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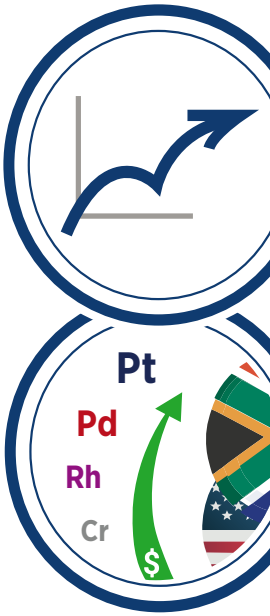

THE PALLADIUM STANDARD

September 2024

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Foreword

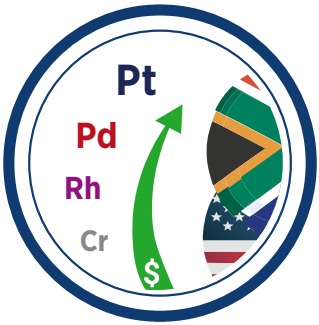
Chrome, basket price and all things nice

With the global average PGM basket price now more than 35% below the peak of 2022, the by-product metals of the South African Bushveld, North America and the Russian Far North are more crucial than ever to miners' balance sheets.

In our feature article, ***The squeeze is on — managing the margins***, Dr Ralph Grimble delves into the PGM basket, bringing to light the metals that typically play minor roles in revenue generation but now have the potential to tip the balance between profit and loss for primary PGM producers.

The 'easy' cost-cutting is in progress or has already been done: trim expansion and stay-in-business CAPEX, and cut excess overheads and labour where possible. In the months ahead, the industry might face tougher decisions: whether to cut production, close unprofitable mines, or still hope for a rebound in PGM prices. As PGM miners navigate these uncertain waters, those operations with diversified revenue streams and greater by-product credits may better weather the downturn. Shafts exploiting the UG2 Reef, or operations with significant UG2 tailings resources for example, benefit currently in varying degrees from strong chrome concentrate sales which have helped to offset some of the decline in PGM prices.

Mine operators can cut headcount, reduce spending and improve efficiency, but what they cannot do is change the ground on which they operate, and the metals below. As the demand profile of PGMs shifts and evolves, it is the geology that may ultimately determine the future of primary supply.



THE SQUEEZE IS ON — MANAGING THE MARGINS

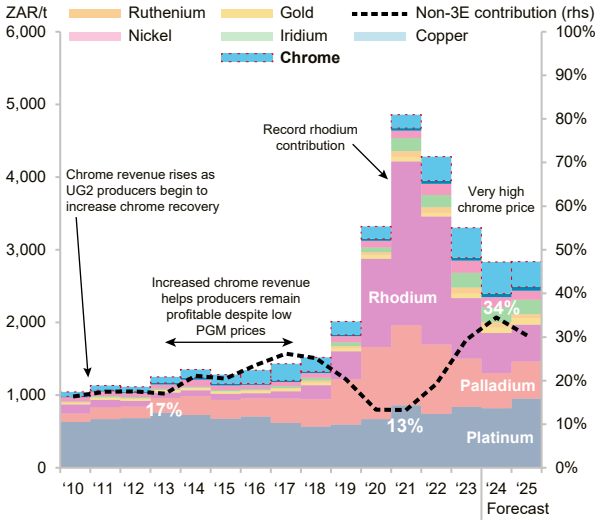
The squeeze is on — managing the margins

Dr Ralph Grimble, Operations Director, SFA (Oxford)

PGM miners' revenues have collapsed with the fall in palladium and rhodium prices and this, combined with steep mining cost inflation over the past five years, has dramatically reduced margins and made the highest-cost mining areas loss-making. For South African miners, the bulk of the revenues come from the three main PGMs, platinum, palladium and rhodium. However, the ore bodies mined host a variety of precious metals and base metals in varying proportions. The little-mentioned chrome that is recovered from UG2 ore and UG2 tailings has become an increasingly important contributor and is now the fourth-largest source of revenue.

Revenues from the 3E basket have plummeted...

South Africa PGM mine revenues per tonne 2010-2025



Source: SFA (Oxford). Note: 3E is platinum, palladium & rhodium.

...making by-products more important than ever for PGM miners

Producers in South Africa have begun to implement cost-cutting measures which have had a limited impact on mine output so far, with most efforts being directed at reducing capital expenditure, overheads and other business costs, with natural labour attrition and voluntary retrenchments where possible. North American production is heavily weighted towards palladium (almost 80%) and cost inflation has been significant there as well. Some cost-saving initiatives have been implemented but with little impact on near-term production. However, if prices continue to languish, further action may need to be taken.

Cost reductions have mostly been above-ground to date

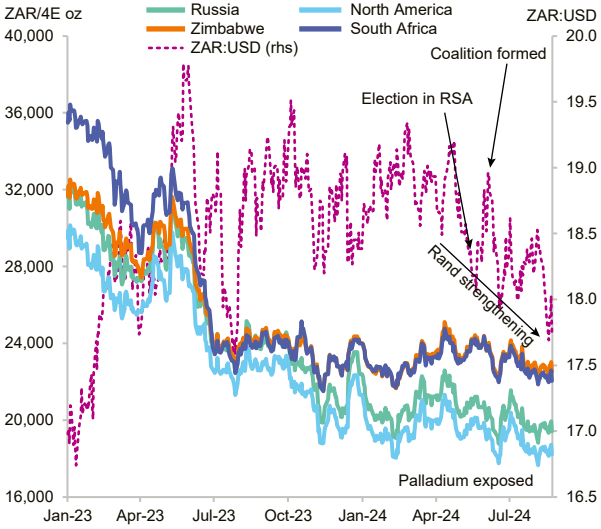
It is hard to see which metals might rally and lift revenues in the short term. PGM prices have been moving sideways to lower, and base metal prices are also falling. The economic outlook is subdued in China, with the US and European economies slowing and still at risk of recession. Automotive PGM demand may have peaked and, despite negative headlines on BEV sales momentum and rapidly rising hybrid sales, BEVs are still taking market share from combustion engine powered light-vehicles. The copper price remains relatively high but it makes too small a contribution to overall revenues to help, and chrome is also not far from historical highs with perhaps more downside potential than upside. Gold may be best positioned to make further gains but, unfortunately, a record gold price offers only marginal help since gold represents ~2% of total revenues.

Nearly all elements of the basket have been in decline

South African mine production is almost two-thirds UG2 ore by tonnage. The UG2 Reef is more exposed to palladium and particularly rhodium prices than the Merensky Reef and, hence, has seen a relatively larger revenue decline on a 4E basis. Strong chrome prices have, however, assisted some of the miners that recover chrome concentrate as a by-product.

The mix of by-product credits in UG2 exposes it to PGM price volatility

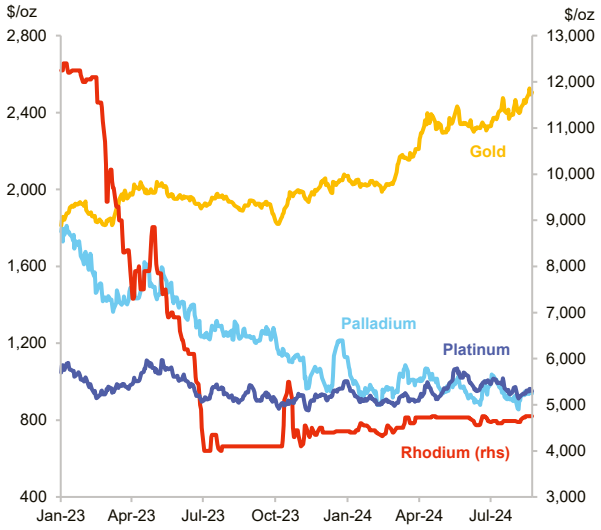
PGM 4E basket price trends 2023-2024



Source: SFA (Oxford), Bloomberg

Platinum's relationship to the rand is not as strong as it was

4E constituents' price trends 2023-2024



Source: SFA (Oxford), Bloomberg

Gold is outshining the other precious metals

Rhodium prices have stabilised at around $4,700/oz, but that is a drop of 61% since 1 January 2023 and 84% from the record $29,800/oz in March 2021. Palladium prices have fallen by 47% over the same period, and by 70% from the peak of $3,177/oz in March 2022. At the same time, the platinum price is down by just 5% since the start of 2023. A weaker rand is typically accompanied by a lower platinum price, but over the last two years while the rand has weakened the platinum price has held up much better than this relationship would imply. The rand has strengthened somewhat over the last few months helped by the formation of a coalition government, which included the more business-friendly Democratic Alliance, as well as a much more stable electricity supply situation. As the link to the platinum price has weakened this may not offer much support.

Rhodium has fared worst in this down-cycle

The gold price is at a record high and could go higher based on the economic and geopolitical backdrop. With ongoing wars in the Middle East and Eastern Europe, the situation is more fraught than usual. Economic fragility remains a factor, with the Chinese economy struggling with the aftermath of a real-estate bust, low growth in Europe and an uncertain situation in the US which is likely to prompt the Federal Reserve to cut interest rates at its September meeting. That could weaken the dollar and continue to support the gold price.

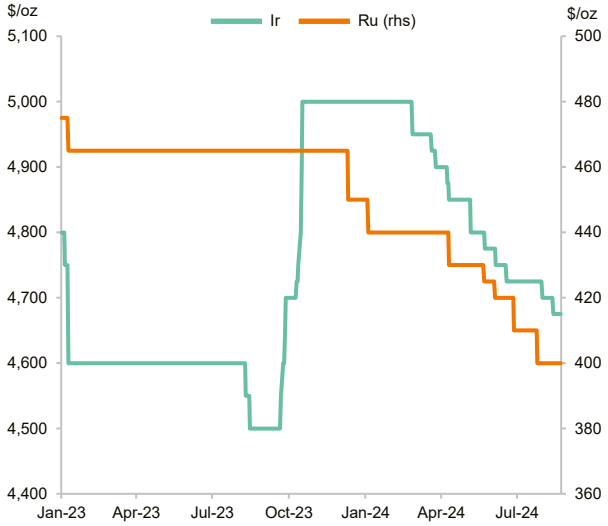
Gold's alternative price drivers have underpinned its record-breaking rally

Iridium and ruthenium are minor contributors to revenues even at what are relatively high prices by historical standards. Iridium prices have been slipping this year as the expansion of the hydrogen economy and green hydrogen production using PEM electrolysers has been slower than anticipated. Economic conditions may need to improve for OEMs to enter the market to secure metal for the hydrogen economy, tighten the market and lift the price.

Iridium waiting on the hydrogen economy

A recovery in electronics demand and growth in data storage is supporting ruthenium demand in hard disks as the transition to non-ruthenium containing technologies continues to be quite gradual.

Ruthenium and iridium prices 2023-2024



Source: SFA (Oxford), Bloomberg

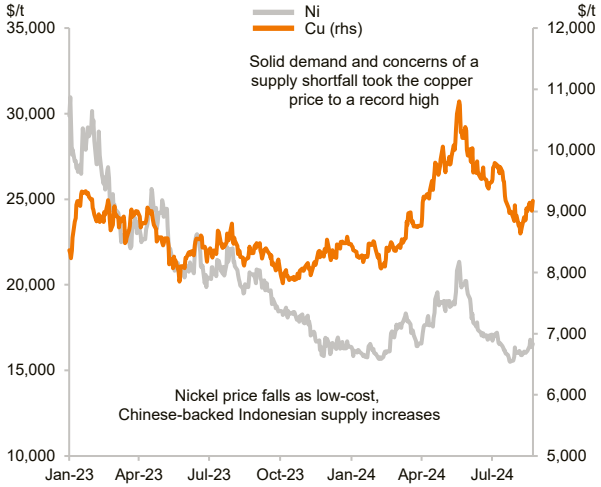
Minor PGMs are down but not out

Chinese investment in Indonesian nickel production has turned Indonesia into the largest producer of nickel. The surge in lower-cost nickel from Indonesia has flooded the market and led to a decline in the nickel price. Even with some loss-making production in other countries being shut down, the market looks likely to be in surplus for some time which could keep the price subdued.

Nickel under pressure

Concerns over market deficits saw copper prices reach record levels earlier this year. However, with lacklustre growth in China amid an ongoing slowdown in real-estate construction, the price has fallen back but remains high relative to historical real prices ($5,000-6,000/t).

Nickel and copper prices 2023-2024



Source: SFA (Oxford), Bloomberg

Copper tarnished by the outlook for China, despite short-term tightness

Chrome is the final by-product that can be produced from the UG2 Reef but it often receives less attention than the other metals. However, it has become an increasingly important source of revenue for South Africa's PGM miners, now being the fourth-largest contributor to revenues.

This contribution can vary considerably per operation however, depending on chrome offtake contract terms and chrome recovery plant ownership structures. At over $300/t, chrome ore prices are at a historically high level. China is the largest producer of ferrochrome in the world, having overtaken South Africa, whose historically large ferrous smelting industry has shrunk significantly following years of steep electricity price increases. Consequently, South African exports of chrome ore to China have increased and the Chinese market plays a significant role in setting the price. Chrome ore imports by China have grown by over 50% in a decade, from 12,062 kt in 2013 to 18,333 kt in 2023, with South Africa its most important supplier.

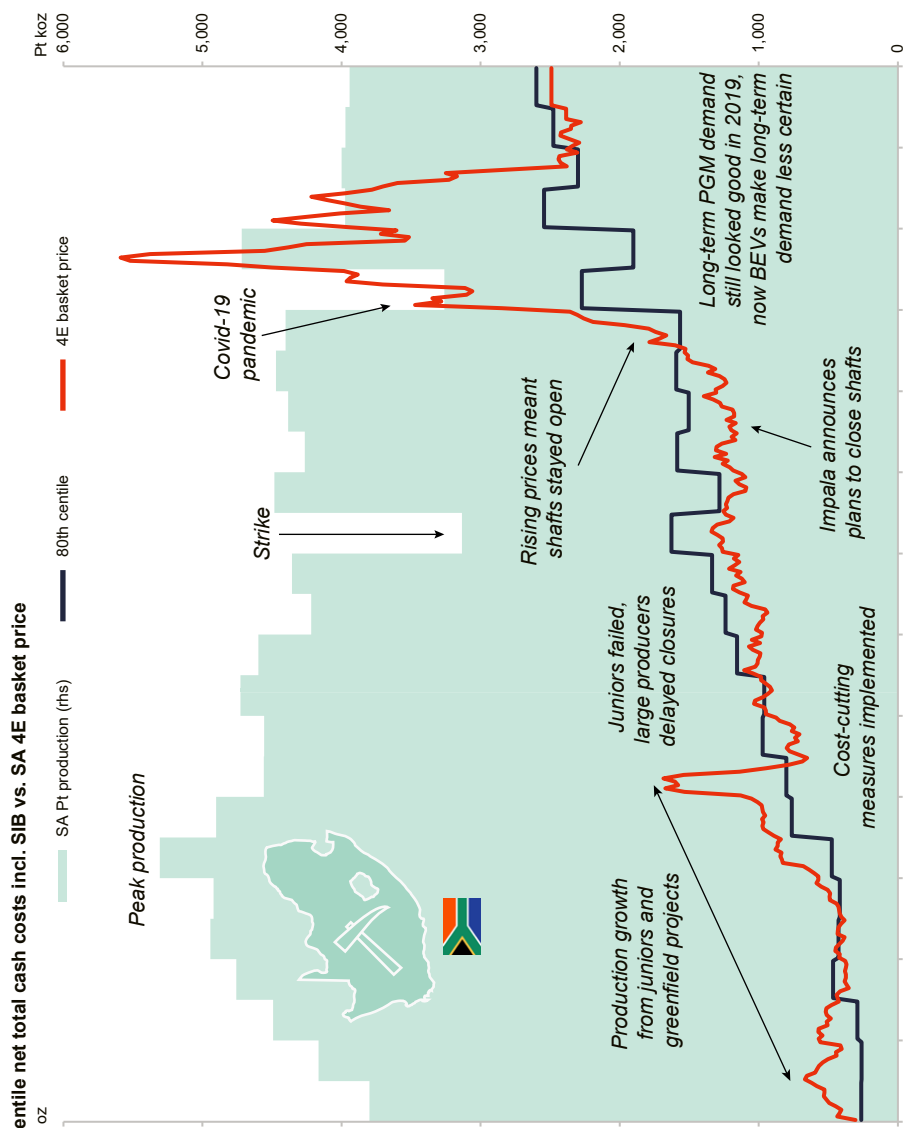
China effectively sets the price of South African chrome ore

Chrome ore prices and Chinese port stocks typically have an inverse correlation. Chrome ore stocks hit a low point in mid-2023 which helped to support a price above $300/t. However, stocks have been rebuilt and are in the middle of their typical range, while the price is still above $300/t, suggesting there could be some more price downside. If prices were to fall, UG2 production relying on chrome revenue to stay profitable could become even more marginal.

Chrome price risk could be to the downside

Chrome ore price

Source: SFA (Oxford), Bloomberg



Source: SFA (Oxford), Bloomberg. Note: SIB is stay-in-business capital expenditure.

Since 2019, total operating costs for mines have increased by 69% in South Africa. Cost pressures will continue so even if there were to be a recovery in the basket price next year, producers could still have loss-making output from the highest-cost areas. If the chrome price were to fall, that would reduce the viability of the higher-cost UG2 areas on the Western Limb. The question then is: how much longer will losses continue before companies have to address loss-making production?

Costs are up 69% in South Africa...

...and some shafts are now loss-making

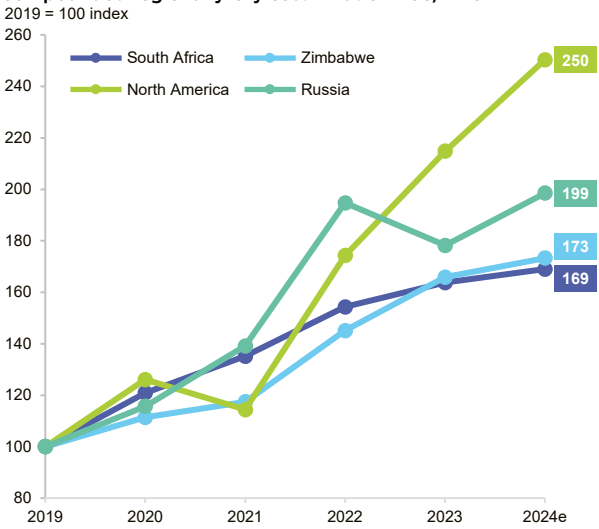
Taking Impala Platinum as an example, with revenues under pressure from falling PGM prices in the mid-2010s, it took several years to progress from cutting CAPEX to announcing major shaft closures that would occur in two to three years' time. Luckily, PGM prices recovered before the closures were made. However, at that point BEVs were a novelty with tiny sales figures and the outlook for PGM demand appeared robust as emissions standards continued to be tightened. Now, however, BEVs are a significant and growing part of light-vehicle sales and the future of continued growth in palladium and rhodium demand from gasoline autocatalysts is now much less certain. Whether that will induce a faster response this time remains to be seen, as all producers are acutely aware of the impact on unit costs of having to cover a large fixed-cost base with fewer production ounces.

Closing unprofitable shafts can be a long, slow process

North American operations could be under more immediate pressure as palladium is around 80% of production and still represents over 70% of revenue at the current price. North American mines saw very high cost inflation of 30.9% year-on-year in 2023, mainly at Stillwater, while at Impala Canada costs also increased significantly. In 2023, Stillwater mine was just profitable on an operating basis, but a large SIB component resulted in losses during a challenging year. Impala Canada has had its mine life shortened and Sibanye-Stillwater is taking steps to reduce capital and operating costs at Stillwater. The situation has not improved in 2024 with the palladium price falling further, meaning additional action will be required to stop the cash burn.

Palladium-rich mines are poorly positioned

Compounded regional y-o-y cost inflation TCC/4E oz



Source: SFA (Oxford)

North American cost inflation is compounded by labour shortages

What would it take for PGM prices to rise and improve profitability? If primary supply cuts at scale are not forthcoming, then demand needs to improve. Apart from what has already been legislated, significant further tightening of vehicle emissions standards appears unlikely, so the sales of combustion engine-powered vehicles needs to increase. A soft economic landing with lower interest rates, more affordable cars, higher consumer confidence and a continued shift in the recent trend to purchasing PHEVs over BEVs might do it. However, this also requires continued subdued PGM supply from the recycling sector, which is not a given if PGM prices start rising again.

Demand must rise in the absence of production cuts to lift PGM prices

THE PGM MARKETS IN 2024

The PGM markets in 2024

Dr Ralph Grimble, Operations Director, SFA (Oxford)

The palladium market

Pressure on primary and secondary supply keeps palladium in deficit

The palladium market is forecast to have a deficit of 450 koz this year owing to a moderate drop in automotive demand offset by constrained supply, with smelter maintenance in Russia cutting around 250 koz from refined output and secondary supply struggling to improve.

Light-vehicle production is estimated to advance to 91.3 million units this year, a marginal increase on 91.0 million last year. However, with BEVs continuing to increase their market share, combustion engine vehicle production is set to fall and drag down automotive palladium demand.

Eskom has reduced the intensity of power cuts in South Africa this year

Nornickel's smelter rebuild was undertaken during the summer, with the impact on refined output taking effect later in the year owing to the length of the processing pipeline. The company is likely to have stock to meet customer requirements over this period. South African refined output is expected to expand modestly this year as stockpiled material is processed. Further disruption to power supplies appears to be a receding risk as Eskom has managed to avoid imposing power cuts during the higher demand southern hemisphere winter.

Mine supply

Primary palladium production is forecast to drop by 4% to 6.21 moz in 2024. Russian refined output is expected to be 2.45 moz, around 250 koz lower than in 2023, owing to Nornickel delaying the replacement of a furnace at the Nadezhda smelter until the middle of this year. South African supply is expected to be slightly higher than last year as it is boosted by processing some work-in-progress stock. The return of power stability with no load-shedding since April should enable this to continue through the remainder of the year. Production in Zimbabwe is predicted to be steady, whereas North American output is estimated to be 6% lower at 740 koz, as Impala Canada's output and by-product palladium from nickel mining are anticipated to drop.

South African supply should grow slightly in 2024

Recycling

Secondary palladium supply is projected to rise by 3% to 2.67 moz. Autocatalyst recycling has remained subdued, particularly in the US and Europe. The number of scrapped vehicles is still lower than would be expected given the recovery in new light-vehicle sales. There have been reports of hoarding of catalysts in the US and also in China as collectors wait for higher prices to sell. Some growth is still anticipated from China and the RoW, but the Chinese market has its own challenges with the implementation of new tax rules, which could result in lower recycling than anticipated.

Recycling is forecast to grow but remain below pre-Covid levels

Demand

Global palladium demand is forecast to shrink by 1% to 9.33 moz, mostly owing to lower automotive demand as industrial demand is little changed. Although light-vehicle production has advanced this year, the market share of BEVs has grown faster than the overall market. In addition, Chinese automakers initially used quite high loadings to

BEV sales are growing faster than the larger market

meet China 6 emissions limits but have been increasingly thrifting metal, reducing their palladium requirements.

Automotive demand

Automotive demand for palladium is seen slipping by 1% to 7.76 moz this year. Light-vehicle production is forecast to be slightly higher than last year at 91.3 million units. BEV market share gains have not been as rapid as initially predicted, and PHEV sales have been growing more quickly, particularly in China. The removal of subsidies by the German government last year has resulted in lower BEV sales there than last year. However, global BEV sales are set to increase by more than 2 million units compared to 2023 and so automotive palladium demand is contracting slightly as a result.

Subsidy removal has hurt BEV sales growth in Germany

Industrial demand

Industrial palladium requirements are forecast to be unchanged at 1.38 moz this year as modestly higher electrical and other uses offset lower dental usage. The electronics sector is experiencing a recovery after a slump following the Covid-induced work-from-home boom.

Industrial demand is forecast to remain stable this year

Investment

Palladium has seen a modest increase in investment in ETFs so far this year, with holdings rising by 135 koz to 674 koz by mid-August. The gains came in the first half of the year, with holdings slipping from a peak of 724 koz in June. The majority of the additions were in the US (100 koz), with Swiss and UK holdings also growing modestly. The non-commercial traders have maintained a net short futures position on NYMEX for three years which stood at -1.2 moz in mid-August, down from a peak of -1.4 moz in June.

Investors added 135 koz to ETF holdings to August

The platinum market

The platinum market is forecast to have a moderate deficit of 290 koz (excluding investment) in 2024. Gross demand is marginally higher year-on-year owing to gains in industrial uses outweighing small reductions in jewellery and automotive demand. Automotive demand edges lower as BEVs' market share gains outweigh growth in the overall light-vehicle market, while a lacklustre Chinese economy holds back jewellery demand. Total production dips slightly as a fall in primary supply outweighs a slight gain for secondary supply.

Platinum is also expected to remain in a deficit in 2024

Global platinum supply is predicted to slip by 2% to 5.48 moz. Platinum production in South Africa is forecast to hold at around 4.0 moz as some work-in-progress stock is processed. The country has not had to contend with load-shedding since April so this should be achievable, as long as Eskom manages to maintain its performance. Russian output is expected to dip to 610 koz owing to the replacement of a furnace at the Nadezhda smelter. North American supply is predicted to be flat, while production in Zimbabwe is set to dip slightly.

South African supply is flat

Secondary platinum supply is projected to rise to 1.43 moz in 2024. Jewellery, autocatalyst and WEEE recycling are all expected to be slightly higher this year.

Automotive demand is estimated to dip slightly to 3.28 moz this year. While light-vehicle production is expected to be marginally higher this year, the market share of BEVs has continued to climb with the result that fewer combustion engine vehicles will be produced. As the rollout of gasoline autocatalysts with higher platinum loadings has been achieved, demand gains from replacing some palladium with platinum have run their course and this translates into a small loss of demand.

Automotive demand to fall incrementally

Platinum jewellery demand continues to struggle...

Global platinum jewellery demand is predicted to slip to 1.28 moz. China's economy has continued to struggle with the real-estate downturn and subdued consumer sentiment. Despite record high gold prices, platinum remains less favoured. India remains the best performing large economy and that should support jewellery demand, but the weakening economic outlook and constrained consumer spending following a period of high inflation are expected to weigh on jewellery demand in the US, Europe and Japan.

...as industrial demand ticks higher

Industrial platinum requirements are projected to reach 2.35 moz in 2024 as a result of higher usage by the chemical, electrical and petroleum industries. Chemical demand growth is expected to come predominantly from significant propane dehydrogenation (PDH) capacity expansions in China. Usage in the electrical sector is set to recover as the electronics industry is starting to rebound from a post-pandemic slump. The petroleum industry is likely to see some improvement in demand following a weak year in 2023.

The rhodium market

The rhodium market is predicted to have a deficit of 45 koz this year. Automotive demand is slightly lower than last year as BEVs continue to gain market share. Net industrial demand is forecast to be higher on much reduced sales of stock by the fibreglass industry in China. Primary supply is expected to dip slightly owing to lower output in South Africa, whereas secondary supply is set to be little changed.

Rhodium slips into a deficit

Automotive rhodium demand is estimated to fall by 3% to 920 koz. While light-vehicle production is expected to edge up this year, BEVs are taking further market share from combustion engine vehicles and reducing the need for rhodium in autocatalysts.

Automotive demand is expected to contract

Industrial rhodium requirements are projected to rebound to 110 koz in 2024. The glass industry is anticipated to be much less of a drag on demand as stock sales in China are likely to be much lower than last year. Rhodium demand from the various other end-use sectors is expected to be little changed.

Far lower stock sales raises net industrial demand

Primary rhodium supply is forecast to drop by 3% to 705 koz. South African output is predicted to fall by 3% to 570 koz, mostly as a result of lower production from Marikana mine. A small amount of rhodium is coming from work-in-progress stock that is being processed this year. Russian rhodium output is anticipated to dip by 5 koz owing to a furnace being replaced at the Nadezhda smelter, while production in North America and Zimbabwe is expected to be little changed. Recycled rhodium is forecast to be marginally higher this year owing to a slight increase in secondary supply from autocatalysts.

Rhodium supply is set to fall in 2024

The price outlook for the next six months

Palladium: $935/oz

The palladium market is in deficit with supply constraints from both primary and secondary supply. Nornickel's smelter rebuild will impact refined output in the second half of the year but output should recover by 2025, and the company may have stock to meet any shortfall in the meantime. Autocatalyst recycling remains subdued, with fewer old vehicles being scrapped than the pick-up in light-vehicle sales would imply.

OEMs may have run down their extra working inventory that was built up as a result of the supply uncertainty after the Russian invasion of Ukraine. However, with automotive demand representing 84% of total demand, the fact that combustion engine light-vehicle sales are dropping this year as BEVs continue to gain market share means that automotive demand is set to shrink. The economic outlook is gradually weakening in the US and China's economy is still struggling with a real-estate bust and low consumer confidence.

An announcement of further production cuts, along with typical seasonal strength in Q4 as automaker buying picks up after the summer, could result in some upside price volatility. However, a confirmed recession in the US or Europe with commensurately lower light-vehicle sales is a downside price risk. The price is predicted to average $935/oz over the next six months.

Platinum: $955/oz

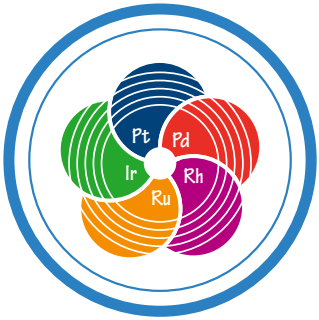
The fundamentals look reasonably good for platinum with the market predicted to have a deficit this year. Both industrial and automotive demand have gone up, more than offsetting the decline in jewellery demand, and supply is somewhat constrained. However, the price has essentially moved sideways this year and a stronger rand has not helped to lift the price.

Automotive demand has picked up as a result of the recovery in light-vehicle production and substitution of some platinum into gasoline autocatalysts but that makes it vulnerable to deteriorating light-vehicle sales in the event of a recession in the US or Europe, or further market share loss to BEVs. With ample stocks to cover the deficit, the price is forecast to average $955/oz over the next six months.

Rhodium $4,550/oz

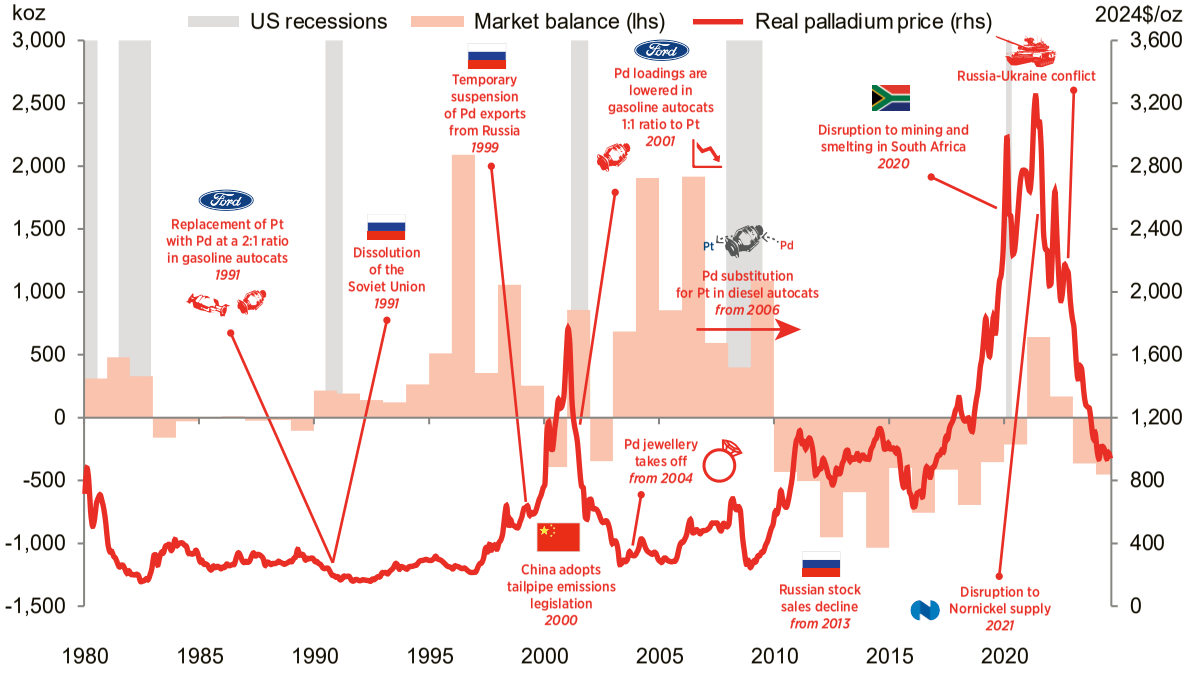
The rhodium market is predicted to be in deficit this year as supply is constrained. Supply disruptions appear less likely in South Africa, although any further production cuts could disproportionately hit rhodium if the chrome price continues to fall and high-cost UG2 Reef areas are closed.

Rhodium net demand has recovered this year, with much less stock being sold in China by the glass industry. However, automotive demand is slipping as BEVs take further market share from combustion engine vehicles. Rhodium may struggle in a deteriorating economic environment and so the price is forecast to average $4,550/oz over the next six months.



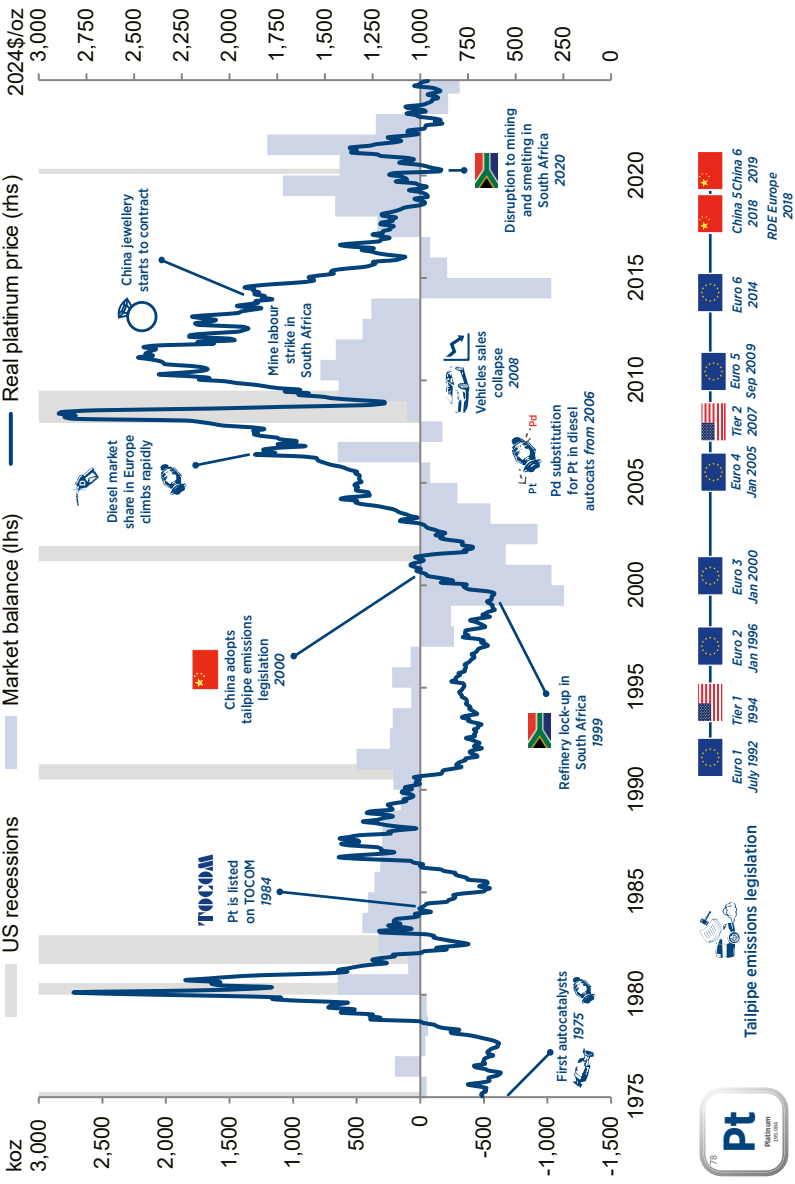
PGM PRICE HISTORY

Palladium



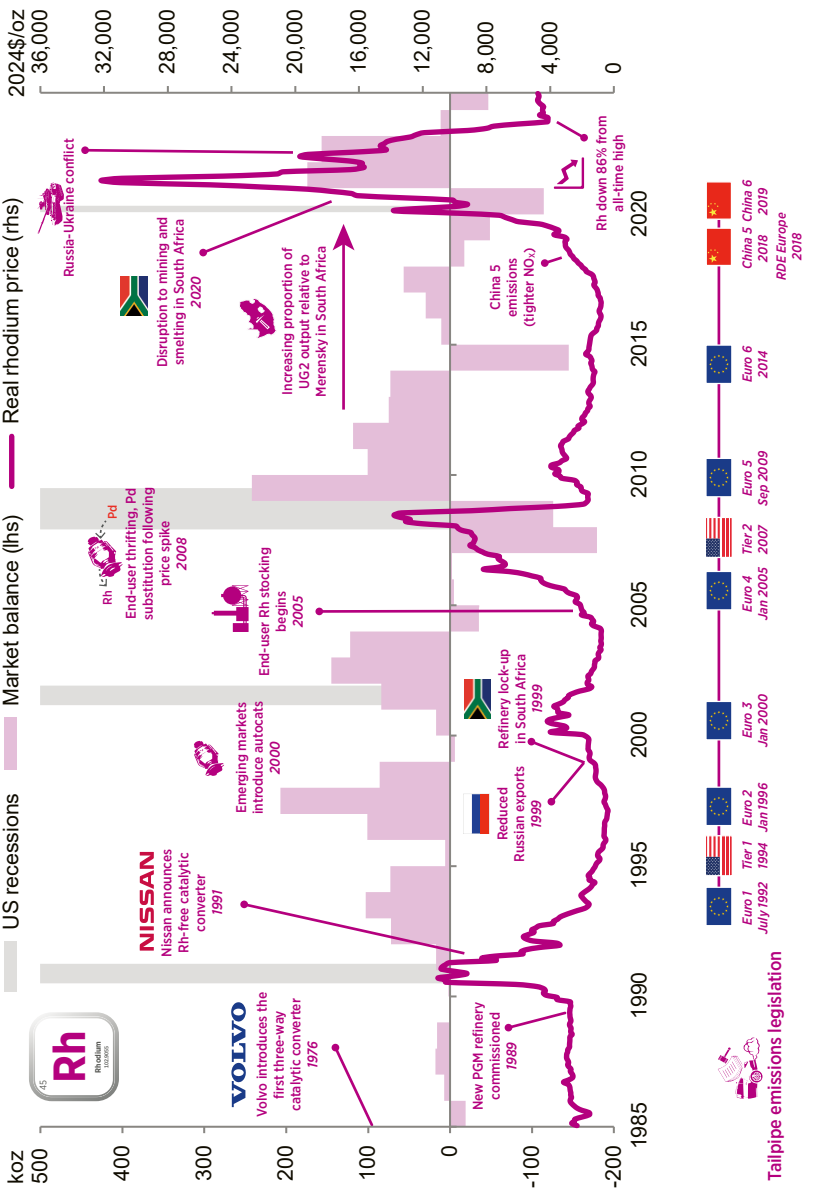
Source: SFA (Oxford), Bloomberg

Platinum



Source: SFA (Oxford), Bloomberg

Rhodium



Source: SFA (Oxford), Bloomberg

APPENDIX

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	2,325
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**	**6,210**
Demand & recycling									
Autocatalyst									
Gross demand	7,910	8,125	8,455	8,590	7,545	7,825	7,710	7,885	7,800
Recycling	2,020	2,265	2,410	2,565	2,395	2,840	2,670	2,215	2,290
Net demand	5,890	5,860	6,050	6,025	5,150	4,990	5,040	5,670	5,510
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**	**1,375**
Hydrogen	**0**	**0**	**0**	**0**	**10**	**20**	**20**	**25**	**30**
Other recycling	**390**	**380**	**370**	**365**	**335**	**415**	**365**	**350**	**345**
Gross demand	**10,050**	**10,190**	**10,515**	**10,520**	**9,390**	**9,500**	**9,355**	**9,415**	**9,330**
Recycling	**2,485**	**2,715**	**2,845**	**2,990**	**2,780**	**3,295**	**3,070**	**2,595**	**2,670**
Net demand	**7,565**	**7,475**	**7,670**	**7,530**	**6,610**	**6,205**	**6,285**	**6,825**	**6,660**
Market balance									
Balance (before ETFs)	-760	-415	-695	-355	-215	640	170	-365	-450
ETFs (stock allocation)	-640	-375	-560	-90	-115	50	-90	80	
Balance after ETFs	**-120**	**-40**	**-130**	**-265**	**-100**	**590**	**260**	**-445**	

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	1,625	1,660	1,785	1,830
Western Europe	1,685	1,705	1,720	1,675	1,280	1,195	1,090	1,110	1,040
Japan	775	805	840	870	760	720	715	735	675
China	1,960	2,040	2,060	2,290	2,465	2,135	1,730	1,695	1,680
India	225	240	320	285	240	340	415	415	425
RoW	1,325	1,490	1,655	1,650	1,345	1,815	2,100	2,145	2,145
Total	**7,910**	**8,125**	**8,455**	**8,590**	**7,545**	**7,825**	**7,710**	**7,885**	**7,800**
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	200
China	375	415	485	415	485	390	415	370	375
RoW	430	410	420	415	395	350	340	335	335
Total	**1,900**	**1,840**	**1,840**	**1,715**	**1,640**	**1,500**	**1,485**	**1,375**	**1,375**
Hydrogen	**0**	**0**	**0**	**0**	**10**	**20**	**20**	**25**	**30**
Total gross demand									
North America	2,345	2,225	2,200	2,150	1,740	1,905	1,935	2,035	2,085
Western Europe	2,065	2,070	2,070	2,015	1,590	1,500	1,375	1,380	1,310
Japan	1,225	1,215	1,225	1,220	1,055	1,000	980	965	905
China	2,410	2,515	2,600	2,760	2,995	2,560	2,175	2,100	2,085
RoW	2,005	2,170	2,420	2,375	2,000	2,520	2,870	2,910	2,915
Total	**10,050**	**10,190**	**10,515**	**10,520**	**9,380**	**9,480**	**9,330**	**9,390**	**9,300**

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	1,155	1,270	1,360	1,430	1,370	1,580	1,355	1,085	1,085
Western Europe	375	440	475	480	445	550	505	390	390
Japan	125	145	180	200	190	215	210	220	220
China	160	165	155	165	150	180	245	185	220
RoW	205	245	240	290	240	315	350	335	375
Total	**2,020**	**2,265**	**2,410**	**2,565**	**2,395**	**2,840**	**2,670**	**2,215**	**2,290**
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	1,235	1,345	1,430	1,495	1,435	1,645	1,420	1,145	1,140
Western Europe	450	520	550	555	510	625	575	455	450
Japan	280	295	320	340	310	350	330	330	325
China	255	250	240	250	230	270	325	265	310
RoW	265	305	295	345	295	405	425	400	440
Total	**2,485**	**2,715**	**2,845**	**2,990**	**2,780**	**3,295**	**3,070**	**2,595**	**2,670**

Source: SFA (Oxford)

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	3,970
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**	**5,475**
Demand & recycling									
Autocatalyst									
Gross demand	3,345	3,300	3,120	2,870	2,440	2,805	2,960	3,490	3,460
Recycling	1,210	1,325	1,420	1,495	1,310	1,425	1,280	1,080	1,100
Net demand	2,135	1,975	1,700	1,370	1,130	1,380	1,680	2,410	2,360
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	245	280
Net demand	1,885	1,890	1,740	1,595	1,150	1,380	1,180	1,060	1,000
Industrial demand	**1,970**	**1,845**	**1,965**	**2,010**	**1,990**	**2,170**	**2,195**	**2,320**	**2,390**
Hydrogen	**45**	**50**	**70**	**40**	**10**	**15**	**20**	**60**	**60**
Other recycling	**25**	**30**	**30**	**30**	**30**	**45**	**40**	**40**	**45**
Gross demand	**7,875**	**7,645**	**7,395**	**7,010**	**6,000**	**6,770**	**6,610**	**7,180**	**7,190**
Recycling	**1,860**	**1,915**	**1,955**	**2,025**	**1,755**	**1,865**	**1,570**	**1,365**	**1,425**
Net demand	**6,010**	**5,730**	**5,440**	**4,985**	**4,245**	**4,900**	**5,040**	**5,815**	**5,765**
Market balance									
Balance (before ETFs)	35	395	690	1,120	700	1,310	455	-230	-290
ETFs (stock allocation)	-10	85	-240	995	505	-265	-560	-25	
Balance after ETFs	**40**	**310**	**930**	**130**	**200**	**1,575**	**1,015**	**-205**	

Source: SFA (Oxford)

Platinum demand and recycling summary

koz	2016	2017	2018	2019	2020	2021	2022
Gross demand							
Autocatalyst							
North America	410	390	390	375	285	400	510
Western Europe	1,630	1,555	1,340	1,150	870	825	790
Japan	450	435	425	395	300	280	275
China	195	230	220	275	470	565	485
India	170	175	200	160	110	175	220
RoW	495	515	545	520	400	560	685
Total	**3,345**	**3,300**	**3,120**	**2,870**	**2,440**	**2,805**	**2,960**
Jewellery							
North America	265	280	280	275	210	255	265
Western Europe	240	250	255	260	175	190	185
Japan	335	340	345	330	245	260	270
China	1,450	1,340	1,095	945	755	875	510
India	145	175	195	210	120	135	160
RoW	70	75	75	75	55	60	50
Total	**2,510**	**2,450**	**2,245**	**2,090**	**1,560**	**1,780**	**1,435**
Industrial							
North America	390	350	350	300	230	280	335
Western Europe	280	275	295	285	260	255	270
Japan	85	65	100	105	120	100	105
China	725	645	550	620	820	1,020	910
RoW	490	505	665	700	560	515	580
Total	**1,970**	**1,845**	**1,965**	**2,010**	**1,990**	**2,170**	**2,195**
Hydrogen	**45**	**50**	**70**	**40**	**10**	**15**	**20**
Total gross demand							
North America	1,065	1,015	1,020	950	725	935	1,105
Western Europe	2,150	2,080	1,890	1,690	1,305	1,270	1,245
Japan	870	840	865	830	670	645	650
China	2,370	2,215	1,870	1,840	2,045	2,460	1,900
RoW	1,375	1,445	1,680	1,660	1,245	1,445	1,690
Total	**7,830**	**7,600**	**7,325**	**6,970**	**5,990**	**6,755**	**6,590**

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

Platinum demand and recycling summary (continu

koz	2016	2017	2018	2019	2020	2021	2022
Recycling							
Autocatalyst							
North America	535	585	640	640	560	570	475
Western Europe	400	440	465	515	445	520	465
Japan	95	100	110	110	105	115	105
China	40	40	35	40	30	35	40
RoW	150	160	170	190	170	185	190
Total	**1,210**	**1,325**	**1,420**	**1,495**	**1,310**	**1,425**	**1,280**
Jewellery							
North America	5	5	5	5	5	5	5
Western Europe	5	5	5	5	5	5	5
Japan	150	160	145	140	110	115	105
China	460	385	340	340	285	265	125
RoW	5	5	5	10	10	10	10
Total	**625**	**560**	**505**	**500**	**410**	**400**	**250**
WEEE	**25**	**30**	**30**	**30**	**30**	**45**	**40**
Total recycling							
North America	545	600	650	650	575	580	490
Western Europe	410	450	480	530	455	535	480
Japan	245	265	260	255	215	235	215
China	500	425	380	385	320	305	170
RoW	165	175	185	205	190	210	210
Total	**1,860**	**1,915**	**1,955**	**2,025**	**1,755**	**1,865**	**1,570**

Source: SFA (Oxford)

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Rhodium supply-demand balance

2023	2024f	koz	2016	2017	2018	2019	2020	2021	2022	2023	2024f
		Primary supply									
		Regional									
370	370	South Africa	615	620	625	640	475	670	595	585	570
385	385	Russia	70	75	75	80	80	75	75	75	70
110	110	Zimbabwe	45	45	40	40	45	40	45	45	45
30	35	North America	25	25	20	20	20	20	15	20	15
185	205	Other	10	10	10	10	10	5	5	5	5
1,080	**1,100**	**Total**	**765**	**775**	**770**	**790**	**630**	**815**	**735**	**725**	**705**
		Demand & recycling									
5	5	**Autocatalyst**									
5	5	Gross demand	835	865	915	1,020	935	925	910	945	920
105	110	Recycling	280	305	335	350	325	360	325	275	275
120	150	Net demand	555	565	580	670	610	570	585	670	645
10	10	**Industrial demand**	**180**	**155**	**210**	**170**	**135**	**75**	**-5**	**45**	**110**
245	**280**	**Other recycling**	**2**	**2**	**2**	**2**	**2**	**3**	**3**	**2**	**3**
40	**45**	**Gross demand**	**1,015**	**1,025**	**1,125**	**1,195**	**1,070**	**1,005**	**905**	**995**	**1,030**
		Recycling	**280**	**305**	**340**	**355**	**330**	**360**	**330**	**275**	**280**
385	385	**Net demand**	**735**	**720**	**790**	**840**	**745**	**640**	**580**	**715**	**750**
400	400										
215	225	**Market balance**									
160	195	Balance (before ETFs)	30	55	-15	-50	-115	175	155	10	-45
205	225	ETFs (stock allocation)	5	-20	-50	-15	-10	-5	0	0	
1,365	**1,425**	**Balance after ETFs**	**25**	**75**	**30**	**-35**	**-105**	**180**	**155**	**10**	

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	210	220
Western Europe	210	215	230	290	225	210	205	225	200
Japan	125	125	130	130	110	100	100	105	100
China	125	150	155	205	275	235	185	170	170
India	20	20	25	25	20	25	35	30	35
RoW	115	130	150	155	125	160	185	200	200
Total	**835**	**865**	**915**	**1,020**	**935**	**925**	**910**	**945**	**920**
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	-45	50
RoW	45	40	70	55	30	15	0	55	20
Total	**180**	**155**	**210**	**170**	**135**	**75**	**-5**	**45**	**110**
Total gross demand									
North America	255	245	245	240	190	205	220	230	235
Western Europe	225	225	245	300	235	220	205	230	210
Japan	135	135	140	140	120	110	110	115	110
China	220	225	250	280	345	265	155	130	220
RoW	180	190	250	230	180	205	215	285	255
Total	**1,015**	**1,025**	**1,125**	**1,195**	**1,070**	**1,005**	**905**	**995**	**1,030**
Recycling									
Autocatalyst									
North America	160	165	180	185	175	190	165	130	130
Western Europe	50	55	60	65	60	70	65	50	50
Japan	35	35	45	45	40	45	40	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**	**350**	**325**	**360**	**325**	**275**	**275**

Source: SFA (Oxford)

GLOSSARY OF TERMS

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

BEV
Battery electric vehicle.

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.

PEM electrolyser
Electrolysis technology using a proton-exchange membrane.

PGMs
Platinum-group metals.

PHEV
Plug-in hybrid electric vehicle.

Primary supply
Mine production.

SIB
Stay-in-business costs. Overheads not including the cost of goods sold.

Secondary supply
Recycling output.

Thrifting
Using less metal in order to reduce costs.

TOCOM
Tokyo Commodity Exchange.

UG2 Reef
Found in South Africa, this chromite-rich layer of rock contains fewer by-products than the Merensky Reef.

WEEE
Waste electrical and electronic equipment.

4E
Platinum, palladium, rhodium and gold.

Currency symbols:

$	US dollar.
ZAR	South African rand.

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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ABOUT HERAEUS

Heraeus Precious Metals Trading Desks

Europe, Middle East, Africa & other regions
Phone: +49 6181 35 2750
tradinghu@heraeus.com

South East Asia
Phone: +852 2773 1733
tradinghk@heraeus.com

USA
Phone: +1 212 752 2180
tradingny@heraeus.com

China
Phone: +86 21 3357 5658
tradingsh@heraeus.com

The Heraeus Group is a broadly diversified and globally leading family-owned technology company, headquartered in Hanau, Germany. The company's roots go back to a family pharmacy started in 1660. Today, Heraeus bundles diverse activities in the Business Platforms Metals and Recycling, Health, Semiconductor and Electronics as well as Industrials. Customers benefit from innovative technologies and solutions based on broad materials expertise and technological leadership.

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Heraeus Precious Metals GmbH & Co. KG
Heraeusstrasse 12–14
63450 Hanau, Germany
www.heraeus-precious-metals.com

SFA (Oxford) Ltd
United Kingdom
Phone +44 1865 784366
www.sfa-oxford.com
The Oxford Science Park,
Oxford, United Kingdom, OX4 4GA