THE PLATINUM STANDARD

May 2024

SFA Oxford

THE PLATINUM STANDARD

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Designed and typeset by Daniel Croft and Joel Lacey.

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The TPS Collection

The Platinum Standard was first launched in May 2014

One-half review, one-half preview, The Platinum Standard *comprises analytical commentary on those issues we believe will set the PGM agenda for the year ahead*

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FOREWORD

Foreword

Recycling — coming to whose rescue?

Once again, the SFA (Oxford) team is delighted to be hosting the Oxford Platinum Lectures, the flagship event of the platinum industry calendar, and to present this year's edition of ***The Platinum Standard***. The overriding theme of this year's lectures is an exploration of the role that recycled (or secondary) PGMs are set to play in the years ahead and how the rest of the industry needs to adapt. Recycling volumes across the PGMs are down over the last two years thanks to disruptions to light-vehicle production and bear markets in all three major metals. However, with on-road vehicle volumes growing, we should expect a recovery of sorts.

To better understand the present state of the secondary PGM markets, and the base from which our mobility will evolve, this edition of ***The Platinum Standard*** winds back the clock and examines how the scale and composition of the market has changed over the last 35 years. Once a vital supplement to primary supply during the ascendency of the humble passenger car, the recycling industry has grown to become a major source of PGMs in its own right.

As autocatalyst demand slips into stasis and, ultimately, decline, can products with superior sustainability credentials take precedence in the era of ESG? And what could the consequences be for the miners and car manufacturers? There are tens of millions of ounces of platinum, palladium and rhodium taking to the world's roads every day, and much of this metal will find its way into scrapyards and refineries in growing volumes in the years ahead. The rate at which this happens could be a major factor in shaping the future of the industry.

THE AUTOCATALYST: A POTTED HISTORY

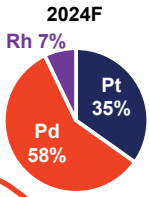
The autocatalyst: a potted history

Daniel Croft, Commodity Analyst, SFA (Oxford)

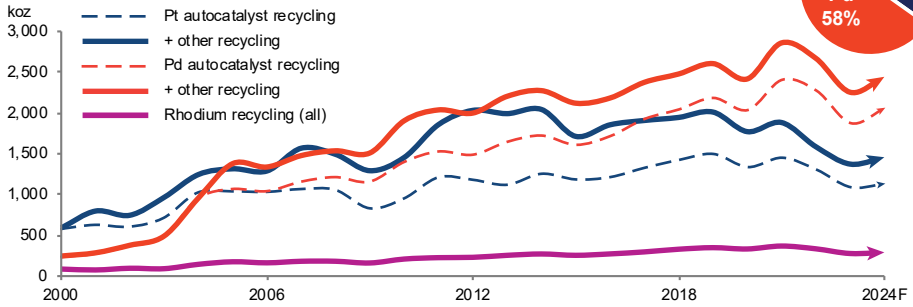
From humble beginnings...

Platinum-group metals' (PGMs) open-loop recycling is estimated to have grown from ~500 koz in the mid-1990s and less than 1 moz in 2000 to 4.21 moz forecast for 2024 in 3E PGM terms. From 2000 to 2019, PGM recycling grew by an average of 9% p.a., peaking at just below 5 moz just as the Coronavirus began to spread around the globe. Post-pandemic, and excluding an initial rebound in 2021, secondary volumes have struggled to maintain growth, as the chip crisis, rising interest rates and economic uncertainty prompted a shift in consumer behaviour in favour of holding on to vehicles for longer. Post-pandemic growth rates in recycled PGM volumes have averaged -5% p.a.; also not helped by a steep decline in PGM prices post-2022. Despite recent struggles in autocatalyst recycling, total secondary supply of PGMs is still comparable to the mined output of Russia and Zimbabwe combined.

Secondary supply has grown into a major source of PGMs



PGM recycling: global yield



Source: SFA (Oxford)

Complexity and scale of autocatalyst recycling

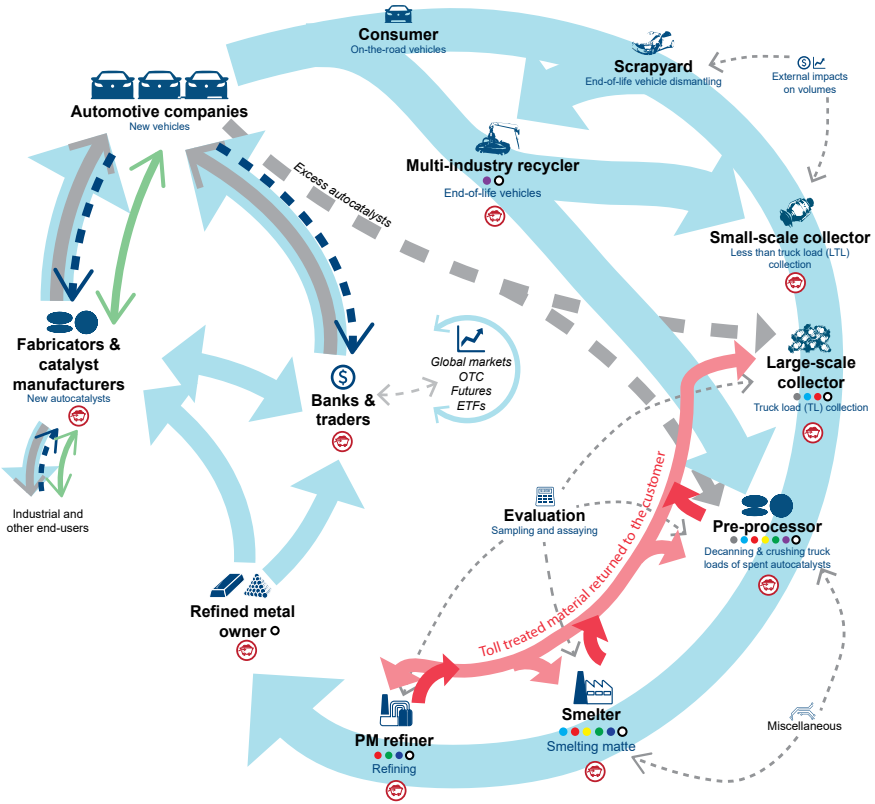
The recycling value chain is complex, crowded, opaque and multi-layered, with more than 10,000 first-line dismantler/collectors (garage/scrapyard) per industrialised country, serviced by some 1,000 collectors feeding into around 100 global decanning/processing companies, which in turn provide recycled feed to smelters and refiners worldwide. Spent autocatalysts are traded on a global scale.

The big recyclers operate international collection operations. The contained PGM value is such that an individual catalyst's material could criss-cross the globe as it passes from collector to collector to processor, smelter and refiner. Some processing companies will have sorting, decanning and processing plants in multiple global locations, which in turn collect catalysts from numerous surrounding countries.

Recyclers source spent autocats from around the world

The USA dominates the global recycling of autocatalysts. With the longest history of automotive emissions legislation (1970s) and PGM loadings on catalytic converters (1975), as well as the largest passenger car engines globally (2.9 litre average displacement), the country has the majority of autocatalyst recyclers. Therefore, a recycler can have a 10% share of the global recycling market, but only be based in the USA.

Global PGM recycling market structure



Value chain integration and strategic partnerships:

- Large collector/pre-processor
- Large collector/pre-processor/smelter
- Large collector/pre-processor/smelter/refiner
- Pre-processor/smelter
- Pre-processor/smelter/refiner
- Smelter/refiner
- Multi-industry recycler/pre-processor
- Precious metal management

- Purchasing/sales channels
- Leasing
- Metal ownership unchanged
- Metal paid for after lease
- Tolling
- Stockpiles (ELVs / spent autocatalysts / processed ceramic / smelted matte / refined metal)

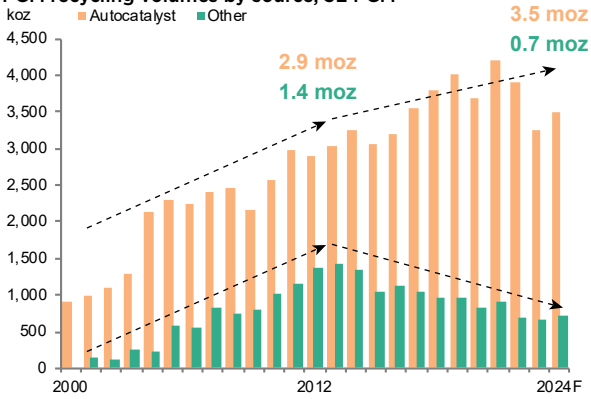
Source: SFA (Oxford)

Non-autocatalyst PGM recycling

While the spent autocatalyst market is the largest component of PGM recycling, smaller volumes of secondary metals are yielded from the jewellery sector and waste electronics. Thanks to growth in the volume of metal yielded from spent autocatalysts, non-autocatalyst recycled PGMs are forecast to make up just 17% of total 3E PGM recycling in 2024. Looking back a decade, the proportion of non-autocatalyst recycling was almost twice as large. The peak and decline of non-autocatalyst recycled PGM volumes is largely related to the peak and decline of the platinum jewellery market in China. PGMs are also recovered from electrical and electronic waste (WEEE). Palladium is the more significant PGM recovered from WEEE owing to its long-standing use in multi-layer ceramic capacitors (MLCCs). However, with the increasing use of hard disk drives that contain a small quantity of platinum, the proportion of platinum recovered from WEEE has grown. Overall volumes from WEEE have declined, owing to thrifting and substitution over many years, as a result of the rise and volatility in the palladium price.

Non-autocatalyst PGM recycling has taken a back seat

PGM recycling volumes by source, 3E PGM



Source: SFA (Oxford)

Maturing autocatalyst market requires less input from other industries

PGMs need cars, cars need PGMs

In a nutshell, PGMs are needed to clean up the wide range of gaseous and particulate emissions produced during the chemical and physical processes in internal combustion engines. As vehicle ownership grew, and with it air pollution, the world needed a way to clean up the air in urban areas, and PGMs were the answer. As a result, the automotive sector became the dominant force in raising PGM demand. In the decades since their first introduction, demand growth was assured through rising car sales, continued tightening of emissions legislation, spreading of emissions legislation to more and more countries, and increasing categories of combustion engines being included in emissions legislation, such as trucks, off-road machinery and 2- and 3-wheel motorbikes.

Emissions control is key to global PGM demand

Spent autocatalysts

Source: SFA (Oxford)

Substitution away from PGMs' use in autocatalyst aftertreatment is challenging as no other elements have comparable catalytic properties and durability in the hot exhaust environment. Platinum with rhodium in 'two-way' catalyst systems were used at first to control carbon monoxide (CO) and unburnt hydrocarbons (HCs). This was advanced in 'three-way catalysts' later which succeeded in the simultaneous oxidation of carbon monoxide and unburnt hydrocarbons plus the reduction of oxides of nitrogen (NO_x) in a single unit. Finally, as the popularity of diesel engines rose, and the damaging health impact of particulate matter emissions became clear, various diesel particulate filter technologies were introduced, some of which used some PGMs.

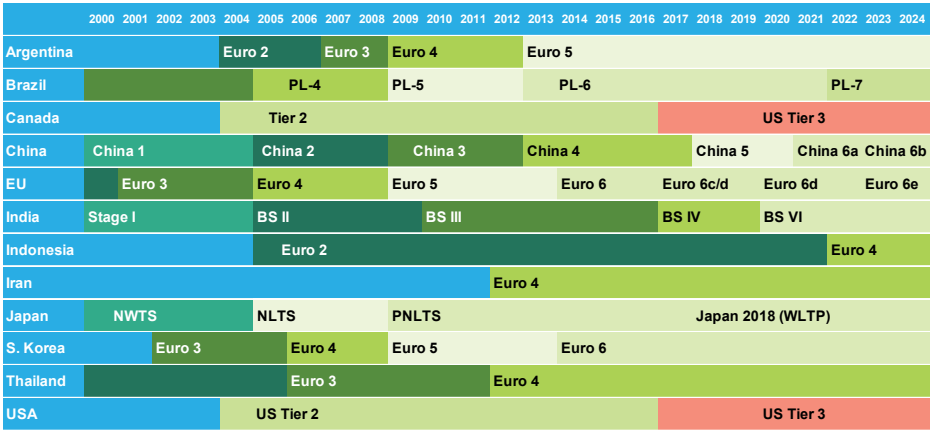
PGMs are the best metals for the job

Palladium is more susceptible to sulphur poisoning than platinum, which meant that for dirtier diesel powertrains, platinum remained as the preferred catalyst. The introduction of Euro 4 legislation in 2005 cut the maximum acceptable sulphur content in diesel fuel to one-seventh of the previous limit, which meant some (at the time) lower cost palladium to be used in diesel car catalysts.

Palladium also helped to stabilise the catalyst at higher engine temperatures which also helped to boost demand. By 2015, palladium autocatalyst demand had reached a milestone of >10 moz.

Shifting PGM requirements in autocatalysts

Light-duty vehicle emissions legislation table



Source: SFA (Oxford), Transportpolicy.net

At the time of the dissolution of the Soviet Union in the late 1980s/early 1990s, the palladium price was hovering around $85/oz, and demand for palladium in the automotive sector totalled less than 250 koz, but over the next seven years demand would grow ten-fold. By 2001, demand in gasoline autocatalysts had reached 4.5 moz, and a combination of speculation, commercial panic buying and delays in Russian exports had pushed the price over $1,000/oz – a price that would not be seen again until 2017.

The price spike demonstrated the relative elasticity of demand as development shifted to the engineering-out of some palladium. In the years prior to 2001, autocatalysts were overloaded with PGMs as manufacturers substituted platinum with palladium at a near 2:1 ratio. As the price spiked, replacement was lowered to 1:1 palladium for platinum.

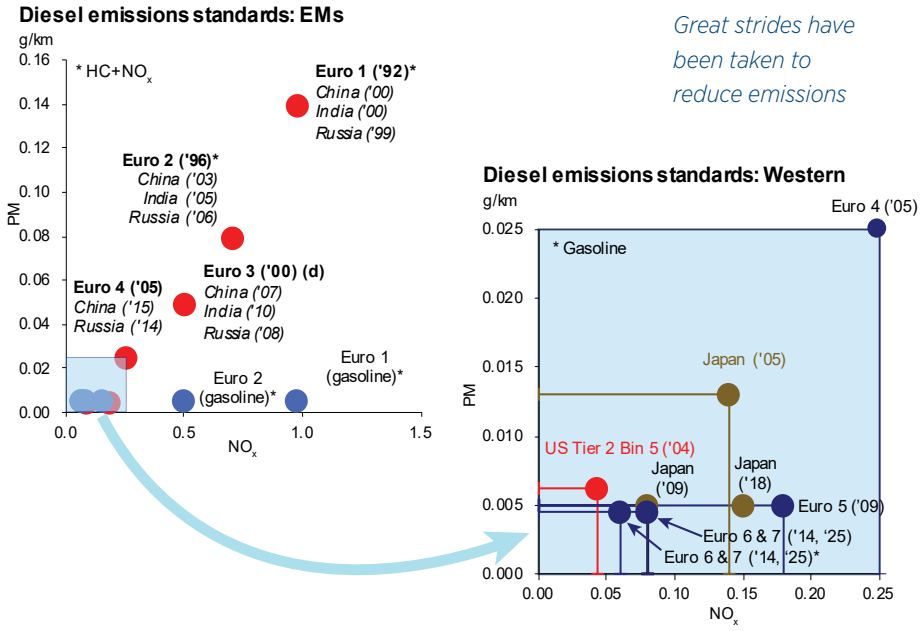
Palladium first spiked in 2001

Annual global light-vehicle sales grew by nearly 100% from 1990 to 2017. At the peak in 2017, vehicle production reached 76 million units. With this growth came growth in PGM demand, particularly in palladium, as average global loadings in autocatalysts also rose by nearly nine times in response to increasingly stringent global emissions legislation.

Light-vehicle production peaked in 2017

There have been regional differences in emissions legislation over time. The USA has focused more on tougher NO_x limits, while the focus in Europe has been on particulate matter and, in the 2000s, cleaning up diesel powertrains. Generally, sequentially lower limits on tailpipe emissions have resulted in PGM loadings on autocatalysts outpacing the rate of thrifting, as shown in the chart overleaf.

Great strides have been taken to reduce emissions

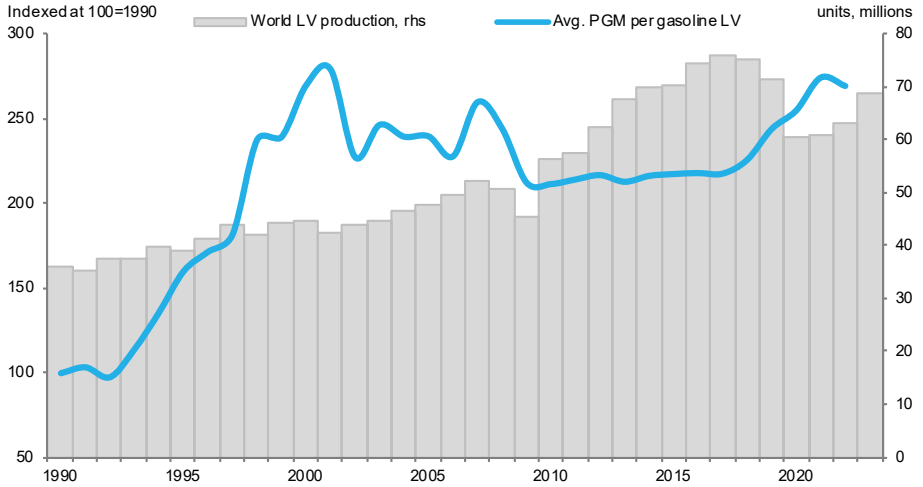


Source: SFA (Oxford)

Rhodium is particularly effective at reducing NO_x in engine emission gases, and therefore countries and regions that have emphasised the control of NO_x have tended to have higher loadings. SFA's data shows that gasoline light vehicles produced in Western Europe have seen the largest increase in average rhodium loadings since 1990.

Vehicle sales growth has outpaced thrifting

Average loadings per gasoline light vehicle: Global



Source: SFA (Oxford), GlobalData

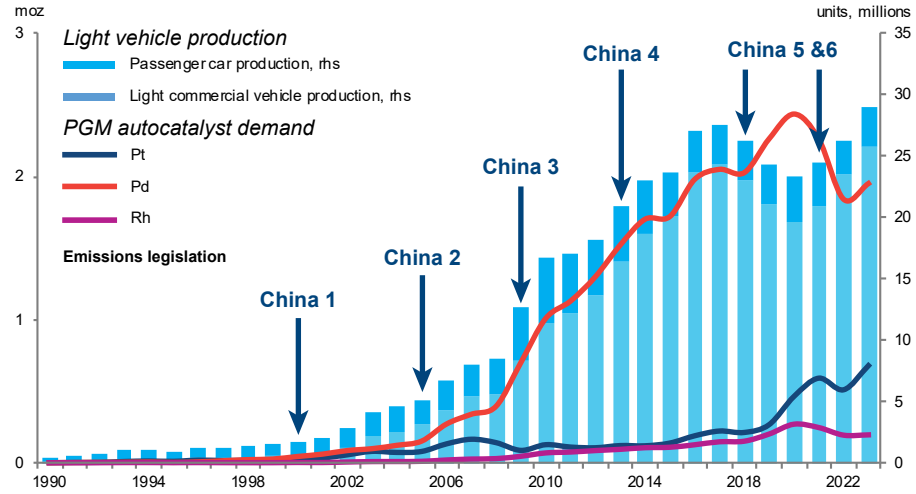
China's economic boom in the 1990s and 2000s went hand-in-hand with an explosion in the nation's demand for commodities, and PGMs were no exception. China first introduced tailpipe emission standards in 2000, which were based on Euro 1 standards. China could, however, progress its standards much more rapidly, as car manufacturers could apply 'off the shelf' technology developed elsewhere in the preceding decades. Cumulative automotive palladium demand from 2005-2015 totalled only 504 koz in the Chinese market.

However, in the following decade, cumulative demand multiplied to 8,500 koz as vehicle production capacity rapidly expanded to satisfy demand from the growing middle class, and emission standards tightened.

In the last few years, record-high palladium prices prompted autocatalyst manufacturers and automotive OEMs to initiate substitution of palladium for platinum in gasoline three-way autocatalysts. This has been concentrated in the US and Chinese markets. However, higher total average loadings, particularly in China, have gone some way to offset this trend. Ultimately though, the metal used in today's catalysts will take at least a decade to enter the pool of recovered secondary metal.

China has played catch-up and is now the largest single market

China's autocatalyst expansion



Source: SFA (Oxford), GlobalData

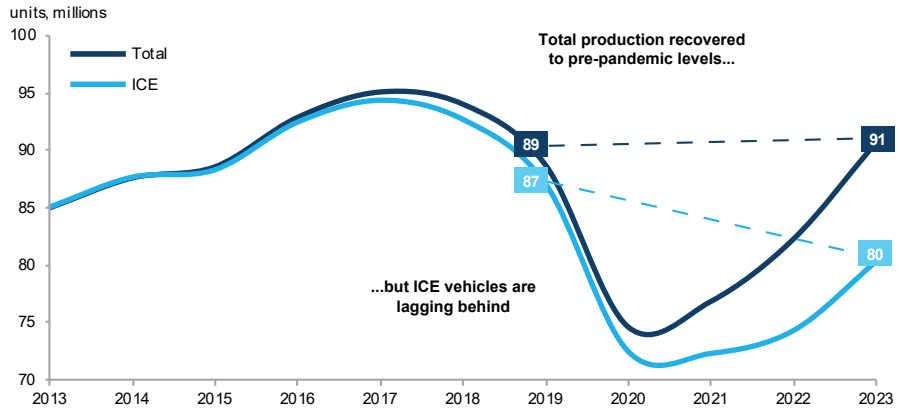
Autocatalyst demand growth has been huge as China and other emerging markets have begun to align emissions legislations with those in the EU and US. The way to make this expansion sustainable and cost-effective is through the use of recycled PGMs in these new autocatalyst markets, and across the globe.

The rapid shift in automotive production is slowly unwinding

The impacts of the Covid-19 pandemic on the global automotive industry were seismic in terms of both the ability to produce vehicles and consumer behaviour. The drop in demand for new vehicles in 2020-2021 was compounded by the semiconductor chip crisis – an effect of the shift in consumer preferences towards hand-held electronics and PCs in the early stages of the pandemic, disrupted global supply chains, and China's late and strict Covid lockdowns. Global light-vehicle production dropped by 10 million units year-on-year in 2021, and although most supply chain disruptions have now been worked out of the system, internal combustion light-vehicle production numbers have yet to return to pre-pandemic levels. As BEV sales also rose rapidly in the recovery period, combustion engine vehicle sales are unlikely to match the pre-Covid peak again.

ICE vehicle production has never recovered to pre-Covid levels

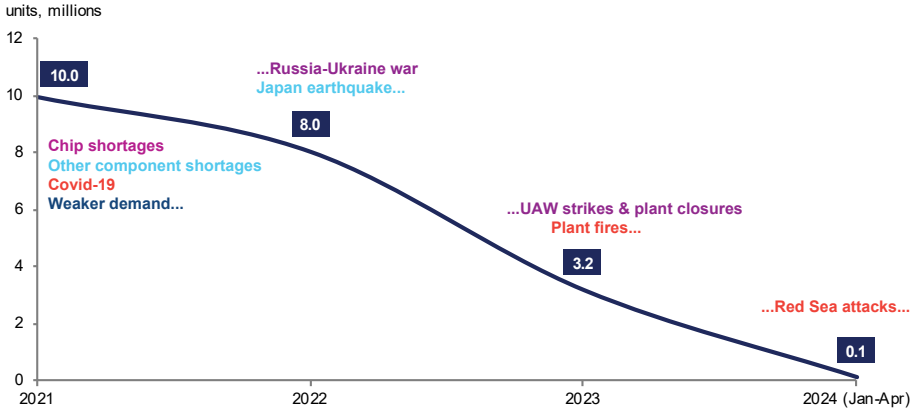
Global light-vehicle production



Source: SFA (Oxford), GlobalData

The combination of limited driving of cars during Covid lockdowns, the shortage of new vehicles, the rise in second-hand car values as a result, and increasing interest rates affecting disposable incomes seems to have led to cars staying on the roads for longer, effectively starving scrapyards of old, end-of-life cars, and the autocatalysts that come with them.

Disruptions to light-vehicle production



Source: SFA (Oxford), GlobalData

Many millions of PGM ounces are still on the road

Autocatalyst recycling volumes have suffered a decline as a result in recent times. However, the return of growth is highly likely, as vehicles age and reach the end of their lives, and more of those vehicles will have higher PGM loadings on their autocatalysts. Some of this scrapping will be boosted through government policy, with both 'carrot' and 'stick' being applied: China, for example, has just announced a subsidy scheme, encouraging owners of older, more polluting cars to scrap them and replace them with a new model. An increasing number of European countries are imposing no-go zones or higher parking fees for older polluting cars in their bigger cities.

Short-tern doubts, longer-term certainty

In SFA's view, the question of the growth in recycling volumes is therefore a longer-term certainty, while the timing of near-term directional momentum still has several question marks hanging over it.

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Find out more

THE PGM MARKETS IN 2023/24

The PGM markets in 2023/24

Beresford Clarke, Director of Research, SFA (Oxford)

The platinum market

The year 2023 was key for platinum with the market shifting into deficit for the first time in a decade. In 2014, mine workers in South Africa embarked on a five-month-long wage strike leading to a one-off market deficit of a million ounces. Is the market shortfall of 320 koz in 2023 a one-off, or has platinum shifted into an enduring structural deficit?

A structural deficit for the first time in a decade...

This time it is most likely that the deficit will be structural as demand improves and supply growth remains lacklustre. However, critically the industry needs to work through a legacy of built-up stocks before we see a meaningful tightening of the market being reflected in platinum prices.

...but a legacy of stock to work through before being reflected in prices1

A combination of flat primary supply, recovering demand and lower recycling was enough to tip the platinum market into deficit in 2023.

Eskom, the South African electricity utility supplier, continued a programme of nationwide load-shedding that was enough to prevent the processing of excess PGM working inventory concentrate throughout the year. This limited the ability of mining companies to increase refined output. South Africa now appears set to remain a sub-4 moz platinum producer, as capital programmes are ratcheted back as metal prices have fallen and costs increased.

Recycling of PGM-containing autocatalysts continued to contract in 2023 after a poor 2022. The greater age profile of the vehicle parc with fewer vehicles entering scrapyards, as consumers held on to cars for longer, combined with some hoarding of scrapped catalytic converters, led to reduced feed to collectors, smelters and refineries.

Secondary supply struggled in 2023

Nonetheless, the semiconductor chip shortage was much improved throughout 2023 with only tens of thousands of vehicles affected due to a lack of certain chips. As a result, global vehicle production was much improved relative to 2022 which, along with some platinum now being used in gasoline vehicle catalytic converters and tighter emissions standards in heavy-duty vehicles in China and India, helped to lift demand.

SFA (Oxford) forecasts a duplication of last year's deficit of 320 koz for 2024. However, this is not due to strong demand pull which SFA expects to remain subdued in the current weak economic and consumer environment. Rather, a steady contraction in mine supply and a limited recovery of recycling are likely to lead to another fundamental market shortfall, excluding stock movements and changes to investment. ETF investment is relatively stable, with increases in some regions being offset by declines elsewhere.

Mine supply

Global platinum supply rose slightly by 90 koz year-on-year in 2023, to 5,580 koz. This includes an assumed net build of 60 koz of excess work-in-progress stocks in South Africa during the year owing to increased Eskom load reduction which impacted processing operations. South African output was therefore limited to just shy of 4 moz, which is pretty much flat year-on-year.

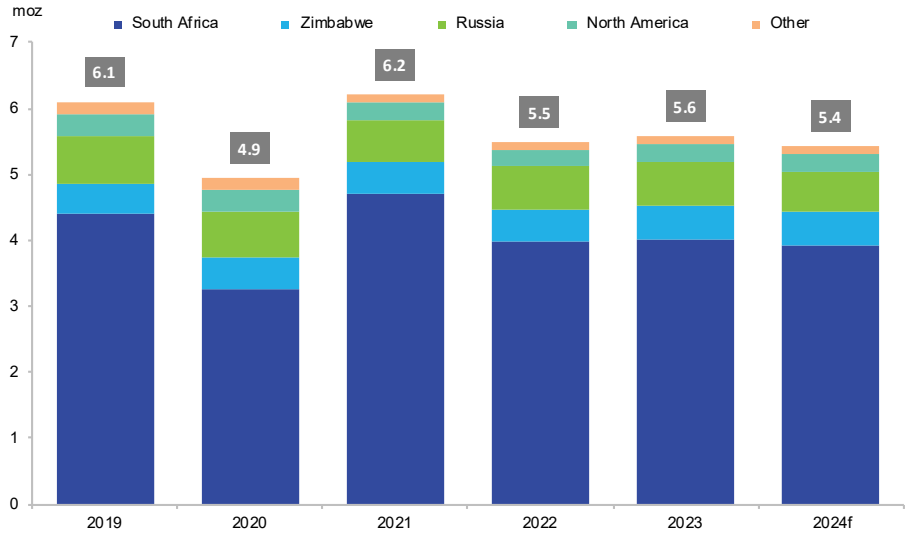
Supply falls incrementally in 2024 with risks of further curtailment ahead

Elsewhere, Russian platinum supply was up just 15 koz year-on-year, at 670 koz. Smelter maintenance was delayed until the first quarter of 2024 and guidance was exceeded despite challenges related to replacing an international mining fleet with Asian alternatives. Output also improved in other regions (Zimbabwe +35 koz to 520 koz, North America +20 koz to 270 koz and other regions almost flat at 130 koz).

Smelter maintenance could impact Russian palladium supply in 2024

However, platinum output is forecast to drop by close to 3% in 2024, to 5,420 koz. This includes a 60 koz reduction from Russia as planned smelter work rolls over into this year. The expected release of 115 koz of work-in-progress stock from South Africa is projected to limit the drop in output there to 80 koz, at 3,920 koz, despite challenging economics at high-cost operations. However, there is a risk of announcements of further production curtailments from mining companies as the year progresses.

Global primary platinum supply



Source: SFA (Oxford)

Recycling

Recycled supplies of platinum dropped below 1.4 moz in 2023; this is the first time since 2010 that volumes have been below 1.5 moz. Recycling was also ~30% lower than 2019 levels. Covid outbreaks continued to plague jewellery store footfall and therefore recycling in China, particularly in early 2023, thereby limiting recycling to 260 koz. However, autocatalyst recycling was hit the hardest, falling to 1,090 koz from 1,305 koz in 2022, a contraction of 16.5%.

Recycling bottoming out after a large correction

The outlook for recycling in 2024 is not much improved. It has been a poor start to the year with most collectors reporting a stabilisation, rather than a meaningful recovery in scrapped autocatalyst volumes. Total secondary supply (including jewellery) is forecast to marginally improve to just shy of 1.5 moz but, in reality, that is still well down on pre-pandemic levels of over 2 moz.

Demand

Demand for platinum (excluding investment) reached 7,295 koz in 2023, a healthy ongoing recovery of 9.2% on the previous year. This is well down on the highs of the mid-teens, when platinum demand reached close to 8 moz, but is back to 2018 levels.

Demand for platinum starting to emerge, led by autos

A significant lift in gross automotive demand combined with lower recycling, as mentioned above, helped to offset still lacklustre jewellery demand, while industrial demand was boosted by a preference in glass plants and chemical applications.

Automotive demand

With the semiconductor chip shortage and supply-chain issues largely behind us, vehicle production has been able to return to over 90 million units, and vehicles with internal combustion engines (including hybrids with PGM autocatalysts) recovered to over 80 million units, the first time since 2019. However, key regions, particularly Europe and North America, have some way to go to return to pre-pandemic levels, with inflation and affordability a drag on consumption. China is leading the recovery after being impacted by Covid outbreaks at the end of 2022/early 2023.

Auto production is improving but key markets are behind pre-Covid levels

Platinum has benefited somewhat from a recovery in heavy-duty vehicle production in China, with tighter emissions legislation lifting demand along with some use of platinum in gasoline three-way catalysts. This helped to boost platinum auto demand in China by 32% to 685 koz in 2023, though much of this metal demand was likely to have been met by significant imports during 2021 and early 2022. Other markets also witnessed increased use of platinum, helping global demand to rise by 20% year-on-year to 3,385 koz.

Automotive demand growth for platinum in 2024 is likely to take a pause owing to car affordability issues off the back of strong inflation. As a result, platinum requirements are forecast to slip by 2% to 3,325 koz for the year.

Jewellery demand

It was another challenging year for platinum jewellery demand in 2023. Although not falling at the same speed as in 2022, platinum demand was still down by an estimated 9% to 1,310 koz. The ongoing contraction in demand in China remains the biggest drag on platinum jewellery, down by an estimated 15% to 435 koz.

Despite improved jewellery retail sales in China after Covid outbreaks severely impacted sales in 2022, platinum and gem-set jewellery failed to recover, rather there was a consumer preference for gold. Elsewhere, falling wedding registrations in the US and platinum's inability to benefit from being cheaper than gold in Japan saw consumption in both countries slip. Platinum demand in India improved, but it was not enough to offset weaker buying elsewhere.

Retail demand for jewellery improving, but only for gold

Platinum demand is forecast to decline by 2% to 1,280 koz in 2024. China remains relatively stable with a full year without a major Covid outbreak, while we expect demand in Europe and North America to be adversely affected by the higher cost of living. In Japan, except for the popularity of platinum Kihei chains, jewellery retailers are struggling to motivate higher sales of other platinum products, so a further slight decline is predicted.

Industrial demand

Platinum demand in industrial applications rose by 6% to 2,305 koz in 2023. A combination of chemical, glass and petroleum applications lifted demand, whilst other applications remained largely stable. Requirements for silicone continue to grow, particularly in China, while nitric acid use of platinum staged a recovery in 2023, led by emerging markets. Platinum also benefited from high ratios relative to rhodium in glass manufacturing.

In 2024, some evidence of a recovery in the hard disk drive sector is expected following a difficult couple of years of overstocking and limited new orders after very high demand during the Covid period. Petroleum demand for platinum is likely to come under pressure, particularly in Japan. As a result, total industrial demand for platinum is set to remain flat year-on-year at 2,345 koz.

Industrial demand set to remain flat overall in 2024...

Demand growth expectations have been dialled back for platinum use in hydrogen applications to 90 koz in 2024, with high costs and regulatory pressures weighing on investment.

...but hydrogen requirements are stuttering

Investment and movement of above-ground stocks

Despite some fluctuations during 2023 and some regional variations, ETF holdings fell by only 25 koz to just shy of 3 moz and have continued to drop slightly in early 2024 before picking up at the end of April. Platinum coin sales were notably lower than in 2022, partly owing to far fewer platinum American Eagle coins being sold by the US Mint.

ETFs holding up at close to 3 moz

The palladium market

The collapse of autocatalyst recycling over the last couple of years, combined with a steady recovery in automotive palladium demand following Covid outbreaks and the semiconductor chip crisis, created a market shortfall in 2023 of close to a million ounces (excluding investment). Looking ahead to 2024, SFA projects a narrower market shortfall of 775 koz.

Sliding autocatalyst recycling widens fundamental market shortfall...

...but there is no shortage of metal for buyers

However, with lease rates back to very low levels and metal prices well down on recent highs, there is clearly no evidence of panic buying or a shortage of metal availability, as opposingly indicated by supply-demand fundamentals.

Recycling fell by a further 16% in 2023 after peaking in 2021 on the back of record rhodium and palladium prices, which destocked autocatalyst collection pipelines. A reduction in end-of-life vehicles reaching scrapyards and some hoarding of autocatalysts have severely impacted collection rates.

Primary supply was flat year-on-year in 2023 at 6,460 koz. A dip in output due to reduced equipment efficiencies in Russia was offset by a slight rise in supplies from South Africa (via processing of excess work-in-progress stocks) and Canada.

Temporary recovery for auto demand

Gross automotive demand rose by 3% year-on-year in 2023 and breached 8 moz for the first time since 2019, as global vehicle production exceeded 90 million units and, more importantly, catalyst-containing vehicles exceeded 80 million units.

The outlook for 2024, however, sees autocatalyst palladium demand dip back below 8 moz from expectations of flat global vehicle production and increased battery electric vehicle shares, albeit EV sales growth is slower than in previous years.

Meanwhile, the ongoing decline in dental and electrical demand, along with softer auto demand, helps to reduce overall palladium requirements by a projected 3% to 9,390 koz in 2024. However, SFA does see opportunities

for palladium to recover some lost ground in electronics owing to a widening price differential to gold in the years ahead.

Palladium supply is forecast to be down just 1% this year. A 9% drop in Russian output to 2,450 koz due to delayed smelter maintenance helps to reduce primary supplies by 4.3% to 6,180 koz, while recycling tentatively bottoms out and starts to recover. Nonetheless, there is a large degree of uncertainty regarding the projected availability of autocatalysts at scrapyards for the remainder of the year, which suggests volume risks to the downside.

The rhodium market

Rhodium market shifted from oversupply to balance in 2023

The rhodium market was estimated to be balanced in 2023 after being oversupplied by 155 koz in 2022 which correspondingly led to a collapse in metal prices.

Autocatalyst demand continued to recover, reaching 970 koz in 2023, an increase of 4% year-on-year, but was still down on pre-pandemic levels of over 1 moz. Nonetheless, because recycling contracted by 16% to 285 koz, net autocatalyst requirements were up by a healthy 17% to 690 koz.

Excessive stock sales by the glass industry weighed on rhodium

The glass industry continued to be a net supplier of rhodium to market (-75 koz in 2023), as companies offloaded stocks built up on the back of shifting metal ratios in plant glass-making equipment towards platinum at the expense of rhodium.

SFA now estimates that a total of >200 koz of rhodium was substituted out of the fibreglass sector between 2021 and 2023. Chemical demand is forecast to have largely recovered last year, driven by nitric acid industry requirements. Therefore, overall rhodium demand is forecast to have recovered to just over 1 moz in 2023.

Primary supplies of rhodium slipped by 1% to 730 koz as some stoppages at rhodium-rich UG2 mines and a lack of throughput of work-in-progress stocks limited output from South Africa. Production from other regions grew slightly, but was not enough to offset losses from South Africa. Supply is therefore still down by 8% relative to pre-pandemic levels.

Rhodium supply slips...

A contraction in primary supplies and a slight recovery in industrial end-uses are forecast to shift the rhodium market into a slight deficit of 35 koz in 2024. SFA is assuming limited further stock sales from the glass industry, but this is still a risk to the market in 2024. Meanwhile, demand pull from the autocatalyst industry is set to be lacklustre, with a 5% drop in requirements at 925 koz.

...and potentially shifts the market into a narrow deficit in 2024

On the other hand, refined mine output is forecast to fall by 4% to 700 koz, and the possibility of further cuts to supply through the year cannot be ruled out.

The price outlook for the next six months

Platinum $940/oz

Logically, a second year of market deficits could indicate the possibility of a rising price environment. However, during the pandemic period alone, the platinum market built up in excess of 2 million ounces of additional stock that demand did not absorb. Therefore, the market is likely to require a number of years of fundamental market shortfalls before we see a meaningful impetus for higher prices.

Platinum prices started the year at $1,000/oz but have averaged below $950/oz. On the basis of a weaker economic environment this year and with platinum being more associated with industrial production than safe-haven investment, as well as the possibility of a further weakening of the rand on the back of South Africa's forthcoming elections, SFA forecasts a six-month price average of $940/oz.

Palladium $900/oz

Palladium prices have held up exceedingly well so far in 2024, with a number of short-covering rallies to over $1,000/oz. Arguably, the collapse of autocatalyst recycling has helped to prop up palladium prices as the demand pull for the metal is set to soften during the course of the year.

Automakers in general are far less concerned about supply security than they have been in recent years, and there has been a move towards holding less safety stock and returning to normal levels of inventory management.

The bifurcation of the market, with Russia providing much of China's metal requirements, and reduced open competition for metal on the spot market weigh on palladium's prospects. This, as well as exceedingly low lease rates, indicates plenty of metal availability. However, with excessive short positions on exchanges, there is always the risk of a short covering rally based on material events in mine supply. With planned smelter maintenance in Russia likely to impact refined metal pipelines later in the year, there is always the possibility of higher prices. However, based on softening demand and metal availability, SFA forecasts a palladium price average over the next six months of $900/oz, which is currently lower than prevailing prices.

Rhodium $4,350/oz

The rhodium market size is back to a million ounces, but with an over-exposure to the automotive industry at just shy of 90% of end-use and with demand starting to fall back after a solid recovery last year, the potential for meaningful price rallies is becoming less likely.

Nonetheless, SFA is forecasting a minor market deficit of 35 koz owing mainly to a drop in primary supply. It is also likely that any meaningful rally will be short-lived, with remaining glass industry stocks likely to be sold back to the market, or motivation to trvansfer some scrapped autocatalysts to collectors that are still held by some scrapyards. Prices are therefore likely to trade towards $4,000/oz for the remainder of the year, with a six-month average of $4,350/oz. Of course, any meaningful announcements on supply cutbacks from South Africa could raise average rhodium prices, but prices are unlikely to reach last year's average of over $6,000/oz unless a major processing plant disruption occurs.

PGM Recycling Market Study

78 Pt Platinum 195.084

46 Pd Palladium 106.42

45 Rh Rhodium 102.9055

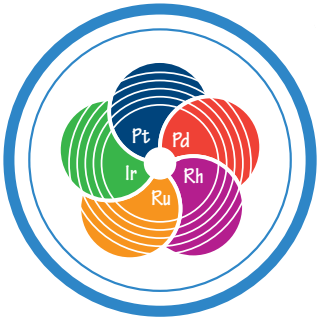
Secondary supply of PGMs is forecast to increase substantially in the coming years. However, autocatalyst recycling has seen a decline of 20% to 50%, depending on the source.

How and when might PGM recycling recover and grow?

Are there fundamental changes to autocatalyst recycling or is this a temporary setback?

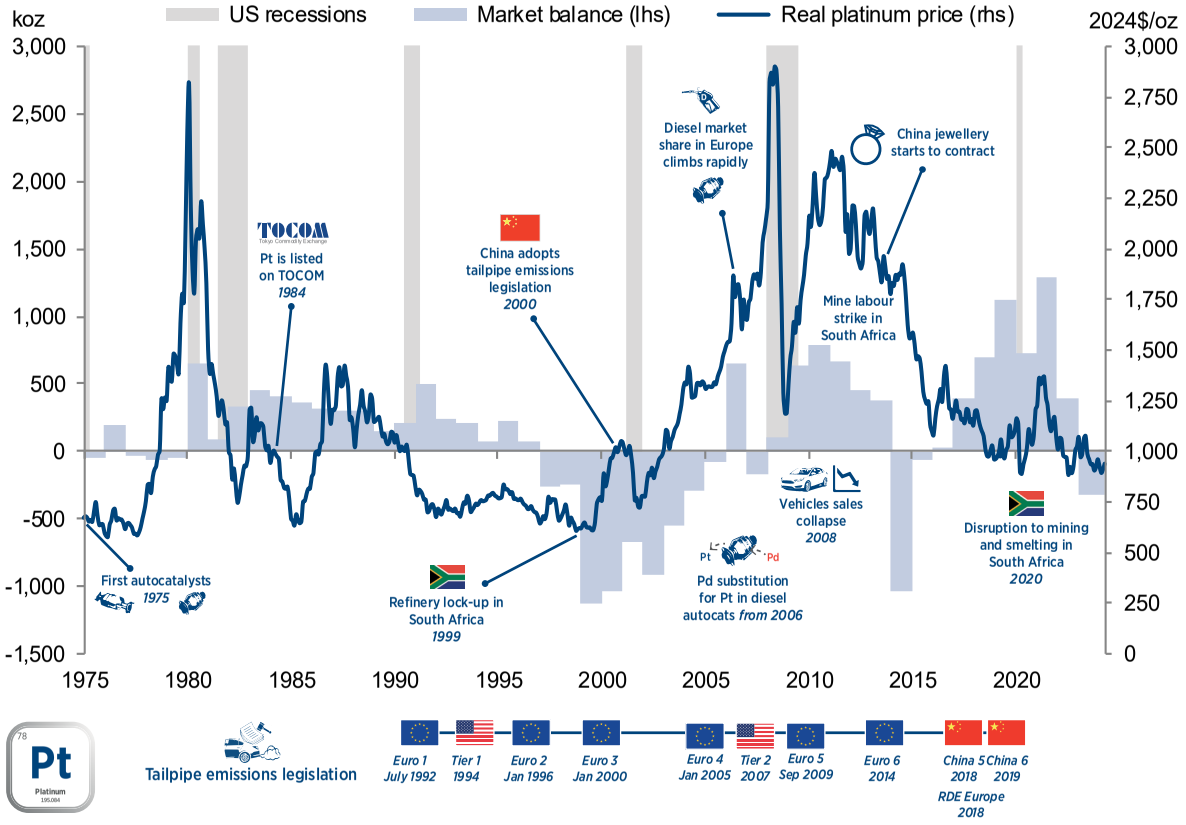
SFA has undertaken a major market study that takes a deep dive into the PGM recycling sector. We have compiled these granular insights into a comprehensive report, providing clients with detailed analysis and an independent view of the autocatalyst recycling market.

This unique report is supported by direct interaction with SFA's team of analysts.



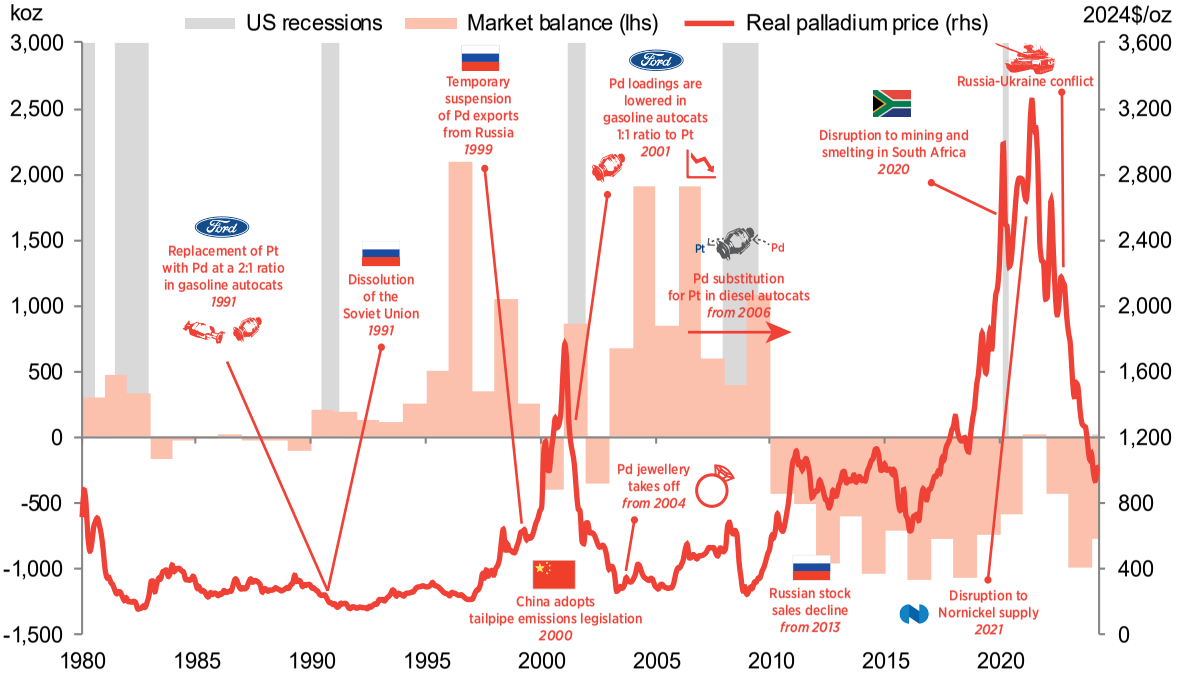
PGM PRICE HISTORY

Platinum



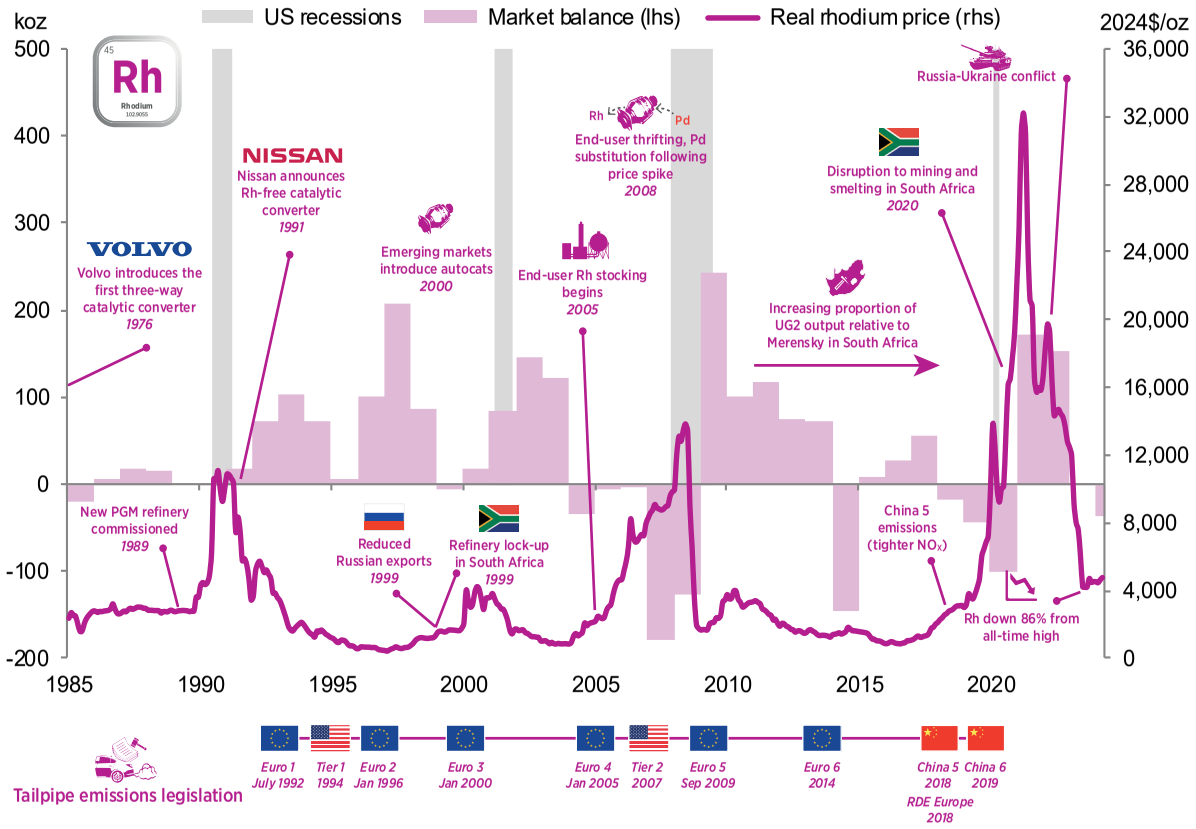
Source: SFA (Oxford), Bloomberg

Palladium



Source: SFA (Oxford), Bloomberg

Rhodium



Source: SFA (Oxford), Bloomberg

APPENDIX

Platinum supply-demand balance

koz	2016	2017	2018	2019	2020	2021	2022	2023	2024f
Primary supply									
Regional									
South Africa	4,265	4,385	4,470	4,405	3,260	4,715	3,975	4,000	3,920
Russia	715	720	665	710	700	640	655	670	610
Zimbabwe	490	480	465	460	480	470	490	520	510
North America	390	360	345	350	330	255	250	265	265
Other	185	185	180	185	175	125	125	130	120
Total	**6,045**	**6,125**	**6,130**	**6,105**	**4,950**	**6,210**	**5,490**	**5,580**	**5,425**
Demand & recycling									
Autocatalyst									
Gross demand	3,350	3,300	3,115	2,865	2,435	2,830	3,005	3,560	3,505
Recycling	1,210	1,325	1,420	1,495	1,335	1,445	1,305	1,090	1,135
Net demand	2,135	1,975	1,695	1,375	1,105	1,385	1,705	2,470	2,375
Jewellery									
Gross demand	2,510	2,450	2,245	2,090	1,560	1,780	1,435	1,310	1,280
Recycling	625	560	505	500	410	400	250	260	295
Net demand	1,885	1,890	1,740	1,595	1,150	1,380	1,180	1,045	985
Industrial demand	**1,970**	**1,845**	**1,965**	**2,010**	**1,990**	**2,170**	**2,205**	**2,345**	**2,345**
Hydrogen	**45**	**50**	**70**	**40**	**15**	**30**	**35**	**80**	**90**
Other recycling	**25**	**30**	**30**	**30**	**30**	**45**	**40**	**40**	**45**
Gross demand	**7,875**	**7,645**	**7,395**	**7,005**	**6,000**	**6,815**	**6,685**	**7,295**	**7,220**
Recycling	**1,860**	**1,915**	**1,955**	**2,020**	**1,780**	**1,890**	**1,590**	**1,390**	**1,475**
Net demand	**6,010**	**5,730**	**5,440**	**4,985**	**4,225**	**4,920**	**5,090**	**5,905**	**5,745**
Market balance									
Balance (before ETFs)	30	395	690	1,120	725	1,290	400	-320	-320
ETFs (stock allocation)	-10	85	-240	995	505	-265	-560	-25	
Balance after ETFs	**40**	**310**	**930**	**130**	**220**	**1,555**	**960**	**-295**	**-320**

Source: SFA (Oxford)

Platinum demand and recycling summary

koz	2016	2017	2018	2019	2020	2021	2022	2023	2024f
Gross demand									
Autocatalyst									
North America	410	390	390	375	285	400	510	565	570
Western Europe	1,630	1,555	1,340	1,145	870	820	785	925	860
Japan	450	435	425	395	300	280	275	305	310
China	195	230	220	275	470	600	520	685	700
India	170	175	200	160	110	175	235	235	230
RoW	495	515	545	515	400	560	680	840	835
Total	**3,350**	**3,300**	**3,115**	**2,865**	**2,435**	**2,830**	**3,005**	**3,560**	**3,505**
Jewellery									
North America	265	280	280	275	210	255	265	235	220
Western Europe	240	250	255	260	175	190	185	160	160
Japan	335	340	345	330	245	260	270	255	235
China	1,450	1,340	1,095	945	755	875	510	435	435
India	145	175	195	210	120	135	160	165	170
RoW	70	75	75	75	55	60	50	60	65
Total	**1,970**	**1,845**	**1,965**	**2,010**	**1,990**	**2,170**	**2,205**	**2,345**	**2,345**
Industrial									
North America	390	350	350	300	230	280	330	350	355
Western Europe	280	275	295	285	260	255	270	290	295
Japan	85	65	100	105	120	100	105	140	90
China	725	645	550	620	820	1,020	865	890	925
RoW	490	505	665	700	560	515	635	680	675
Total	**1,840**	**1,970**	**1,845**	**1,965**	**2,010**	**1,990**	**2,215**	**2,235**	**2,275**
Hydrogen	**45**	**50**	**70**	**40**	**15**	**30**	**35**	**80**	**90**
Total gross demand									
North America	1,065	1,015	1,020	950	725	940	1,105	1,145	1,145
Western Europe	2,150	2,080	1,890	1,690	1,300	1,265	1,240	1,375	1,315
Japan	870	840	865	830	670	645	650	700	630
China	2,375	2,215	1,870	1,840	2,045	2,495	1,890	2,010	2,060
RoW	1,375	1,445	1,680	1,655	1,245	1,440	1,760	1,980	1,975
Total	**7,875**	**7,645**	**7,395**	**7,005**	**6,000**	**6,815**	**6,685**	**7,295**	**7,220**

Source: SFA (Oxford). Note: Regional totals exclude hydrogen demand.

Platinum demand and recycling summary (continued)

koz	2016	2017	2018	2019	2020	2021	2022	2023	2024f
Recycling									
Autocatalyst									
North America	535	585	640	645	595	600	505	395	395
Western Europe	400	440	465	505	435	510	460	375	380
Japan	95	100	110	110	105	120	110	105	115
China	40	40	35	40	30	35	40	30	40
RoW	150	160	170	190	170	185	190	185	205
Total	**1,210**	**1,325**	**1,420**	**1,495**	**1,335**	**1,445**	**1,305**	**1,090**	**1,135**
Jewellery									
North America	5	5	5	5	5	5	5	5	5
Western Europe	5	5	5	5	5	5	5	5	5
Japan	150	160	145	140	110	115	105	115	120
China	460	385	340	340	285	265	125	130	155
RoW	5	5	5	10	10	10	10	10	10
Total	**625**	**560**	**505**	**500**	**410**	**400**	**250**	**260**	**295**
WEEE	**25**	**30**	**30**	**30**	**30**	**45**	**40**	**40**	**45**
Total recycling									
North America	545	600	650	660	605	615	515	405	410
Western Europe	410	450	480	520	450	525	475	390	395
Japan	245	265	260	255	215	240	220	220	240
China	500	425	380	385	320	305	170	165	205
RoW	165	175	185	205	190	210	210	205	230
Total	**1,860**	**1,915**	**1,955**	**2,020**	**1,780**	**1,890**	**1,590**	**1,390**	**1,475**

Source: SFA (Oxford)

Palladium supply-demand balance

koz	2016	2017	2018	2019	2020	2021	2022	2023	2024f
Primary supply									
Regional									
South Africa	2,375	2,530	2,500	2,555	1,845	2,755	2,240	2,285	2,295
Russia	2,555	2,740	2,670	2,870	2,810	2,585	2,790	2,690	2,450
Zimbabwe	395	395	380	385	405	395	410	430	430
North America	1,065	985	1,035	975	950	840	740	785	740
Other	420	415	395	395	385	265	270	270	265
Total	**6,810**	**7,065**	**6,975**	**7,180**	**6,395**	**6,845**	**6,450**	**6,460**	**6,180**
Demand & recycling									
Autocatalyst									
Gross demand	7,935	8,140	8,450	8,585	7,535	7,970	7,865	8,125	7,835
Recycling	1,710	1,920	2,035	2,175	2,030	2,395	2,265	1,870	2,055
Net demand	6,220	6,220	6,415	6,410	5,510	5,570	5,600	6,255	5,775
Jewellery									
Gross demand	240	225	220	210	195	155	140	130	125
Recycling	75	70	60	55	50	40	35	30	35
Net demand	165	155	155	155	145	115	105	100	90
Industrial demand	**1,900**	**1,840**	**1,840**	**1,715**	**1,640**	**1,500**	**1,485**	**1,375**	**1,360**
Hydrogen	**0**	**0**	**0**	**0**	**20**	**45**	**60**	**65**	**70**
Other recycling	**390**	**380**	**370**	**365**	**335**	**415**	**365**	**350**	**345**
Gross demand	**10,075**	**10,205**	**10,505**	**10,510**	**9,390**	**9,665**	**9,545**	**9,690**	**9,390**
Recycling	**2,175**	**2,370**	**2,470**	**2,600**	**2,410**	**2,850**	**2,665**	**2,245**	**2,435**
Net demand	**7,895**	**7,840**	**8,035**	**7,915**	**6,980**	**6,815**	**6,880**	**7,445**	**6,950**
Market balance									
Balance (before ETFs)	-1,090	-775	-1,060	-735	-585	30	-430	-985	-775
ETFs (stock allocation)	-640	-375	-560	-90	-115	50	-90	80	
Balance after ETFs	**-450**	**-400**	**-500**	**-650**	**-470**	**-20**	**-340**	**-1,065**	**-775**

Source: SFA (Oxford)

Palladium demand and recycling summary

koz	2016	2017	2018	2019	2020	2021	2022	2023	2024f
Gross demand									
Autocatalyst									
North America	1,935	1,850	1,860	1,815	1,460	1,620	1,660	1,735	1,725
Western Europe	1,685	1,705	1,720	1,670	1,275	1,200	1,090	1,120	1,075
Japan	775	805	840	870	760	715	715	730	680
China	1,985	2,055	2,060	2,290	2,465	2,285	1,865	1,980	1,840
India	225	240	320	285	240	340	445	445	450
RoW	1,325	1,490	1,650	1,645	1,340	1,805	2,085	2,115	2,070
Total	**7,935**	**8,140**	**8,450**	**8,585**	**7,535**	**7,970**	**7,865**	**8,125**	**7,835**
Jewellery									
North America	35	35	35	35	35	30	25	25	25
Western Europe	55	55	55	55	50	40	35	35	30
Japan	50	50	50	50	45	35	30	30	30
China	75	60	55	50	45	35	35	30	30
RoW	25	25	25	25	20	15	15	15	15
Total	**240**	**225**	**220**	**210**	**195**	**155**	**140**	**130**	**125**
Industrial									
North America	370	340	305	295	245	250	245	225	230
Western Europe	325	310	295	290	260	260	250	235	235
Japan	400	360	335	300	255	245	235	205	195
China	375	415	485	415	485	390	415	370	380
RoW	430	410	420	415	395	350	340	335	325
Total	**1,900**	**1,840**	**1,840**	**1,715**	**1,640**	**1,500**	**1,485**	**1,375**	**1,360**
Hydrogen	**0**	**0**	**0**	**0**	**20**	**45**	**60**	**65**	**70**
Total gross demand									
North America	2,345	2,225	2,200	2,150	1,740	1,900	1,930	1,985	1,975
Western Europe	2,065	2,070	2,070	2,015	1,590	1,500	1,375	1,385	1,335
Japan	1,225	1,215	1,225	1,220	1,055	995	980	965	900
China	2,430	2,530	2,600	2,760	2,995	2,710	2,310	2,380	2,245
RoW	2,005	2,170	2,410	2,370	1,990	2,510	2,890	2,910	2,860
Total	**10,075**	**10,205**	**10,505**	**10,510**	**9,390**	**9,665**	**9,545**	**9,690**	**9,390**

Source: SFA (Oxford). Note: Regional totals exclude hydrogen demand.

Palladium demand and recycling summary (continued)

koz	2016	2017	2018	2019	2020	2021	2022	2023	2024f
Recycling									
Autocatalyst									
North America	960	1,060	1,135	1,190	1,140	1,315	1,115	895	935
Western Europe	260	305	330	335	310	385	350	270	275
Japan	125	145	180	200	185	205	195	185	200
China	160	165	155	165	150	180	245	185	260
RoW	205	245	240	290	240	315	350	335	385
Total	**1,710**	**1,920**	**2,035**	**2,175**	**2,030**	**2,395**	**2,265**	**1,870**	**2,055**
Jewellery									
Japan	20	20	15	15	15	10	10	5	5
China	60	50	45	40	35	30	25	25	30
Total	**75**	**70**	**60**	**55**	**50**	**40**	**35**	**30**	**35**
WEEE									
North America	80	75	70	70	60	70	60	55	55
Western Europe	75	80	80	75	70	75	70	65	60
Japan	135	130	125	120	110	120	110	100	100
China	35	35	40	45	45	60	55	60	60
RoW	60	60	60	60	55	90	70	70	65
Total	**390**	**380**	**370**	**365**	**335**	**415**	**365**	**350**	**345**
Total recycling									
North America	1,040	1,130	1,205	1,255	1,200	1,380	1,180	950	995
Western Europe	335	385	410	410	375	460	420	335	340
Japan	280	295	320	335	305	340	315	295	305
China	255	250	240	250	230	270	325	265	350
RoW	265	305	295	345	295	405	425	400	450
Total	**2,175**	**2,370**	**2,470**	**2,600**	**2,410**	**2,850**	**2,665**	**2,245**	**2,435**

Source: SFA (Oxford)

Rhodium supply-demand balance

koz	2016	2017	2018	2019	2020	2021	2022	2023	2024f
Primary supply									
Regional									
South Africa	615	620	625	640	475	670	595	585	565
Russia	70	75	75	80	80	75	75	75	70
Zimbabwe	45	45	40	40	45	40	45	45	45
North America	25	25	20	20	20	20	15	20	15
Other	10	10	10	10	10	5	5	5	5
Total	**765**	**775**	**770**	**790**	**630**	**815**	**735**	**725**	**700**
Demand & recycling									
Autocatalyst									
Gross demand	835	870	915	1,020	935	945	930	970	925
Recycling	280	305	335	355	340	375	340	285	295
Net demand	555	565	580	665	595	570	590	690	630
Industrial demand	**180**	**155**	**210**	**170**	**135**	**75**	**-5**	**40**	**110**
Other recycling	**2**	**2**	**2**	**2**	**2**	**3**	**3**	**2**	**3**
Gross demand	**1,015**	**1,025**	**1,125**	**1,190**	**1,070**	**1,020**	**925**	**1,010**	**1,035**
Recycling	**280**	**305**	**340**	**355**	**340**	**375**	**345**	**285**	**300**
Net demand	**735**	**720**	**790**	**835**	**730**	**645**	**580**	**725**	**735**
Market balance									
Balance (before ETFs)	30	55	-15	-45	-100	170	155	0	-35
ETFs (stock allocation)	5	-20	-50	-15	-10	-5	0	0	
Balance after ETFs	**25**	**75**	**30**	**-30**	**-90**	**175**	**155**	**0**	**-35**

Source: SFA (Oxford)

Rhodium demand and recycling summary

koz	2016	2017	2018	2019	2020	2021	2022	2023	2024f
Gross demand									
Autocatalyst									
North America	235	230	225	220	175	190	205	205	205
Western Europe	210	215	230	290	225	215	205	225	205
Japan	125	125	130	130	110	100	100	105	100
China	130	150	155	205	275	255	200	200	185
India	20	20	25	25	20	25	35	35	35
RoW	115	130	150	155	125	160	185	200	195
Total	**180**	**155**	**210**	**170**	**135**	**75**	**-5**	**40**	**110**
Industrial									
North America	20	15	20	20	15	15	15	20	20
Western Europe	10	10	20	15	10	5	5	10	10
Japan	10	10	10	10	10	10	10	10	10
China	95	75	90	70	65	30	-30	-50	50
RoW	45	40	70	55	30	15	0	50	15
Total	**180**	**155**	**210**	**170**	**135**	**75**	**-5**	**40**	**110**
Total gross demand									
North America	255	245	245	240	190	205	220	225	225
Western Europe	225	225	245	300	235	220	210	235	220
Japan	135	135	140	140	120	110	110	115	110
China	225	225	250	280	345	280	170	155	235
RoW	180	190	250	230	180	205	220	285	245
Total	**1,015**	**1,025**	**1,125**	**1,190**	**1,070**	**1,020**	**925**	**1,010**	**1,035**
Recycling									
Autocatalyst									
North America	160	165	180	190	185	205	175	140	145
Western Europe	50	55	60	65	60	65	60	50	50
Japan	35	35	45	45	45	45	45	40	40
China	5	5	5	5	5	10	15	10	15
RoW	30	35	45	50	45	45	45	45	45
Total	**280**	**305**	**335**	**355**	**340**	**375**	**340**	**285**	**295**

Source: SFA (Oxford)

GLOSSARY OF TERMS

Basket price
Collective revenue of metals divided by 4E oz.

BEV
Battery electric vehicle.

ESG
Environmental, social and governance.

Eskom
South Africa's public energy producer and supplier.

ETF
Exchange-traded fund.

Gross demand
A measure of intensity of use.

ICE
Internal combustion engine.

koz
One thousand troy ounces.

moz
One million troy ounces.

Net demand
A measure of the theoretical requirement for new metal, i.e. net of recycling.

Net supply
Proxy supply of metal surplus to requirements.

OTC
Over-the-counter trade. Trading via a broker-dealer network rather than a centralised exchange

oz
Troy ounce.

PGMs
Platinum-group metals.

Primary supply
Mine production.

Secondary supply
Recycling output.

Thrifting
Using less metal in order to reduce costs.

TOCOM
Tokyo Commodity Exchange.

WEEE
Waste electrical and electronic equipment.

4E
Platinum, palladium, rhodium and gold.

Currency symbols:

$ US dollar.

METHODOLOGY

Primary supply is calculated from actual mine production and excludes the sale of stock in order to provide pure production data. Stock sales are treated separately in SFA's database as movement of stocks. Therefore, state stock sales from Russia are excluded in tabulations.

Gross demand is a measure of intensity of use.

Net demand is a measure of the theoretical requirement for new metal, i.e. net of recycling.

Automotive demand is based on vehicle production data not sales.

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