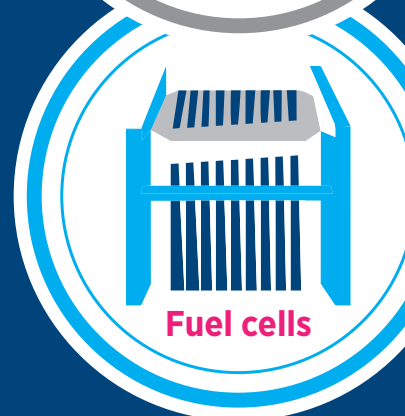
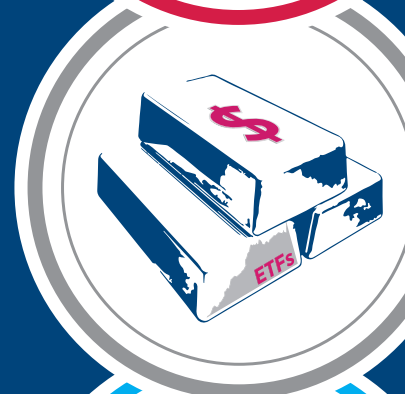
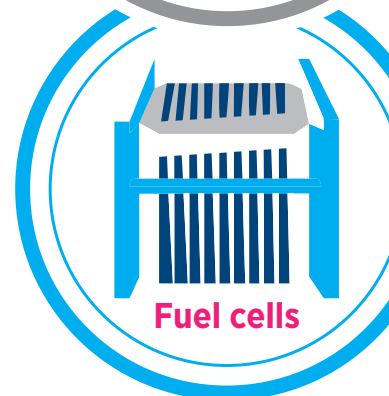


# THE PLATINUM STANDARD

May 2019





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May 2019

Issue 10

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# TPS COLLECTION: AGENDA-SETTING COMMENTARY



*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 years ahead*



*If you are interested in reading the collection, you can now download the editions via our new website*



**FOREWORD**



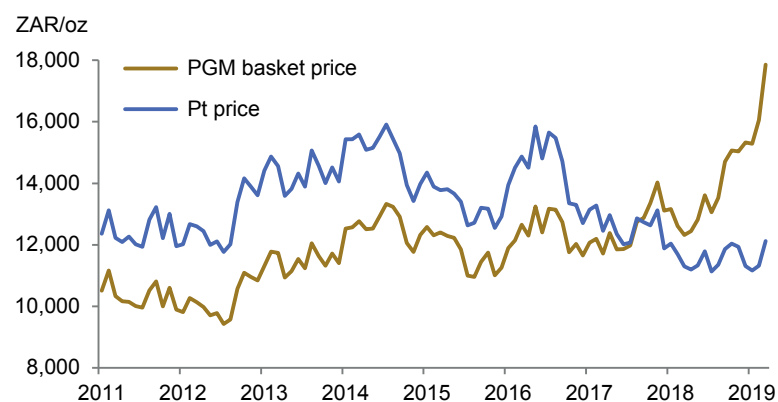
## Foreword

### Adopting platinum for the future

In 2019, a conjunction of platinum mine supply sustained by high by-product prices and a continuing decline in jewellery and auto demand is keeping the platinum market in surplus. Strong ETF investment demand has not been sufficient to fully absorb it. There is no immediate prospect of a demand change that will shift the platinum market into deficit.

Samantha Trickey looks at the evolution of platinum production and the rise of PGM miners. Platinum mines produce a mix of metals and, even with a depressed platinum price, high prices for the other metals in the basket are helping to incentivise new production and keep existing mines open for longer. Historically, rhodium's price volatility has been responsible for driving platinum production: firstly by encouraging the start-up of UG2 mines as the rhodium price rose to \$10,000/oz and secondly by forcing closures in the subsequent slump. With the price back at around \$3,000/oz it is starting to exert a modest influence again.

#### South Africa's PGM basket disassociated from platinum



Source: SFA (Oxford)

However, with the palladium price reaching record highs it is now the metal driving plans for production expansion and development of palladium-rich projects. While these new sources of palladium are necessary to provide metal in a market with a structural deficit, they will also add platinum to a market that may not need it. An additional 1.4 moz of platinum supply is plausible over the next decade, compared to 1.8 moz for palladium.

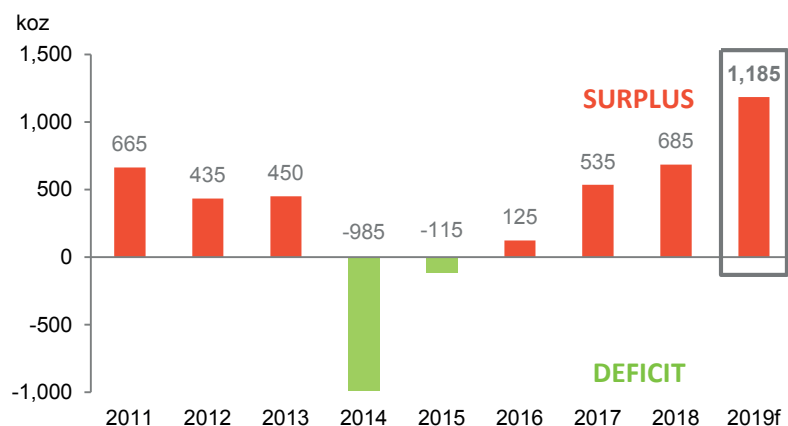
## The Platinum Standard

Upstream players should not get too comfortable with such a high basket price. At some point the palladium and rhodium prices will come down and then marginal output will be underwater again. Isn't this an opportunity to hedge what was considered a by-product (palladium) and become platinum miners again? Banks may insist upon it if they are to provide funds for project CAPEX.

If the palladium price holds up then the additional platinum supply will constrain any price recovery, so with ample supply and a subdued price it really is time for adoption.

Near term the outlook for demand is challenging, to say the least. SFA expects the platinum market to be in a record surplus this year (before investment), as demand is tailing off while supply holds up. Platinum's two main end-use segments, diesel autocatalysts and jewellery, continue to be weak. The ongoing shift away from diesel cars has cut 400 koz from annual demand since 2015. While the low platinum price has supported jewellery demand in some regions, in its largest market of China platinum jewellery demand is still declining and could soon shrink to half of its 2 moz peak, leaving global jewellery demand down over 700 koz since 2014.

### Platinum industrial market balance



Source: SFA (Oxford). NB: Industrial market balance excludes investment.

So it is most fortunate that ETF investment has just had a record quarter with almost 700 koz of platinum being bought by investors. Platinum was historically cheap compared to palladium and gold in the first quarter, but was there more to it than bargain hunting? ETF holdings have held up remarkably well despite the platinum price's poor performance over the last few years, and the purchases in the first quarter took global holdings to over 3 moz for the first time. Do the new investors have a similarly long-term view? Dr Ralph Grimble examines the reasons ETF investors may have had for purchasing such a large amount of metal and what the future trends in investment might be.

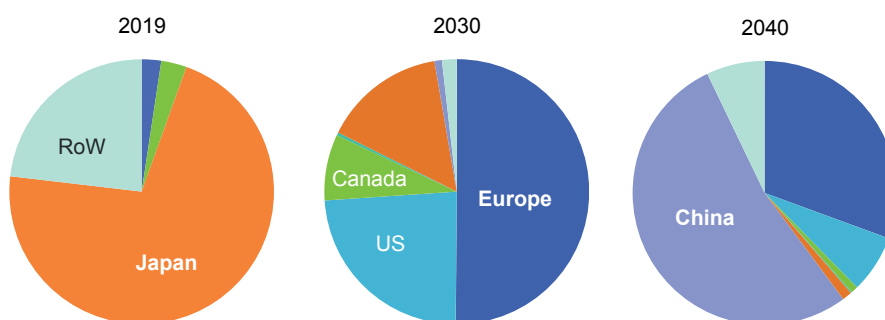


## The Platinum Standard

Is the platinum-catalysed fuel cell on the cusp of delivering high demand for platinum? Climate change concern can provide the opportunity. Dr Jenny Watts examines the current prospects.

Fuel cell light-duty vehicles will no doubt become part of the increasingly diverse powertrain mix. But new opportunities are also out there – trains, planes, boats – and making the fuel cell a major part of the fuel production process. With a tough regulatory market and political motivation coexisting, global warming can be tackled and air quality improved. Decarbonisation of our energy and transport is gaining momentum and a wave of national and regional governments have declared a ‘climate emergency’ and are adjusting policies in response.

### FCEV passenger car production\*



Source: SFA (Oxford), LMC Automotive. NB: \*US includes light commercial vehicles.

Heavy-duty vehicles can lead near-term growth more than light-duty, as fuel cells compete very favourably with plug-in battery electric powertrains, because the incremental mass increase to obtain greater range is far lower with a fuel cell than with a battery. Fuel cells complement other powertrain technologies; it is a case of matching the right powertrain to the right application in the right geography.

Electricity from renewable energy can be used in a fuel cell to electrolyse water to make ‘green’ hydrogen, providing solutions to industrial users as well as for transport fuel.

Fuel cell technology is competing in commercial applications. New company alliances are forming and automakers are partnering with hydrogen producers to ensure fuel is available.

This long-term future market for platinum (and other PGMs) is going to be driven as much by political, legislative, environmental and human factors, as it is by the more familiar technical and financial factors. Fuel cells could well be part of the future for platinum, but right now platinum used in fuel cells amounts to a few tens of thousands of ounces. It is anticipated that it will take until the 2030s for fuel cells to make a significant contribution to platinum demand.

**REVENUE SPLITS OVER TIME:  
THE RISE OF THE PGM MINERS**



# Revenue splits over time: the rise of the PGM miners

Samantha Trickey, SFA (Oxford) Ltd

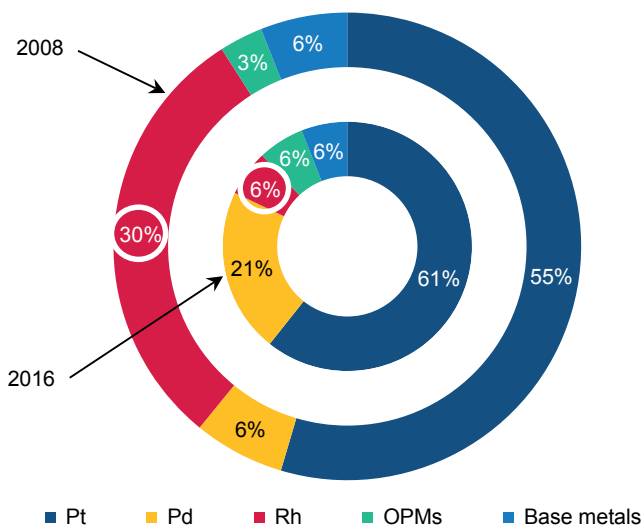
## Rhodium has shaped the Bushveld we know today

Low revenue from rhodium has been responsible for the most mine closures across the Bushveld, and put paid to extensive development plans on the Eastern Bushveld. Since 2008, shaft closures have cut out over 1.3 moz of platinum capacity, 0.7 moz of palladium capacity and almost 0.2 moz of rhodium capacity in South Africa. Predominantly UG2 operations were affected because these are rhodium-rich, but are typically poorer in PGM by-products such as nickel and copper. Indicative capacity for the range of mothballed projects on the Eastern Bushveld collectively totals between 2.1 and 2.2 moz 4E PGMs. Again, these are mainly UG2 projects, with a couple of mixed reef assets.

Over 80% of global primary rhodium supply is mined in South Africa. At peak rhodium price (2008), the metal accounted for 30% of producer revenues on average, generating \$870 per platinum ounce produced. For pure UG2 producers, rhodium accounted for 36% of revenues, compared to 16% for a pure Merensky producer and 13% for a Platreef miner. At its lowest (2016), rhodium contributed just 6% of total revenues on average, or just \$97 per platinum ounce produced. For UG2 producers, that meant rhodium generated 8% of revenues and only 2-4% for Merensky and Platreef miners.

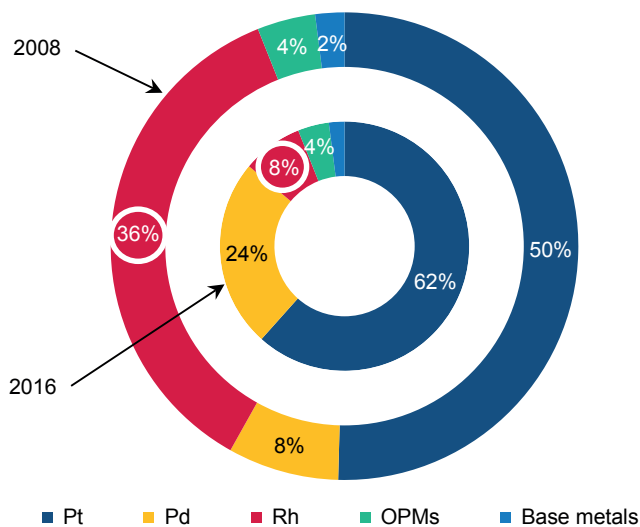
*Rhodium's revenue contribution for UG2 mines fell from 36% in 2008 to 8% in 2016*

### Revenues by metal (South Africa)



Source: SFA (Oxford)

Revenues by metal (UG2 Reef)



Source: SFA (Oxford)

The rhodium price resurgence has started, creeping up from less than \$700/oz in 2016 to average over \$2,200/oz in 2018 and over \$3,000/oz today. This trend is expected to continue, building towards \$6,000/oz over the next 5-6 years. As the platinum price has tumbled to a 13-year low, rhodium's contribution in the revenue basket has recovered to an average of 15% for South African miners, and up to 21% for pure UG2 producers. The rhodium price is currently trading at 30% of peak levels.

*Rhodium's revenue contribution has recovered back to 21% for UG2 mines, at the expense of platinum*

Already, we are seeing end-of-life shafts remaining open for longer, and trial mining planned for a mothballed UG2 mine on the Western Bushveld this year. Acceleration of technical work on early-stage projects on the Eastern Bushveld is plausible in the near term.

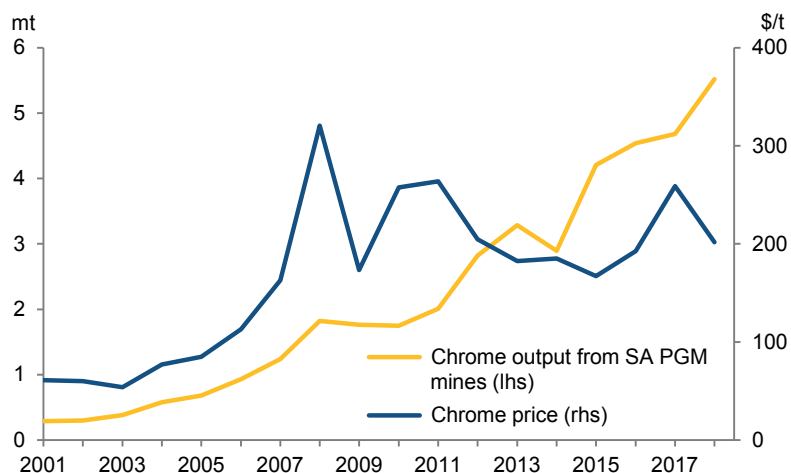
Chrome is a lifeline for those that recover it

The UG2 Reef comprises thin seams of chromitite, and platinum mines on the Bushveld report Cr<sub>2</sub>O<sub>3</sub> grades in the 15-35% range. Eleven PGM mines currently recover chrome, and have done so since 2016, compared to six mines in 2010 and three mines in 2004. Chrome ore production has grown from 580 kt in 2004 to 5,520 kt in 2018. More than half of that growth has occurred since 2014 when the platinum price accelerated its fall.

*Chrome ore production by PGM miners has grown almost 10-fold since 2004*

There was an average year-on-year reduction in the platinum price of 7% p.a. between 2012 and 2014, followed by an average 10% p.a. reduction between 2015 and 2018. At the same time, producer costs have risen by an average of 10% p.a. since 2012 on a total cash cost per tonne milled basis, and by 11% p.a. on a total cash cost per 4E PGM oz basis (excluding by-product credits).

Chrome ore prices vs. production



Source: SFA (Oxford)

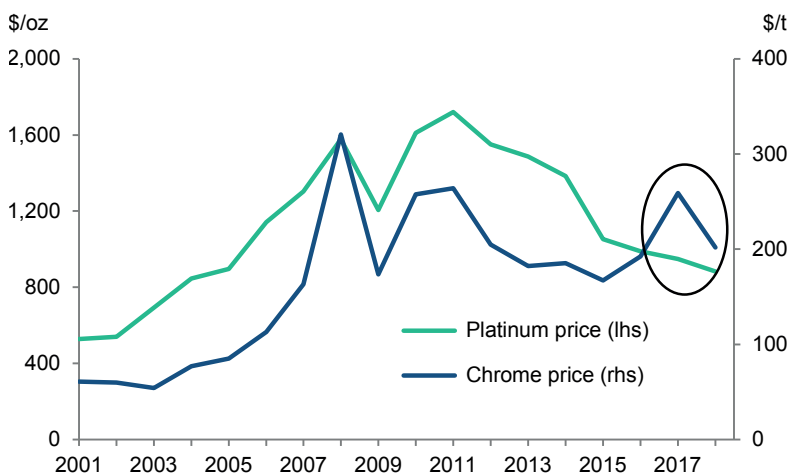
Interestingly, the chrome price followed a similar pattern of peaks and troughs as the platinum price throughout the 2000s and early 2010s. This symmetry deviated in 2016 and 2017 though, with the chrome ore price increasing by \$92/t (+55%), while the platinum price continued its downward trend of the past five years.

Not all South African PGM producers recover chrome. For those that do, attributable revenues from chrome increased by 74% (ZAR2,240 m) collectively between 2016 and 2018. This additional revenue lifted margins (after cash costs, before capital expenditure) by an average of 6 percentage points in these years.

*An additional ZAR2.2 bn generated from chrome revenues since 2016*

For three producers, chrome revenues allowed them to turn loss-making operations – with combined annual platinum production of 1.2 moz – into break-even and profitable ones.

Platinum vs. chrome ore prices

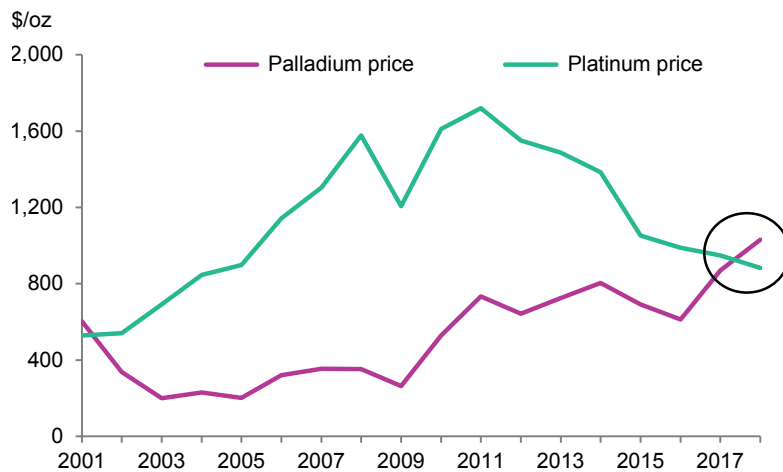


Source: SFA (Oxford)

## Palladium: the new rhodium?

Palladium reached price parity with platinum in September 2017, and has gone on to trade at a premium since. This price movement is primarily benefitting palladium-dominant producers – Lac des Iles, Nornickel, Mogalakwena and Marula. Broadly speaking, the Pt:Pd ratio increases from north (Pt0.97:Pd1 at Marula) to south (Pt2.1:Pd1 at Booyendal) on the Eastern Bushveld. However, all of these UG2-dominant operations are benefitting from higher rhodium prices.

### Platinum vs. palladium prices



Source: SFA (Oxford), Bloomberg

*Palladium has traded at a premium to platinum since September 2017*

Western Bushveld operations have the highest Pt:Pd ratios – as high as Pt2.3:Pd1 on the central part of the limb, where operations are Merensky-dominant (70-90% of total output). This means that rhodium’s proportion of 4E PGM output is limited to just 5-6%. The central part of the Western Bushveld is therefore the region most disadvantaged by relative PGM price movements over the past 12 months or so. This has slowed brownfield and greenfield project development in the region, with one project downsizing considerably (Bakubung).

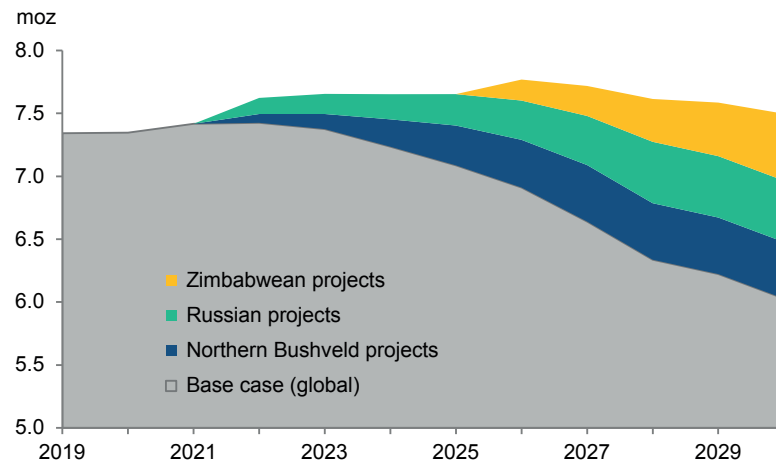
Elsewhere, the rising palladium price has allowed a life-of-mine extension at Lac des Iles, and is incentivising expansions by Nornickel and possibly at Mogalakwena. Nornickel approved development of the Southern Cluster in March 2019, which could reach steady-state ore production of 9 mt p.a. (600-650 koz p.a. PGMs) by 2027. Anglo American Platinum has optimised the mine plan for Mogalakwena, which now supports long-term output of 1.1-1.2 moz PGMs, and studies are underway for an expansion which could potentially lift total annual output towards 1.7-1.8 moz PGMs.

## The Platinum Standard

Including projects on the Northern Bushveld – the Platreef Project (construction stage) and Waterberg (feasibility stage) – collective annual supply from these palladium-dominant projects could total almost 760 koz Pt, 1.3 moz Pd and 2.2 moz 4E PGMs.

Very early-stage and ambitious plans for Zimbabwe could see an additional 1.4 moz PGMs within a decade, shown in the following charts.

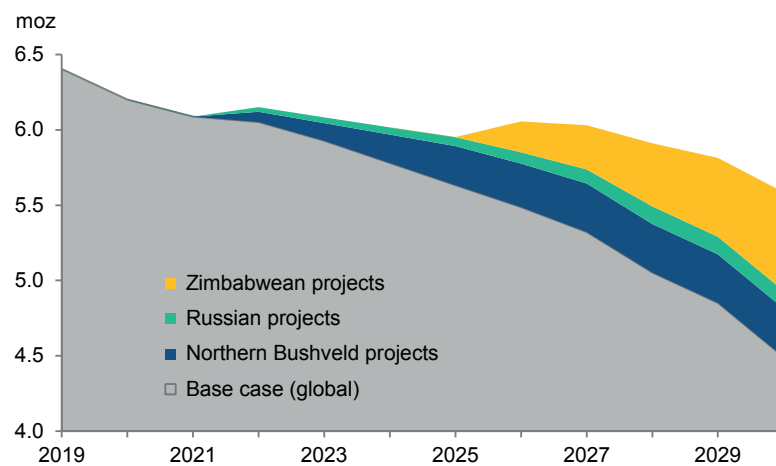
### Palladium production



Source: SFA (Oxford), Bloomberg

*Palladium-dominant projects could produce up to 1.8 moz of palladium by 2030*

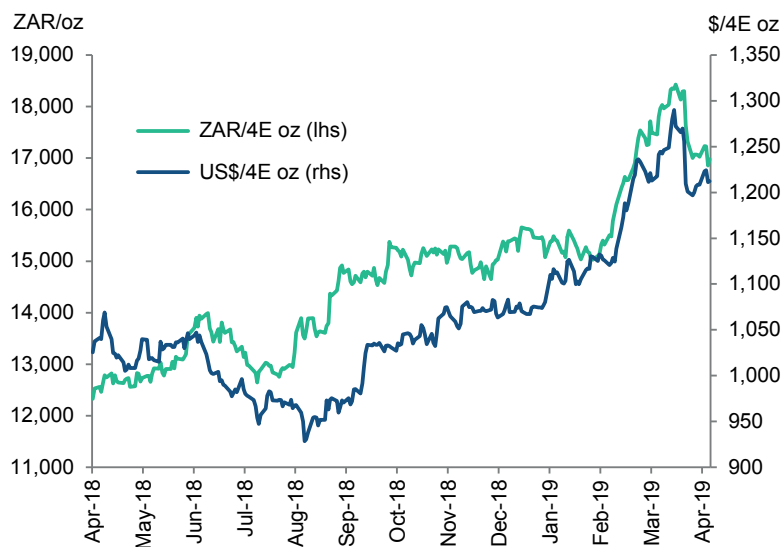
### Platinum production



Source: SFA (Oxford), Bloomberg

*Palladium cannot be produced in isolation; an associated 1.4 moz of platinum would stifle any platinum price recovery*

South African 4E basket prices



Source: SFA (Oxford), Bloomberg

Rhodium has been the key factor in shaping the Bushveld we know today. The boom of 2005-08 saw five UG2 mines commissioned, with two more UG2 operations just missing the boat by starting up in 2009. The bust of 2008-09 and further rhodium price deterioration in 2012-13 removed 1.3 moz of platinum production capacity altogether. With rhodium prices now over \$3,000/oz, we are starting to see small green shoots re-emerging for UG2 supply, but it is palladium that very much has centre stage.

The rising palladium price – arguably now the most important factor in shaping PGM supply over the next decade – mostly benefits the lowest-cost PGM producers. The palladium price is incentivising expansions and greenfield projects in palladium-rich regions. This will ultimately put increased pressure on platinum-rich mines in the upper part of the cost curve – from the expansion of low-cost supply, yes, but these projects are also not insignificant for their platinum content. An additional 1.4 moz of platinum supply is plausible over the next decade, versus 1.8 moz for palladium. The global Pt:Pd ratio of supply may only change from Pt0.9:Pd1 today to Pt0.7:Pd1 by 2030.

*Palladium's price movements mainly benefit the lowest-cost producers*

Not only will this additional supply hinder a platinum price recovery, but also there will come a point when the palladium price will be moderated, which could expose a large amount of platinum-rich supply to hefty losses. It is critical that these high-risk producers do not become complacent with the improved basket price of today – they must continue to optimise their operations as far as possible. Rand depreciation – from an average ZAR14:\$1 in 2019 to over ZAR18:\$1 by 2030 (forecast by Oxford Economics) – will also fuel producer cost inflation in the long run, and mining companies must be cognisant of this in their shaft scheduling.



**WHY ARE INVESTORS  
TAKING A PUNT ON  
PLATINUM?**



# Why are investors taking a punt on platinum?

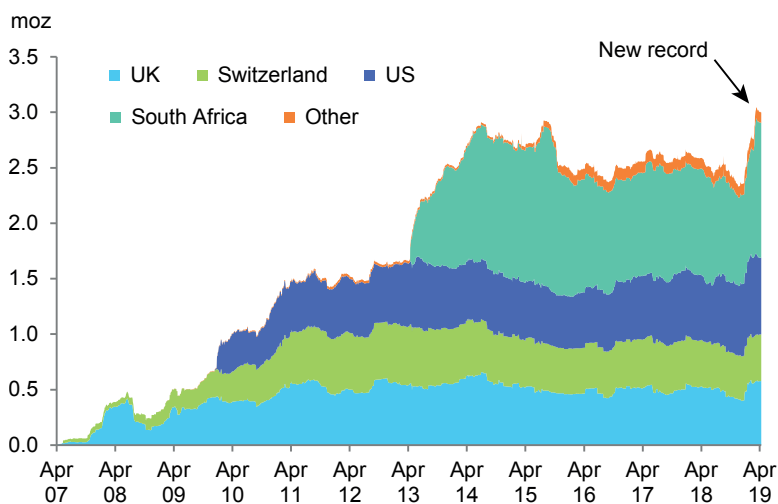
Dr Ralph Grimble, SFA (Oxford) Ltd

## Platinum ETF holdings rocket in Q1'19

Platinum ETF investment has rebounded in a big way in 2019. Globally, platinum ETFs had the largest quarterly inflow ever seen in the first quarter of the year, increasing by 690 koz. This reversed the trend of 2018, when global ETF holdings fell by 247 koz, and took the global total to a new record of over 3.0 moz. Most of the investor interest came from South Africa where ETFs gained 418 koz. The UK was the next largest source of purchases, with investors adding 178 koz to their holdings, while US investors bought 79 koz.

*Q1'19 saw 690 koz of investment in platinum ETFs – the largest quarter ever*

### ETF holdings



Source: SFA (Oxford), Bloomberg

*Global platinum ETF holdings reached 3 moz in March*

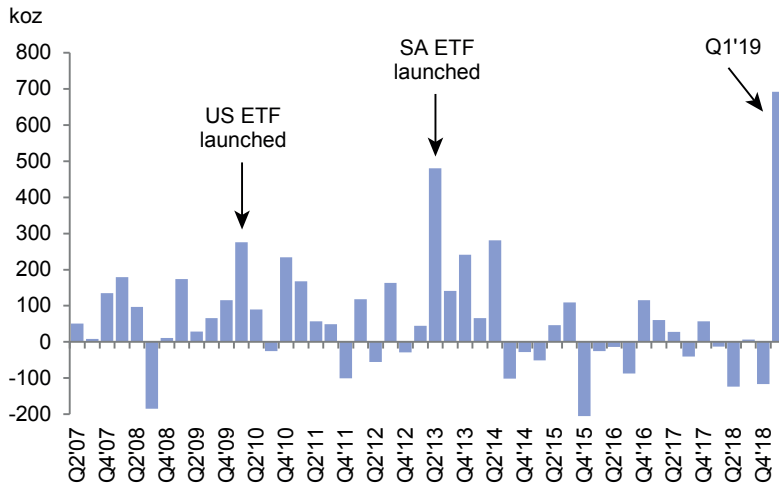
Until this year, the largest addition to platinum ETFs in a single quarter was 480 koz in the second quarter of 2013, which was when Absa launched the first platinum ETF in South Africa. Of that, 428 koz was added to the new South African ETF, with most of the balance being in the US. Prior to that, the biggest quarter was Q1'10 when the US ETF began trading. The US ETF gained 310 koz, but the overall quarterly total was 275 koz as there were sales from UK ETFs. The first platinum ETFs were launched in the UK and Switzerland in 2007. They had a slow start, gaining just over 25 koz each in their first three months of existence, although interest picked up later in the year.

## The Platinum Standard

The first quarter of this year saw the second-largest increase in platinum ETF holdings in US dollar terms at \$571 million, behind the \$709 million inflow in Q2'13 when the platinum price averaged \$1,467/oz, compared to \$822/oz in Q1'19. The third-largest gain in dollar terms was \$429 million in Q1'10 when the US ETF opened for business.

*\$571 million was invested in platinum ETFs in Q1'19*

### Quarterly change in platinum ETF holdings

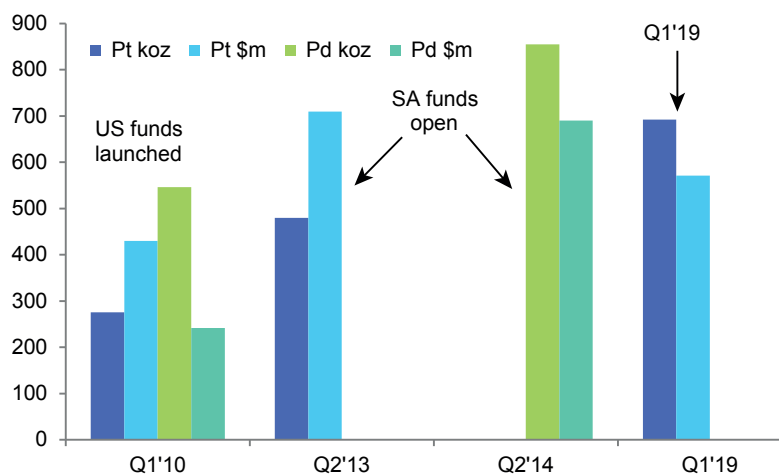


Source: SFA (Oxford), Bloomberg

The launches of palladium ETFs in the US and South Africa resulted in even larger inflows in ounce terms in their first quarter than for the equivalent platinum ETFs. In the US, the palladium ETF was launched at the same time as the platinum fund at the start of 2010 and it gained 546 koz in Q1'10, which represented \$242 million. Two South African palladium funds began trading in late March 2014 and during the second quarter grew by 838 koz combined, with global holdings going up by 855 koz or \$690 million.

*The largest amount invested in platinum ETFs in one quarter was \$709 million in Q2'13*

### Platinum and palladium ETF inflows



Source: SFA (Oxford), Bloomberg

*Palladium ETFs saw a larger increase in ounce terms in Q2'14 - 855 koz*

## The Platinum Standard

However, investing in PGMs is a niche area and the inflows pale in comparison to those of gold. In Q1'19, gold ETFs had a fairly average quarter with holdings increasing by 1.2 moz, which equates to \$1.5 billion, or roughly three times the amount that flowed into platinum ETFs. At the end of the quarter, total gold ETF holdings of 72.3 moz were worth \$93.5 billion compared to 3 moz and \$2.5 billion for platinum.

Such large fund additions suggest that institutional investors have been increasing their exposure to platinum. PIMCO publicly noted that platinum is cheap relative to other precious metals. In March, platinum was trading at the widest discounts to gold and palladium ever seen: -\$530/oz and -\$745/oz respectively. South African investors may be betting on a platinum price recovery, expecting platinum to catch up to the other PGMs whose strong performances have lifted the basket price to the highest level since 2008. There may also have been a rotation from mining equities, which performed very well in the second half of 2018, to platinum as it is perceived to be undervalued. The potential for local issues to disrupt supply may have been a factor. Wage negotiations are due to start later in the year at the three largest producers and these have been accompanied by strikes in the past. Also, Eskom has had problems with supplying sufficient electricity, and this was one of the factors that helped to push platinum up to \$2,000/oz in 2008.

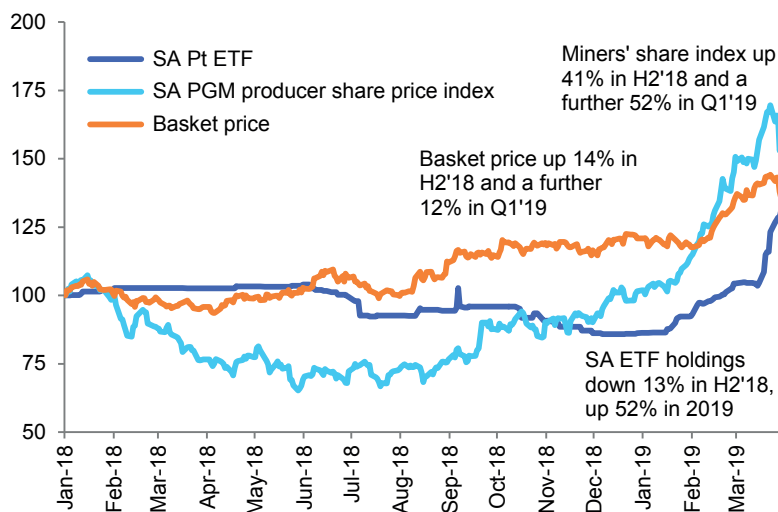
*What drove the investment?*

*Was it valuation? Platinum was very cheap compared to gold and palladium in Q1'19*

*Rotation from equities to ETFs?*

*South Africa specific issues?*

### Prices indexed from 1 January 2018



Source: SFA (Oxford), Bloomberg

The current situation is different to that in 2013 when the first South African ETF became available. In 2013, the miners' share prices had been falling and investing in the metal was seen as a way to hedge inflation and the rand while reducing equity and company-specific risk, as the industry was going through a period of strikes and labour unrest. In addition, South African investors were limited in how much they could invest overseas which had restricted their access to ETFs, so a domestic ETF allowed them to invest without a cap on the holding.

## The Platinum Standard

South African investors may think platinum could soon be substituted back into gasoline autocatalysts, replacing some palladium, which is what happened in 2001, the last time palladium traded at a premium to platinum. This is unlikely in the short term for a number of reasons. The relative costs of the two metals is only one consideration for automakers and is probably not even the main one. Security of supply is important. Palladium's supply is much more geographically diversified than platinum's, reducing reliance on South Africa.

*The rumoured substitution of platinum back into gasoline autocatalysts?*

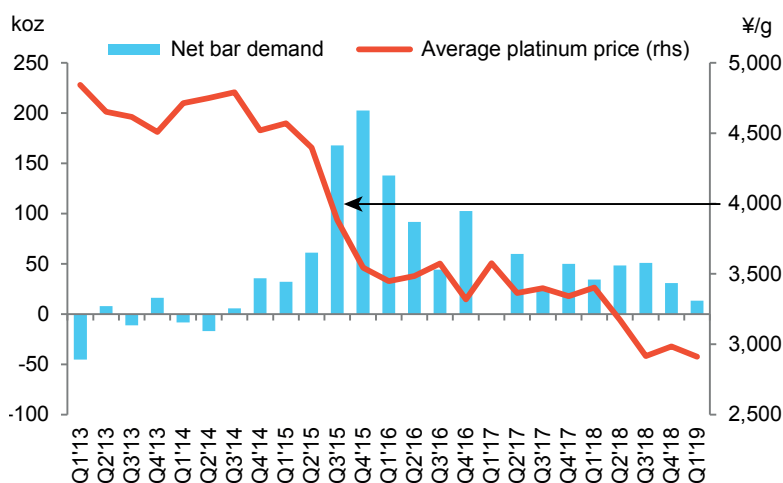
Developing new catalyst formulations takes time and money, and technological developments in gasoline engines mean substitution is significantly more challenging than in 2001. Auto manufacturers' R&D effort is being focused on developing electric vehicles and complying with tightening emissions legislation. Fleets have just become aligned with WLTP and RDE rules in Europe and there is no appetite to change catalyst formulations when missing CO<sub>2</sub> emissions targets could lead to large fines. However, the institutions' investment horizon could be up to five years, in which case it might be possible on that longer-term view for the substitution to happen.

In the US and UK most of the ETF purchases occurred in January and February when the price had fallen, making it appear as if the purchasers were taking advantage of the low price. However, in South Africa the buying accelerated through the quarter, climbing from 56 koz in January to 111 koz in February and to 250 koz in March. In fact, three-quarters of the buying occurred as the price was rising and coincided with the load-shedding caused by Eskom's electricity supply problems. Perhaps some investors were expecting the power disruptions to reduce mine output.

*US and UK investment looks as if it was driven by platinum's low price*

*South African purchases might have been more about local issues*

### Japanese bar investment



Source: SFA (Oxford), Bloomberg, Tanaka

## The Platinum Standard

In stark contrast to the rise in ETFs, bar purchases have tailed off. Japanese investors have been buying platinum bars for several decades and Japan remains by far the largest market for the bars. Accumulation plans allow regular investments and tend to be used for long-term investing, but Japanese investors also purchase bars directly and opportunistically. Platinum has historically been more expensive than gold, but the price falling below gold in early 2015 and then below ¥4,000/g in the second half of 2015 sparked a big jump in platinum bar purchases in Japan. However, Japanese investors seem to have become accustomed to the low platinum price because over the last couple of years investors' bar purchases have eased even though the price has continued to fall. In Q1'19, bar demand in Japan was the lowest since Q1'17 despite the price averaging less than ¥3,000/g.

*Japanese investors  
have reduced their bar  
purchases*

The platinum market is forecast by SFA to have a large surplus this year, which ETF investors have been doing their best to mop up. However, the fundamental outlook for the platinum market is one of continued surpluses over the next few years and therefore a subdued price, so the question is: will investors continue to buy platinum?

*The good news is  
platinum is cheap but...*

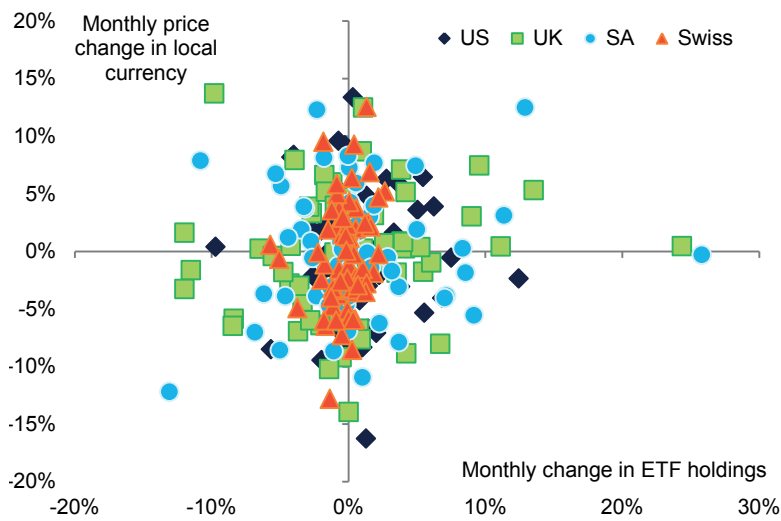
Overall ETF holdings have been remarkably sticky despite platinum's poor price performance over the last few years. Anyone buying the platinum ETF in South Africa in Q2'13 and holding on would currently be down between ZAR800/oz and ZAR1,300/oz. However, that is a better outcome than for anyone investing in dollars who would be down nearly \$600/oz over the same period.

The first quarter buying was a mostly South African affair and while the new investors globally bought 690 koz, that still leaves 2.3 moz of metal that other investors were already holding. Unfortunately, the trip above 3 moz was short-lived, with US investors selling 43 koz in April and overall ETF holdings slipping by 46 koz.

The relative value proposition seems to be the strongest reason for investors to buy or hold platinum. Unfortunately, Japanese investors have become accustomed to a low price and are no longer buying large quantities of bars. In addition, the non-commercial futures traders are showing little interest as they spent the first quarter reducing their long positions. It is also hard to see this burst of enthusiasm in South Africa being repeated since investors have now built up their positions. Whether they hold on will depend on their reasons for buying in the first place.

*...not everyone is  
buying – ETF holdings  
slipped back in April...*

Platinum ETFs vs. price, 2014-Q1'19

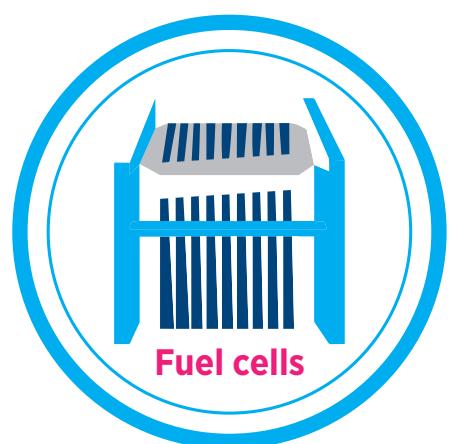


Source: SFA (Oxford), Bloomberg

There is no reliable correlation between ETF purchases and the platinum price so even if the way the price is going to move appears to be clear, that will not help with forecasting what will happen to ETF holdings. So the rally in platinum might prove to be short-lived, but overall platinum ETF holdings are unlikely to tumble as those in palladium ETFs have done.

*...and whatever happens to ETFs, platinum's price might not have a big part in it*

**PLATINUM, FUEL CELLS  
AND HYDROGEN: RACING  
TO AVERT A CLIMATE  
EMERGENCY**





# Platinum, fuel cells and hydrogen: racing to avert a climate emergency

*Dr Jenny Watts, SFA (Oxford) Ltd*

This time, it's for real – technology and politics combine to decarbonise our planet

After decades of thwarted hope, is the platinum fuel cell on the verge of delivering substantial demand for platinum? Increasing concern about climate change might just be about to provide the opportunity. SFA examines the current prospects.

We start on terra firma with light-duty vehicles, where fuel cells are set to be a growing part of the increasingly diverse powertrain mix over the next couple of decades.

But we also suggest that the market and the opportunities are far greater – it's not just about swapping platinum demand out of diesel cars and into fuel cell cars, but it's about putting platinum into places where it has barely been seen before – trains, planes, boats – and as a major part of the hydrogen fuel production process.

*Potential for new platinum demand*

These are applications subject to some of the strongest regulatory and political drivers ever seen as we strive to avert global warming and improve local air quality.

Renewable energy is elegantly and efficiently linked to fuel cells, as we cannot store or transport wind, but we can hydrogen, so electricity from renewable energy can be used in a fuel cell to electrolyse water to make 'green' hydrogen.

Companies in the fuel cell value chain are taking matters into their own hands by forming alliances to grow their markets; automakers are partnering with hydrogen producers to ensure fuel is available and with governments to ensure they are aligned with policy, legislation and incentives.

*Platinum forges a new destiny for itself in a decarbonised world*

This long-term future market for platinum (and other PGMs) is going to be driven as much by political, legislative, environmental and human factors, as it is by the more familiar technical and financial factors. Enjoy the ride, platinum!

## Fuel cell technology and hydrogen economy poised for growth

Demand for PGMs in the fuel cell industry, as a part of the hydrogen economy, will become significant in the long term only if fuel cell electric vehicles (FCEVs) win a sizeable share of light-duty vehicle production. Fuel cell-powered electric car production is currently approaching 10,000 per year, but is predicted to grow by orders of magnitude over the next two decades. While the PGM demand upside is clearly there, in vehicles and in the electrolyzers to produce hydrogen fuel, it is also several years away from being significant.

*Light-duty vehicles contribute to fuel cell demand in the longer term*

A constant in the recent history of fuel cells is the need for PGMs as catalysts in several of the most rapidly growing technologies. Initially, we will explore the potential market for one of the most visible uses for fuel cells – in passenger vehicles – and its implications for demand for the PGMs, mainly platinum and, to a smaller extent, ruthenium and iridium.

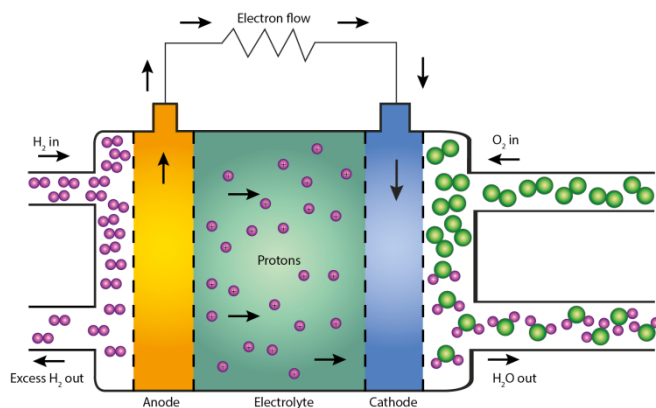
Several very different fuel cell technologies exist, each of which has advantages and disadvantages related to the materials required; each is suited to different end-uses and scales of operation.

## PEM fuel cells have the greatest relevance for PGMs

The fuel cell technology of principal interest to the PGM markets is the proton-exchange membrane fuel cell (PEMFC). It runs at relatively low temperatures (40-90°C) and reacts quickly to demand for power, so works well for both transport and stationary applications (with efficiencies of 60% and 35% respectively). PEMFCs contain platinum and platinum-ruthenium catalysts in their electrodes, and run on pure hydrogen and ambient oxygen.

*Several fuel cell variants, but the PGM-containing PEMFC is well-suited to making hydrogen and powering vehicles*

### PEMFC flow diagram



Source: SFA (Oxford)

## The Platinum Standard

Platinum and ruthenium are used in fuel cells for the same fundamental reasons as they are in the automotive and chemical industries – they are excellent catalysts that make chemical reactions take place at higher speed, at a lower temperature and at higher rates of conversion than would otherwise be the case, and they are robust under a fuel cell's harsh operating conditions.

*A new role for ruthenium too*

Fuel cell vehicles are really just an alternative type of electrified vehicle powertrain to battery-powered vehicles. Despite these two apparently disparate technologies often being pitted against each other, they share much of the core electrified componentry leading to economies of scale; the size of the battery is the key differentiator, with a much smaller battery in a fuel cell vehicle than in a full battery electric vehicle (BEV).

*No battle of the powertrains as fuel cells and battery electric vehicles each have their place*

## Outlook for light-duty FCEVs – the visible face of FCs

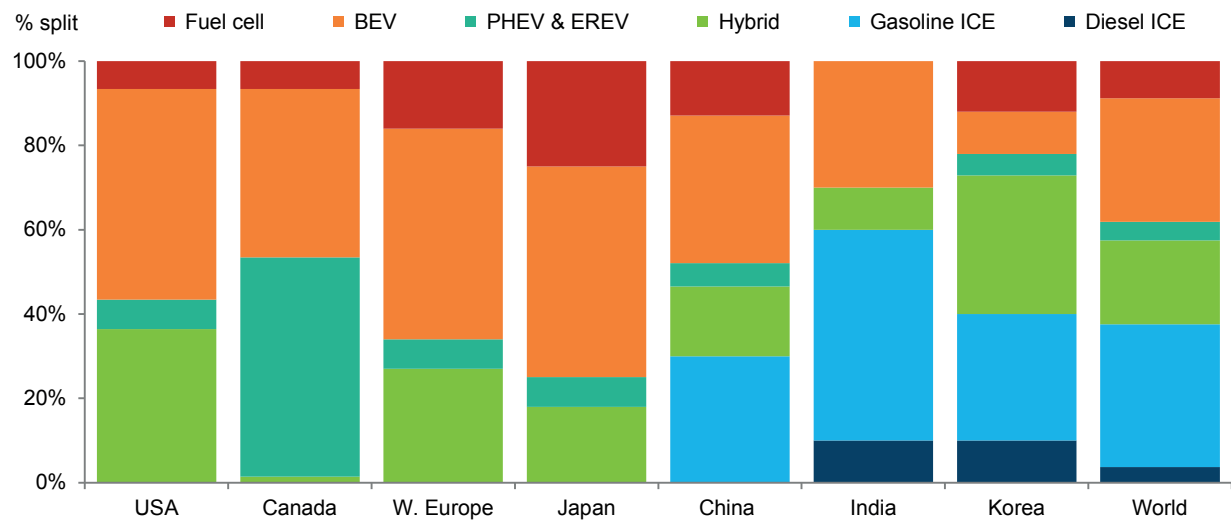
The rate of adoption of FCEVs into the light vehicle mix over the medium term will vary substantially by region, depending on prosperity, domestic automaker expertise, government policies, driving landscape (distances covered, urban/rural mix), fuelling infrastructure and energy availability. Infrastructure is key – it is vital that the green hydrogen economy develops at a sufficient pace to enable a fuel cell vehicle market to develop.

*Regional differences in the rate of adoption*

Japan, the technical pioneer of fuel cells, currently has the highest national FCEV market share. Market pioneers Toyota and Honda, coupled with a national priority to make green and safe energy available within a relatively prosperous, small and self-contained country, have put Japan at the forefront of the FCEV wave. Despite this, the lead times to develop the fuelling infrastructure and vehicle technology should not be underestimated; FCEVs are expected to break through to only 1% of light vehicle production in Japan by 2028.

*Japan leads the way*

Passenger car production: 2040



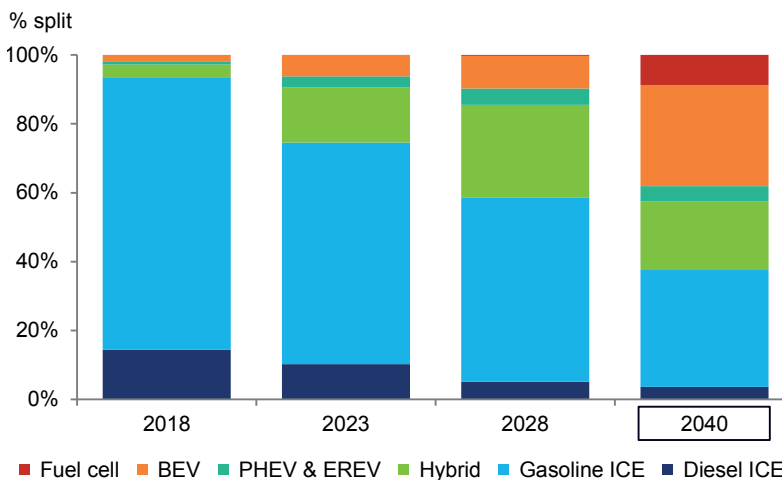
Source: SFA (Oxford), LMC Automotive

Western Europe, with legislated needs to cut all forms of emissions from transport, follows closely, with strengths in the development of fuelling infrastructure and in building collaborations throughout the technology chain. South Korea, with strength in vehicle technologies, is next.

*Western Europe is strongly legislatively driven*

North America and Western Europe are expected to take up FCEVs rapidly in the late 2020s to satisfy the ongoing need for long-distance personal mobility under stringent emissions legislative control. These two regions are estimated to make up three-quarters of production in 2030, but by 2040, China is forecast to account for almost half of the global market.

Global car production



Source: SFA (Oxford), LMC Automotive

## The Platinum Standard

China, however, leads the way by absolute FCEV demand thanks to subsidies and air-quality drivers. China is expected to emerge post-2035 and to dominate by 2040. Though a relative laggard in the rate of adoption of fuel cell and hydrogen technology, the sheer size of China's passenger vehicle market means that by 2040, China will produce almost twice the number of cars as Western Europe, more than three times as many as North America and five times the output of first-mover Japan.

*China leads the long-term potential*

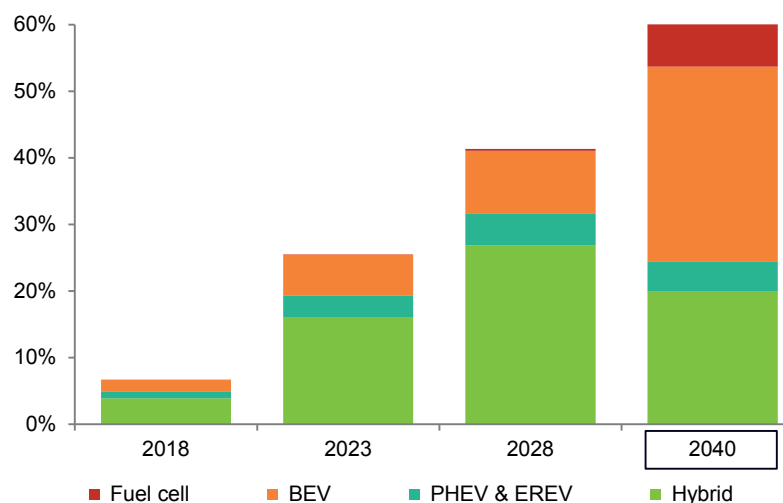
## Potential upside for PGM demand

Projections of platinum demand rely on assumptions about platinum loadings per vehicle. Fuel cell cars on the market today from Hyundai, Honda and Toyota have fuel cell stack power outputs ranging from 100 kW to 114 kW. The Toyota Mirai is reported to contain around 30 g of platinum, or 0.26 g per kW. The US Department of Energy (DOE) sponsors research into meeting long-term targets for fuel cell stack performance: its 2020 target for platinum loading is 0.125 g per kW for an 80 kW stack, a loading of 10 g per car.

*Platinum loadings will be thrifted as confidence in technology increases*

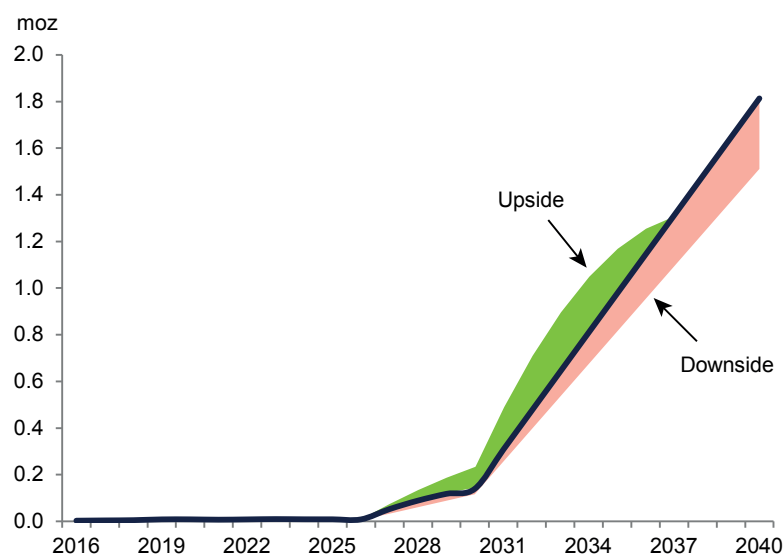
Our current central case assumes 30 g in 2017, reducing to 12 g by 2021 and to 6 g by 2030, with the latter number broadly equivalent to the platinum loadings on today's diesel passenger cars. On this basis, demand for platinum would grow to 140,000 oz in 2030 and reach **1.9 moz by 2040**.

### Passenger cars: FCEV platinum demand, 2018-2040



Source: SFA (Oxford). NB: Excludes ICE only.

### Platinum demand in fuel cell cars



Source: SFA (Oxford)

There would be supplementary demand for ruthenium, which is used to protect platinum catalysts from poisoning by trace carbon monoxide in the hydrogen fuel, and for iridium, used in combination with platinum in electrolyzers.

### Heavy-duty transport can benefit quickly from FCs

Fuel cells are already taking platinum on a journey into more modes of transport than it has previously experienced as an autocatalyst metal. The PEMFC has been adopted for fuel cell-powered passenger cars and forklift trucks, and is already in commercial use or testing as an alternative electric powertrain for buses, delivery trucks, trains and, excitingly, marine vessels and small aerial vehicles. The need for alternatives to internal combustion engines (diesel, gasoline) is driven by air-quality legislation and the shortcomings of alternatives – for example, electrification of railway lines is very costly; LNG has minimal CO<sub>2</sub> improvement in marine applications.

*Fuel cells can already make a difference for freight transport*

Fuel cells are proving to be a good fit for fleets of vehicles which operate on defined routes out of central depots, as this makes planning the refuelling with hydrogen easier. Fuel cells are a good alternative to diesel power in cities where air pollution is a public health concern: zero emissions at the point of use and a low carbon footprint when hydrogen has been generated from renewable energy are welcomed by city authorities, public transport operators, freight companies and consumers. Consequently, large orders have been placed for heavy-duty fuel cell vehicles by city transport operators (London, Beijing) and haulage contractors (for Budweiser) on the strength of their environmental credentials.

*Fuelling infrastructure for heavy-duty vehicles will be available to support emerging light-duty vehicles too*

## Horses for courses: fuel cells for larger vehicles and longer distances but battery electrics for smaller vehicles and shorter distances

For heavy-duty vehicles, fuel cells make great sense; to increase the range of a vehicle, it is simply a case of adding more hydrogen fuel storage tanks, at a far lower weight penalty than adding more batteries to a fully electric powertrain vehicle. For heavier, longer-range vehicles, the freight industry currently views fuel cell powertrains as lower cost and more suited to applications where a range beyond 350 km is required, while battery electric powertrains are more suited to shorter journeys.

*Matching the powertrain to the journey is vital for operators*

Hyundai (Korea) and H2 Energy (Switzerland) have identified fuel cell trucks as the route to grow the European hydrogen mobility ecosystem. Hyundai will supply 1,600 fuel cell-powered heavy-duty trucks to the new JV, Hyundai Hydrogen Mobility, between 2019 and 2025, some 600 more than initially announced in 2018. The vehicles will be made available to Swiss customers, initially from the Swiss H2 Association, which includes fuel station operators, retailers and others. Switzerland is a good place to begin, with a stringent road tax on diesel trucks incentivising fleet operators to switch to zero emission vehicles.



Source: Hyundai

## Collaborations are key

Those who have been in the PGM industry for some time will be familiar with the mantra that a sizeable fuel cell market, using PGM catalysts, is always 'just a few years away'. Why are we saying it's different this time? We see two key themes that are now in place, but were not there previously. Constructive collaborations and partnerships between companies throughout the supply chain, governments and research institutes bring the commitment, funds, knowledge and vested interest in a successful outcome. Renewable energy, too, has recently improved in efficiency and scale, often supported by state subsidies, to the extent that generated energy is sometimes wasted, but hydrogen is a very convenient storage medium.

Watching the fuel cell industry news announcements, it is very clear now that almost all involve at least two parties; this much deeper level of collaboration than previously seen certainly contributes to upping the pace of progress. At the apex, we have the Hydrogen Council, formed at the beginning of 2017 and grown to over 50 member companies across the value chain, several of whom are very familiar in the PGM industry. The coalition collectively represents total revenues of over €1.8 trillion and close to 3.8 million jobs around the world.

*The Hydrogen Council leads partnerships through the value chain*

One of the best examples of strategic progress made in collaboration was announced very recently, where a Japanese company is to partner with a Chinese university, which would have been unheard of previously. Toyota, one of the leading Japanese automakers in the global market, recently announced it will set up a research institute with Tsinghua University in Beijing, China. Toyota aims to share more technology in China to grow its business, expanding manufacturing capacity and enhancing distribution channels. Research at the Tsinghua-Toyota Joint Research Institute will aim to solve environmental problems in China, working on consumer cars and on the wider use of hydrogen energy. Toyota is already acting on its plans in the market with strong near-term prospects, announcing in April that it has begun supplying fuel cell vehicle components to Chinese commercial vehicle manufacturers Foton and SinoHytec.

*Toyota and Tsinghua University bring together the best of Japanese and Chinese skills*

The Chinese government has recently confirmed that it will fully support hydrogen fuel cell technology together with BEVs for the automotive future. The Ministry of Industry and Information Technology said, "Hydrogen fuel-cell vehicles in the future will co-exist and complement electric vehicles to jointly meeting the people's transportation needs. Both lithium battery powered electric vehicles and hydrogen fuel cell vehicles are important technical solutions for the new energy vehicle segment". The Chinese authorities recognise that the two technologies serve different markets; battery-powered electric vehicles are well suited to be passenger cars in urban areas, while hydrogen-powered vehicles are better suited as larger commercial vehicles required to cover greater distances.

*Chinese government signals long-term strategic support*



## How companies are managing the steady transition from an oil-based to a hydrogen-based economy

Efficiency gains in renewable energy generation fit very well into the fuel cell industry. Hydrogen, to use as a fuel and as an industrial chemical, can be produced through electrolysis – using electricity to split water into hydrogen and oxygen in an electrolyser, which is effectively a fuel cell operating in reverse. And, like a fuel cell, the electrolyser uses PGMs – in this case, platinum- and iridium-based electrodes to split the water. Coupling locally generated renewable energy (wind, solar) with electrolyser technology allows hydrogen to be used very effectively as a carrier to store excess energy produced from renewables which might otherwise be wasted if the electricity grid cannot take it, and which can later be converted by a fuel cell back into electrical power when required. Producing a practical fuel with minimal carbon content meets environmental legislation and avoids the cost and risks of trucking or piping fuel (such as oil derivatives) from centralised production facilities to customers.

Two of the leading companies in their sectors are collaborating to grow the hydrogen economy in Australia; Toyota has purchased a 0.25 MW rapid response PEM electrolyser from ITM Power. The electrolyser will use renewable energy to split water and generate hydrogen on-site at Toyota's facilities, for refuelling its fuel cell electric vehicles, including the Toyota Mirai passenger car. Government scientists suggest that Australia could cut global carbon emissions and create a profitable export business producing hydrogen as an energy source to replace fossil fuels for vehicles.

*Toyota and ITM Power unite vehicles and fuel supply*

Established companies in the automotive supply chain are also adapting seamlessly to serve the anticipated migration from internal combustion engines to fuel cell powertrains. The Bosch Group has been one of the leading suppliers of innovative components and systems into diesel and gasoline internal combustion engines over many decades. Indeed, the company continues to innovate to support diesel powertrains, with the announcement a year ago of technology which can substantially reduce NO<sub>x</sub> emissions, keeping diesel powertrains competitive for longer. However, Bosch (Germany) has just announced it will cooperate with PowerCell (Sweden) to co-develop PEM fuel cells that Bosch will then produce globally under licence for trucks and cars, launching in 2022 at the latest.

*Established automotive OEMs such as Bosch add fuel cell capability to combustion engine technology*

**THE PGM MARKETS  
IN 2018/19**



# The PGM markets in 2018/19

*Beresford Clarke, SFA (Oxford) Ltd*

## The platinum market

If investment is excluded and the platinum market is evaluated specifically on supply-demand fundamentals which can be measured and predicted with a level of confidence, then it is a market that can be interpreted as heading for a heavy oversupply in 2019 (by an estimated 1,185 koz).

Nonetheless, much of the additional supply is finding a home. Record increases in ETF holdings of 690 koz in Q1'19 have helped to absorb the excess supply. Furthermore, 2019 is unusual because of the one-off excess concentrate stock built up from smelter outages and new builds in 2018, which is likely to be processed in 2019. Beyond 2019 the market should start to normalise.

The net result of greater mine supply and recycling against steadily shrinking automotive and jewellery demand left the industrial market with an excess of 700 koz in 2018, while investment managed a 15 koz increase, limiting the absorption of excess inventory. Industrial demand (mainly petroleum and glass) performed exceptionally well, rising 12% to 1,905 koz.

### Mine supply

Despite relatively low platinum prices through 2018 at an average of \$879/oz (down 7.3% on 2017, while the rand price dropped 8.3%), primary supply increased by 2% year-on-year in South Africa to 4,460 koz. On a global basis, however, supply dropped 1% to 6,115 koz as production fell by 5% (-90 koz) in countries outside South Africa. The drop was mainly attributable to Russia where depletion of alluvial sources was recorded, and there was a small pipeline lock-up at Norilsk.

In South Africa, low metal prices concentrated the efforts of producers to optimise their operations. The year 2018 can be characterised by a major step-up in efficiencies and improved safety, which meant more ounces produced per employee and far fewer stoppages from mine accidents. Regrettably, 10 platinum employees lost their lives in 2018 and while any loss of life is a major setback for the industry, the number of lives lost was down by more than half of the levels recorded in 2017 and 2016.

A combination of improved operating performances and increased concentrator recoveries led to record production at Mogalakwena

*A 1 moz industrial surplus in prospect in 2019...*

*...mostly absorbed by ETF buying*

*South African mining companies significantly improved efficiencies and safety*

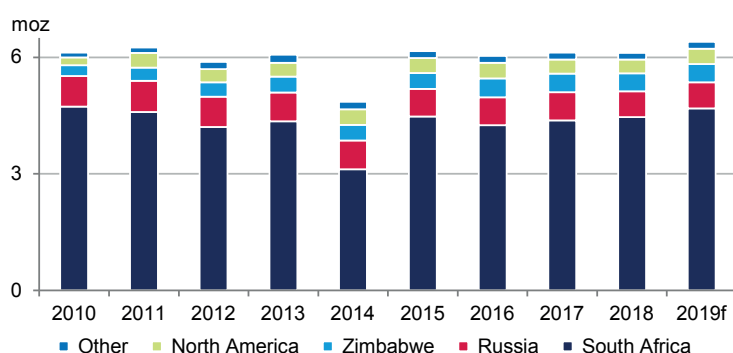
## The Platinum Standard

and Kroondal, while the ongoing ramp-up to steady-state production at the Impala Lease Area 16 and 20 shafts and Styldrift 1 helped to lift supply.

Notably, while mine production rose, there was a considerable amount of concentrate that built up over the year, leading to an increase in 'work-in-progress' inventory which is more than likely going to add to 2019 refined production. A combination of planned and unplanned smelter shutdowns and the construction of a new smelter was the cause. South African supply is forecast to be temporarily boosted by 5% to 4,685 koz in 2019, while growth in all other regions should help to lift global supply by 5% to 6,400 koz.

*Excess work-in-progress stocks likely to boost 2019 supply*

### Primary platinum supply



Source: SFA (Oxford)

### Recycling

Higher palladium and rhodium prices have incentivised the flow of scrap catalytic converters, leading to a boost in PGM volumes worldwide.

However, the recycling of diesel catalysts has become increasingly challenging owing to the complication of diesel particulate filters (DPFs) (legislated from Euro 5 in 2009, and introduced from 2006) entering the recycling stream and being mixed with diesel oxidation catalysts (DOCs), which have different substrate materials. Smelters were built to accept ceramic cordierite which is employed in gasoline three-way catalysts and DOCs, but DPFs tend to have a silicon carbide substrate and high carbon material is very difficult to treat if mixed with other catalysts.

*Despite rising platinum recycling volumes, DPFs are leading to significant challenges*

Despite the hold-ups and supply chain challenges in Europe related to new sorting procedures for end-of-life catalytic converters according to substrate material, the amount of platinum recovered globally in 2018 was up by 7% to 1,420 koz. Nonetheless, the majority of the increase in platinum recovered from autocatalysts was from North America, where a 9% rise in volumes was recorded, while in Europe recycling grew by 6%.

## The Platinum Standard

Platinum recycling is forecast to increase by 5% in 2019 to 1,495 koz, but the challenges highlighted above as well as restricted furnace availability to recycle DPFs may lead to bottlenecks and material delays.

### Demand

Demand on an industrial basis (including jewellery, but excluding investment) continued to fall in 2018, down 1.5% to 7,365 koz, but the level of decline has more than halved compared to the drops witnessed over the last two years. Nonetheless, it was a mixed bag of a year as declines in the automotive and jewellery sectors accelerated to -6.5% and -4.5% year-on-year respectively, while industrial demand staged a strong recovery, rising 12.1%. Investment could not fully compensate, with growth of just 15 koz for 2018.

*What was once an 8 moz industrial market is increasingly heading towards 7 moz*

The outlook for 2019 shows a further decline of 2.1% in demand to 7,210 koz, as industrial demand remains flat, but at elevated levels, while automotive demand drops 3.1% and jewellery falls by 1.9%. ETF investment, however, has made the strongest start to any year, with growth of 690 koz recorded in Q1 and overall demand growth of 765 koz including other physical investment.

### Automotive demand

Autocatalyst demand for platinum was down 6% year-on-year to 3,105 koz in 2018. Western Europe accounted for the majority of the contraction (-255 koz) and use in Japan dipped slightly (-20 koz), but there was some demand growth in the US and the emerging markets (+65 koz).

*Western European demand set to fall by 7% in 2019, but is far less than the 16% fall in 2018*

A large leg-down in diesel market share in Western Europe during 2018 to 36.5% (from 44.8% in 2017, source ACEA) and the introduction of new test procedures (WLTP and RDE) on 1 September affected diesel car sales and severely impacted demand for platinum with a drop of 16% to 1,305 koz.

The accelerated downswing in diesel sales in the UK, Germany and France, as well as sales declines in Spain and Italy (catching up with the first three countries), contributed to the contraction across the region of more than 1 million units.

The outlook for 2019 indicates more of the same, with a further decline of just over 100 koz of platinum demand in Western Europe to 1,210 koz. This is significantly less than the fall witnessed in 2018 but nonetheless contributes to a global drop of 3.1% year-on-year to 3,010 koz.

## The Platinum Standard

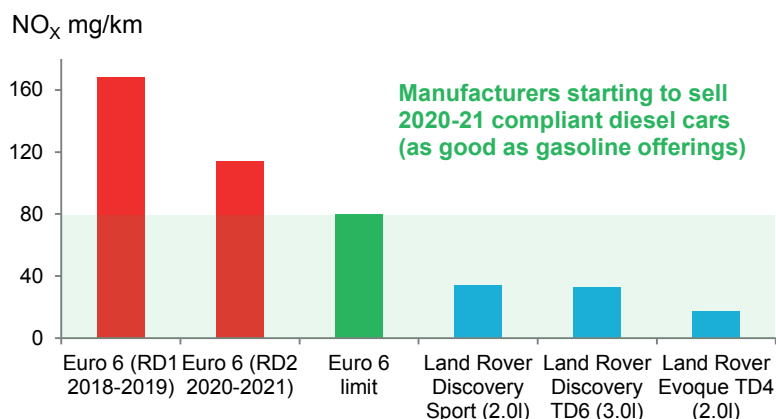
Large corrections in the diesel share have already taken place in Germany, France, Spain and the UK, so the loss in demand is expected to moderate this year. In Italy, however, there is forecast to be a 30% drop in platinum demand in 2019. Fortunately, Italy's consumption is far smaller than other major European countries, so the actual loss in demand in Italy is expected to be around 15 koz.

Now that all diesel vehicles on sale comply with new WLTP and RDE test procedures (from 1 September 2018), the latest offerings from OEMs will be significantly cleaner than 2018 diesel vehicles, with major reductions in NO<sub>x</sub> emissions in 'real-world driving' conditions.

*New 2019 diesel models are far cleaner – well below Euro 6 limits*

The new independent AIR Index for consumers shows that 2019 models from Jaguar Land Rover (JLR) (the first OEM to offer its cars to the independent tester) achieve real-world NO<sub>x</sub> levels that are well below the official Euro 6 level of 80 mg/km. The availability of emissions standard-beating models should help to slow the rapid shift away from diesel passenger cars in Europe.

### EU diesel emission standards vs. AIR test results for JLR



Source: SFA (Oxford), JLR, AIR (allowair.org)

### Jewellery demand

Global platinum jewellery demand is estimated to have dropped by 105 koz in 2018, leaving demand at 2,355 koz for the year. The reduction was expected as China's platinum jewellery retail sales continue to underperform. A combination of lower platinum prices impacting plain jewellery sales and the shift to fashion jewellery favouring gold led to a 12% drop in China's platinum demand to 1,175 koz. The outlook for 2019 indicates a further steady decline to 2,310 koz.

*Slower decline of jewellery demand forecast in 2019*

### **Industrial demand**

A strong recovery in petroleum demand combined with growth in glass fabrication helped industrial demand to rebound from a particularly weak 2017 with growth of 12% (+205 koz) in 2018 to 1,905 koz. Upgrading of refining capacity in India ahead of tighter emissions standards, as well as a recovery in Japan, saw net petroleum demand for platinum increase by 140 koz to 240 koz. In Europe and the emerging markets, new glass fabrication facilities helped to lift platinum requirements by 55 koz to 240 koz. Demand is forecast to hold up at elevated levels in 2019, dropping only 1% to 1,890 koz.

*Industrial demand  
forecast to hold up at  
elevated levels in 2019*

### **Investment and movement of above-ground stocks**

Investment of 280 koz of platinum bars in Japan offset the 245 koz contraction in ETF holdings and the slight reduction in exchange holdings (-20 koz) during 2018, leaving the net change in investment at +15 koz for the year. However, investment in 2019 has got off to an exceptional start (see the investment article) with inflows of 690 koz into ETFs and 75 koz of bar purchases in Q1. The majority of the ETF investment was from South Africa (+420 koz), followed by the UK (+180 koz) and the US (+80 koz).

## The palladium market

The palladium market ended 2018 in a very similar position to 2017, with a deficit of 830 koz (excluding investment). Primary supply contracted by 1.6% year-on-year to 6,970 koz, mainly owing to a pipeline lock-up at Nornickel, while demand was flat year-on-year as high prices forced industrial usage lower, offsetting higher autocatalyst demand. Unsurprisingly, higher palladium (and rhodium) prices lifted recycling by 5.3% to 2,495 koz.

*Supply shortfall kept the palladium market tight in 2018*

Owing to a significant increase in supply in 2019 (some of it a one-off processing of concentrate stock), there is forecast to be a narrowing of the palladium industrial market deficit (before investment) to 385 koz, compared to deficits of more than 800 koz p.a. over the previous five years.

*Extra supply can alleviate some pressure in 2019, but the market remains in structural deficit*

A combination of additional work-in-progress stocks of around 90 koz expected to be processed in South Africa, a recovery of Sudbury supply in North America and the ongoing ramp-up at the Blitz mine, as well as a planned increase in supply from Nornickel, contributes to a forecast 5.3% expansion in primary supply to 7,340 koz in 2019.

Recycling is also likely to continue the strong growth witnessed in 2018, rising by 5.8% to 2,640 koz. Higher palladium and rhodium prices continue to motivate greater collection of scrap autocatalysts through the recycling value chain, despite smelting and refining capacity challenges and limited availability of upfront cash to buy scrap stock. The net result of growth in mine and recycling output in 2019 is just over half-a-million ounces of additional supply.

Demand, meanwhile, is forecast to remain largely flat. Ongoing steady growth of autocatalyst demand (+1.6% to 8,435 koz) against the ongoing decline of other end-uses (-3.0% to 1,930 koz) leaves total demand growth projections up by just 0.7% to 10,365 koz for 2019.

Investors in palladium ETF products have continued to sell their holdings, with a drop of 560 koz in 2018, following three previous years of redemptions totalling 1,685 koz. Global holdings in ETFs at the end of Q1'19 have lost only 2.9 koz, although there was selling in Europe (-37 koz) which was offset by purchasing elsewhere. At the end of Q1'19, palladium ETF holdings were just over 700 koz, which is well down on the peak levels of over 3 moz in 2014/15.



## The rhodium market

South African rhodium supply remained stable at 630 koz in 2018, with a reduction in output from Bokoni (closed in 2017) and Lonmin offset by a recovery in production at Mototolo and Marula, as well as record output at Kroondal. Overall mine production fell by 1.5% to 775 koz, mainly due to a slight drop in supply from Zimbabwe after a strong year in 2017 (pipeline stocks).

*An additional 45 koz of primary supply forecast in 2019 should soften the rhodium market (but depends on timing)*

As with platinum and palladium, rhodium supply is likely to be impacted by the processing of excess concentrate (+35 koz) in 2019. Some growth from rhodium-rich UG2 ore mines is expected this year, including higher yield from the Booyesdal South, Styldrift and Two Rivers mines. Therefore, total supply is forecast to grow by 45 koz this year to 820 koz, with an additional 40 koz from South Africa and 5 koz from North America. South African supply is projected to temporarily reach 670 koz.

Recycling of autocatalysts is also predicted to continue growing, with higher rhodium (and palladium) prices motivating the collection of scrapped autocatalysts, particularly in the US where loadings are higher. Recycling, therefore, has the potential to rise by 6.1% in 2019 to 350 koz.

Global autocatalyst demand is forecast to continue to increase steadily to 875 koz, with China remaining the engine of growth. Tightening emission standards to curb NO<sub>x</sub> emissions helped to boost China's demand by over a third over the last four years.

Industrial demand is expected to settle at an estimated 210 koz in 2019 after a 45 koz rise in 2018 due to strong demand for rhodium in glass fabrication. Some price-related substitution held back overall growth, but rhodium was still required for glass-fibre capacity expansions in the US, Europe and emerging markets. Limited new glass facilities and expansions in 2019 should curb rhodium usage by the glass industry this year.

The net result for 2019 is a rhodium market that is temporarily weaker (+85 koz surplus) than in 2018 (+15 koz surplus), mainly because of excess supply from South Africa.

## The price outlook for the next six months

### Platinum \$825/oz

Platinum prices increased by 7% in Q1'19 to just shy of \$850/oz, and during April exceeded \$900/oz for a short time. Investors ploughed into platinum, with ETF holdings increasing by a record 690 koz in the quarter. The wide price differential to gold and palladium, a platinum equity rebound, the possibility of substituting platinum for more expensive palladium in gasoline autocatalysts, as well as the prospect of labour strikes and power disruptions in South Africa, helped to capture investor interest in platinum.

*Additional supply from South Africa may cut short the Q1 price rally*

However, on a fundamental basis, excluding investment, the platinum market is forecast to weaken in 2019, primarily owing to the processing of excess work-in-progress concentrate from 2018 following smelter rebuilds and new builds in Southern Africa. On this basis, mine supply could reach 6,400 koz, an increase of 285 koz compared to 2018, so even if wage negotiations or power disruptions take place, there is plenty of flexibility in the platinum market to ensure supply. On this basis, platinum prices are likely to trade back towards \$800/oz as we move through 2019.

### Palladium \$1,325/oz

SFA correctly forecast the palladium price rally at our sister publication event (*The Palladium Standard*) in New York in September 2018, calling the price to \$1,500/oz in 2019 when the price was under \$1,000/oz. Once SFA's target was met in February 2019, SFA correctly predicted a correction in its quarterly PGM market report to clients.

*Palladium price rally takes a pause in 2019*

Clearly, there is some slack in the palladium market now with stocks immediately available to purchase by industrial users. Lease rates reached over 30% last year on strong demand and limited supplies, but are back to 5-7% currently. The market is still in backwardation, but it is not as steep as it was, and NYMEX net speculative long positions have been falling since February. Over the next six months there is limited palladium price upside, but an ongoing structural deficit and tightening emissions standards (particularly in China) suggest another rally in future.

### Rhodium \$2,820/oz

Extra production from South Africa should keep the rhodium market well supplied in 2019. Rhodium is being caught up in palladium's price correction owing to the two metals' common use in gasoline three-way catalysts. Of course, the timing of rhodium supply through 2019 is critical and any disruptions to mine yield from labour strikes during wage negotiations, potentially combined with smelter outages, could tighten the market and firm prices.

*Potential oversupply could dampen rhodium prices...*

*...but mine disruptions could reverse price direction*

**APPENDIX**



## Platinum supply-demand balance

koz	2011	2012	2013	2014	2015	2016	2017	2018	2019f
<b>Primary supply</b>									
<b>Regional</b>									
South Africa	4,595	4,210	4,355	3,115	4,480	4,255	4,380	4,460	4,685
Russia	800	780	740	740	710	715	720	665	670
Zimbabwe	340	365	405	405	405	490	480	465	470
North America	375	345	355	400	385	395	365	355	400
Other	145	180	215	195	180	180	180	170	175
<b>Total</b>	<b>6,255</b>	<b>5,880</b>	<b>6,070</b>	<b>4,855</b>	<b>6,160</b>	<b>6,035</b>	<b>6,125</b>	<b>6,115</b>	<b>6,400</b>
<b>Demand &amp; recycling</b>									
<b>Autocatalyst</b>									
Gross demand	3,130	3,175	3,170	3,310	3,380	3,465	3,320	3,105	3,010
Recycling	1,210	1,175	1,120	1,255	1,185	1,210	1,325	1,420	1,495
Net demand	1,920	2,000	2,050	2,055	2,195	2,255	1,995	1,685	1,515
<b>Jewellery</b>									
Gross demand	2,450	2,750	2,945	3,000	2,840	2,505	2,460	2,355	2,310
Recycling	630	840	855	775	515	625	560	510	495
Net demand	1,820	1,910	2,090	2,225	2,325	1,880	1,900	1,845	1,815
<b>Industrial demand</b>									
<b>Other recycling</b>	10	5	5	5	5	5	5	5	5
<b>Gross demand</b>	7,440	7,465	7,600	7,875	7,980	7,750	7,480	7,365	7,210
<b>Recycling</b>	1,850	2,020	1,980	2,035	1,705	1,840	1,890	1,935	1,995
<b>Net demand</b>	<b>5,590</b>	<b>5,445</b>	<b>5,620</b>	<b>5,840</b>	<b>6,275</b>	<b>5,910</b>	<b>5,590</b>	<b>5,430</b>	<b>5,215</b>
<b>Market balance</b>									
Balance (before ETFs)	665	435	450	-985	-115	125	535	685	1,185
ETFs (stock allocation)	175	195	905	215	-240	-10	105	-245	
<b>Balance after ETFs</b>	<b>490</b>	<b>240</b>	<b>-455</b>	<b>-1,200</b>	<b>125</b>	<b>135</b>	<b>430</b>	<b>930</b>	

Source: SFA (Oxford)



## Platinum demand and recycling summary

koz	2011	2012	2013	2014	2015	2016	2017	2018	2019f
<b>Gross demand</b>									
<b>Autocatalyst</b>									
North America	385	425	425	465	485	445	410	430	445
Western Europe	1,495	1,340	1,350	1,440	1,550	1,705	1,560	1,305	1,210
Japan	500	600	580	590	510	455	440	420	395
China	120	115	130	120	125	165	195	190	180
India	180	200	160	160	175	165	165	190	190
RoW	450	495	525	535	535	530	550	570	590
<b>Total</b>	<b>3,130</b>	<b>3,175</b>	<b>3,170</b>	<b>3,310</b>	<b>3,380</b>	<b>3,465</b>	<b>3,320</b>	<b>3,105</b>	<b>3,010</b>
<b>Jewellery</b>									
North America	160	185	200	230	250	265	280	305	320
Western Europe	175	175	220	220	235	240	250	255	260
Japan	315	325	335	335	340	335	340	345	355
China	1,670	1,915	1,990	1,975	1,765	1,450	1,340	1,175	1,070
India	80	95	140	175	180	145	175	200	225
RoW	50	55	60	65	70	70	75	75	80
<b>Total</b>	<b>2,450</b>	<b>2,750</b>	<b>2,945</b>	<b>3,000</b>	<b>2,840</b>	<b>2,505</b>	<b>2,460</b>	<b>2,355</b>	<b>2,310</b>
<b>Industrial</b>									
North America	265	320	325	325	265	395	350	355	360
Western Europe	290	260	190	240	315	270	280	315	310
Japan	200	90	90	30	95	90	60	125	115
China	305	370	515	445	540	570	535	475	540
RoW	800	500	365	525	545	455	475	635	565
<b>Total</b>	<b>1,860</b>	<b>1,540</b>	<b>1,485</b>	<b>1,565</b>	<b>1,760</b>	<b>1,780</b>	<b>1,700</b>	<b>1,905</b>	<b>1,890</b>
<b>Total gross demand</b>									
North America	810	930	950	1,020	1,000	1,105	1,040	1,090	1,125
Western Europe	1,960	1,775	1,760	1,900	2,100	2,215	2,090	1,875	1,780
Japan	1,015	1,015	1,005	955	945	880	840	890	865
China	2,095	2,400	2,635	2,540	2,430	2,185	2,070	1,840	1,790
RoW	1,560	1,345	1,250	1,460	1,505	1,365	1,440	1,670	1,650
<b>Total</b>	<b>7,440</b>	<b>7,465</b>	<b>7,600</b>	<b>7,875</b>	<b>7,980</b>	<b>7,750</b>	<b>7,480</b>	<b>7,365</b>	<b>7,210</b>
<b>Recycling</b>									
<b>Autocatalyst</b>									
North America	600	575	560	560	510	530	585	640	645
Western Europe	420	405	365	470	370	400	440	465	505
Japan	115	115	95	105	95	90	100	110	115
China	5	10	20	30	55	40	40	35	40
RoW	70	70	80	90	155	150	160	170	190
<b>Total</b>	<b>1,210</b>	<b>1,175</b>	<b>1,120</b>	<b>1,255</b>	<b>1,185</b>	<b>1,210</b>	<b>1,325</b>	<b>1,420</b>	<b>1,495</b>
<b>Jewellery</b>									
North America	0	0	0	0	5	5	5	5	5
Western Europe	0	0	0	5	5	5	5	5	5
Japan	285	285	250	235	160	150	160	150	140
China	345	555	600	530	340	460	385	345	340
RoW	0	0	5	5	5	5	5	5	5
<b>Total</b>	<b>630</b>	<b>840</b>	<b>855</b>	<b>775</b>	<b>515</b>	<b>625</b>	<b>560</b>	<b>510</b>	<b>495</b>
<b>WEEE</b>	<b>10</b>	<b>5</b>	<b>5</b>	<b>5</b>	<b>5</b>	<b>5</b>	<b>5</b>	<b>5</b>	<b>5</b>
<b>Total recycling</b>									
North America	600	575	560	565	515	535	590	645	650
Western Europe	425	405	365	475	375	405	445	470	510
Japan	400	400	345	340	255	240	260	260	255
China	355	570	620	560	395	500	425	380	380
RoW	70	70	90	95	165	160	170	180	200
<b>Total</b>	<b>1,850</b>	<b>2,020</b>	<b>1,980</b>	<b>2,035</b>	<b>1,705</b>	<b>1,840</b>	<b>1,890</b>	<b>1,935</b>	<b>1,995</b>



## Palladium supply-demand balance

koz	2011	2012	2013	2014	2015	2016	2017	2018	2019f
<b>Primary supply</b>									
<b>Regional</b>									
South Africa	2,550	2,355	2,360	1,855	2,570	2,370	2,545	2,485	2,665
Russia	2,705	2,630	2,580	2,690	2,605	2,555	2,740	2,670	2,770
Zimbabwe	265	280	315	330	325	395	395	380	360
North America	865	895	975	1,055	995	1,065	985	1,045	1,145
Other	390	445	450	460	455	420	415	390	400
<b>Total</b>	<b>6,775</b>	<b>6,605</b>	<b>6,680</b>	<b>6,390</b>	<b>6,950</b>	<b>6,805</b>	<b>7,080</b>	<b>6,970</b>	<b>7,340</b>
<b>Demand &amp; recycling</b>									
<b>Autocatalyst</b>									
Gross demand	6,195	6,690	7,145	7,535	7,745	8,045	8,220	8,305	8,435
Recycling	1,525	1,485	1,645	1,720	1,610	1,710	1,920	2,050	2,200
Net demand	4,670	5,205	5,500	5,815	6,135	6,335	6,300	6,255	6,235
<b>Jewellery</b>									
Gross demand	680	545	350	295	240	240	225	220	210
Recycling	135	130	145	120	80	80	70	60	55
Net demand	545	415	205	175	160	160	155	160	155
<b>Industrial demand</b>	<b>2,465</b>	<b>2,325</b>	<b>2,065</b>	<b>1,940</b>	<b>1,995</b>	<b>1,955</b>	<b>1,850</b>	<b>1,770</b>	<b>1,720</b>
<b>Other recycling</b>	<b>370</b>	<b>375</b>	<b>410</b>	<b>430</b>	<b>435</b>	<b>400</b>	<b>380</b>	<b>385</b>	<b>385</b>
<b>Gross demand</b>	<b>9,340</b>	<b>9,560</b>	<b>9,560</b>	<b>9,770</b>	<b>9,980</b>	<b>10,240</b>	<b>10,295</b>	<b>10,295</b>	<b>10,365</b>
<b>Recycling</b>	<b>2,030</b>	<b>1,990</b>	<b>2,200</b>	<b>2,270</b>	<b>2,125</b>	<b>2,190</b>	<b>2,370</b>	<b>2,495</b>	<b>2,640</b>
<b>Net demand</b>	<b>7,310</b>	<b>7,570</b>	<b>7,360</b>	<b>7,500</b>	<b>7,855</b>	<b>8,050</b>	<b>7,925</b>	<b>7,800</b>	<b>7,725</b>
<b>Market balance</b>									
Balance (before ETFs)-535	-965	-680	-1,110	-905	-1,245	-845	-830	-385	
ETFs (stock allocation)-530	285	-5	940	-665	-645	-375	-560		
<b>Balance after ETFs</b>	<b>-5</b>	<b>-1,250</b>	<b>-675</b>	<b>-2,050</b>	<b>-240</b>	<b>-600</b>	<b>-470</b>	<b>-270</b>	



Source: SFA (Oxford)

## Palladium demand and recycling summary

koz	2011	2012	2013	2014	2015	2016	2017	2018	2019f
<b>Gross demand</b>									
<b>Autocatalyst</b>									
North America	1,505	1,745	1,835	1,970	2,070	2,135	2,030	2,020	2,020
Western Europe	1,500	1,425	1,530	1,655	1,725	1,635	1,690	1,745	1,730
Japan	670	735	745	750	745	775	805	820	850
China	1,130	1,300	1,515	1,670	1,745	2,015	2,090	2,065	2,170
India	160	155	165	165	180	225	245	265	280
RoW	1,230	1,330	1,355	1,325	1,280	1,260	1,360	1,390	1,385
<b>Total</b>	<b>6,195</b>	<b>6,690</b>	<b>7,145</b>	<b>7,535</b>	<b>7,745</b>	<b>8,045</b>	<b>8,220</b>	<b>8,305</b>	<b>8,435</b>
<b>Jewellery</b>									
North America	45	45	40	35	35	35	35	35	35
Western Europe	65	80	75	60	55	55	55	55	55
Japan	90	95	65	55	50	50	50	50	45
China	450	295	145	120	75	75	60	55	50
RoW	30	30	25	25	25	25	25	25	25
<b>Total</b>	<b>680</b>	<b>545</b>	<b>350</b>	<b>295</b>	<b>240</b>	<b>240</b>	<b>225</b>	<b>220</b>	<b>210</b>
<b>Industrial</b>									
North America	495	480	420	390	405	400	365	345	320
Western Europe	375	335	305	290	295	290	270	260	245
Japan	550	565	420	425	430	415	375	350	325
China	425	405	445	395	415	410	405	395	410
RoW	620	540	475	440	450	440	435	420	420
<b>Total</b>	<b>2,465</b>	<b>2,325</b>	<b>2,065</b>	<b>1,940</b>	<b>1,995</b>	<b>1,955</b>	<b>1,850</b>	<b>1,770</b>	<b>1,720</b>
<b>Total gross demand</b>									
North America	2,045	2,270	2,295	2,395	2,510	2,570	2,430	2,400	2,375
Western Europe	1,940	1,840	1,910	2,005	2,075	1,980	2,015	2,060	2,030
Japan	1,310	1,395	1,230	1,230	1,225	1,240	1,230	1,220	1,220
China	2,005	2,000	2,105	2,185	2,235	2,500	2,555	2,515	2,630
RoW	2,040	2,055	2,020	1,955	1,935	1,950	2,065	2,100	2,110
<b>Total</b>	<b>9,340</b>	<b>9,560</b>	<b>9,560</b>	<b>9,770</b>	<b>9,980</b>	<b>10,240</b>	<b>10,295</b>	<b>10,295</b>	<b>10,365</b>
<b>Recycling</b>									
<b>Autocatalyst</b>									
North America	975	930	1,005	975	895	960	1,060	1,135	1,190
Western Europe	335	325	345	365	270	260	305	330	345
Japan	130	125	125	135	125	125	145	165	180
China	15	20	50	60	115	160	165	155	165
RoW	70	85	120	185	205	205	245	265	320
<b>Total</b>	<b>1,525</b>	<b>1,485</b>	<b>1,645</b>	<b>1,720</b>	<b>1,610</b>	<b>1,710</b>	<b>1,920</b>	<b>2,050</b>	<b>2,200</b>
<b>Jewellery</b>									
Japan	15	20	20	20	20	20	20	15	15
China	120	110	125	100	60	60	50	45	40
<b>Total</b>	<b>135</b>	<b>130</b>	<b>145</b>	<b>120</b>	<b>80</b>	<b>80</b>	<b>70</b>	<b>60</b>	<b>55</b>
<b>WEEE</b>									
North America	70	75	75	70	85	75	70	65	65
Western Europe	80	85	90	95	80	75	75	75	75
Japan	135	120	135	145	165	135	120	120	115
China	20	30	40	30	25	35	35	40	45
RoW	65	65	70	90	80	80	80	85	85
<b>Total</b>	<b>370</b>	<b>375</b>	<b>410</b>	<b>430</b>	<b>435</b>	<b>400</b>	<b>380</b>	<b>385</b>	<b>385</b>
<b>Total recycling</b>									
North America	1,045	1,005	1,080	1,045	980	1,035	1,130	1,200	1,255
Western Europe	415	410	435	460	350	335	380	405	420
Japan	280	265	280	300	310	280	285	300	310
China	155	160	215	190	200	255	250	240	250
RoW	135	150	190	275	285	285	325	350	405
<b>Total</b>	<b>2,030</b>	<b>1,990</b>	<b>2,200</b>	<b>2,270</b>	<b>2,125</b>	<b>2,190</b>	<b>2,370</b>	<b>2,495</b>	<b>2,640</b>



## Rhodium supply-demand balance

koz	2011	2012	2013	2014	2015	2016	2017	2018	2019f
<b>Primary supply</b>									
<b>Regional</b>									
South Africa	645	600	590	425	620	615	630	630	670
Russia	75	75	70	75	70	70	75	75	75
Zimbabwe	30	30	35	35	35	45	45	40	40
North America	30	30	35	30	30	25	25	20	25
Other	10	10	10	10	10	10	10	10	10
<b>Total</b>	<b>790</b>	<b>745</b>	<b>740</b>	<b>575</b>	<b>765</b>	<b>765</b>	<b>785</b>	<b>775</b>	<b>820</b>
<b>Demand &amp; recycling</b>									
<b>Autocatalyst</b>									
Gross demand	740	770	785	835	865	840	850	860	875
Recycling	235	240	260	275	265	280	300	330	350
Net demand	505	530	525	560	600	560	550	530	525
<b>Industrial demand</b>	170	150	155	180	175	195	175	230	210
<b>Other recycling</b>	1	1	1	2	2	2	2	2	2
<b>Gross demand</b>	910	920	940	1,015	1,040	1,035	1,025	1,090	1,085
<b>Recycling</b>	235	240	260	275	265	280	300	330	350
<b>Net demand</b>	<b>675</b>	<b>680</b>	<b>680</b>	<b>740</b>	<b>775</b>	<b>755</b>	<b>725</b>	<b>760</b>	<b>735</b>
<b>Market balance</b>									
Balance (before ETFs)	115	65	60	-165	-10	10	60	15	85
ETFs (stock allocation)	15	35	50	5	-5	5	-20	-50	
<b>Balance after ETFs</b>	<b>100</b>	<b>30</b>	<b>10</b>	<b>-170</b>	<b>-5</b>	<b>5</b>	<b>80</b>	<b>65</b>	

Source: SFA (Oxford)





## Rhodium demand and recycling summary

koz	2011	2012	2013	2014	2015	2016	2017	2018	2019f
<b>Gross demand</b>									
<b>Autocatalyst</b>									
North America	180	200	220	235	255	250	235	230	230
Western Europe	215	190	195	220	240	205	205	215	215
Japan	135	150	140	140	125	125	125	125	125
China	75	90	95	105	110	130	150	155	170
India	20	20	15	15	15	20	20	20	20
RoW	115	120	120	120	120	110	115	115	115
<b>Total</b>	<b>740</b>	<b>770</b>	<b>785</b>	<b>835</b>	<b>865</b>	<b>840</b>	<b>850</b>	<b>860</b>	<b>875</b>
<b>Industrial</b>									
North America	20	15	15	15	15	20	15	15	15
Western Europe	20	20	15	20	15	15	15	25	25
Japan	45	45	35	30	35	30	30	35	35
China	40	30	45	55	55	65	55	65	60
RoW	45	40	45	60	55	65	60	90	75
<b>Total</b>	<b>170</b>	<b>150</b>	<b>155</b>	<b>180</b>	<b>175</b>	<b>195</b>	<b>175</b>	<b>230</b>	<b>21</b>
<b>Total gross demand</b>									
North America	200	215	235	250	270	270	250	245	245
Western Europe	235	210	210	240	255	220	220	240	240
Japan	180	195	175	170	160	155	155	160	160
China	115	120	140	160	165	195	205	220	230
RoW	180	180	180	195	190	195	195	225	21
<b>Total</b>	<b>910</b>	<b>920</b>	<b>940</b>	<b>1,015</b>	<b>1,040</b>	<b>1,035</b>	<b>1,025</b>	<b>1,090</b>	<b>1,085</b>
<b>Recycling</b>									
<b>Autocatalyst</b>									
North America	140	145	165	160	150	160	165	180	190
Western Europe	60	60	55	60	45	50	55	60	65
Japan	25	25	25	30	30	35	35	40	40
China	0	0	5	5	10	5	5	5	5
RoW	10	10	10	20	30	30	40	45	5
<b>Total</b>	<b>235</b>	<b>240</b>	<b>260</b>	<b>275</b>	<b>265</b>	<b>280</b>	<b>300</b>	<b>330</b>	<b>350</b>

Source: SFA (Oxford)



## GLOSSARY OF TERMS

### **Basket price**

Collective revenue of metals divided by 4E oz.

### **BEV**

Battery electric vehicle.

### **By-products**

Copper, nickel, iridium and ruthenium.

### **EREV**

Extended range electric vehicle.

### **ETF**

Exchange-traded fund.

### **FCEV**

Fuel cell electric vehicle.

### **Gross demand**

A measure of intensity of use.

### **HDV**

Heavy-duty vehicle.

### **koz**

A thousand troy ounces.

### **LCV**

Light commercial vehicle.

### **Merensky Reef**

A PGM-bearing horizon within the Bushveld Igneous Complex, South Africa. Also contains nickel and copper sulphides that are mined as by-products.

### **moz**

A 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.

### **oz**

Troy ounce.

### **PEMFC**

Proton-exchange membrane fuel cell.

### **PGMs**

Platinum-group metals.

### **PHEV**

Plug-in hybrid electric vehicle.

### **Platreef**

A PGM-bearing horizon mined on the Northern Limb of the Bushveld Igneous Complex. Characterised by a wide reef and base metal by-products.

### **Primary supply**

Mine production.

### **Producer sales**

Mine output plus inventory sold to market.

### **RDE**

Real Driving Emissions test.

### **Secondary supply**

Recycling output.

### **The Great Dyke**

A PGM-bearing horizon in Zimbabwe.

### **TOCOM**

Tokyo Commodity Exchange.

### **UG2 Reef**

A PGM-bearing horizon within the Bushveld Igneous Complex, located stratigraphically below the Merensky Reef. One of the main chromite-bearing reefs of the Bushveld Igneous Complex. Typically comprises lower base metals contents than the Merensky Reef.

### **WLTP**

Worldwide Harmonised Light Vehicle Test Procedure.

### **4E**

Platinum, palladium, rhodium and gold.

### **Currency symbols**

ZAR South African rand.

\$ 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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