PLATINUM

South African Platinum Mine Supply in Decline as Demand Gains Significant Traction
Part I

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Introduction

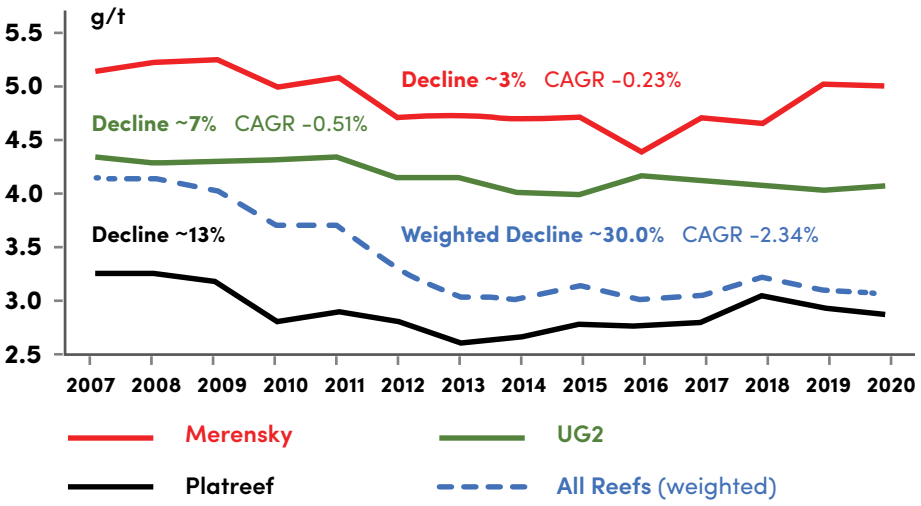
This review provides insight into the impact of the continuous long-term decline in South Africa's Platinum (PGM) mine supply in an environment where Platinum and PGM demand is gaining significant traction as a result of the increasing pressures surrounding climate change.

Global Platinum mine supply is heavily dependent on supply from South Africa (72%) as well as Russia (12%), North America (6%) and Zimbabwe (7%). South African Platinum mine supply has declined at a CAGR of -1.4% between 2006 and 2019.

In my view, there are many reasons for the gradual decline in the supply of Platinum. In this review, I have attempted to show the significance of these reasons by quantifying them, where possible. These reasons are of fundamental and strategic importance concerning the future demand for Platinum, Palladium, Rhodium and Iridium. Other factors, which are equally important, are the ore grade and price of these metals.

In this regard, I discuss the complexities arising from the geological structure of the PGM reefs of the South African PGM mines.

Reserve grades of: Merensky, UG2 and Platreef and the weighted average grade (Amplats 2020, 4E reserves)



Source: Amplats, Davis

Economic concentrations of PGMs occur mainly within three distinct reefs within the Bushveld Complex (BIC) in South Africa. The Merensky Reef; the Upper Group 2 (UG2) Chromitite; and the Platreef.

The Merensky Reef and the UG2 Reef occur around the Eastern and Western limbs of the complex, while the Platreef is found only along the eastern edge of the Northern Limb (Amplats). In summary, I am of the view that the decline in Platinum mine supply is due to a combination of factors:

These factors include the declining grade of the three reefs over time, the unequal depletion of reserves and the historical evolution of the mining mix ratio of the PGM reefs to higher mining ratios of the UG2 Reef (which has lower Platinum grades when compared to the Merensky Reef). It is important to note that there are additional factors which are likely to accelerate the decline in Platinum supply, in particular the loss of PGM supply associated with South Africa's looming energy crisis (Eskom).

Under these circumstances, Platinum will move into a continuous deficit, which will put upward pressure on the price. Furthermore, the decline in mine supply will accelerate Platinum's move into an overall market balance deficit.

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.

A decline in supply together with overwhelming demand is a formula for a build-up of a 'perfect storm". *As Platinum moves into an increasing market balance deficit, thereby stimulating PGM prices to move higher.* ***We can expect the price of Platinum to continue substantially higher than its highest ever recorded price of US$2,253/oz.***

It is important to note that a decline in ore grade over time will

ultimately impact mine throughput and consequently milling and refinery may have to be upgraded where necessary. Under these circumstances, the industry will likely require additional expansion capital.

Strong demand for Platinum (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 load ratios) of Palladium, Platinum and Rhodium (PGMs) in autocatalysts to meet the stricter limits, especially for heavy-duty vehicles (HDV). The additional quantum of PGM autocatalyst loadings is significant despite the expected increase in battery electric (BE) vehicles. Furthermore, radical shifts in the types of vehicles being offered, which include BEVs, HEVs and FCEVs, is becoming a moving target as governments strive to meet zero net emissions by 2050.

Future platinum demand will stem from the additional quantum of PGM autocatalyst loadings and the rapid development of hydrogen fuel cell and green technologies.

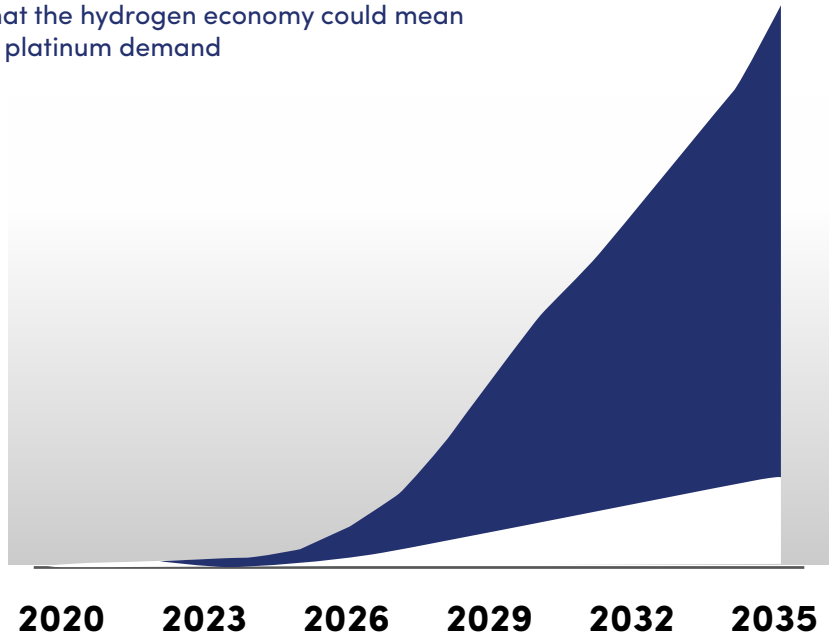
Furthermore, price mismatches between Palladium and Platinum have driven vehicle manufacturers to substitute Palladium for Platinum in petrol-driven vehicles. ***These three influences will drive Platinum demand significantly.***

In this regard, I have used public figures drawn from platinum mining company data.

PGM demand ('000 ounces)

~6.0moz

What the hydrogen economy could mean for platinum demand



Source: Amplats, 2021

For example, Sibanye-Stillwater (SS) forecasts that platinum substitution will likely increase demand in light petrol vehicles of around ~1.75moz by 2025. By the end of the decade, SS forecasts platinum demand for (auto and stationary) fuel cells to grow at a rate of ~13% of total platinum demand, compared to just 1% in 2019. This amounts to well over 1moz by 2030.

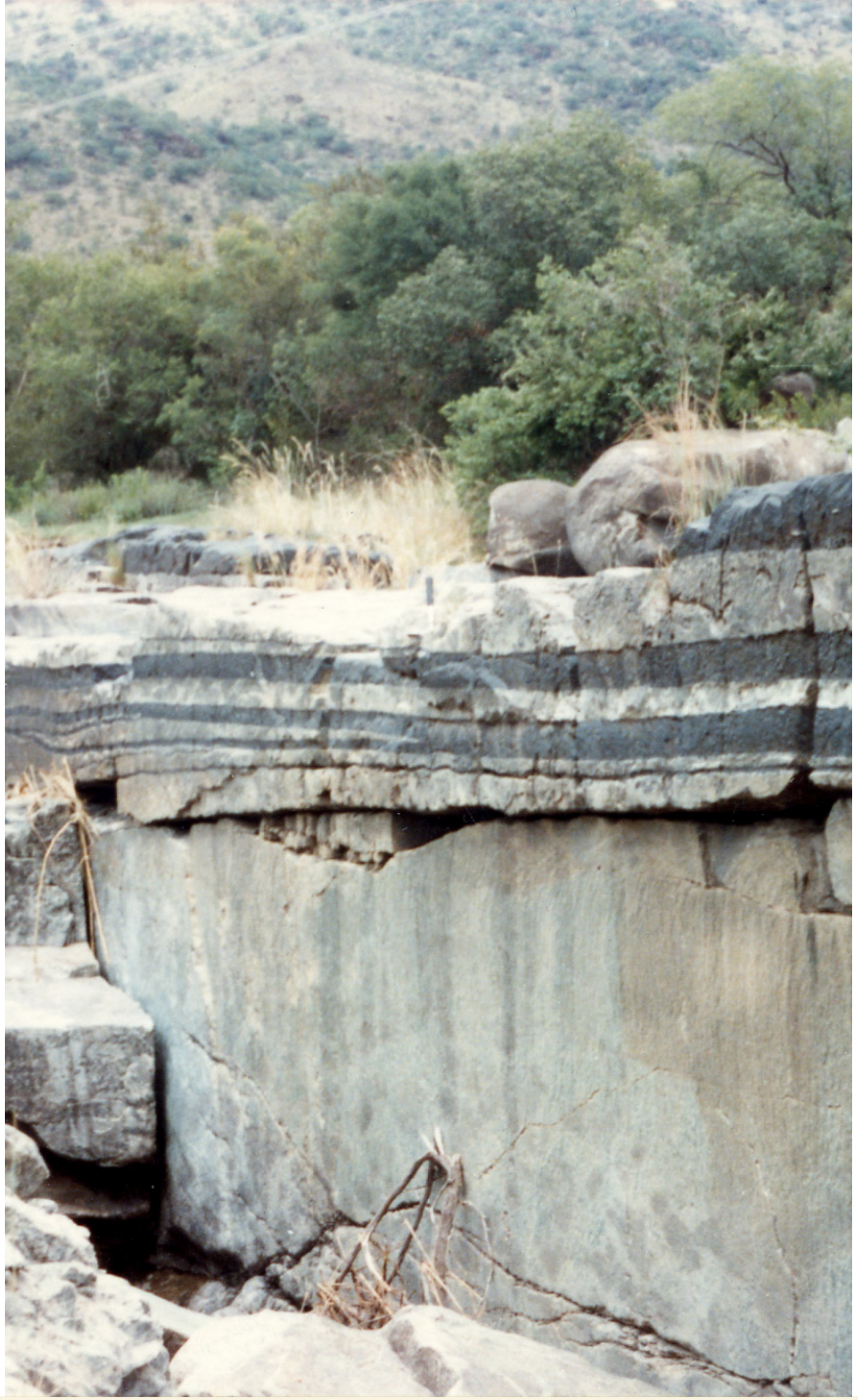
Anglo American Platinum (Amplats) talks about the "potential" additional quantum of platinum demand that will be required for

FCEVs. Amplats indicates that “if fuel cells power a third of HHD vehicles and an eighth of light-duty vehicles this could generate annual demand of almost ~6moz by 2035” or approximately by extrapolation around ~400koz by 2025 and 3moz by 2030.

Amplats also forecasts that additional PGM loadings together with an increase in vehicle supply: LDV petrol loadings will increase by ~17% between 2019 and 2030 due to tighter emissions legislation, LDV diesel loadings will increase by ~10% between 2019 and 2030 from already high levels. HDV loadings will increase by~60% between 2019 and 2025 as China and India adopt tougher emissions standards in China and Europe. Platinum loadings per truck in China will be ~3 times higher by 2023 or some 360kozs than in 2019.

The exponential forecast quantum of additional platinum demand is “mind boggling”. Given extrapolation estimates, the figure amounts to some ~2.51moz by 2025, this figure reduces to ~750koz, excluding substitution.

It should be noted that hydrogen / Platinum demand for stationary fuel cell applications, including PEM technology, has not been included in this estimate, nor has the additional Platinum loadings required to meet the newest emission standards.



Where is all The Additional Platinum Going to Come From?

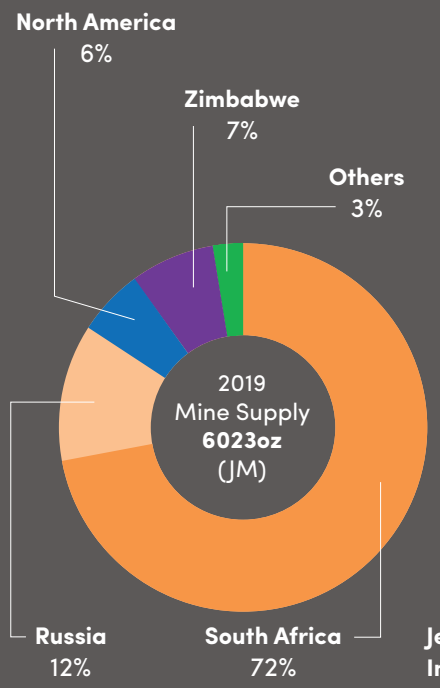
Secondary recycling of Platinum will not likely bolster Platinum supply for at least 5 to 10 years (Amplats). According to Johnson Matthey, gross mine Platinum demand was some 8,535koz, and net demand was c.6,400koz in 2019, after discounting recycling. Sibanye-Stillwater forecasts that platinum substitution in light petrol vehicles will likely increase demand by around 1.75moz by 2025. In my view, substitution alone will likely push the market balance of Platinum into a clear deficit.

It is noted that there has been volatility in PGM supply and demand and prices over the past two years. Supply was disrupted to varying extents as a result of Covid-19 as well as the breakdown of Amplats' ACP plants, which resulted in a significant backlog of over 1moz. Also, Norilsk had to face noteable environmental, flooding and concentrator incidents during this period.

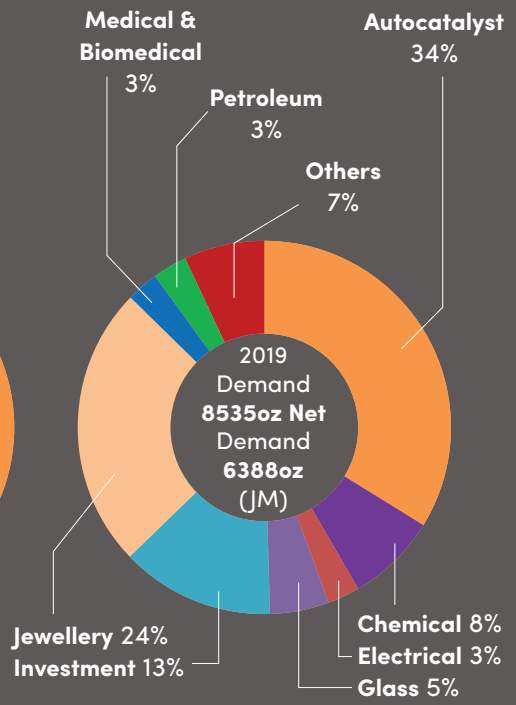
Industry analysts indicate that the shortage of semiconductors, which is currently hampering vehicle production and platinum Demand will likely run through into 2022. However, there is likely to be pent-up demand when chip shortages are eventually resolved. In this regard, PGM demand is likely to heighten, which will translate into higher Platinum prices as global auto manufacturers ramp up production.

PGM demand is likely to heighten as chip shortages are resolved, which will translate into higher Platinum prices as manufacturers scale-up production.

Global Platinum Mine Supply by Region:

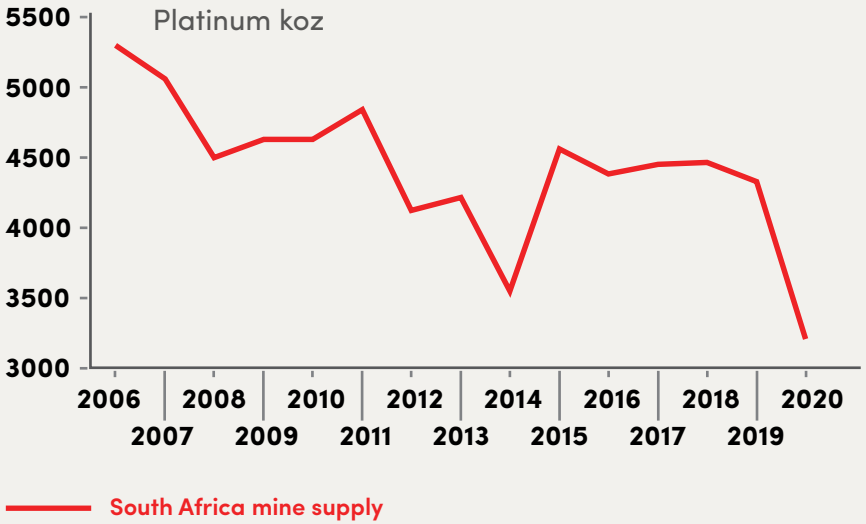


Global Platinum Demand by Application:



This review continues the discussion mapped out in this introduction and in particular, the conversation focuses on the complexities arising from the geological structure of the PGM reefs of one of the largest South African PGM mines. I am of the view that it is important to describe the complexities of the PGM reefs as simply as possible, to help readers put into perspective the strategic overview of the decline in Platinum mine supply from South Africa.

Decline in Platinum Mine Supply



Source: Johnson Matthey, Davis analysis and estimates

I am of the opinion that the decline in South African Platinum mine supply has not been given the attention it deserves by industry research organisations; after all, the market balance equation relies on both supply and demand. Research organisations seem to "shy away" from this subject and focus mainly on the demand side of the supply-and-demand equation. Many of these organisations hint at an "appreciably" weaker Platinum supply going forward, but do not follow up with reasons to support this claim.

Many potential investors are missing out on this piece of the puzzle which is of critical importance.

Why is the Decline in Platinum Supply Important to Investors?

South African supply conditions have a significant impact on global supply and impact the Platinum price.

Global Platinum mine supply depends heavily on the South African PGM mining industry, which supplies about 72% of global platinum. Under these circumstances, global Platinum mine supply between 2006 and 2019 declined by c.-1.0% CAGR. South African Platinum mine supply declined by c.-1.4% CAGR, *ceteris paribus*.

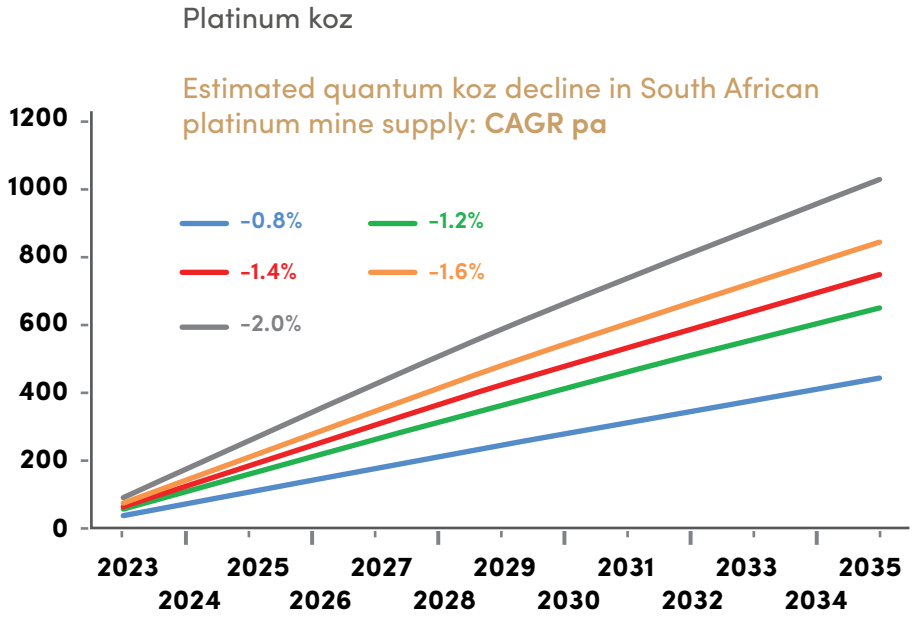
I am of the view that South African Platinum mine supply will continue to decline at a CAGR of c.-1.4%, at least over the long term. This will tighten the supply market and put upward pressure on the price.

What Does This Mean?

At an annual decline of 1.4% CAGR, I estimate the cumulative quantum in decline from 2022 onwards will likely be approximately -190koz (by 2025), -480koz (by 2030) and -760koz (by 2035) - *see graph.*

Note, these figures are based on past results. Note, SFA estimates that reserve depletion in South Africa (125koz Pt pa.) remains a feature in mine profiles over the next decade. This decline represents a decline of 1moz by 2030, a figure which is close to double my estimates. PGM reserves are undergoing structural change and, in this regard, the above figures may be conservative. Much also depends on ore reserve replacement, which will require significant capital expenditure.

There are of course additional factors that will likely accelerate the decline in Platinum supply, in particular the loss of PGM supply as a result of South Africa's looming energy crisis.



Source: Davis

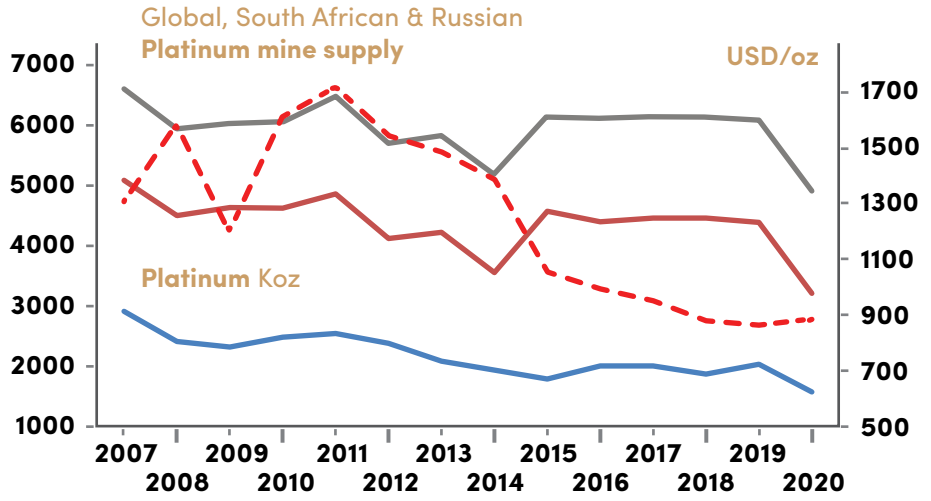
Comparative Palladium Supply

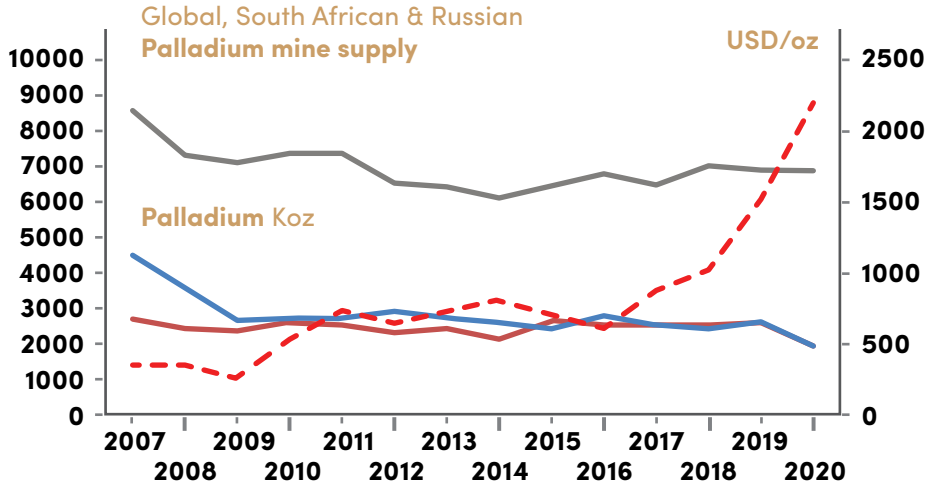
It is important at this stage of the conversation to put into perspective global Platinum mine supply in comparison to South African Platinum and Palladium mine supply. Global Palladium mine supply between 2006 and 2019 declined by -1.8% CAGR. South African Palladium mine supply declined by -2.4% CAGR, while Russian mine supply declined -2.8% over the same period.

Norilsk announced on 1 December 2020 that it is 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 Norilsk'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 easily "flood" the market with Palladium by 2030.





South Africa platinum mine supply
Global mine supply
Russia mine supply
Platinum price USD/oz (rhs)

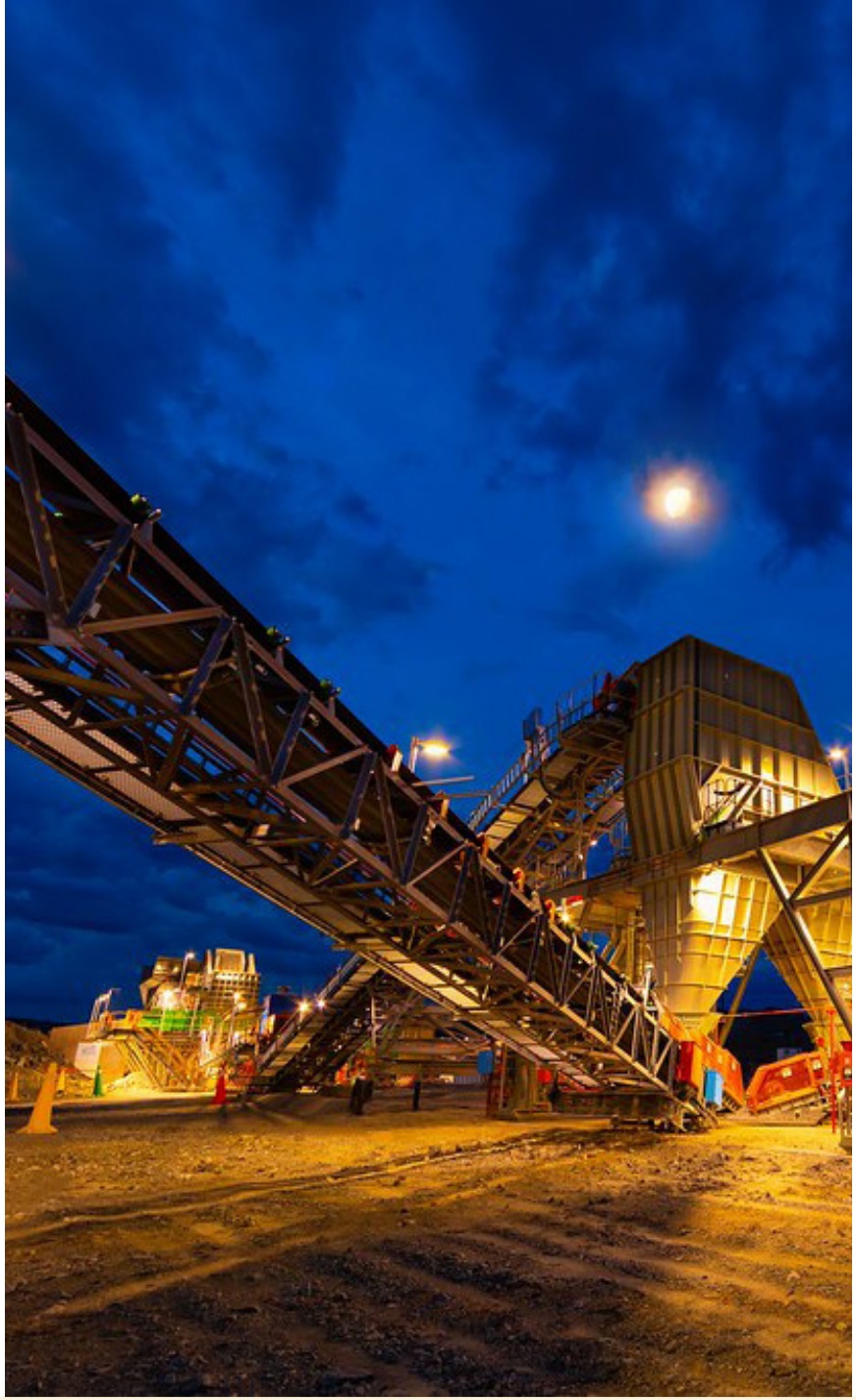
Source: Johnson Matthey, Davis analysis and estimates

South African PGM Supply Risk

It is noted that almost every global mining company faces a large number of risks at varying levels. Some of these risks include operational and high-impact risks such as the Covid-19 pandemic and climate change.

The South African PGM mining industry is not secure; the industry has faced numerous challenges in the past with the combined effects of prolonged industrial action, electricity shortages and increasing costs. The industry has also been starved of expansion and ore reserve replacement capital for a number of years. The investment and political climate are not conducive to the commitment of large amounts of capital and there is a distinct lack of appetite from investors. That being said, it will take at least 5 to 10 years to ramp up new PGM capacity, given the availability of capital.

Miners are beginning to invest in reserve replacement (2021). This quantum of investment is, however, unlikely to stave off the overall decline in Platinum supply or return the platinum market to positive.



Looming Energy Crisis

At this stage of the conversation, it is important to put into perspective the potential impact of the looming 'energy crisis' on South Africa's Platinum mine supply. I believe that loadshedding will widen significantly over the next five years, caused mainly by "slippage" in the new build programmes (three to four years) and capital constraints. Together, with political interference, meddling and vacillation with respect to the recovery plan, this will likely cause a rise in PGM supply losses. In this regard, PGM supply from South Africa will probably start to decline within the next two to three years if the frequency and higher stages of load shedding persist, ceteris paribus. This is already beginning to happen.

Political interference, meddling, vacillation and availability of capital costs are delaying the recovery plan. This situation will likely go unresolved for at least another two years, thereby heightening the likelihood of PGM losses, which means the recovery plan could be delayed by six years. This is despite the capital allocated to this project by COP-26 *(See our report: The Impact of South Africa's Energy Crisis on PGM Mine Supply August 2021).*

In mitigation, in June this year South Africa's President Cyril Ramaphosa announced that the licence-exemption cap on self or distributed-generation plants would be raised from 1MW to 100MW. The increase in the threshold will enable mining companies and other entities to build power generation units of up to 100MW without applying for a licence through the National Energy Regulator of South Africa (Nersa). This move was welcomed by the mining industry.

In this regard, almost the entire mining industry is implementing plans to build solar PV plants of up to 100MW at their operations. Night-time storage and ageing grid capacity will, however, present a problem.

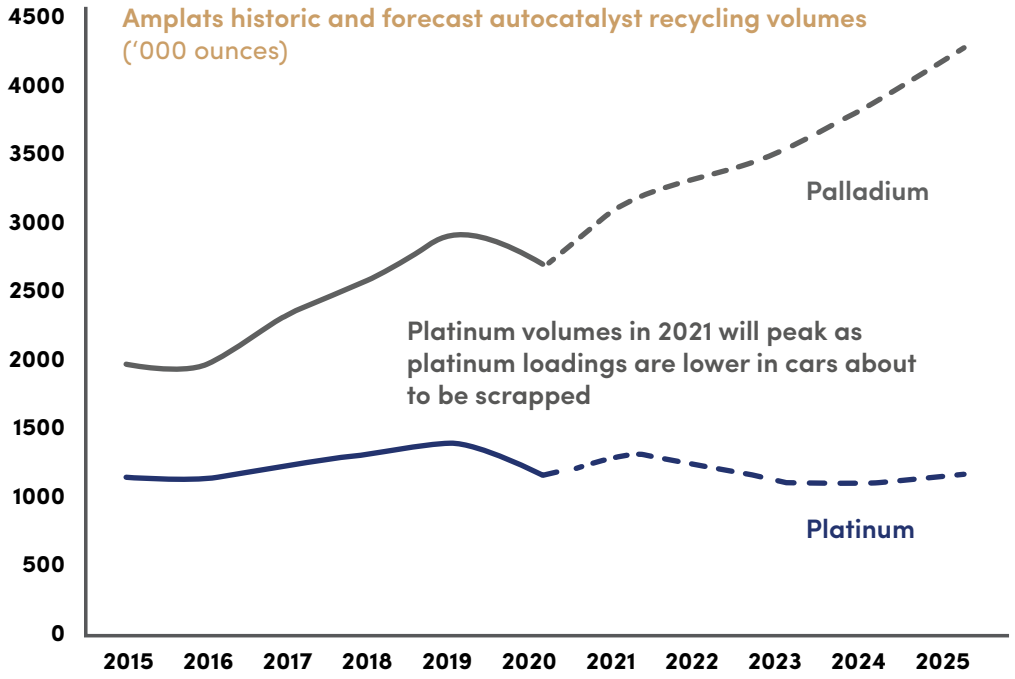
Once again, industry research organisations are not, in my view, fully appraised of the looming energy crisis in South Africa and as a result, have not given it the attention it deserves.

Potential investors are missing out on this key piece of information which ought to be "factored in" when considering a medium to longer-term investment decision in Platinum.

Will Secondary Recycling Supply Support the Decline in Mine Supply?

Growth in the secondary supply of Platinum (recycling) from 2011 to 2020 was virtually flat (average 1.2moz). The quantum of Platinum autocatalyst recovered by recycling is not expected to grow significantly going forwards (2025) as Platinum loadings are historically lower in light vehicles that are about to be scrapped, given the average age of light-duty vehicles is around 12 years. In comparison, the quantum of Palladium autocatalyst recovered by recycling is expected to climb to over 4moz by 2025 from around 2moz (JM, Amplats).

Secondary recycling of Platinum will not likely bolster Platinum supply for at least 5 to 10 years. (Amplats).



Source: JM until 2019, Anglo American afterwards using simple assumptions on scrappage rate

Strong Demand for Platinum

It is important to note that in the mid-1970s, the first catalytic converter used to neutralise harmful vehicle emissions from petrol vehicles used Platinum as the primary PGM. This set of circumstances initiated the continuous demand for Platinum and PGMs, which in turn, resulted in elevated metal prices. The Platinum price, however, peaked in 2011 before going into a steady decline following a drop in demand.

The increase in demand over time for Platinum was however constrained "twice" during the intervening period since the mid-1970s. Firstly, advances in autocatalyst and fuel technology over time has permitted the gradual substitution of Platinum for Palladium in petrol vehicle autocatalysts to around 95% palladium and above, and the partial substitution

of Platinum with Palladium in diesel autocatalysts. Secondly, by Dieselgate, which resulted in a loss of diesel market share from 2016, which had a consequential impact on Platinum demand. In this regard, autocatalyst demand for Platinum declined by 2.9% CAGR between 2007 and 2019. In comparison, Palladium autocatalyst demand increased by 6.5% CAGR over the same period (JM).

The additional quantum of PGM autocatalyst loadings is significant despite the expected increase in battery electric (BE) vehicles. Under these circumstances, the market balance deficit will likely deepen, forcing upward pressure on PGM prices. This scenario is also supported by the introduction of hydrogen fuel cell and green hydrogen technologies. Particularly in the case of Platinum and Iridium demand.

Additional Platinum Demand

The hydrogen fuel and green technology segment will drive Platinum demand significantly higher. Platinum will play a critical role in the reduction of global warming. The advent of fuel cell technology has changed. There are now two types of proton exchange membrane (PEM) hydrogen fuel cells, which will ultimately increase platinum demand: The first application surrounds the PEM fuel cell drivetrains of electric vehicles, particularly heavy-duty vehicles. All of which meet the zero-emission standard. The second type of hydrogen fuel cells are called PEM electrolysers, which are used in the production of green hydrogen from solar power, wind power and hydro power.

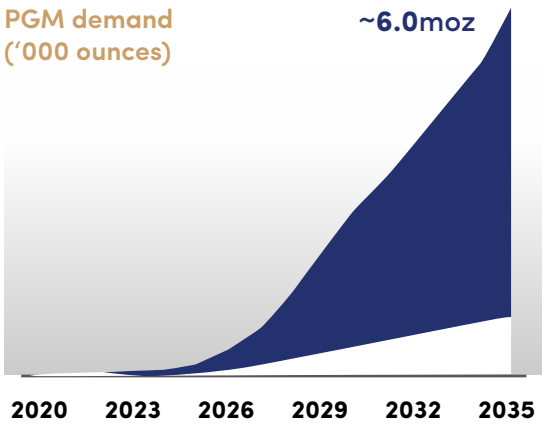
What do These Figures Mean With Regards to Platinum Supply?

It is important to gain a 'sense' of the possible quantum of *Platinum required to drive zero emissions by 2050*. I have used public figures drawn from Platinum mining company data. For example, Sibanye Stillwater (SS) forecasts that Platinum substitution will likely increase demand in light petrol vehicles by around 1.75moz by 2025. By the end of the decade, SS forecasts Platinum demand for (auto and stationary) fuel cells to grow at a rate of 13% of total Platinum demand, compared to just 1% in 2019. This amounts to well over 1moz by 2030!

Amplats (22 February 2021) presented a strategic scenario of what the hydrogen economy could mean for Platinum demand to 2035. This presentation was based on the percentage penetration of FCEVs and hydrogen electrolysis at optimal thrifting levels for passenger vehicles of 15%, heavy-duty trucks 50%, buses 25% and small passenger vehicles 5%. Amplats indicated that these levels of FCEV penetration could generate annual demand of around 6moz by 2035 *(see graphic on the next page)*.

Obviously, there are numerous combinations of scenarios that may be applied to the Amplats model, which would result in alternative annual demand rates.

Amplats puts its forecasts another way: if fuel cells power a third of HHD vehicles and an eighth of light-duty vehicles this could generate annual demand of almost 6moz by 2035 or by extrapolation around 400koz by 2025 and 3moz by 2030.



% Fuel cell vehicles		Potential PGM oz
Passenger vehicle (m/l)	15%	3,000
Heavy duty trucks	50%	2,000
Passanger vehicle (small)	5%	350
Buses	25%	80

if fuel cells power a third of heavy duty vehicles and an eight of light duty vehicles this could generate annual demand of almost 6moz in the longer term

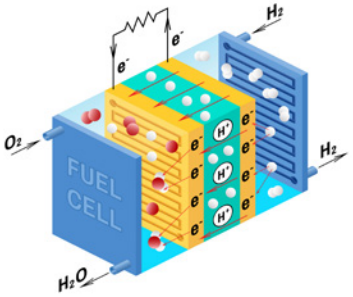
Source: Anglo American Platinum. Note: 1 Assumes 0.125 g/kW. 2 Assumes 0.15 g/kW for iridium and 0.10g/kW for platinum

Additional PGM Autocatalyst Loadings

Amplats also forecasts additional PGM loadings together with an increase in vehicle supply: LDV petrol loadings will increase by 17% between 2019 and 2030 due to tighter emissions legislation, LDV diesel loadings will increase by 10% between 2019 and 2030 from already high levels and HDD loadings will increase by 60% between 2019 and 2025 as China and India adopt tougher emission standards. Platinum loadings per truck in China will be 3 times higher or an additional 350koz by 2023 than in 2019.

Future Platinum demand consequently stems from the additional quantum of PGM autocatalyst loadings and hydrogen fuel cell and green technology. Furthermore, the price mismatch between Palladium and Platinum is driving vehicle manufacturers to substitute Palladium for Platinum in petrol-driven vehicles. These three influences will drive Platinum demand significantly.

It should be noted that hydrogen / Platinum demand for stationary fuel cell applications, including PEM technology, have not been included in this estimate, nor have the additional Platinum loadings required to meet new emission standards.



In Summary

This review provides insight into the impact of the continuous long-term decline in South Africa's Platinum (PGM) mine supply in an environment where Platinum and PGM demand is gaining significant traction as a result of the increasing pressures surrounding climate change.

In this regard, the conversation initially focused on Platinum supply and demand factors that will drive the market balance into a continuous deficit.

I am of the view that South African Platinum mine supply will continue to decline at a CAGR of at least c.-1.4% over the long term. ***This will tighten the supply market and continue to put upward pressure on the price of Platinum.***

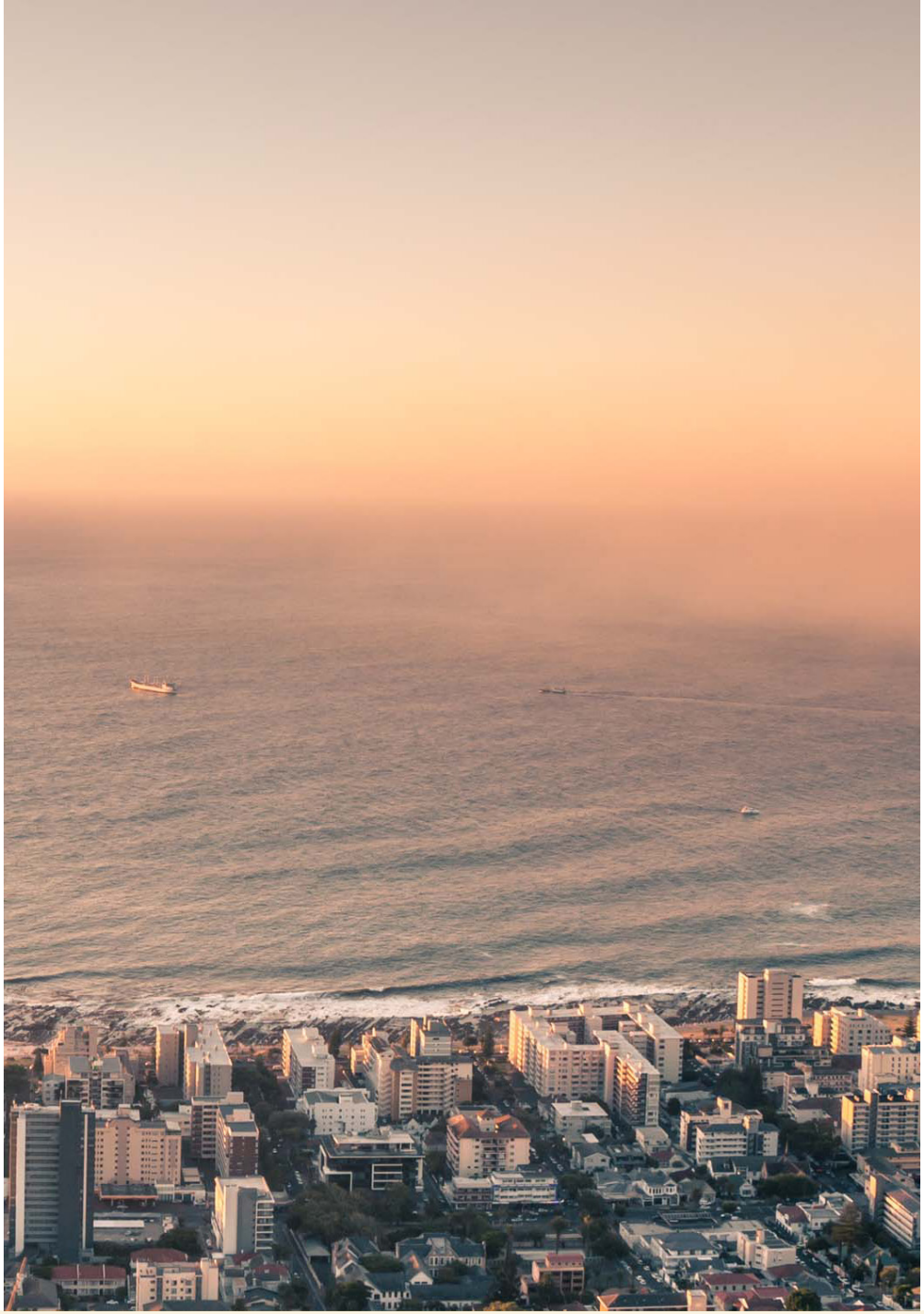
There are of course additional factors that will likely accelerate the decline in Platinum supply, in particular the loss of PGM supply as a result of South Africa's looming energy crisis and a decline in overall reserves and ore grade. Growth in the secondary supply of Platinum (recycling) from 2011 to 2020 was virtually flat (average 1.2moz). The quantum of Platinum autocatalyst recovered by recycling is not expected to grow significantly going forwards.

Many investors are missing out on this important piece of information which should be factored-in when considering a medium to longer-term investment decision.

There is overwhelming demand for PGMs going forward which 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 worldwide regulation since 1970. In response, vehicle manufacturers have been increasing the PGM content (loading and loading ratios) of Platinum, Palladium and Rhodium (PGMs) in autocatalysts to meet the stricter limits imposed.

Future Platinum demand consequently stems from the additional quantum of PGM autocatalyst loadings plus the introduction of hydrogen fuel cells and green technology. Furthermore, price mismatches between Palladium and Platinum have driven vehicle manufacturers to substitute Palladium for Platinum in petrol-driven vehicles.

These three influences will drive platinum demand significantly. ***A decline in supply together with overwhelming demand is a formula for the creation of a 'perfect storm', as Platinum moves into an increasing market balance deficit, thereby stimulating PGM prices.***



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

David has been associated with the South African mining industry and mining investment industry for the past 45 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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