6E PGM production profiles respectively. All the LOM profiles, as expected, are similar and show:

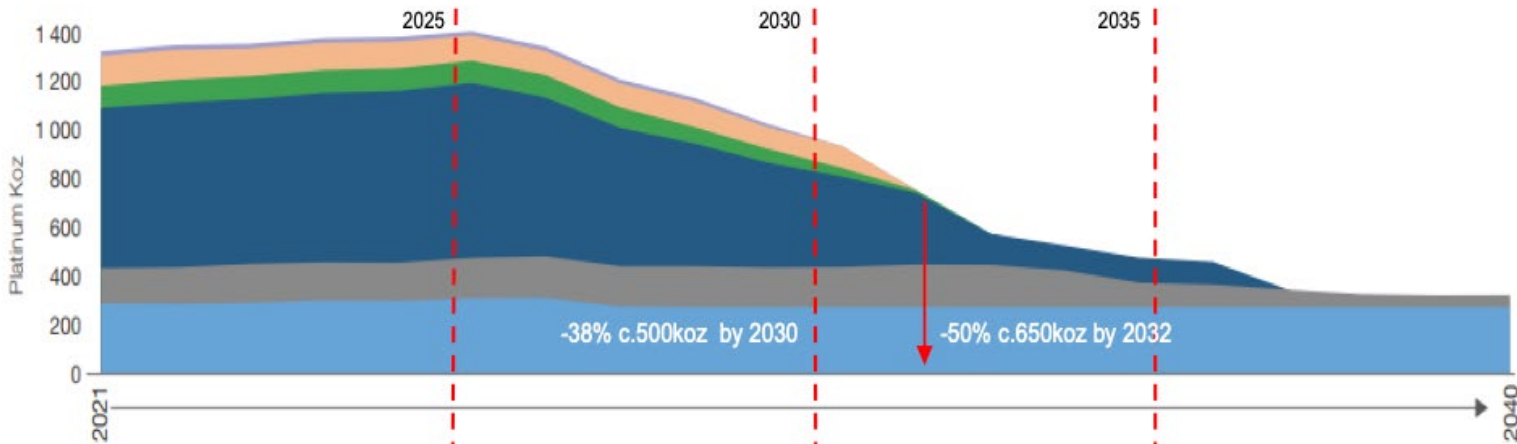
- A sharp decline after 2025, and by 2030 production will likely have declined roughly between 30% and 38%. The 6E PGM LOM production plan implies a decline of c. 1.0moz by 2030 from the production levels experienced in 2021.
- By 2032, total 6E PGM production will have likely declined c.1.5moz.

Implats is conducting feasibility studies at Impala, Two Rivers, Zimplats, Marula, Mimosa and the Waterberg project to evaluate future opportunities and ore reserve replacement.

Figure 4: Life-of-mine (20 year) production plans for Impala Platinum as at 30 June 2020 (100%)

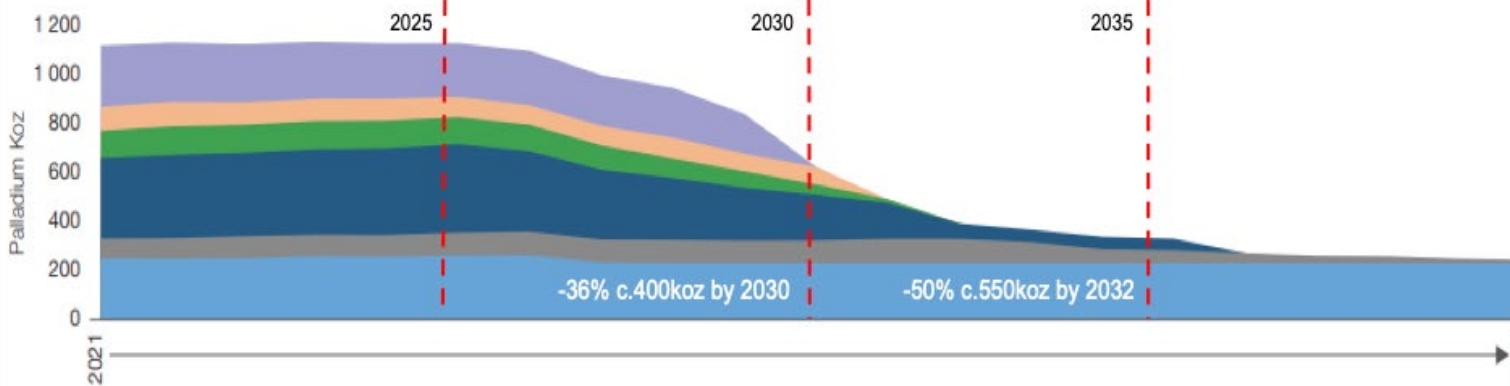
Estimated Group 20-year platinum production profile LoM I

as at 30 June 2020 (100%)



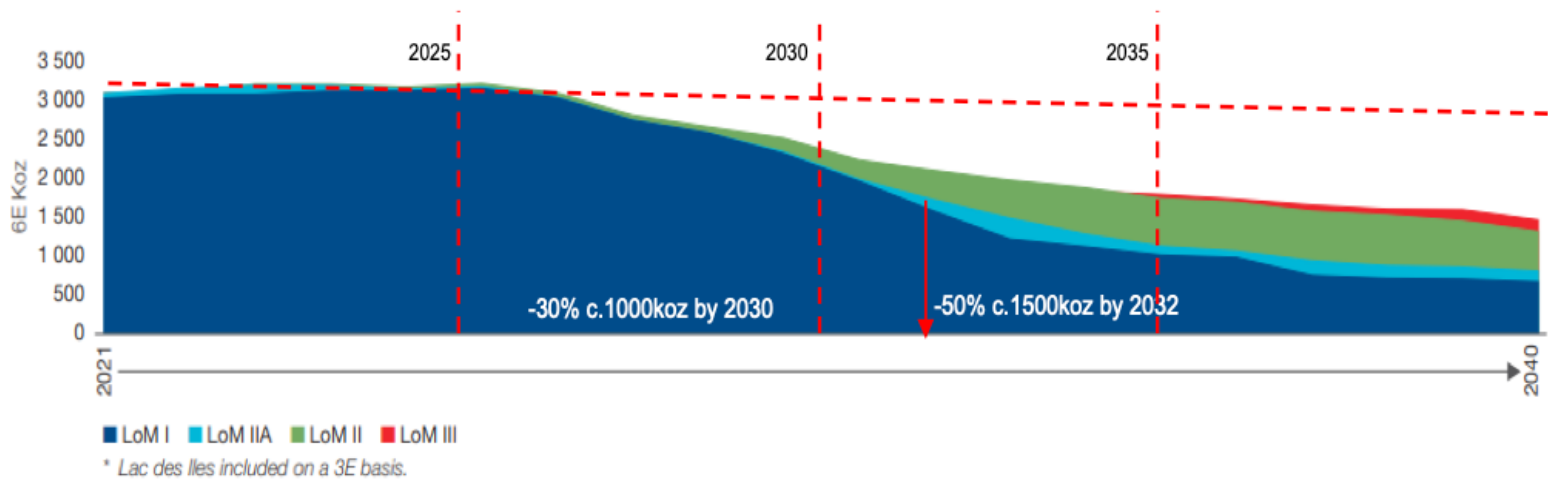
Estimated Group 20-year palladium production profile LoM I

as at 30 June 2020 (100%)



Source: Impala Platinum, Davis analysis and estimates

Estimated Group 20-year 6E production profile LoM I, IIA, II and III*
as at 30 June 2020



Source: Impala Platinum, Davis analysis and estimates



It is important to reiterate that without ore reserve replacement:

Impala Platinum's PGM LOM production plan implies a decline of roughly c. 1.0moz by 2030 from the production levels experienced in 2021.

Sibanye-Stillwater



Figure 5, on the next page, illustrates the LOM production profile for Sibanye-Stillwater's (SS), South African PGM mines as at 2019.

SS' portfolio of brownfields PGM projects could extend life further (K4, E3 and Pandora) given the availability of capital and economic viability. SS also has a pipeline of exploration projects which are at varying stages of development: Blue Ridge, Akanani, Hoedspruit and Limpopo.

It should be noted that in Figure 5, the LOM profile does not include production from surface treatment operations.

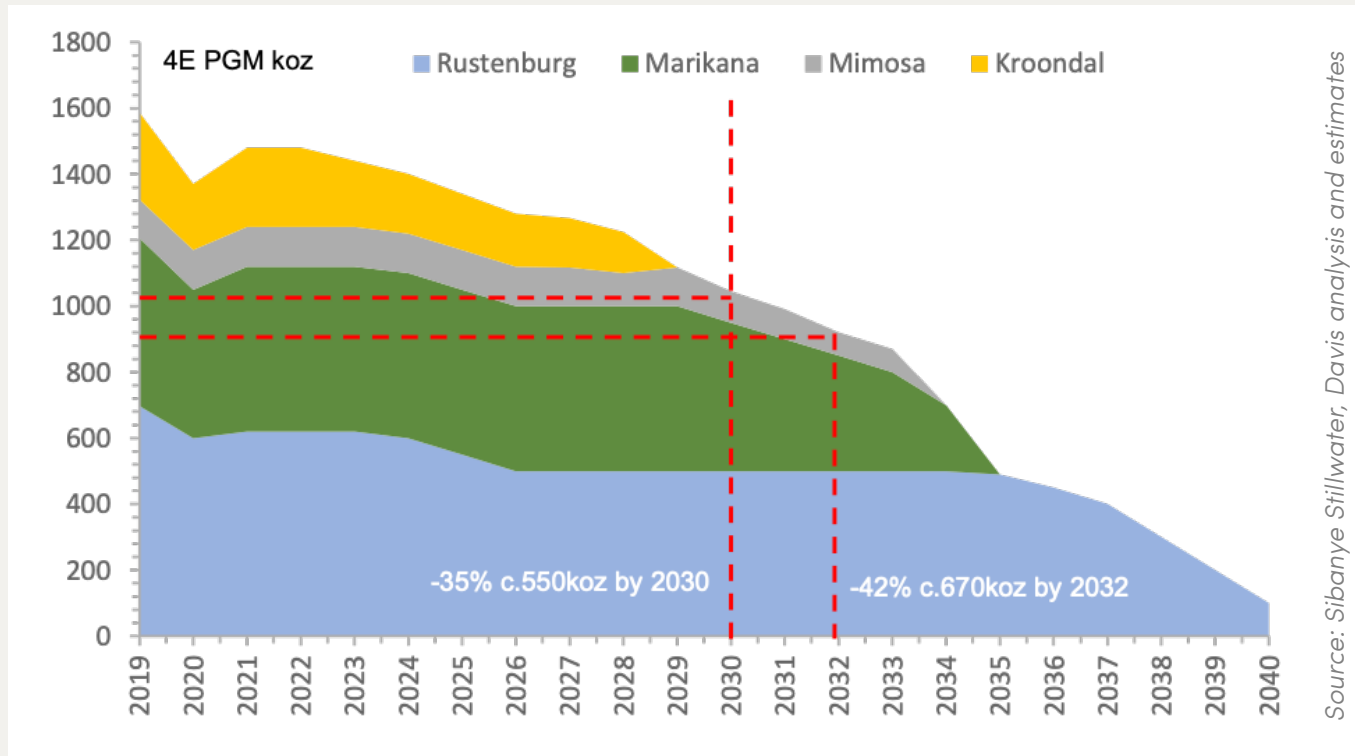


Figure 5: Life-of-mine (20 year) production plans for Sibanye-Stillwater's South African PGM mines as at 30 June 2020

The SS LOM plan shows a continuous decline in production from 2021 to 2040. By 2030 production will likely have declined by around 35% or 4E PGM 550koz, without ore reserve replacement.



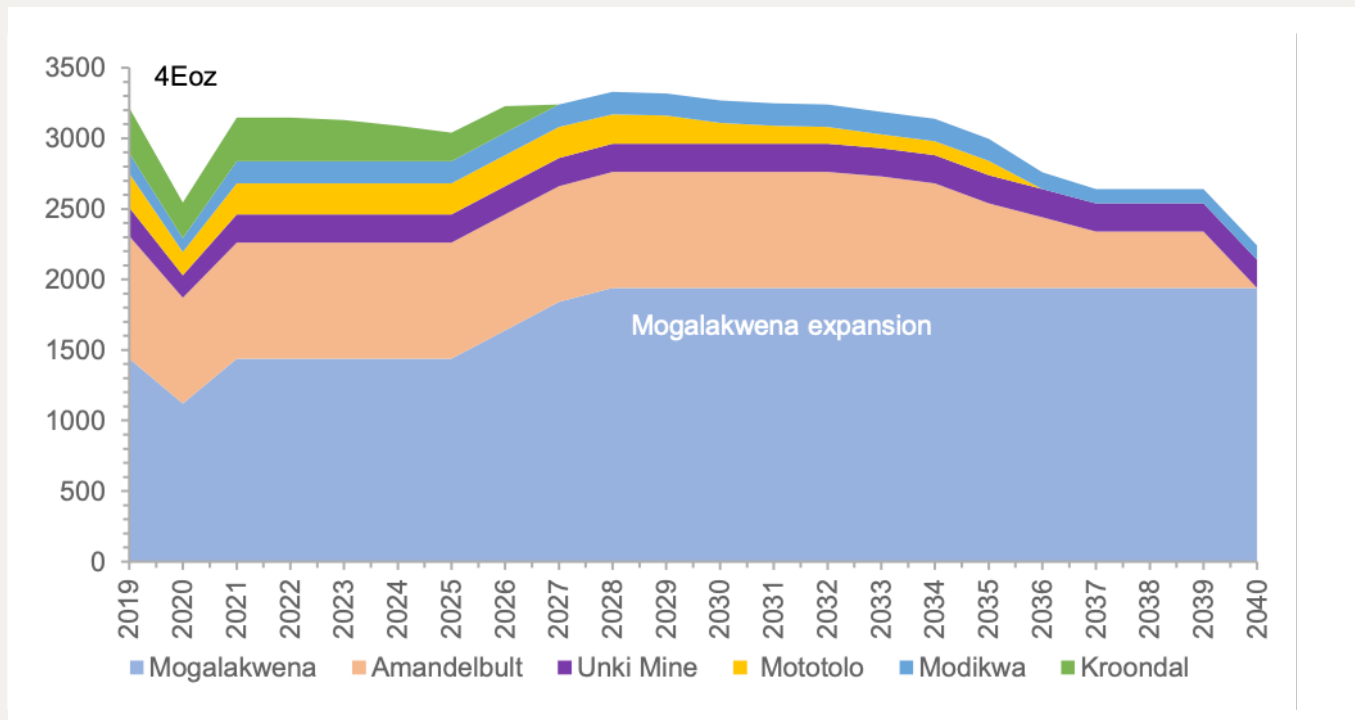
Anglo American Platinum



Figure 6, on the next page, illustrates the 4E PGM LOM (20 year) production plan for Amplats at 30 June 2020.

The LOM (Figure 6) includes the Mogalakwena expansion project, which is expected to increase production by around PGM c.500koz. It is noted that processing capacity, water, mine economics and Eskom power supply are likely to constrain further expansions.

Additional reserve replacement projects at Der Brochen/Mototolo are currently undergoing feasibility studies.



Amplats expects annual production between 2020 and 2030 to remain stable provided there is no increase in uncertainty relating to the impact of Covid-19 and the commissioning of probable projects to replace depleting supply is completed.

Source: Amplats, Davis analysis and estimates

Figure 6: Life-of-mine (20 year) production plan for Anglo American Platinum as at 30 June 2020



New mines on the horizon in SA



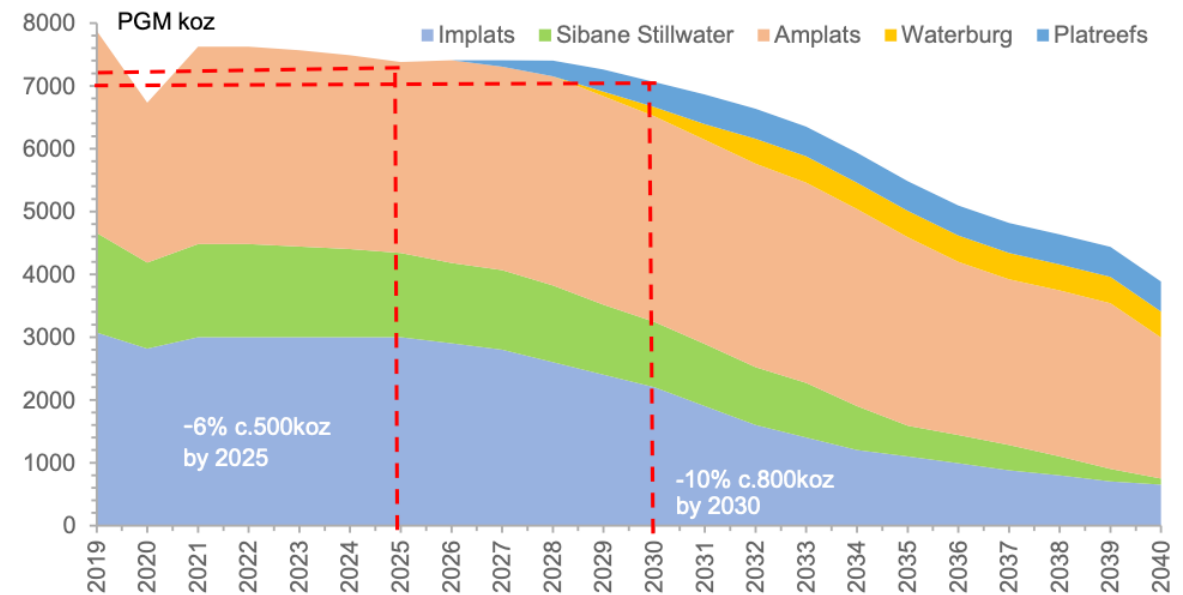
New mines on the horizon in South Africa are the Waterberg project and the Ivanhoe Platreef project. The Waterberg project is expected to reach steady-state production of around 3E PGM plus gold of 420koz by 2027, should financing be available. The Ivanhoe Platreef project plans an initial average annual production rate of 476koz PGM plus gold. I note that details of the timing to reach steady-state production are yet to be announced, I would, however, expect this date to be at least to 2027 to 2030.

Figure 7, on the right side, illustrates the combined PGM LOM (20 year) production plan for Implats, Sibanye-Stillwater and Amplats at 30 June 2020. The LOM profile of these combined mines includes the projected LOM profiles of the Waterberg and Platreefs projects. The Mogalakwena expansion project is included in the Amplats LOM profile.

The combined PGM LOM profiles including projects show:

- A decline in production after 2028, and by 2030 production will likely have declined roughly 10% or around 800koz.
- Over this period and beyond, the PGM mining mix will change. This change will result in a continued downward decline in the supply of platinum and rhodium and conversely an upward trend in the supply of palladium. The impact of the change in the PGM mining mix ratio will be discussed in the following sections of this report.

Figure 7: Life-of-mine (20 year) production plan for Amplats, Implats and Sibanye-Stillwater together with the projected LOM profile of the Waterberg and Platreefs projects.



Source: Company reports, Davis analysis and estimates

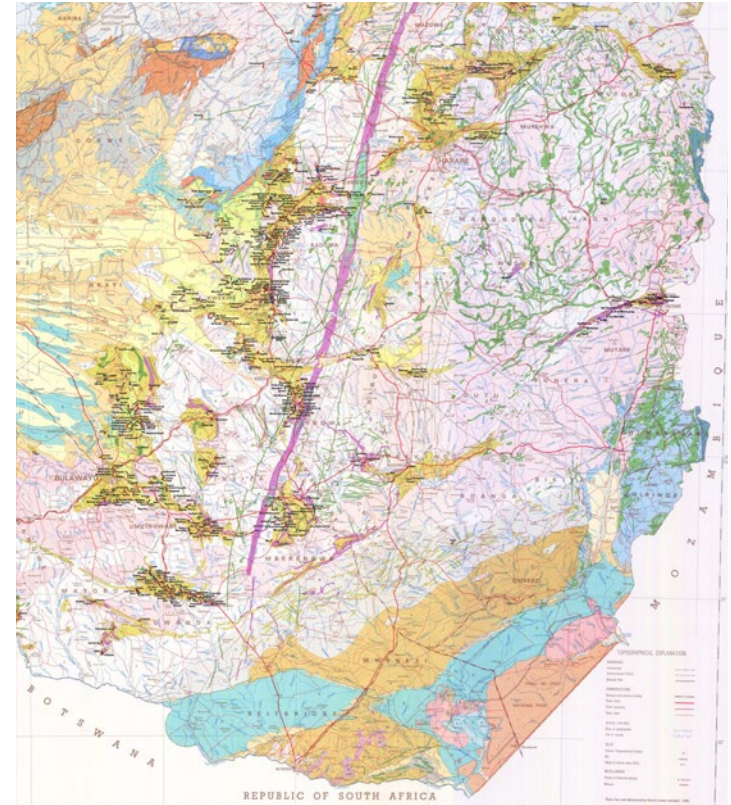
In summary, the:

PGM supply from Implats, SS and Amplats represents some 68% of global PGM supply and between 92% and 97% of South African PGM supply. Under these circumstances, the importance of continuing replacement of reserves becomes an imperative in maintaining global PGM production levels.

Zimbabwe

The Darwendale project in Zimbabwe is being implemented by a Zimbabwean company, Great Dyke Investments, which is controlled on a parity basis by Russian and Zimbabwean shareholders. The Darwendale project is situated close to the Zimplats tenements. I am given to understand that the PGM ratios (prill split) between the two are very similar to Zimplats. Darwendale ores are, however, a bit less favourable in terms of PGM content (lower ppm).

Phases 1, 2 and 3 of this project targets c. PGM 280koz, c. PGM 570koz and c. PGM 860koz respectively, Phase 1 is due to come on stream by mid-2022. Phase 2 requires a concentrator upgrade and commissioning of a smelter. Phase 3 requires a concentrator and smelter upgrade. I believe the build-up of the Darwendale project will likely be slower to come on stream than planned.



SOUTH AFRICAN PGM SUPPLY RISK

The continuity of South African production is not secure: currently, there are power outages in South Africa. These power outages are likely to be in place for at least five years and will have an impact on PGM production. The South African PGM mining industry has faced numerous challenges in the past caused mainly by the combined effects of prolonged industrial action and electricity shortages, increasing costs and a significant reduction in capital expenditure.

The CEO of Sibanye–Stillwater, Neal Froneman, commented in a recent presentation that “the increased ZAR PGM prices may have delayed selected shaft closures, however, the current investment climate and market outlook for platinum is not conducive to the commitment of large amounts of capital”. It is also noted that Impala Platinum has opted not to pursue majority ownership of the undeveloped Waterberg platinum group metals (PGMs) prospect in South Africa and has instead kept its minority stake. Impala Platinum also indicated that there is a lack of appetite from investors to finance large new mines from scratch.

Worse still, there have been a number of broken promises regarding the government’s Mining Charter and the gazetting of new iterations of this Charter. Miningmx’s Paul Miller, in a recent review wrote: “From a foreign investor’s point of view, this reveals the Charter to be less about creating a firm foundation for mining growth and social cohesion in South Africa, and more about the expropriation of growing portions of their already inherently risky future returns. Unfortunately, the future of the industry has rarely been less certain.

South Africa doesn’t have, and has never had, a large enough savings base to be able to fund the mining industry on its own. It depends on foreign investors for new investment. The bottom line is that there is now not even the slightest glimmer of certainty regarding Charter 4, 5 or 6”.

The risk is to the downside.

WHAT THEN IS THE FUTURE of global PGM supply?



In the conversation above, I have described LOM profiles of Implats, SS and Amplats; Implats and SS display a significant decline in PGM production after 2025 due mainly to a decline in reserves. The additional supply of PGMs from the Waterberg and Platreefs projects and the Mogalakwena expansion project may well offset his decline to 2030, *ceteris paribus*.



Expansion projects in Zimbabwe are harder to read. However, I am of the view that these projects will have an impact on future global supply by 2030.

Russia's Nor Nickel announced on 1 December 2020 that its targeting brownfields production growth of up to 15% for nickel, 20% for copper and between 45% and 50% for PGMs by the early 2030s, from 2020 levels, to ensure supply availability. I note that the PGM mix ratio from Nor Nickel's growth target is highly skewed towards palladium at 80% or 1,400koz, 18% or 313koz platinum and 2% or 32koz rhodium.

Under these circumstances, Russia could “flood” the market with palladium by 2030, especially when PGM supply from South Africa is also becoming palladium rich. Under these circumstances, I would expect the supply of platinum to decline further in an environment of overwhelming and increasing demand for platinum from around 2025.

MAJOR GLOBAL PLAYERS: Estimated life-of-mine production

In this section of the conversation, I have attempted to “assess the impact” and get a “sense” of the quantum of additional production and/or replacement of PGMs that will likely accrue globally when the new projects described above have been commissioned in South Africa, Zimbabwe and Russia. In this regard, I have used the 20-year estimated life-of-mine production of Amplats, Implats and SS.

The figures used in this forecast exercise were derived from annual reports and news releases and come with assumptions and limitations and should be viewed as such.

The objective of this exercise is to estimate the continuity of global PGM production over the next 20 years. Figure 8 illustrates the estimated 20-year LOM production from Zimbabwe, Russia and South Africa (Amplats, Implats and Sibanye-Stillwater).

The new LOM estimated production profile highlights a number of significant changes with regard to the forward-looking PGM ratio mix, ceteris paribus.

- Despite additional production from Russia and Zimbabwe, the global LOM profile starts to decline around 2031.
- It is clear that the South African PGM industry will require a significant capital injection to reverse the decline in production, particularly with regard to supply of platinum.

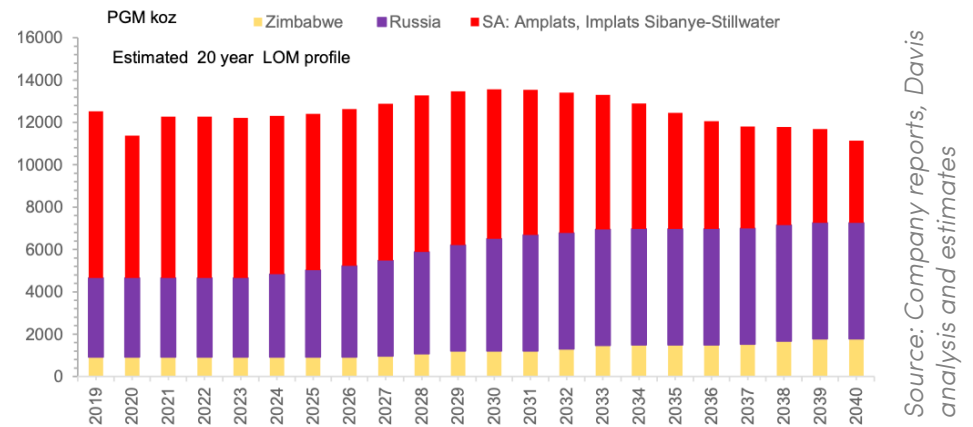


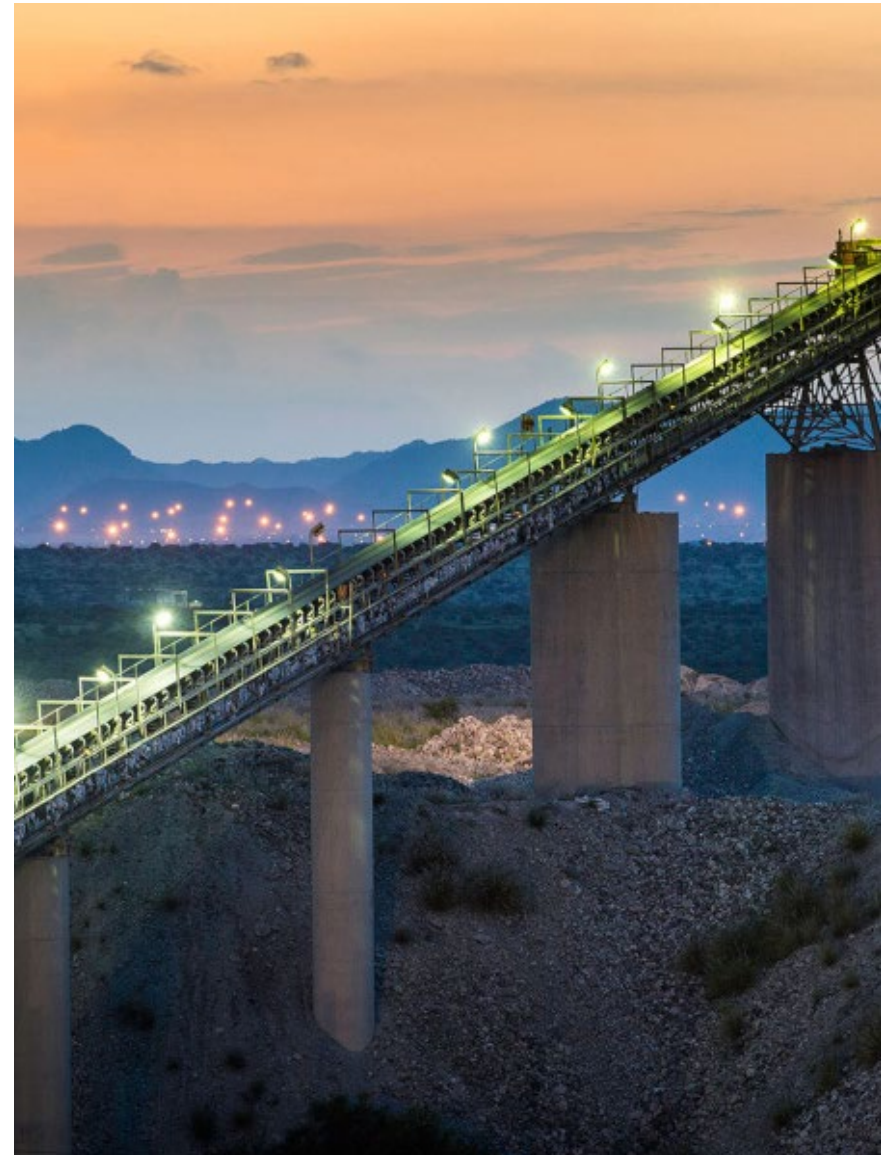
Figure 8: Estimated 20-year LOM production from Zimbabwe, Russia and South Africa (Amplats, Implats and Sibanye-Stillwater)

In summary:

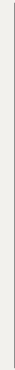
Global PGM mine supply will most likely remain roughly constant with an average of around PGM c.13moz, with a recognisable downward trend starting around 2031.

The major players surrounding the global PGM LOM production profile implies that the centre of primary PGM production is moving away in the long term from South Africa towards Russia and Zimbabwe, given these circumstances, it follows that the PGM mix ratios of platinum, palladium and rhodium will change to higher palladium and lower platinum and rhodium supply.

This, given that all the projects described above are commissioned on time and have reached planned output levels, ceteris paribus.



PLATINUM TO TAKE THE LEAD



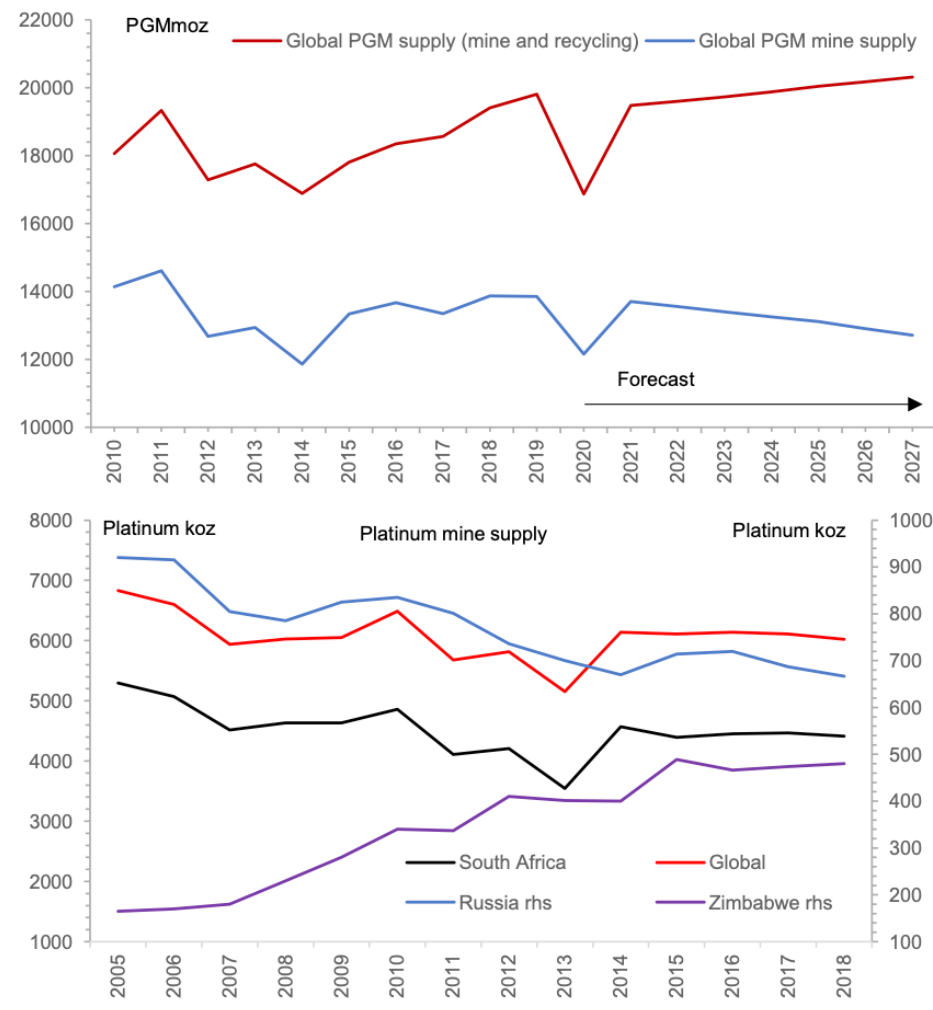
It is important at this stage of the conversation to put into perspective global platinum mine supply in comparison to South African platinum mine supply. Global mine supply between 2006 and 2019 declined by CAGR -1.0%, South African platinum supply declined by CAGR -1.4%, Russian mine supply declined by CAGR -2.4%, while platinum mine supply from Zimbabwe grew by CAGR 8.6%. It should be noted that mine supply from South Africa, Russia and Zimbabwe represents around 73%, 11% and 7.7% respectively of global platinum mine supply. Figure 9, on the next page, illustrates the decline in global, South African and Russian mine supply.

The gradual decline in the supply of platinum is attributed mainly to the historical evolution of the mining mix ratio of the PGM reefs to a swing to higher mining ratios of the UG2 Reef from the Merensky Reef and Platreef.

I note that the UG2 Reef generally contains larger quantities of rhodium than Merensky Reef and Platreef. The Merensky Reef contains relatively higher PGM grades and ratios of platinum (vs palladium). The Platreef is palladium rich. The swing to higher mining ratios of the UG2 Reef from the Merensky Reef has enabled PGM mining companies to take full advantage of the increased palladium and rhodium price environment.

However, the decline in platinum supply from South Africa will likely be aggravated, in time, with the introduction of increasing quantities of Platreef into the mining mix, which has low levels of rhodium and relatively low levels of platinum. Furthermore, I am of the view that the increase in Russian production by 2030 is unlikely to halt the decline in platinum supply.

Under these circumstances, I am also of the view that the supply of platinum and rhodium will likely be increasingly under pressure, as the mining mix moves to increased quantities of lower platinum and rhodium grades. This scenario could have an impact on physical availability and potentially impact price.



Source: Johnson Matthey. Davis analysis and estimates

Figure 9: Forward estimates of global PGM mine supply plus recycling, and platinum supply

I am of the view that South African platinum mine supply will continue to decline at a CAGR of c.-1.4% at least over the long term. This will tighten the supply market and put upward pressure on the price. This emphasises the need for capital investment in the South African PGM mining industry.

FORWARD LOOKING supply and demand trends

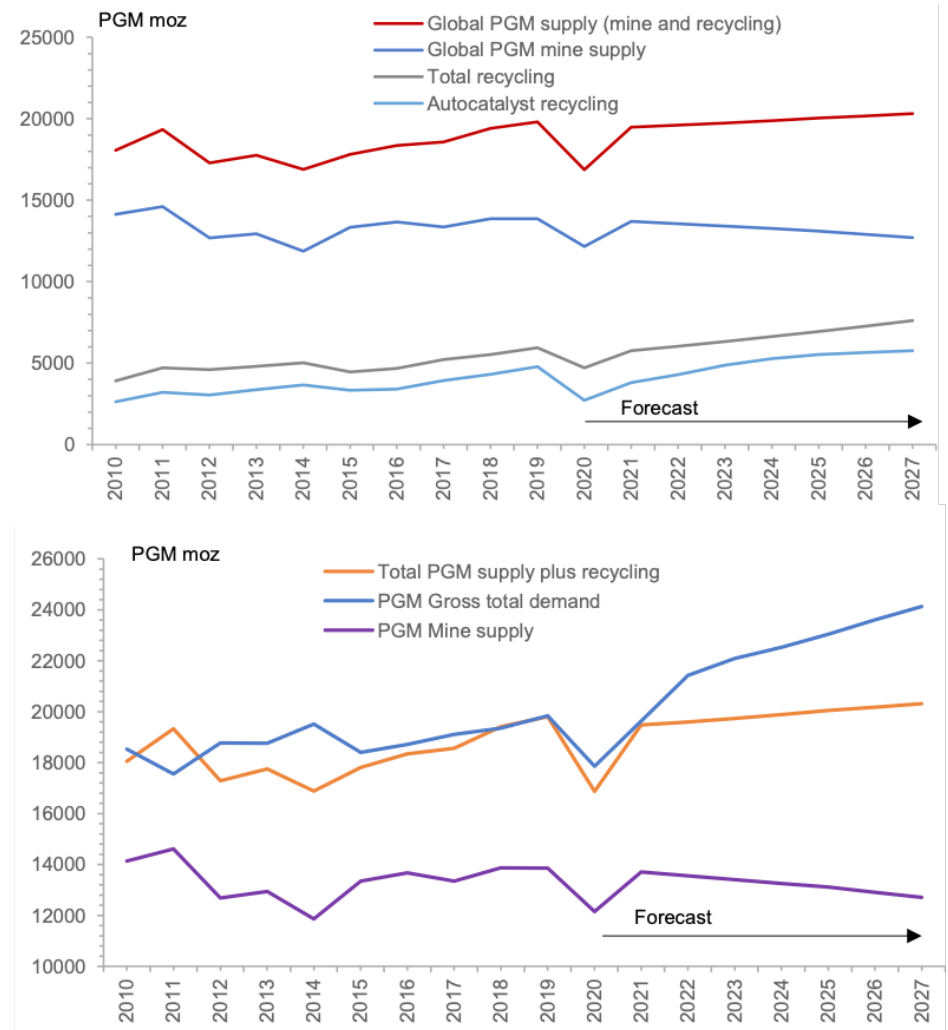
Figure 10, on the next page, illustrates a PGM forecast of the main elements in the supply-and-demand equation from 2020 to 2027. Figure 10 also shows an upward and continuous step change in demand in 2022, which I suggest is linked to an increase in total PGM loadings. The quantum increase in PGM autocatalyst demand will likely be around c.3.7moz, which will take demand to c.16moz, or 35%, by 2027, given a 9,2% increase in the number of LDVs sold between 2019 and 2027. Note that Amplats' figures were used as a "base case" when calculating forward-looking demand scenarios.

Note also, that Amplats' figures surrounding forward-looking LDV sales do not take into account the increasing demand for platinum for use in fuel cell drive trains of heavy-duty trucks or the increase loadings required by tighter emissions legislation.

Between 2021 and 2027, my calculations imply that global PGM autocatalyst demand will likely grow at a rate of (CAGR) around 3.9%. It is interesting to note that Global Data reports (21 October) a similar quantum for autocatalyst platinum demand of (CAGR) 3.8% between 2020 and 2024 and expects global platinum demand to increase by a CAGR of 4.3% over the same period. My calculations imply that global PGM demand will likely grow at a rate of (CAGR) around 3.5%. In this regard, my estimates are not too dissimilar from GlobalData’s estimates.

In summary:

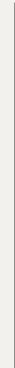
I am of the view that the forward looking PGM demand trends clearly, cannot be met by the forward looking supply by PGM supply.



Source: Johnson Matthey. Davis analysis and estimates

Figure 10: PGM forecast of the main elements in the supply-and demand equation from 2020 to 2027

DRIVERS OF PGM DEMAND



It is important to recognise that there is a significant difference between the sectors and the quantum of demand associated with the application of platinum and palladium. For platinum, autocatalysts, jewellery and investment at c.34%, 25%, and 13% respectively, are the main drivers of demand. For palladium, autocatalysts and electronics at 84% and 6% respectively, are the main drivers of demand. It is clear that platinum demand is also influenced by jewellery demand and is therefore subject to the vagaries of choice and societal economic factors. It is also clear for similar reasons that platinum investment demand for ETPs, bars and coins can be considerable, and as such can act as a significant swing factor in demand fundamentals and market balance, particularly for platinum.

For example, the WPIC reported continued strong investment demand in Q3 2020, with investment volumes expected to be up 32% to a record high of 1,659koz. Bar and coin demand is forecast to grow by 123% to 629koz in 2020.

Figure 11 illustrates the major drivers of PGM demand, Clearly, platinum autocatalyst demand is lagging. This is mainly because a palladium and rhodium metal mix is used in petrol catalytic converters, whereas a platinum, palladium and rhodium metal mix is used in diesel catalytic converters. Platinum is the predominant PGM in the metal mix in diesel autocatalysis and palladium is the predominant PGM in the metal mix in petrol autocatalysis.

Figure 11 also highlights a significant and potentially overwhelming demand for platinum, which is now looming at a

pace because of the increased applications of hydrogen fuel cells. This area now becomes the focus of the remainder of my conversation.

Figure 11: Drivers of the PGM demand

PGM Demand	Percent distribution (current)			Main Drivers 2021 to 2030
	Pt	Pd	Rh	
Chemical	7	4	6	
Electrical	3	6		
Glass	5		5	
Investment	13	0		Pt: Highly variable and significant driver
Jewellery	25	1		Pt: Evidence of green shoots.WPIC expects demand increase by 20% by 2021
Medical and biomedical	3			
Petroleum	3			
Dental		3		
Other	7	2	4	
Sub total	66	16	15	
Autocatalyst	34	84	85	Pt and Rh: Pt substitution for Pd. Increase in loadings
Fuel cells				Pt: Hydrogen-powered heavy duty trucks and LDV
Green Hydrogen production				Pt: Electrolysis used in the production green hydrogen
Battery technology				PGMs:Improving the range of distance that battery electric vehicles could travel and lower recharge time.
Conversion of BEV to FCEV				Pt: Municipal BEV buses and trucks are being converted into hydrogen fuel cell vehicles by China.
Total Demand	100	100	100	

Source: Johnson Matthey. Davis analysis and estimates

ADDITIONAL DRIVERS SET TO SUPPORT PLATINUM DEMAND

Hydrogen fuel cell technology

Hydrogen fuel cells directly convert the chemical energy in hydrogen to electricity and release water and useful heat as by-products. Hydrogen fuel cells are pollution free and have greater efficiency than traditional combustion technology. Hydrogen fuel cell technology has advanced significantly over the past two decades. It is important to note that fuel cells have many applications apart from vehicles, which include heavy vehicles, buses, forklifts, boats, trains, submarines, aerospace, space and numerous stationary applications, which include powering homes and industry.

There are now two types of hydrogen fuel cells, which will ultimately increase platinum demand.

According to the WPIC, platinum's role in the hydrogen economy is crucial both throughout the EU and beyond; it is used in fuel cells for fuel cell electric vehicles, as well as in the production of green hydrogen.



THE PRODUCTION OF GREEN HYDROGEN



Heraeus recently made a breakthrough in the production of green hydrogen by electrolysis, using new platinum and a much-reduced iridium containing cathode, which has resulted in making the production green hydrogen cost effective and more efficient.

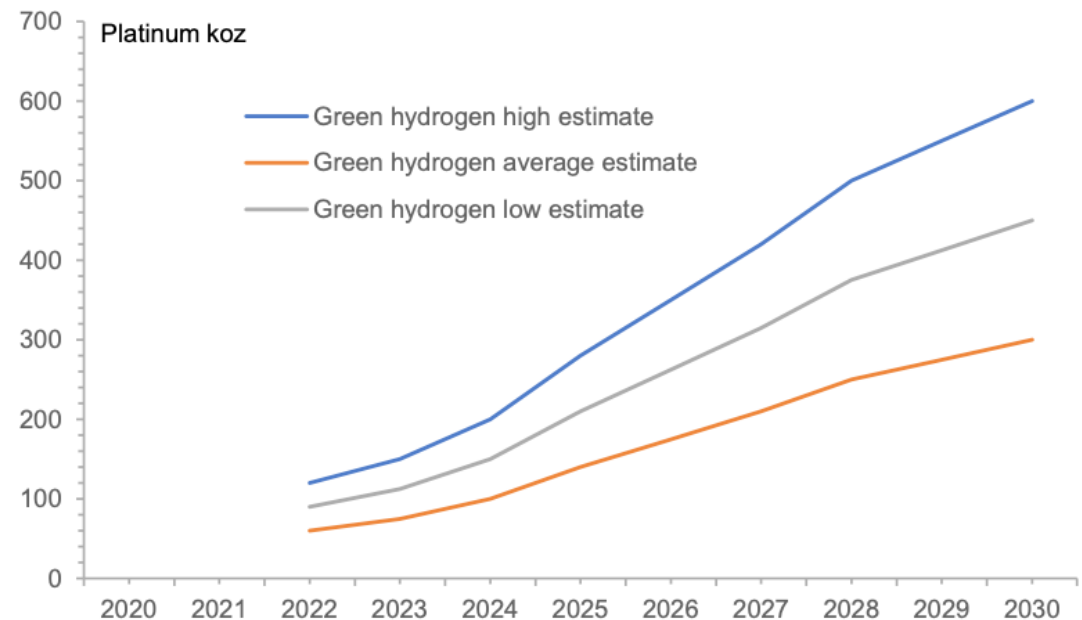
Many governments, including the EU, Japan, South Korea and China, have put the development of fuel cell technology high on their agendas and are investing heavily in technology, development and infrastructure for hydrogen and fuel cells.

The development of infrastructure to support refuelling vehicles and industry is also expanding at a pace. IHS Markit recently reported (3 December 2020) that investment in the production of hydrogen powered by renewable sources, or green hydrogen, is likely to exceed USD1 billion by 2023. IHS Markit also indicates that green hydrogen production costs have decreased by 40% since 2015 and are expected to fall by a further 40% through to 2025. IHS Markit expects green hydrogen costs could drop below USD2/kg where it would compete with hydrogen produced from natural gas with carbon capture, also known as blue hydrogen.

A road map for reducing the EU economy's carbon emissions through a hydrogen ecosystem was among the initiatives under the European Green Deal, the EU released its Hydrogen Strategy in July 2020. In this regard, a strategic objective to install at least 40GW of hydrogen electrolyzers by

2030 with annual production of up to 10 million tonnes of 'green' hydrogen across the region was agreed upon.

The WPIC indicated that the generation of green hydrogen capacity targets "alone" in the EU and China would require, cumulatively, between 300koz and 600koz of additional platinum by 2030.



Source: WPIC. Davis analysis and estimates

Figure 12: Additional cumulative platinum demand required to install at least 40GW of hydrogen electrolyzers in the EU and China by 2030

It is important to note that the additional platinum demand only considers the EU and China.

What about the additional platinum demand required to produce green hydrogen in Japan and the US?

I recognise, however, that green hydrogen can be produced by wind and solar sources and, in this regard, there is likely to be an economic trade-off between these production methods.

The use of fuel cell technology in the production of green hydrogen has been described as a “game changer” for platinum demand and together with substitution, higher autocatalyst demand will inevitably cause upward pressure on the platinum price.



ESTIMATED IMPACT of additional demand for platinum



In this section, I discuss the potential impact of the additional demand for PGMs from increased autocatalyst loadings and particularly the additional platinum demand from FCEV, heavy-duty trucks and production of green hydrogen.

It is important to note that my estimates of additional demand are based on published figures “only” and in this regard represent the lower level of the demand spectrum. Suffice to say, the lower end of demand will demonstrate the lack of supply to meet the additional demand. Notwithstanding any increase in demand from the industrial, jewellery and investment sectors, together with the additional demand from the US, Japan and the Rest of the World

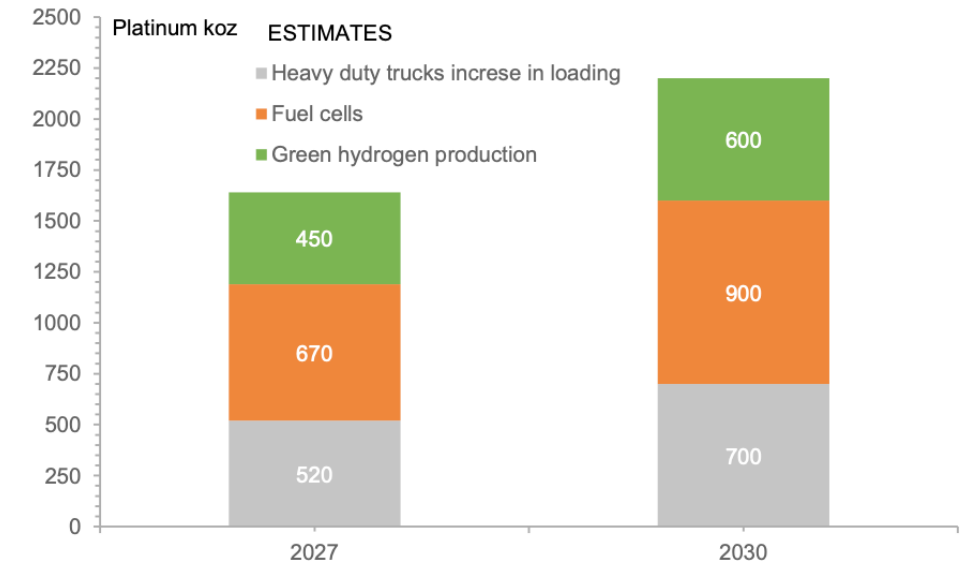
Estimates of the additional demand based on published figures may be attributed to:

- Amplats has described Chinese truck demand as a platinum growth area. All Chinese heavy-duty trucks sold by 2023 will need platinum-based catalysts. Amplats reports that platinum loadings per vehicle will be around 3x higher by 2022 than 2019. Amplats further estimates that the additional demand for platinum would amount to some 280koz by 2023. By extrapolation, Chinese heavy-duty trucks will likely amount to some c.520koz by 2027 and c.700koz by 2030.

- Hyundai will absorb an additional 700koz of platinum demand to be used in the manufacture of fuel cell stacks by 2030 (estimate c.520koz by 2027).
- Assuming there is no double accounting with Hyundai manufacture, the EU will require heavy-duty fuel cell stacks for 100,000 heavy-duty trucks: This would account for an additional 200koz of platinum demand by 2030 (estimate c.150koz by 2027).
- In the EU and China, green hydrogen production would require, cumulatively, between c.300koz and c.600koz of additional platinum by 2030 (estimate c.450koz in 2027).

In summary:

Approximately c.1,640koz and c.2,200koz of additional platinum may well be required in 2027 and 2030 respectively. This additional platinum supply represents some 27% and 36% of global mine supply in 2027 and 2030. Where will this additional supply come from? Above ground stocks?



Source: Amplats, News, Davis analysis and estimates

Figure 13: Estimates: autocatalyst platinum demand for Chinese heavy-duty trucks, fuels cells and green hydrogen production

Clearly, the scenario presented above will likely represent a conundrum for the PGM industry and the environmental emission control regulation authorities.

It becomes obvious that PGM mine supply, particularly platinum and secondary recycling, will not be able to support current thinking with regard to finding the optimal drive train vehicle mix.

As I have previously indicated:

Strategic and structural change and flexibility within the

auto manufacturing industry, in my view, becomes an imperative as PGM supply remains stagnant/diminishes.

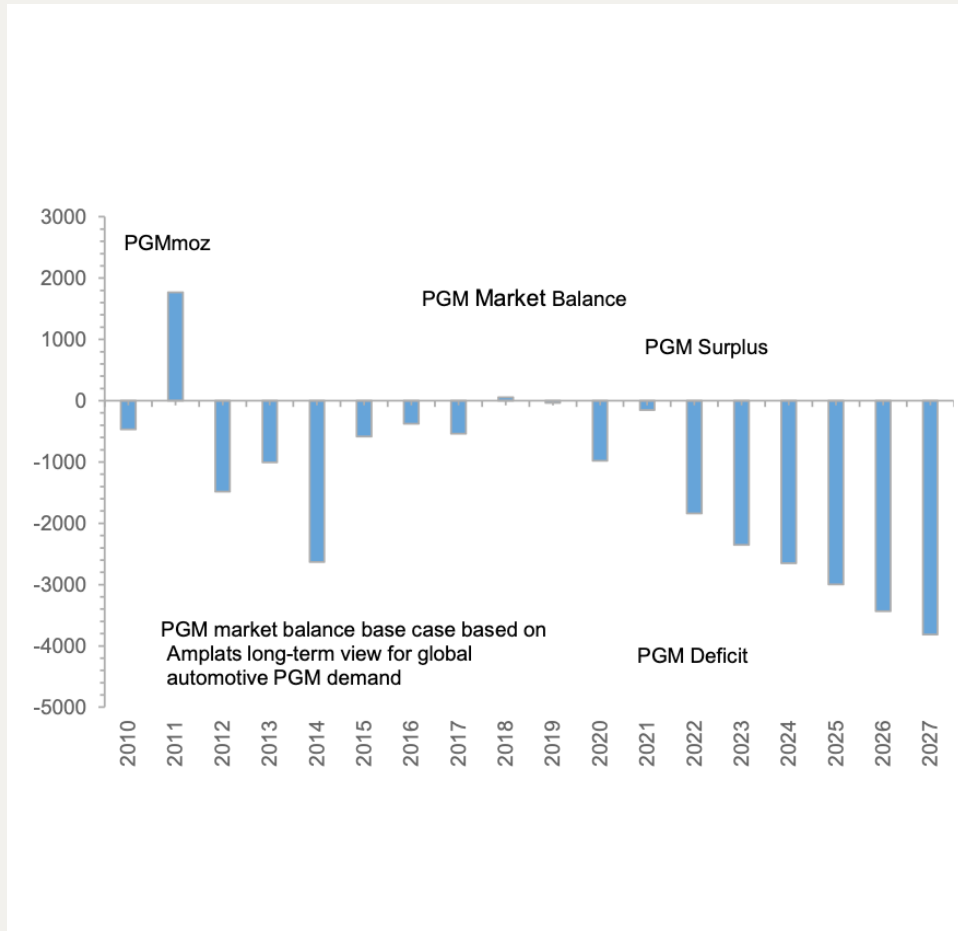
In my view, this will require an upward step change in the production of BEV and fast-tracking FCEVS. Furthermore, it seems that palladium will still have a part to play in the emission control of petrol vehicles, as I am of the view that Russia will likely flood the market with palladium by 2030.



PGM market balance

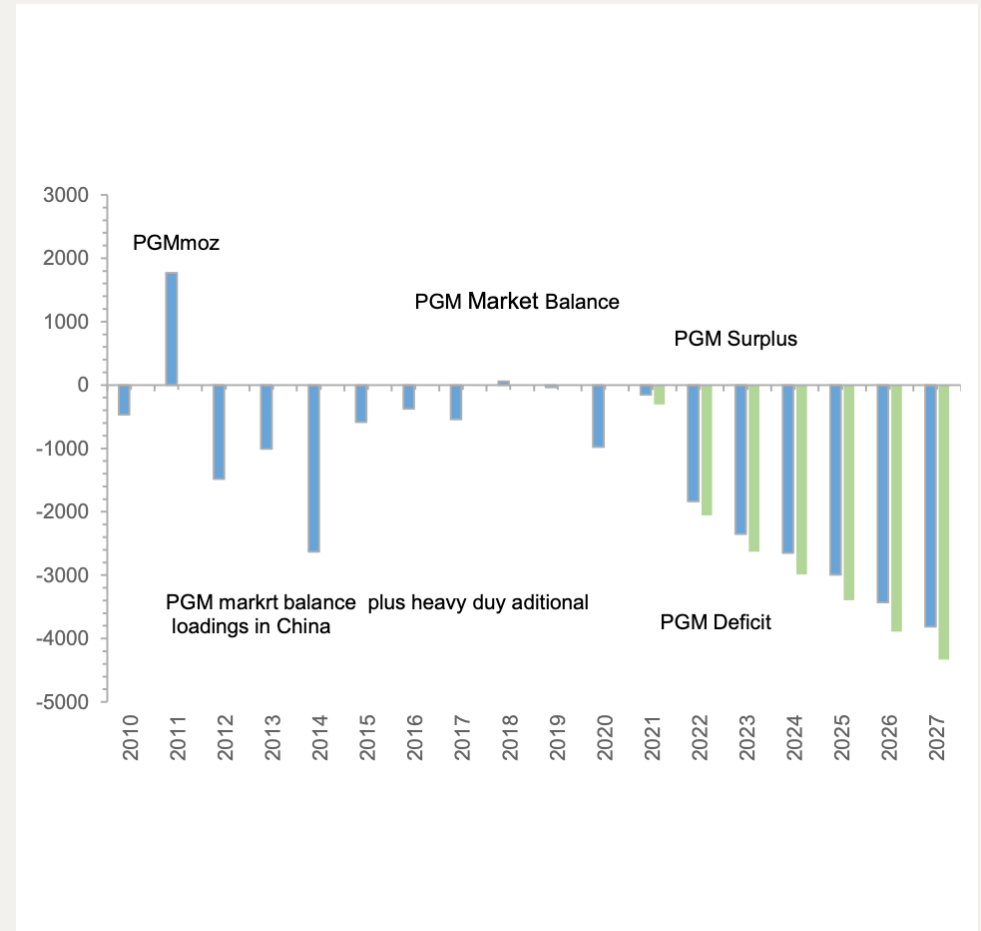
In this conversation, I have estimated a forward-looking PGM market balance based on Amplats' long-term view for global automotive PGM demand supported by higher PGM loadings per vehicle between 2019 and 2027 (base case). In addition, I have included an estimate of the additional demand for platinum catalyst loadings in heavy-duty trucks together with fuel cell requirements and the requirements to produce green hydrogen. Figures 14, 15 and 16 on the next page.





Source: Amplats, Johnson Matthey, Davis analysis and estimates

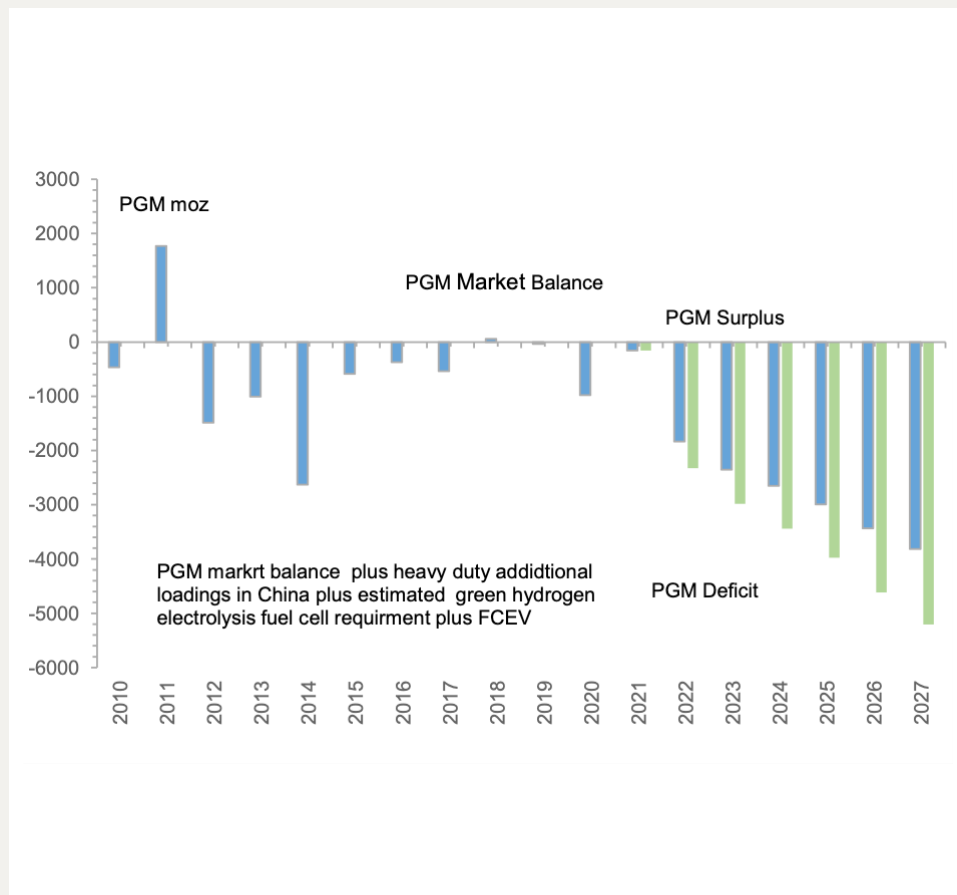
Figure 14: PGM market balance based on Amplats' long-term view for global automotive PGM



Source: Amplats, Johnson Matthey, Davis analysis and estimates

Figure 15: PGM market balance based on the base case plus an estimate of the additional demand for platinum catalyst loadings in heavy-duty trucks in China





Source: Amplats, Johnson Matthey, Davis analysis and estimates

Figure 16: PGM market balance based on the base case plus an estimate of the additional demand for platinum catalyst loadings in heavy-duty trucks in China plus an estimate surrounding the production of green hydrogen plus requirements for FCEV, heavy-duty trucks and LDVs

Figures 14, 15 and 16 illustrate the estimated Impact of the additional demand for platinum emanating from higher autocatalyst loadings in LDVs and heavy-duty trucks, the introduction of fuel cells and the production of green hydrogen on the PGM market balance. Notwithstanding any increase in demand from the industrial, jewellery and investment sectors.

In my view, PGM demand will continuously outstrip stagnant supply in as little as two to three years.

In am also of the view that the demand for PGMs and platinum in particular will inevitably increase at a pace, particularly when a continuous unstainable palladium and rhodium market balance deficit and high price differentials are considered.

What then is the future of PGMs given the scenario described above? The market balance for palladium has been in deficit for at least nine years and rhodium is about to follow suit. In both cases, the supply imbalance has been the main driver of the sky-rocketing price. In my view, platinum will be next to board the price rocket.

It is also clear that the upward movement in the platinum price will be supported by the combination of a number of market indicators characterised by strong consumer demand and tight physical availability, coupled with a continuous supply and demand market balance deficit.

In this regard, it is not impossible for the platinum price to move upward and reach and pass the record price of USD2,080 achieved in early 2008.

STOCK MYSTERY

The conversation thus far has focused on PGMs' supply-and-demand fundamentals and market balance.

The industry provides important and valuable supply-and-demand statistics. I argue, however, that this data is incomplete; furthermore, the PGM industry is mainly silent on one of the most important aspects of supply in the supply-and-demand equation to which, I will allude to in this discussion.

In this regard, it is important to answer two simple questions:

- How is the continuous and ever-increasing market balance deficit being supported?
- When will the "top-up support" to the market balance deficit run out?

In my view, the PGM industry is indecisive in providing a qualitative answer to these questions by indicating palladium remains in a "structural deficit" and/or is

attributed to unknown stocks, possibly from unknown Russian stocks, and/or manufacturers' work-in-process (WIP) inventories, and/or inventories that are quantified in the number of days of inventory excess.

It is, however, unlikely that the top-up of the annual market balance deficit will have originated from Russia or WIP as the cumulative deficit is very large, particularly for palladium.

It is important to note that there is general consensus in the industry that the unknown stocks the "above-ground stocks are in decline".

My calculations (1993 to 2019) imply that the above-ground global platinum stocks are still large, but there's a catch. Of the estimated 33moz of platinum above-ground stocks, China accounts for some 14.6moz leaving 18.4moz of above-ground/investment stock potentially mobile. China does not export platinum and began to accumulate platinum around 2010.

On a regional basis, my estimates imply North America, Japan, Europe and the Rest of the World hold 11.0moz, 2.3moz, 2.8moz and 2.0moz respectively. The most striking observation regarding regional trends in the above-ground / investment stock portion between 1993 and 2019 relates to the continued declining trend associated with Europe. (My figures exclude exchange-traded funds, metal held by exchanges or working inventories of producers, refiners, fabricators or end-users.)

My estimates of the above-ground palladium stocks are also large at around 21moz. On a regional basis, my estimates imply North America, Japan, Europe, China and the Rest of the World hold 2.0moz, 8.2moz, 5.3moz, 3.0moz and 2.5moz respectively. The striking observation regarding the above-ground / investment stock trend associated with the European portion between 1993 and 2019 observed for platinum is repeated for palladium.

It is important to note that once the PGMs go into a continuous decline they are on “borrowed time” and they become price dependent, upon how “sticky” they become. In this regard, they will likely support higher prices.





About Dr David Davis PhD. MSc. MBL. CEng. CChem. FIMMM. FSAIMM. FRIC.

David has been associated with the South African mining industry and mining investment industry for the past 44 years (mainly PGM, gold and uranium). At present, David is working as an independent precious metal consultant. David's PhD involved: "Studies in the catalytic reduction and decomposition of nitric oxide 1976".

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