

THE PALLADIUM STANDARD

September 2019



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FOREWORD



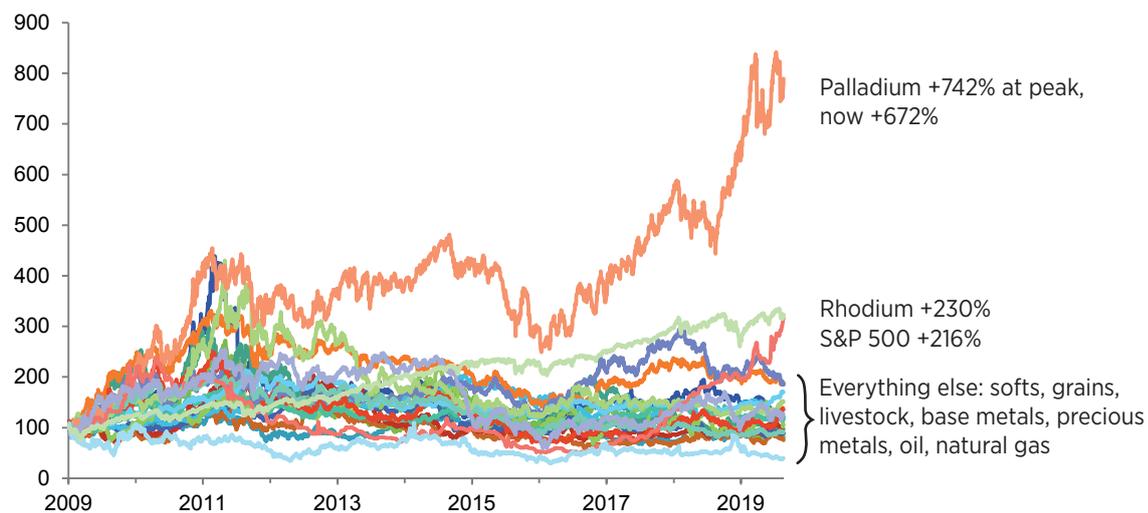
Foreword

Palladium's decade, then decay?

During the last decade, one metal has stood head and shoulders above all other commodities in terms of its price performance — palladium. From the end of the global financial crisis commodity prices rallied into 2011, with some reaching new price highs above those seen prior to the bust, but only palladium held on to those gains and continued to climb.

But will the next few years be as kind to palladium as the last decade? At first glance, the answer is yes. The market is projected to remain in deficit with demand easily exceeding supply. However, there may be one or two bumps in the road along the way.

Prices indexed: 1 January 2009=100



Source: SFA (Oxford), Bloomberg

The recovery from the last recession saw global passenger car sales grow from 49 million units in 2009 to 80 million units in 2018. Over the same period emissions legislation was tightened several times in developed countries, and developing countries also began to tighten emissions standards, requiring heavier loadings of PGMs in autocatalysts.

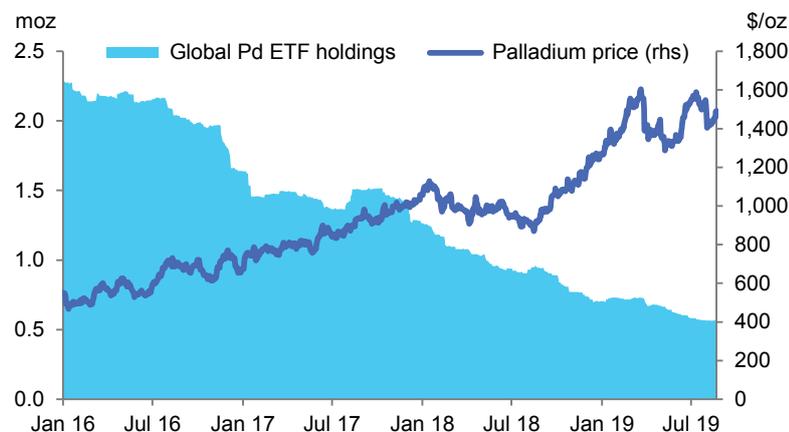
The rise of China has significantly added to palladium and rhodium demand. As a predominantly gasoline market, higher car sales combined with increasing catalyst loadings have taken the country to the top spot in terms of automotive palladium usage, overtaking the US in 2015 and exceeding 2 moz in 2016.

In addition, palladium made inroads into diesel catalysts. On top of which, the VW diesel scandal saw the passenger car diesel market share drop in Western Europe, diesel's largest market, from over 50% to around 33%, boosting gasoline car sales and so palladium demand.

In a decade of rapidly increasing demand, which outpaced supply growth, perpetual large market deficits were the result. Substantial palladium stocks were once available to meet the deficits, but those stocks are now much depleted. The market tightened significantly and lease rates rocketed, most notably in mid-2017. In January 2018, the price surpassed its previous high of \$1,092/oz set in January 2001 and then, after a pull-back, accelerated higher again to \$1,600/oz earlier this year.

In the first article, Matthew Turner considers the influence of investors on the palladium market and price. High prices have mobilised stock sales from ETFs which have helped to balance the market and stabilise the price. But that begs the question: why would investors liquidate their ETF holdings over the course of the last four years while the price was still rising? The most obvious answer is that they think that the price outlook for palladium has worsened.

Palladium ETF holdings vs. price



Source: SFA (Oxford), Bloomberg

Contrary to previous behaviour, futures speculators have also become much less keen on taking long positions in palladium over the last 18 months as the price has made new highs. Previously strong market correlations with the palladium price have broken down making it harder to square real world economic prospects with the price, so speculators are staying clear.

In the second article, Denis Sharypin and Petr Varyushin consider the 'new normal' and future challenges for the PGM market. Nornickel's view is that palladium market deficits are here to stay. The new normal is palladium trading at a significant premium to platinum.

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Emissions legislation is being tightened across China, India, Europe and the US, requiring autocatalyst loadings to be increased. Even with a modest decline in vehicle production this year, palladium demand would still increase. In the medium term, demand growth is not expected to be meaningfully impacted by palladium substitution with platinum in autocatalysts or by the growth in battery electric vehicles (BEVs).

Nornickel has taken a number of steps to improve metal availability. Firstly, increasing production and secondly, launching the Global Palladium Fund to facilitate customers' access to palladium stocks and cover some of the market deficit. In addition, Nornickel is expanding production at a number of sites over the next few years and investigating new production growth opportunities.

In the final article, Lakshya Gupta considers the growth of BEVs and their impact on the metals used in light vehicles — lithium, nickel and cobalt in batteries and on the other side the possible fallout for PGMs.

Over the last couple of years there has been a steady ratcheting up of forecasts for the number of BEVs that will be produced, but even under the most aggressive penetration rates BEVs remain less than 6% of the global automotive market in 2022. So palladium demand is safe for quite a while, but clearly BEVs will eventually become a threat to a metal that has 81% of its demand coming from the automotive sector.

Time to hedge palladium?

With the palladium price trading close to its highest-ever level, it is hard to see further upside in the short term. Market tightness has eased, with lease rates now in single digits and the futures curve moving back into contango in the near months.

Growth in Chinese car sales is expected to resume next year, lifting palladium demand, which, along with tightening emissions legislation, should be more than enough to keep the market in deficit and see the price rally continue. Rhodium demand should similarly benefit. The introduction of BEVs, substitution of platinum for palladium in autocatalysts and increasing mine production are years away from meaningfully moving the market towards balance.

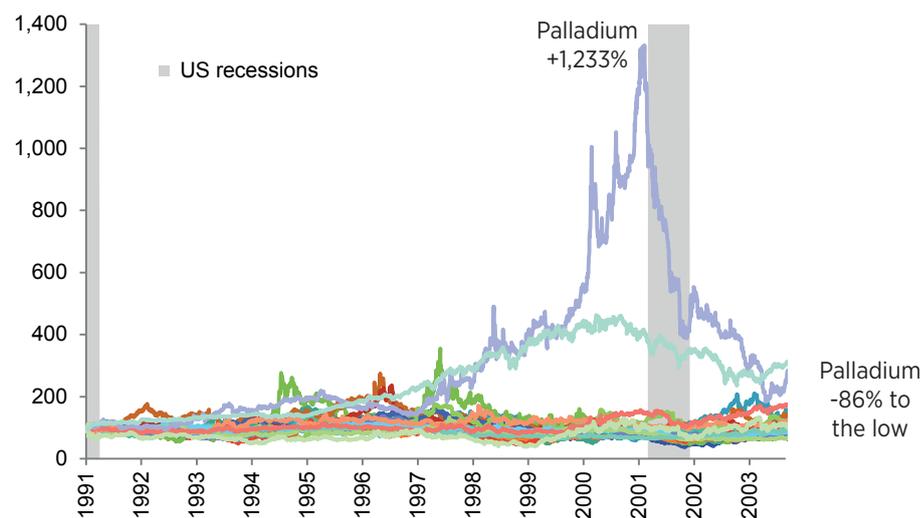
However, the economic forecasts used in the base case outlook do not include a recession in the near future and there are signs that a recession is not too far away in the US. The inverted yield curve is a warning sign that has preceded the last five US recessions.

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A recession could also be just around the corner in Europe. German GDP contracted in Q2 2019 as declining exports and weak manufacturing hit growth. It remains to be seen how long services and consumer spending can hold up the EU economy in the face of ongoing manufacturing weakness. The US has been increasing tariffs on Chinese goods, which has slowed global trade, and Europe could be next in line for similar treatment.

In terms of palladium price performance we have been here before. Palladium was the massive outperformer over the decade to 2001. This time is different to the extent that China now represents 24% of automotive palladium demand compared to 10% in 2009 and, with the introduction of China 6 legislation, loadings are increasing. But will Chinese demand be enough to support the palladium price if the US and Europe end up in recession? If not, then all PGM prices will head lower, but palladium is the most exposed and potentially has a long way to fall.

Prices indexed: 1 January 1990=100



Source: SFA (Oxford), Bloomberg

**PRICED-OUT!
INVESTORS GIVE WAY
TO INDUSTRIALISTS**



Priced-out! Investors give way to industrialists

Matthew Turner, Consultant Commodity Analyst and Economist

Palladium is an industrial metal and its price reflects shifts in supply and demand. But investors have always played a role and in recent years have clearly been a force for good — helping stabilise an otherwise unbalanced market. This era is coming to an end, however: surging palladium is now pricing-out even the most bullish, and even those who still see upside are having to contend with confusing price signals.

Commodity speculators and investors are a much-maligned species. Forever criticised for exacerbating price volatility, in the mid-2000s they faced an even more severe allegation, that a plethora of new investment vehicles and products were ‘financialising’ commodities and bidding up prices in key energy and agricommodities.

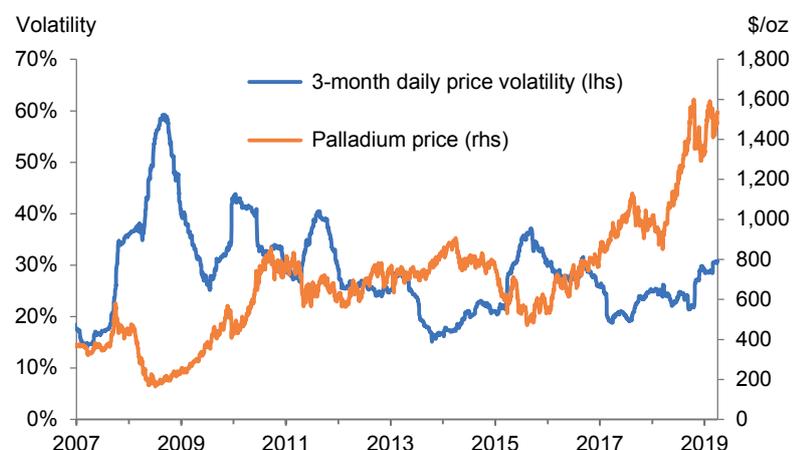
Palladium has never been the most financialised of commodities but it has always had a speculative and investor element, originally through OTC transactions and via the New York futures market. From the mid-2000s this stepped up a gear with the arrival of exchange-traded funds (ETFs).

Yet while palladium has hit repeated price highs in the last few years, this has not been due to investors but strong fundamentals. In fact investors have played a stabilising role, a factor behind keeping price volatility subdued despite the record run-up (Figure 1).

Palladium has never been the most financialised of commodities but has always had speculator and investor interest

Longer-term investors have been stabilising influence

Palladium price volatility (annualised) vs. palladium price (Figure 1)



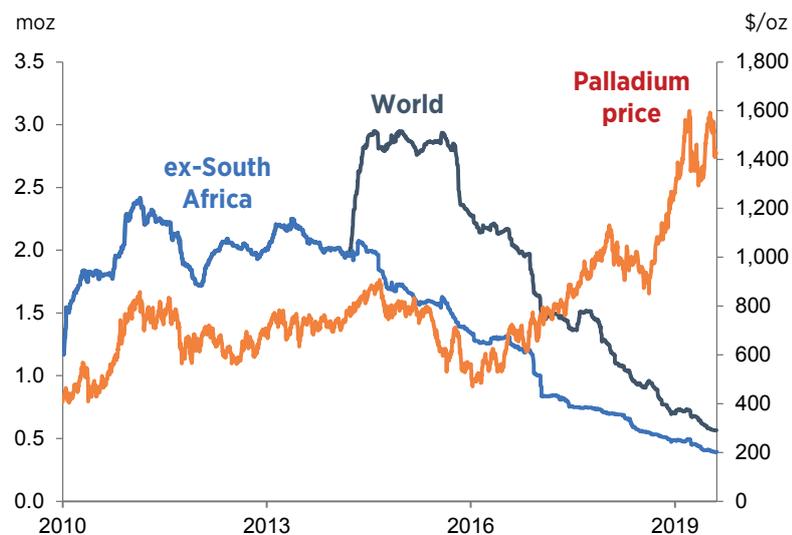
Source: SFA (Oxford)

To see this, note that the main way in which investors have an impact on commodity markets is through the hoarding or dishoarding of inventory — in other words increasing demand or supply over what it would otherwise be and thus pushing the price higher or lower than it would otherwise be. Economist, Milton Friedman, argued that this would likely reduce price volatility, because investors would want to add to their stocks when the price was weak and reduce them when it was high. There is evidence, from many markets at many times, that this is not how it works — investors exacerbate price movements.

Palladium seems to be a shining exception.

ETF holdings of physical palladium peaked in mid-2014 at around 3 moz, more than 1.5 moz higher than four years previously (Figure 2). During this period of accumulation the palladium price averaged \$671/oz. Since 2016 ETFs have seen steady outflows of metal, leaving barely 0.5 moz in the vaults as of mid-August, a period in which the price has averaged \$940/oz.

Global palladium ETF holdings vs. palladium price (Figure 2)



Source: SFA (Oxford)

Palladium ETFs have been stabilisation in action.

This is stabilisation in action — a privately-owned buffer stock.

The role such ETF movements have played would not be so important if it wasn't for the peculiar nature of palladium. For many commodities higher prices quickly curb demand and bring forth new supply (or lower prices the opposite). Palladium has no such luck — both its underlying supply and demand are highly insensitive to price; the former a function of it being a by-product of nickel and platinum

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mining¹, the latter because it is only a small part of the cost of a car that cannot be sold without it or a similar catalyst². If palladium market participants weren't willing to accumulate or liquidate stocks then any supply and demand imbalances would only be resolved by truly huge swings in the palladium price.

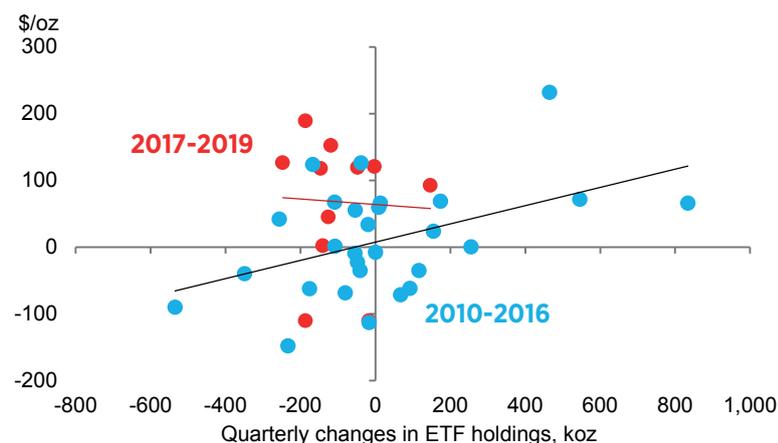
Exactly how large a price rise the recent ETF liquidation has prevented is very hard to calculate.

The best method would be to use estimates of elasticities for palladium demand and supply to work out by how much the palladium price would have had to rise to bring the two into line. But such elasticities are not known with any precision, and in any case would be so low that the changes in the palladium price estimated would be so large as to be nearly meaningless. Long before it had risen enough to curb autocatalyst demand or encourage miners to dig new mines the market would have balanced through the liquidation or accumulation of other, non-ETF stocks.

A statistical analysis also yields only tentative findings. Figure 3 shows the relationship between quarterly changes in palladium ETF holdings and the palladium price. Here we see that that in the period 2010-2016 there was a weak positive relationship between stockbuild and price – that is in quarters where ETFs added metal, the palladium price tended to rise, and vice-versa. About 0.6 moz of stock move was associated with a price change of \$100/oz. In the period since, 2017-2019, the relationship flips. At first glance this might be seen as evidence against stabilisation – ETF selling is not reducing the price – but in fact it suggests the market is pulling the ETF metal out, rather than the ETF investors pushing it onto the market.

The market has been pulling out ETF metal... not investors pushing it in

Quarterly changes in ETF holdings vs. change in price (Figure 3)



Source: SFA (Oxford)

¹ At least it used to be. Norinickel now has a higher revenue from palladium than any other metal, and even the more platinum-rich South African miners are not far off.

² I say 'similar' here because there is always platinum and the possibility of substitution.

It is not the benevolence of the investor...

To understand this further we need to consider the motivations of investors in these periods. An acquaintance with investors will tell you that they act not out of the goodness of their hearts but through profit-maximising self-interest.

The only return from an ETF palladium investment is through capital gains. As such, investors will hold palladium if it offers better (risk-adjusted) returns than they can get elsewhere. In the accumulation phase it seems likely the positive supply and demand case for palladium attracted interest, amplified by the investor flows. But what explains their liquidation since 2016/2017 into a still-increasing price?

The most obvious answer is they think the longer-term price outlook for palladium has soured. There are plenty of reasons this could be: a sluggish Chinese car market or the accelerating shift towards electrification. But a more immediate factor has been the huge rise in the current palladium price. An investor may have become more bullish on palladium prices a few years out — say expecting \$1,250/oz not \$1,000/oz — but a rise in the spot price to \$1,500/oz will have made them a bear. The fear of a repeat of the 2000/2001 price spike, which left palladium longs out of the money for 17 years, must have also played a sobering role.

Investors take their profits quicker and run, this time

Even for those investors who still see further price upside, there could be better ways to play it than ETFs. Most importantly, and especially in 2018, the forward price of palladium rose less strongly than the spot price, sending lease rates soaring. This meant palladium investors would have been better off selling their ETF holdings and buying cheaper futures, or selling their ETF holdings and buying physical palladium to lend out. Both are another way of saying the market wants metal now, and if the investor is prepared to wait they can have it cheaper later.

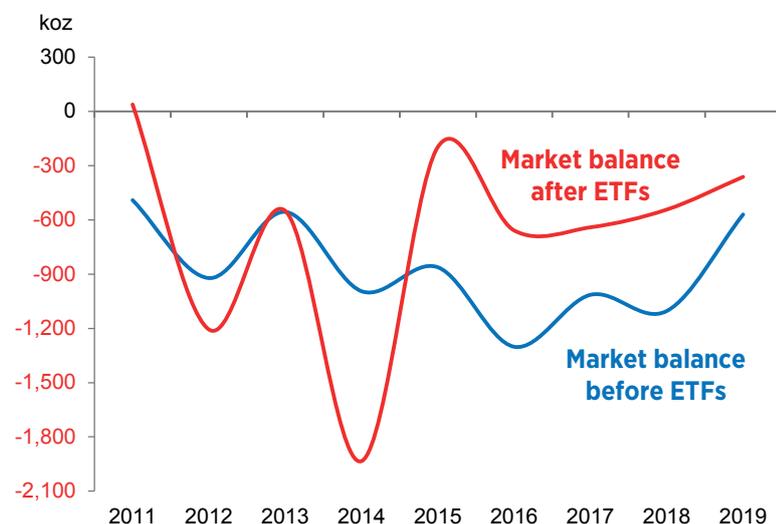
This explanation for ETF liquidation does raise the possibility that there is another crunch to come, when the investors who have lent metal want it back, and indeed potentially even returning to it to ETFs. Certainly in the last few months the forward price of palladium has edged nearer to that of spot, a sign this might be happening, and ETF liquidation has slowed. But it is hard to gauge what proportion of ETF liquidation is explained by such activity. Subdued NYMEX net long investor positions suggest the switch to futures has not been a major factor.

But we'll miss them when they're gone

Assuming the ETF stocks do represent a real fall in inventory, the inevitable question is what happens when there is no more left to sell? Mathematically, the answer is that palladium demand needs to be lower or palladium supply needs to be higher, or some other stocks need to be mobilised. This suggests the price needs to go higher.

After all while ETF investors have acted in a stabilising manner, selling 2.5 moz in the last four years, it plainly wasn't enough. SFA (Oxford)'s supply and demand balance shows the market was in a deficit, i.e. where demand has exceeded supply, of nearly 5 moz in this period, meaning other stockholders had to provide as much metal again as the ETFs.

Market balance before and after ETFs (Figure 4)



Source: SFA (Oxford)

Palladium might once again be lucky — SFA (Oxford) forecasts the 2019 deficit will be 570 koz, the narrowest since 2013. External factors — a slowing world economy, electrification — are working to balance the market, while the impact of the much higher palladium price seen in the last 12 months is still feeding through, especially for recycling. Platinum switching might finally have some impact.

As ETF metal runs out will the palladium market be lucky again?

Nevertheless, without the ETF buffer the margin of error is thin, and although there are other liquid stocks (5 moz), they are far less transparent and the motivation of those who hold them is less clear. The risks ahead look considerable.

Au revoir, not goodbye

One day the palladium market will turn. If you believe the automotive electrification story, palladium’s medium-term future demand prospects are dire.

A major problem for industrial commodities can be ‘hysteresis’, which is when demand that was squeezed out by higher prices does not return at lower prices because of technological or other shifts — an example is MLCC demand for palladium, which did not gain back to its early 2000s demand levels even after the first palladium price spike abated. Investors, as noted above, do have long memories (or access to Bloomberg price data). But unlike the 2000/2001 period, their memories of the current period should be positive — they have been priced-out by autocatalyst demand, but profitably. Good, as we will need them again.

Follow the money? No, money the follower

If the palladium price has had to rally to draw out ETF metal, where does that leave speculators and short-term price drivers? Confused.

Figure 5 shows the correlation over the past 52 weeks between changes in the weekly NYMEX net positions of speculators¹ and changes in the palladium price. It remains as strongly positive as ever.

Rolling 52-week correlation % change in Pd price vs. change in managed money net long (Figure 5)



Source: SFA (Oxford), CFTC

NYMEX net long position (MM and other reportables) vs. palladium price (Figure 6)



Source: SFA (Oxford), CFTC

¹Those held by the money managers and non-reportables.

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But does this mean speculators have been driving the price higher? Surely not, for though futures positioning still rises and falls with the palladium price, the actual level of net speculator activity (Figure 6) is very low by historical standards, and has risen only modestly even as the price has shot up to an all-time high. Speculators at times have done some heavy-lifting for prices, but not this much, with total open interest less than half what it was just two years ago.

Specs still move up and down with price — but it's the price that's leading the way

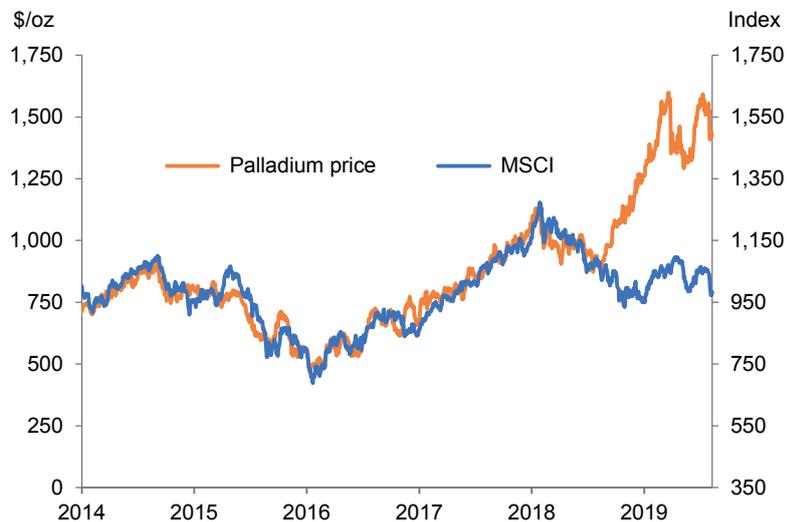
What seems more likely is the few speculators who remain are determinedly price-following.

Palladium decouples from equities

And who can blame them? Many of the traditional market signals of where palladium should be trading are breaking down.

It used to be quite easy. Palladium demand was closely linked to the global auto sector, and the global auto sector linked to future economic prospects in Asia. And what else was a good signal of future economic prospects in Asia? Emerging market equities. But in 2018 emerging market equities soured under relentless pressure from the trade war — 'sell', we all cried — and yet palladium kept on going up.

Palladium price vs. MSCI Emerging Markets Index (Figure 7)



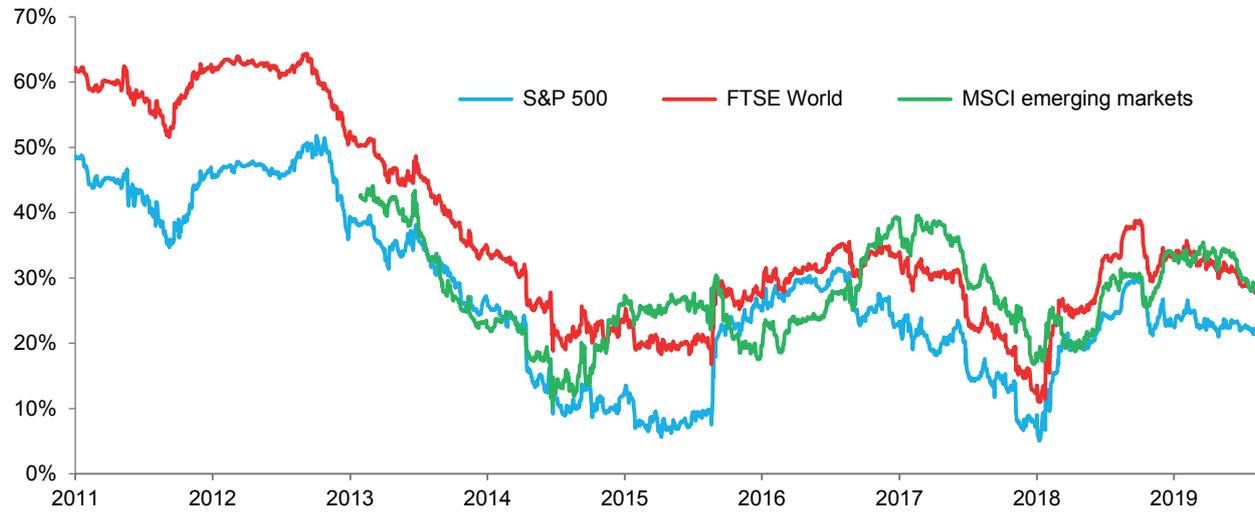
Source: SFA (Oxford), Bloomberg

Equity markets no longer give a steer to the palladium price

Palladium was in big deficit all through the period charted, so decoupling from 2018 can't be only down to deficit.

Short-term we see a similar trend. A rolling 12-month correlation of daily changes in equity indices to the palladium price shows that a very high correlation in 2011-2012 gave way to nearly no correlation in 2014-2015 and a modest correlation since.

12-month correlation of daily price movements in palladium and equity markets (Figure 8)



Source: SFA (Oxford), Bloomberg

This brings us full circle. Investors are exiting the market because the price has gone so high they no longer see value. Speculators are staying clear because they don't understand it.

**PGM MARKET — A ‘NEW
NORMAL’ AND FUTURE
CHALLENGES**



PGM market — a ‘new normal’ and future challenges

Denis Sharypin, Head of Market Research, Nornickel
Petr Varyushin, Principal PGM Market Analyst, Nornickel

First of all, we would like to thank the SFA (Oxford) team for the opportunity to contribute to *The Palladium Standard* again. Since September 2017, when we presented our first article, the PGM market has experienced great changes. The most impressive of them was a spectacular rally of palladium and rhodium prices. The movement we witnessed was primarily caused by the spot market tightness, driven by fundamentals, including tightening of environmental standards and continuing decrease in the European diesel market. These developments have resulted in the palladium price moving to a sustained premium over platinum — and as some readers may now recall that it is exactly the outcome that we forecasted in our previous paper.

Palladium has sustained its price premium over platinum – the new status quo?

In this article, we would like to focus on what has actually happened over the last two years, our expectations, as far as the markets are concerned, and what Nornickel, being the largest global palladium producer, is doing to support the sustainable development of this industry.

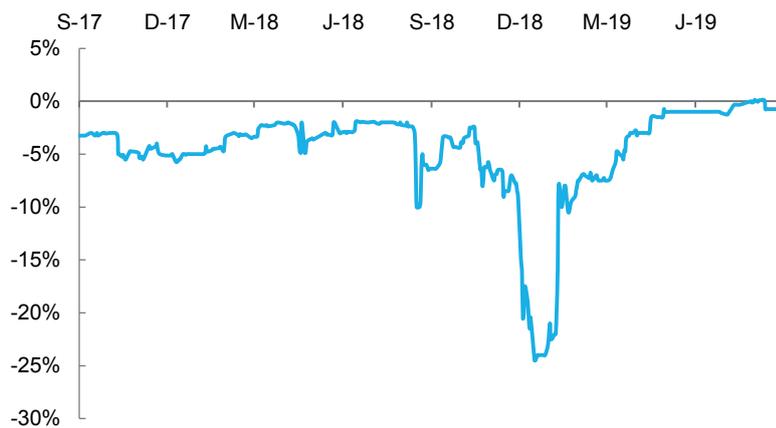
What has changed the long-standing status quo in the PGM market?

Just after SFA (Oxford)'s New York event in September 2017, the palladium to platinum price ratio moved above 1.0 for the first time since 2001. Although many experts thought that it would not be sustainable and the process of price elastic substitution would quickly move the price ratio back to its historical average levels, we believe that palladium has established a new status quo.

The fundamental reasons for that are well known. The analysts' consensus view is that the palladium market will maintain a large deficit at least until 2023-2024, while platinum is expected to be in mild surplus. Albeit being opaque, palladium above-ground stocks (or at the very least their price-elastic part), appear to be close to depletion while, in contrast, investors have accumulated platinum inventories. Global platinum production has not been susceptible to lower prices (compared with 2017, primary platinum production in South Africa is expected to increase by 4% in 2019) as the weak rand and higher credits for by-products such as palladium and minor PGMs support most of the South African mines in rand terms, delaying previously-announced shaft closures. Secondary production shows no response to lower platinum prices as old car scrappage does not really depend on the current PGM prices.

Palladium's liquid above-ground stocks appear to be close to depletion

Palladium three-month forward rates



Source: Refinitiv

The palladium market shifted into backwardation in May 2017, supporting the argument that there was a lack of metal available in the spot market (the tightest market conditions were seen in June 2017, August 2018, and especially between December 2018 and January 2019 when the metal availability was extremely low). The market tightness and market backwardation we believe were triggered by low ingot availability, which had been caused by four factors:

Market tightness triggered by low ingot availability

1. In reality, out of all the variety of palladium products, only ingots are traded on the financial market (other products are priced at a premium/discount to ingots) and thus the metal price is determined largely by the supply-demand balance of this particular palladium product.
2. Ingot stocks are exhausted as their production was very limited in recent years and previously accumulated stocks were consumed during previous years of deficit. Around 90% of palladium is currently consumed and produced in a sponge form and the only sources of ingots are the above-ground stocks originating from the Soviet era and ETFs' liquidation plus some very small portion of the current production.
3. There is high demand for ingots from China, which was spurred by the growing automotive market in 2017 and roll-out of China 6 emission standards in 2018-2019. Chinese customers prefer ingots to sponge as ingots' quality can be easily ascertained at each step of the supply chain from a producer to a Hong Kong trader and eventually to a refiner in mainland China and a final user.
4. As palladium's industrial consumption is higher than production and demand for sponge remains strong, there is no incentive for market participants to switch/convert from sponge to ingots.

~90% of palladium is currently consumed and produced in sponge form

What makes the current situation a ‘new normal’?

Growing catalyst loadings are offsetting lower vehicle output.

Despite the certain weakness in the global automotive market (sales fell by 7% in H1 2019; the trade war between the US and China negatively impacts the Chinese economy, while developed markets are facing the risk of recession), the stricter environmental regulations coming into force in the most important car markets are pushing the OEMs to increase catalyst PGM loadings, which more than offsets the weakness in sales volumes.

This year, the China 6 emissions standard has been launched in 20 provinces that represent approximately 60% of China’s new car sales nationally. This gives a major boost to PGM offtake: according to our estimates, palladium loadings in light-duty gasoline vehicles in China should increase by 15-20% this year and continue to grow further next year.

Moreover, introduction of China 6 for heavy-duty vehicles, which is expected this year in Beijing and a little later in other main provinces, where the absolute majority of trucks are being sold, should also have a significant positive impact on Chinese PGM demand affecting not only platinum (loadings we forecast to triple) but palladium as well (we expect 10-15% increase in loadings).

A similar situation is developing in India, where the new Bharat VI HDD regulation is coming into force in April 2020 and requires the OEMs to start their preparations no later than H2 2019. This standard, which is coming into force right after Bharat IV and skipping Bharat V, requires the automakers to reduce NO_x emissions by 25% for gasoline vehicles and by nearly 70% for diesel trucks. The regulation also introduces an RDE test, which makes meeting its requirements even more challenging.

In Europe, as part of the final stage of Euro 6d, a RDE NO_x conformity factor (CF) of 2.1 was set for all new vehicles, starting from September 2019. From January 2020, it will be reduced from 2.1 to 1.5 for new models, while from January 2021 CF=1.5 will become the standard for all new vehicles. WLTP introduction in 2018 forced OEMs to conduct deep re-engineering of tailpipe systems and increase palladium loadings by more than 5% year-on-year depending on the vehicle type. We forecast that next year the growth will be at the same rate at least.

Stricter emissions standards should increase autocatalyst palladium loadings

China 6 standards should increase palladium content in light-duty gasoline vehicles by 15-20% this year

India skips from Stage IV to Stage VI and RDE

RDE and WLTP drives loadings up in Europe

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In the US, the Tier 3 ruling will continuously support PGM demand until at least 2025 as it is scheduled to raise the fleet average NMOG+NO_x standard every year. For instance, the fleet average NMOG+NO_x FTP standard of 79 mg/mi in 2018 was reduced to 72 mg/mi this year (-9% year-on-year), and is then scheduled to decrease further to 30 mg/mi by 2025 — the level of SULEV-equivalent fleet average NMOG+NO_x emissions. We estimate that this may require more than a 40% increase in palladium and a 10% rise in rhodium loading per vehicle over the current fleet averages.

US Tier 3 regulations may require more than a 40% increase in palladium content per vehicle

In case of flat vehicle output globally this year, we forecast palladium demand could reach 8.9 moz (+0.4 moz year-on-year). In a scenario where global automotive production decreases 2%, we still would expect an increase of global palladium demand by 0.3 moz year-on-year. In the worst case scenario of a 7.5% reduction in global car volumes (as it was in H1 2019), we are expecting only a marginal reduction of palladium consumption this year by approximately 0.2 moz, which would still leave the market in a material deficit.

Automotive scenarios

Scenarios: global auto production growth in 2019, y-o-y (%)	Consumption in 2019 vs. 2018, moz	
	Palladium	Platinum
0%	0.4	0
-2.0%	0.3	-0.1
-7.5%	-0.2	-0.3

Source: Nornickel

Looking ahead, we assume that global economic growth will recover and automotive production will return to annual growth rates of 2-3% starting from 2021. As a result, palladium automotive consumption is expected to reach 11 moz by 2025. As for platinum, our base-case scenario assumes the metal consumption in the automotive industry stabilising this year at the level of 2018 (3.2 moz) with an increase to 3.3 moz by 2025 with further upside potential.

Palladium automotive consumption is expected to reach 11 moz by 2025

Palladium substitution with platinum is currently not happening

because of the technological challenges and specific chemical properties of the two metals, which are not fully interchangeable. Our regular communication with OEMs and fabricators reveals that, currently, automakers have limited appetite for changes in the catalyst chemistry as their engineering resources are focused on meeting new tighter emission legislation and RDE testing, and they do not have enough resources to conduct new catalyst formulation testing. Introduction of the RDE testing and ‘Dieselgate’ multi-billion penalties have raised the industry’s concerns over potential non-compliance with new standards, so automotive producers want to be absolutely sure that the catalytic systems fully meet the tightened requirements before any change to them could be contemplated. **Since the palladium price spike in 2000-2001 and after 2008-2009, when platinum prices spiked to \$2,400/oz, all R&D has been focused on Pd-Rh formulations.**

Automakers have little appetite for palladium substitution

However, fabricators admit that technically, it is possible to replace palladium in, firstly, palladium-rich diesel catalysts, which are widely used in North America, and, secondly, in gasoline catalysts albeit fractionally; but more development work is still needed to match the performance of the existing Pd-Rh systems. Moreover, only a small portion of palladium can be substituted in the close-coupled gasoline converters, which account for approximately 70-80% of PGM content, as platinum sinters in a high-temperature environment. The weight substitution ratio is not determined yet. Even with a proven solution, which might require more platinum than palladium, two years at the very least are needed to certify new formulations and apply them across the whole model line-up.

Palladium substitution to platinum would take at least two years to implement

At the same time, if the market faces a physical shortage of palladium, we see a chance of significant and relatively fast palladium substitution in the automotive market with as much as 1.5 moz of annual consumption being affected based on the following assumptions:

- Substitution with platinum in diesel catalysts (up to 0.5 moz with 1:1 ratio);
- Substitution with platinum in underfloor catalysts (up to 1 moz, ratio is unknown).

Palladium substitution in other industrial applications like chemical, electronics, dental, and jewellery may cumulatively reach 1 moz at most, but only a lack of the metal available for spot purchase can push consumers to start a full-scale replacement.

Platinum is undervalued and has a strong potential for price recovery.

From H2 2018 to H1 2019, the weakening rand allowed South African PGM producers to reduce operating costs and restore operating margins. However, the industry, in our opinion, is still struggling and it is clearly not in a position to increase investments enough to start growing supply. The South African PGM industry has been heavily underinvested for quite a while now, which is expectedly leading to a deterioration of the production base.

Platinum is undervalued — major risks already priced-in

We forecast that global platinum consumption in the automotive industry could eventually stabilize after two years of decline. In spite of the European diesel market remaining under political pressure, the negative impact on demand should be offset positively by the increase in loadings due to tighter environmental regulation, for both passenger cars and diesel trucks, especially in China and India. Consumption in other industries (electronics, chemical, glass industry, medicine) was strong in 2018 and is anticipated to stay strong in 2019-2020.

Major risks for platinum are already priced-in, in our view, the current extremely short market is vulnerable to any positive news, and we believe that some price recovery is likely in the near future. Investors feel that the U-turn is approaching and, taking into account the spot prices, which are near the ten-year minimum, ETF demand has grown significantly, accumulating over 800 koz of platinum in 2019 YTD. The Fed's plans to decrease the interest rates, and the gold rally, should provide some support to platinum prices. However, considering platinum's importance for the global industry and its future use in the hydrogen economy, this metal could be rightly regarded in the long run as more valuable than gold.

ETFs have accumulated more than 800 koz of platinum so far in 2019

Looking ahead, we see strong intrinsic growth opportunities in the platinum market. We see a risk for our forecast market surpluses in the medium term mainly coming from stronger-than-expected growth in the industries where platinum is a preferred metal, which could push both platinum and palladium prices higher and thus removing the cost incentive for automakers to substitute the latter with the former. We find a particularly strong argument for that given that the cumulative balance of platinum, palladium and rhodium markets is expected to be in deficit from 2021-2022.

The vehicle electrification agenda is under pressure this year raising doubts that ultra-high growth rates can be sustained in the future.

The most important move was made by the Chinese government in late March: it drastically reduced its subsidies for electric vehicles and barred provincial governments from subsidising these vehicles, with the goal to terminate the subsidy programme by the end of 2020.

Removal of subsidies may stunt EV growth rates in China

The Palladium Standard

Under the rules that took effect in late March, financial incentives for domestically-built electric vehicles were cut by some 75%. According to the government, this step was mainly designed to curb local protectionism and to prevent the automakers from relying on subsidies to prop up sales. The International Institute of Strategic Studies estimated that China spent RMB 245 billion (USD 36.5 billion) in subsidies for electrified vehicles from 2009 to 2017; and now, it is questionable whether the EV industry would be able to continue its rapid growth without such a generous governmental support. This development can impact the global EV market significantly, as about 60% of the EVs produced globally in 2018 were made in China. New Energy Vehicle (NEV) sales in July 2019 in China fell by 5% year-on-year for the first time in five years.

China accounted for 60% of global EV production in 2018

Nevertheless, we anticipate that the Chinese authorities would still like to see EV sales reaching 20% of the market in 2025 with the implementation of the Dual System — a requirement to produce a certain amount of NEVs vs. ICEs. China, which produces over 70% of Li-ion batteries for EVs, considers this as a great opportunity to become the leader of the global automotive market. ICE technology and emission-after-treatment have been historically controlled by Western companies and so far, Chinese OEMs have faced significant challenges in growing car exports and penetrating other countries.

We also believe that introduction of more stringent CO₂ limits in Europe would drive the EV penetration rates up in Europe. Overall, we expect global EV+PHEV sales to grow six-fold or more to at least 12 million vehicles in 2025. The largest bottleneck, in our opinion, is the supply of battery-grade nickel and cobalt. We estimate that over 1000 GWh of anticipated installed battery capacities (NCM-811 & NCA) will require incremental supply of over 700 kt of nickel (30% of global nickel demand in 2019) and 80 kt cobalt (50% of 2019 demand). This additional demand would come on top of large deficits in the nickel market, which are already anticipated as result of the recently announced Indonesian ban on the export of unprocessed ore coming into force on 1st January 2020. Due to the long period of weak nickel prices lasting for over 10 years, the conventional nickel miners have been significantly underinvested and will not be able to grow the supply quickly. The only countries where we believe there is a high potential to increase nickel production are Indonesia or the Philippines, where combined currently over 43% of nickel units are mined. However, the reserves even in these regions are not infinite. According to the Indonesian Ministry of Energy and Mineral Resources (ESDM), the national proven reserve of nickel in Indonesia is reported at 700 mt of ore, which is sufficient to supply local smelting facilities for just over seven years, and the launch of new capacities would only accelerate the available ore depletion. The reserves of middle/high grade ore in the Philippines are reportedly likely to be largely depleted over the next 10 years.

Global EV sales are likely to grow six-fold by 2025

Nickel and cobalt supply are the main bottlenecks to EV market growth

Nornickel's response to the palladium market deficit

As the largest metal producer with palladium contributing 40% of the company's revenue in H1 2019, Nornickel is interested in a more balanced and transparent palladium market. The company considers sustainable supply of the metal to its industrial consumers, especially in the automotive industry, as a strategic priority. Nornickel believes that the physical metal shortage poses a major risk of demand destruction. To mitigate this risk the company has engaged in a number of initiatives. First of all, Norilsk Nickel increased metal production from its own feed in H1 2019 owing to productivity gains and release of work-in-progress material at Krasnoyarsk Precious Metals Refinery. Secondly, the Global Palladium Fund (GPF) was launched to facilitate our customers' access to some of the above-ground stocks and cover some of the market deficit. In 2017-2018, the GPF delivered more than 1 moz of palladium in excess of the Company's own production, while in 2019 the Fund is aiming to purchase from 0.3 to 0.5 moz of palladium for further resale.

Palladium contributed 40% of Nornickel's revenue in H1'19

More importantly, Nornickel has started to actively explore new production growth opportunities. It has already indicated its potential production growth ambitions in the medium and long term, based on the development of the resources of the Talnakh deposit and the South Cluster project. In March 2019, the Company made the final investment decisions regarding the expansion of the Talnakh Concentrator as well as the development of the South Cluster mining project.

Nornickel is exploring new growth opportunities at Talnakh and South Cluster

The Talnakh Concentrator has been approved for expansion (Talnakh Phase-3 project), which targets an increase of throughput capacity to 18 mtpa from the current 10 mtpa and a rollout of a new and more efficient enrichment technology. Upon the project completion, all of the ore mined at the Talnakh deposit will be processed at the Talnakh Concentrator, which should yield economies of scale and improve overall recovery rates in the concentration process. The project is planned for commissioning in 2023. Upon Talnakh Phase-3 completion, the Talnakh Concentrator should become the world's largest concentrator for nickel sulphide ores. Treating the Talnakh ore at a single concentrator will free up the capacity at the Norilsk concentrator to treat the feed coming from the South Cluster project.

The South Cluster is a mining project developing the Northern part of the Norilsk-1 deposit — the very same ore body that gave birth to Norilsk Nickel back in the 1930s. The project will give this heavily depleted deposit a new life. The total mineable resources of disseminated ore at the South Cluster amount to 165 mt. The ore mining capacity is scheduled to reach 9 mtpa by 2027 with an 75% share of PGMs in the basket value at spot prices. Since Nornickel has all the infrastructure in place, the stripping works were launched in 2019, while the mine ramp-up is expected to start in 2021-2022. In the first phase of the project, the existing open pit mine will be expanded while the underground mine revamp is scheduled for the second

The Palladium Standard

phase. The Company is expecting additional annual production of over 20 tonnes of PGMs at full capacity of South Cluster, as well as some nickel and copper as by-products.

The Company also plans the development of a number of brownfield projects at the Talnakh deposit, which, combined, should increase the ore output from this deposit to 19 mtpa by 2025 from 15.7 mt in 2017. Mine expansion is planned at several existing mines (Oktyabrsky, Komsomolsky, Skalistaya as well as other smaller mines), with all of the mined ore to be treated at the Talnakh concentrator. Talnakh expansion projects have been already started this year.

The South Cluster and Talnakh brownfield expansions are expected to add over 25% to the Company's PGM production volumes by 2025, compared to 2017. These PGM production growth plans should meet the rising industrial demand for PGMs, particularly palladium.

Expansions are set to add >25% to Nornickel's PGM output by 2025

In addition, the Company has a major 'blue sky' mining growth opportunity in PGMs under consideration, Arctic Palladium, a 50/50 joint venture between the Company and Russian Platinum, which was formed last year. Nornickel is contributing its Maslovskoe deposit licence while Russian Platinum brings its licences for the south flank of Norilsk-1 and Chernogorskoe deposits to the JV. Arctic Palladium aims at becoming one of the world's largest PGM producers. The project's investment approval is to be made after the completion of a scoping study in Q1 2020.

Nornickel also has a major 'blue sky' growth opportunity – Arctic Palladium

Subject to the investment approval, the first metal from the ore recovered during the pre-stripping works and mine development is expected to be produced in 2021-2024. However, the volumes of PGM production at Arctic Palladium will require construction of a new concentrator and a new smelter as well as supporting infrastructure. Hence, large-scale PGM production at the project is expected to start in 2025 at the earliest.

The Company will provide an update on the status of the South Cluster and Arctic Palladium projects during the Investor Day to be held in London in November 2019.

POWERTRAIN Metals Quarterly

You know us for autocatalyst chemistries...

....come and get to know us for battery technologies and materials too.



Five circular icons, each mounted on a small four-wheeled base, are arranged in a cluster. The icons represent: 1) A green battery with a plus and minus sign. 2) A blue industrial factory with smokestacks. 3) A blue battery pack. 4) A blue car with a charging cable plugged into its front. 5) A blue hammer and pickaxe tool. The icons are set against a background of light trails from the highway interchange.



3 Li Lithium 6.941	24 Cr Chromium 51.9961	27 Co Cobalt 58.933195	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966589
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Independent insight into the changing nature of markets and prices,
and the likely impact of automotive technological advances

**ARE BEVs ABOUT TO PULL
THE PLUG ON PALLADIUM?**



Are BEVs about to pull the plug on palladium?

Lakshya Gupta, Battery Materials and Technologies Analyst, SFA (Oxford) Ltd

“... and with right this age can claim the name ‘Age of Electricity’.”

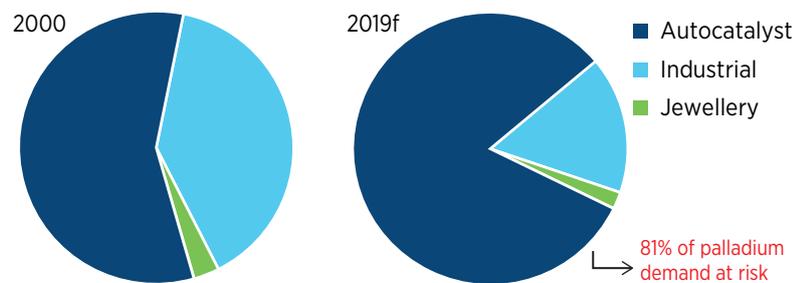
Tesla (Nikola), 12 January 1897

Over 122 years ago Nikola Tesla spoke at a banquet in Buffalo, USA, celebrating the first hydro-electric power plant transmitting the alternating current (AC) that he created from Niagara Falls. His vision came by the torrent: “The past few years have brought forcibly to the attention of the builder the electric motor, with its ideal features. Here was a mode of transmitting mechanical motion simpler by far, and also much more economical. Had this mode been perfected earlier, there can be no doubt that, of the many different types of engine, the majority would not exist.”

Today, battery electric vehicles, or BEVs, are the (baby) elephant in the room during any conversation about palladium. How close BEVs are to mass adoption will determine how soon the now 81% of palladium used in autocatalysts suffers a major shock, as BEVs are a much ‘simpler transmitter of mechanical motion’, emission-free, and cutting out the catalyst completely.

Battery electric vehicles are the elephant in the room during any conversation about palladium

Palladium demand by end-use

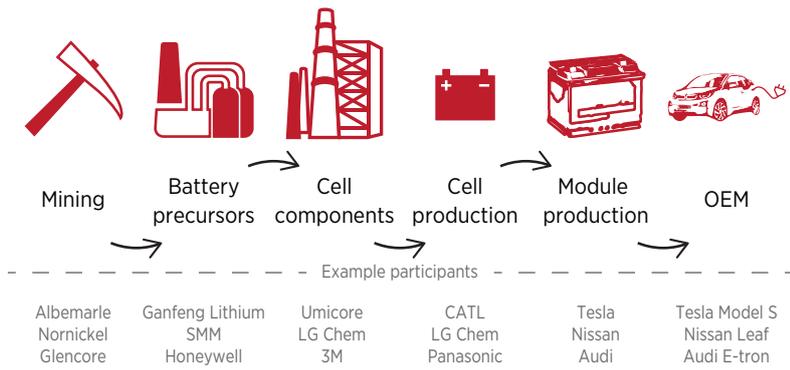


Source: SFA (Oxford)

BEVs will cause a major shock to palladium demand

All stakeholders — end-users, PGM producers, investors — have much to gain by staying ‘current’ in the ‘electric revolution’. So here we attempt to shed light on the complexities of battery technology with a special focus on cathodes.

Lithium-ion battery supply chain



The battery supply chain for BEVs is fragmented, with limited vertical integration

Source: SFA (Oxford)

Battery basics

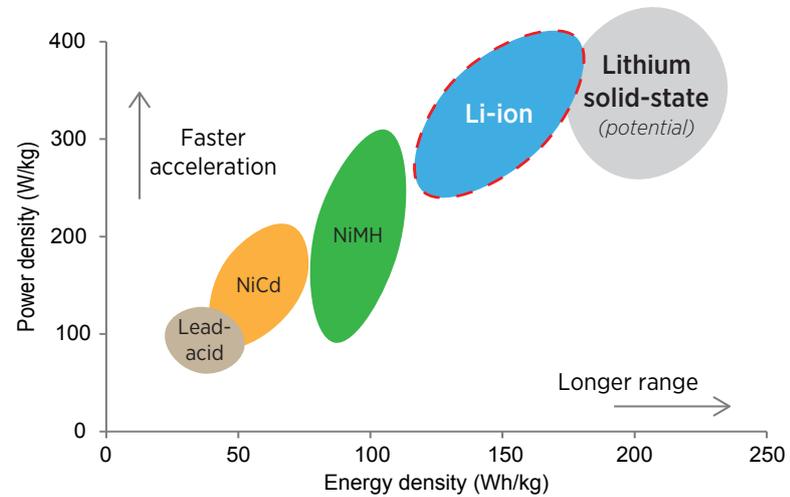
Batteries are certainly not a recent invention. In fact, the first battery, the voltaic pile, was invented in 1800 and the first rechargeable battery, the lead-acid battery, followed in 1859. Since then, there have been numerous technological developments to improve performance, with the most relevant to today being the lithium-ion (Li-ion) battery that was initially commercialised by Sony in 1991.

Sony commercialised the first lithium-ion battery in 1991

Lithium is the lightest metal with the greatest electrochemical potential, giving it the highest theoretical energy density. This gives Li-ion batteries improved energy and power densities compared to other rechargeable batteries, namely lead-acid and nickel-metal hydride (NiMH). Please note, the performance envelope for nickel cadmium batteries (NiCd) is included in the chart below for completeness but these were rendered obsolete in the 1990s by NiMH due to NiCd's poorer performance and high environmental impact caused by the disposal of toxic cadmium.

Lithium is the lightest metal and has the greatest electrochemical potential...

Lithium-ion battery supply chain



... making lithium-based batteries the ideal choice for BEVs

Source: SFA (Oxford), Battery University

The Palladium Standard

Fundamentally, every battery has the same four basic components, regardless of its cell chemistry: cathode, anode, electrolyte and separator. Their functions in a Li-ion battery are summarised in the table below. Battery performance is determined by the materials of these components.

Fundamental components of a Li-ion battery

Component	Function
Cathode	Accepts lithium (Li ⁺) ions during battery operation
Anode	Emits Li ⁺ ions during battery operation
Electrolyte	Acts as a catalyst to facilitate the flow of Li ⁺ ions between electrodes during operation
Separator	A semi-porous physical barrier between the electrodes that prevents a short circuit in the cell, while allowing the flow of Li ⁺ ions

Source: SFA (Oxford)

Every battery has the same four basic components

Lithium-ion batteries

For all batteries, their performance is determined by the material composition of the four battery components. Today's performance variance between Li-ion batteries is mostly caused by differences in the cathode materials. As the most expensive cell component, cathodes have been the focus of intensive R&D efforts to reduce battery production costs.

As the most expensive components, cathodes have been the focus of intensive R&D

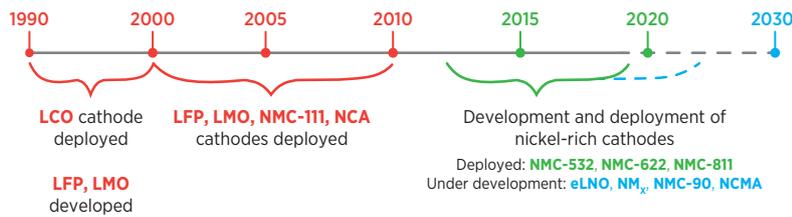
Cathode active materials (CAMs) vary, based on required performance specifications. The first Li-ion battery used a lithium cobalt oxide (LCO) cathode — its high energy density made it highly suitable for consumer electronics where it is still commonly deployed. However, low power density and high cobalt loadings (at prevailing cobalt prices) make LCO unviable for BEV batteries.

Presently, nickel-based cathodes are seen as the answer for BEV batteries as they offer an acceptable compromise between battery performance, life and cost. Nickel manganese cobalt oxide (NMC) and nickel cobalt aluminium oxide (NCA) cathodes have become the industry standard, with NMC being more widely preferred.

Nickel-based cathodes offer an acceptable compromise between battery performance, life and cost

NMC provides OEMs with further flexibility as the ratio of nickel, manganese and cobalt can be varied to customise battery performance. Initial formulations used equal ratios of the three metals (NMC-111), but cost reduction efforts have led to cobalt thrifting with OEMs gradually shifting to higher ratios of nickel.

Timeline of Li-ion cathode developments



Source: SFA (Oxford)

Despite an initial preference for lithium iron phosphate (LFP) cathodes, China started to switch towards NMC in 2017, recognising that LFP will struggle to meet the energy density requirements needed to abate range anxiety in consumers, a prerequisite for mass adoption. New Energy Vehicle (NEV) subsidy criteria were tightened in 2017 to squeeze out BEVs using LFP batteries.

LFP lost market share to NMC in China...

However, the NEV subsidy reductions announced in H1'19 have resulted in a resurgence of demand for LFP batteries, especially in (but not limited to) the E-bus segment. This is caused by NMC-based BEVs being unable to compete on sticker price in the absence of government aid.

... but demand resurgence is likely as NMC struggles to compete without subsidies

All about the cathode

There have been limited non-cathode developments in Li-ion batteries. Anodes are typically composed of graphite, with some recent formulations adding silicon to improve capacity, and electrolytes are made up of an organic solvent containing lithium salts such as lithium hexafluorophosphate (LiPF₆).

Limited developments in other battery components

As a major consumer of various metals, battery cathodes are a key component in understanding how metal requirements will change with the increasing market penetration of BEVs. Keeping track of new cathode developments, and critically assessing their time to market, is crucial in calculating strategic metal requirements and estimating BEV adoption rates.

The market consensus is that BEVs will reach price parity with traditional internal combustion engine cars when battery packs cost \$100/kWh. Mathematics dictates that there are two ways to achieve this:

1. Reduce the numerator – lower manufacturing costs through savings in the bill of materials and/or economies of scale.
2. Increase the denominator – improve energy density.

Two ways to reduce battery costs

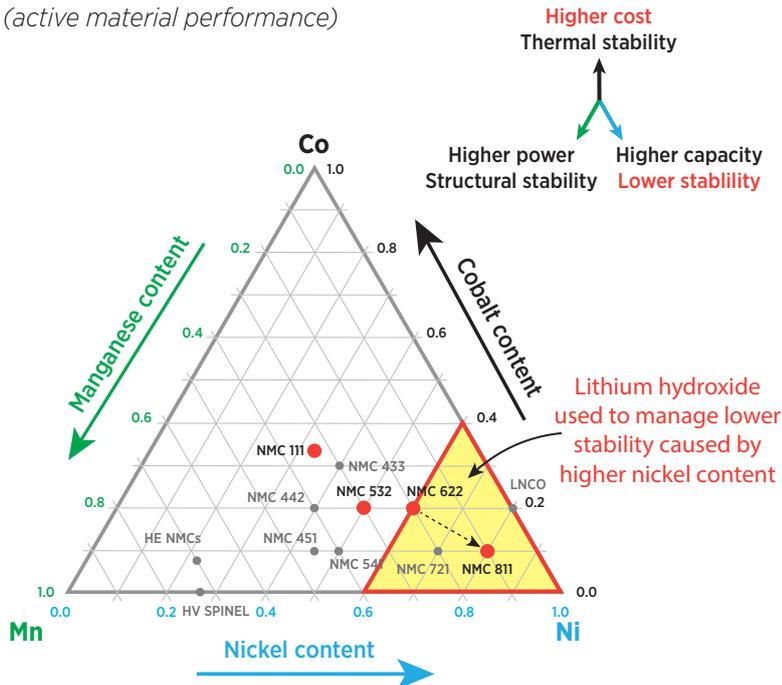
The Palladium Standard

This is another reason why the NMC development route evolved as it did — a higher ratio of nickel in the CAMs achieves both criteria simultaneously: a reduction in the bill of materials and improved energy density (see the diagram below). The trade-off in battery performance (lower cathode stability) is not an issue as consequences can be managed/mitigated, for example, through the use of a higher performance lithium precursor during cathode fabrication (i.e. lithium hydroxide).

Increasing nickel content achieves both cost reduction criteria simultaneously...

NMC phase diagram

(active material performance)



Source: SFA (Oxford)

... at the cost of battery life...

... but consequences can be managed through higher performance precursors

Rapidly shifting market dynamics

SFA (Oxford) has over 10 years' market experience of battery metals, especially lithium. However, production of our new 'Powertrain Metals Quarterly' has given us an unprecedented appreciation of the rate of change in the EV market within six months (first two issues).

EV market developments occur at a rapid pace

Perhaps it is the fragmented nature of a value chain with limited vertical integration, but we have found that, despite extensive media exposure, news announcements about BEVs are often inadequately precise about the impact on underlying metals.

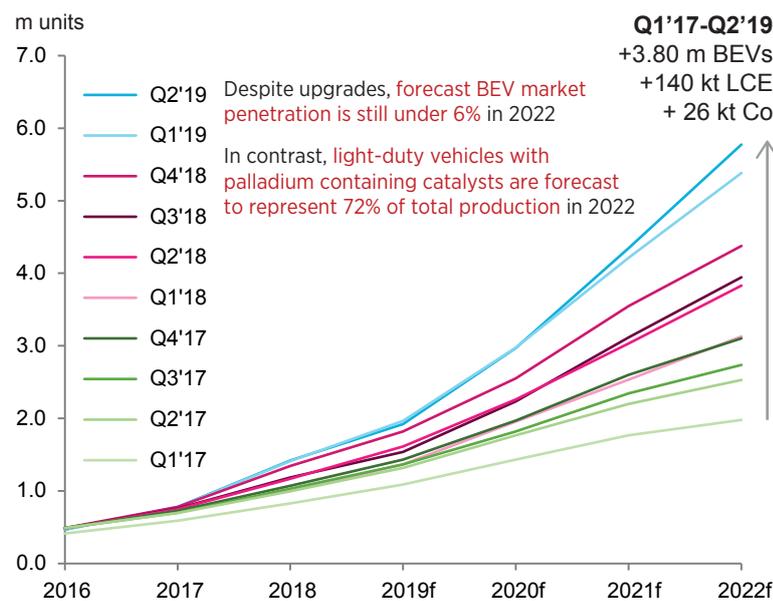
For example, at the end of July, India committed to procuring 5,000 electric buses. Omitted from headlines (and subsequent articles) was the fallout for battery commodities — 1 kt of lithium carbonate

equivalent (LCE) additional demand in a roughly 300 kt market (globally, 2019f). That is a margin of error, not a headline.

BEV production forecasts alone vary significantly quarter-on-quarter. Since 2017, the BEV production forecast for 2022 has been increased by an average of 425,000 units every quarter. This means that predictions for lithium demand from BEVs (in 2022) have, on average, been increasing by 14 kt LCE every quarter since Q1'17 (an average BEV battery pack today contains roughly 35 kg LCE).

2022 BEV production forecast upgraded by 425,000 units on average, every quarter since Q1'17

BEV production forecasts – Global



Source: SFA (Oxford), LMC Automotive

These upgrades are based on a single variable — OEM production plans. Compounded with other factors such as next-generation cathodes, evolving subsidy regimes and concern over ethical supply of key minerals, it becomes apparent that the seemingly innocuous question of “How close are we to being plugged in to BEVs?” is anything but that. One thing is apparent though: with palladium-containing vehicles representing over 70% of total light-duty vehicle production, there is no short circuit for palladium demand just yet.

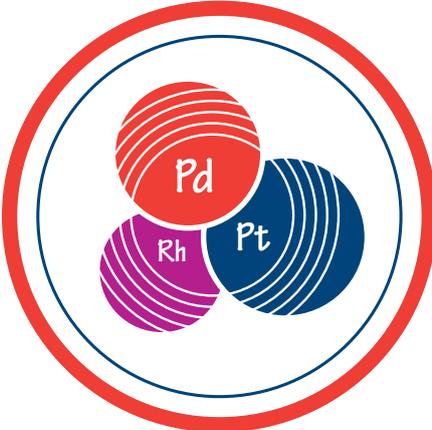
Gasoline vehicles with palladium represent 72% of light-duty vehicle production (2022f)...

... no short circuit for palladium demand just yet

And as Nikola Tesla reminded us over a century ago, almost everything in science is in flux: "... we have something much better to work for, a greater task to fulfill. We have to evolve means for obtaining energy from stores which are forever inexhaustible, to perfect methods which do not imply consumption and waste of any material whatever."

SFA (Oxford)'s new Powertrain Metals Quarterly keeps track of critical developments arising from the rapid rate of change in battery technology, its associated supply chain and the underlying impacts for the battery commodities.

**THE PGM MARKETS
IN 2019**



The PGM markets in 2019

Beresford Clarke, Director of Research, SFA (Oxford) Ltd

The palladium market

Summary

SFA forecasted a \$1,500/oz palladium price target for 2019 which has been achieved. The price is up 16% so far in 2019 at \$1,470/oz and is over 60% higher than at the time of the publication of *The Palladium Standard* in September 2018. That's almost a \$500/oz price increase.

However, palladium lease rates have normalised compared to the excessive levels seen earlier this year and automotive sales have weakened in major palladium-consuming markets suggesting increased availability of metal.

Although the deficit is forecast to narrow to 570 koz in 2019 (mainly owing to supply increases), compared to over a million ounces in 2018, the market has absorbed over 7 moz of stock since 2010 so remains fundamentally tight. Furthermore, the promulgation of China 6a standards nationwide in July 2020 is set to lead to double digit increases in palladium loadings. Some 15 major cities in China have brought the emissions deadline forward to July 2019 to tackle excessive pollution levels, leading to a major increase in palladium requirements, even with a drop in vehicle sales.

Global ETF holdings are down 130 koz in 2019 to only 570 koz after peaking at over 3.1 moz in 2014, so may no longer be relied upon as a source of stock to fill end-user orders if holdings continue to fall.

Mine supply

Refined production of palladium is forecast to grow strongly in 2019 by 5% to 7.3 moz. All regions, except Zimbabwe, are expected to raise their output of palladium this year. Work-in-progress concentrate stocks from 2018 added to higher grade ore mined in 2019 are boosting output.

Similarly in South Africa, mine supply is forecast to grow just 2% to 2.55 moz in 2019, but the build-up of work-in-progress concentrate from smelter outages and new builds is set to lift refined production by 6% to 2.64 moz.

The palladium market has absorbed 7 moz of stock since 2010

Only 570 koz of palladium left in ETFs

Strong growth of palladium supply

The Palladium Standard

The recovery at Stillwater and ongoing ramp-up of the Blitz mine, as well as higher production from nickel mines in Canada, is projected to lift supply from North America by 5.8% to 1.09 moz.

Recycling

For the last two years palladium recycling has grown by an average of 6.5% and is projected to increase by a further 5.4% in 2019. High palladium prices and the strong rise in rhodium prices continue to motivate collection of gasoline three-way catalysts, particularly from the middle of the year as rhodium prices accelerated. Autocatalyst recycling of palladium is therefore forecast to increase by 140 koz (7%) year-on-year to 2.18 moz.

Another year of >5% growth in recycling

Demand

Global demand for palladium is forecast to reach 10.5 moz for the first time in 2019. Non-automotive industrial demand continues to contract, falling by a further 3.1% in 2019 to 1.72 moz as higher palladium prices continue to force industrial users to thrift and switch away from palladium use. Automotive demand's share is therefore forecast to grow to 82% of total palladium demand.

Automotive demand

Against headwinds of falling vehicles sales in major palladium-consuming countries, as well as excessive vehicle inventories, light vehicle production is set to fall by more than 1 million units in China and 200,000-400,000 units each in Europe, the US and Japan. The net result is a reduction of over 2 million units manufactured worldwide in 2019 according to LMC Automotive.

Automotive palladium demand is still growing, even with falling auto sales

Against this backdrop, palladium demand in autocatalysts is still forecast to grow by 85 koz in 2019 to 8.6 moz. Almost all the growth is in China, where tightening emissions standards continue to lift the use of palladium. China 6a standards ('Stage 6'), which come into force on 1st July 2020, require a significant reduction in carbon monoxide emissions leading to increased loadings of palladium. Some cities, such as Shanghai and 14 other major cities, have accelerated the promulgation of China 6 standards by bringing them in a year early on the 1st July 2019. This has further boosted loadings of palladium, but has also impacted vehicle sales in the resulting consumer confusion and high inventories of unsold China 5 compliant vehicles in those cities.

Industrial demand

Palladium use is forecast to fall by 3% year-on-year to 1.72 moz in 2019. Substitution and thrifting (through downsizing) in various electrical components accounts for a 25 koz reduction in demand to 830 koz, while substitution away from palladium-based dental alloys is set to accelerate in Japan, the US and Europe due to high prices, cutting requirements by 45 koz to 290 koz. Minor growth is forecast in chemical demand (+10 koz) to 480 koz, mainly due to new capacity for the production of purified terephthalic acid (PTA) and monoethylene glycol (MEG) in China and India lifting new catalyst purchases. Finally, 'other' demand, which includes end-uses such as petroleum catalysts and medical alloys, is estimated to remain flat at 120 koz, despite a fall in net petroleum requirements.

High prices are leading to reduced palladium usage

Regionally, industrial demand for palladium is falling in every country except China, where minor growth of 5 koz is forecast. The largest decline is expected in Japan (-25 koz), primarily due to the contraction in dental demand.

Investment

Palladium ETF holdings have continued their declining trend. Global holdings are down 130 koz to 570 koz so far in 2019. The majority of the outflows were in Switzerland (-60 koz), followed by South Africa (-40 koz), the UK (-20 koz) and the US (-10 koz). ETF holdings are now over 2.5 moz down from peak levels in 2014.

When palladium prices hit \$1,600/oz for the second time in 2019 in July the large specs' long position on NYMEX was lower than in March (the previous price spike), showing that speculators have little interest in chasing the rally.

The net long position on is currently 1.0 moz, down from 1.3 moz in July. Both long and short positions have slipped back as the price has come down.

The platinum market

Despite weakening fundamentals for platinum (supply vs industrial demand plus jewellery) in 2019, investors have more than offset the changes year-on-year. SFA's market balance before ETFs added up to 715 koz in 2018 and is set to grow to 1.26 moz in 2019. However ETFs, which supplied metal back to the market in 2018 (245 koz), have absorbed 860 koz so far in 2019, this will drop the oversupply (including ETF holdings) to 400 koz.

Investors are helping to offset a weakening platinum market

Demand (excluding investment) is forecast to drop to 7.1 moz in 2019, a reduction of 3% year-on-year. Jewellery continues to be the weakest of the three pillars of demand, the others being automotive and industrial.

Chinese platinum jewellery demand is forecast to drop to just a million ounces in 2019, which is half the level of peak demand in 2013. Nonetheless, China still accounts for 45% of jewellery demand. Jewellery demand growth in India is estimated at 10% year-on-year to 220 koz in 2019, which is too small to offset the drop in demand in the world's major jewellery consumer.

China jewellery demand in 2019 is half what it was at peak levels

Jewellery demand in Japan is forecast to fall 5 koz year-on-year. The new reign of Emperor Reiwa is likely to temporarily boost the number of marriages in 2019 as couples seek to mark the coming of the new era, but demand might be front loaded during the year if the proposed sales tax hike comes into effect in October. Demand in the USA and Europe is forecast to increase by 15 koz and 5 koz respectively where lower platinum prices are boosting metal demand despite a more difficult jewellery retail environment.

Western European automotive demand fell by 410 koz between 2016 and 2018 owing to a drop in diesel share from over 50% to 36%. However, a bounce-back in diesel shares in Germany and a slower decline in diesel sales indicate that diesel shares will settle just above 30% in 2019. Autocatalyst demand is forecast to drop by 110 koz year-on-year to 1.2 moz, which is less than half the decline in 2018. Global autocatalyst demand is forecast to fall 4% year-on-year to 3.0 moz. Growth in the emerging markets (+15 koz) and North America (+15 koz) is helping to offset some of the fall in Western Europe, Japan (-20 koz) and India (-10 koz).

A further decline in autocatalyst demand is expected in 2019 (but half the fall in 2018)

Non-autocatalyst industrial demand is forecast to remain flat at 1.9 moz despite growth (70 koz) in China, mainly due to new chemical plants for paraxylene and propane dehydrogenation production.

Primary supply is projected to grow by 245 koz year-on-year in 2019 as the build-up of working inventories in South Africa and Russia in 2018 (from smelter builds, outages and maintenance) are smelted and refined and added to mine output in 2019. Without work-in-

The Palladium Standard

progress stocks, refined mine production from 2019 is set to remain flat year-on-year. A slight reduction in supply from South Africa to 4.25 moz, is offset by growth in all other major producing countries.

Platinum recycling is forecast to increase by 65 koz to just under 2 moz in 2019. Jewellery recycling is set to dip slightly to 490 koz owing to cooling demand in China, while autocatalyst recycling is estimated to grow by 75 koz to 1.5 moz. Higher palladium and rhodium prices continue to ensure a highly efficient collection network, despite bottlenecks in dealing with more challenging silicon carbide based diesel particulate filters in Europe.

Primary platinum supply is forecast to grow by 245 koz because of excess concentrator stocks

The rhodium market

The market is forecast to be in surplus by 30 koz in 2019, which appears to be against the current strong price rally. However, whether the market is in deficit or surplus during the year is highly dependent on the timing of work-in-progress stock releases of just over 50 koz built up due to smelter outages, new builds and maintenance. Rhodium takes much longer to process than platinum and palladium, so market relief could shift into the backend of H2'2019.

Oversupplied, but is back-loaded to the end of 2019

Meanwhile, stronger automotive demand ahead of another bout of tightening emissions standards in China (China 6b, which requires increased rhodium loadings to meet tighter NO_x standards by 2023) and stringent Real World Driving emissions standards (RDE) in Europe is leading to overloading to ensure compliance. So a mixture of strategic buying, increased demand and supply timing challenges are leading to a period of strong price appreciation.

Stronger automotive demand in China brings in tighter emissions standards

Automotive demand is forecast to increase by a further 20 koz in 2019 to 935 koz. This is primarily due to increased usage in China (+15 koz) despite falling auto sales. Non-autocatalyst industrial demand is set to drop by 10 koz in 2019, partly offsetting growth in autocatalyst demand, and leaving global demand forecasts up 10 koz at 1.14 moz. Rhodium ETF holdings were 27.3 koz at the time of writing, a further 10 koz down in 2019 year to date.

Primary supply (including work-in-progress stock processing) is forecast to increase by 35 koz to 810 koz in 2019, of which most of the rise is from South Africa and the remaining additional supply is from North America. Almost all the extra supply is due to processing of concentrate stocks, with underlying supply remaining flat year-on-year. Autocatalyst recycling is forecast to grow by 20 koz to 355 koz in 2019, which is a result of higher metal prices for both rhodium and palladium with the majority of the increase coming from North America.

The price outlook for the next six months

Palladium \$1,450/oz

The market deficit is narrowing in 2019 on a combination of primary supply growth, flat demand and increasing recycling. A significant one-off impact is the released metal from work-in-progress stocks this year, which is ongoing in H2. Higher loadings in China are helping to offset weaker car sales and lifting automotive demand, but industrial demand is slipping leaving overall demand little changed this year. Sales from ETFs and from Nornickel's Global Palladium Fund are filling most of the deficit for now. Market tightness has eased somewhat and palladium looks richly priced at current levels, so could pull back in the near term.

In deficit but little demand growth

Platinum \$900/oz

The platinum price has recently caught a bid, despite a weaker rand and a fundamental picture that has not improved. The market has a significant surplus and even ETF investors' best efforts have not been enough to soak up all the excess metal.

No improvement to fundamental picture

The high palladium and rhodium prices are encouraging restarts at previously mothballed mines and are keeping what were marginal shafts and mine sections open longer, thus adding to platinum's overproduction. The rate of decline has eased somewhat for automotive demand, but another drop is expected this year, and jewellery demand in China is still weak and likely to decline yet again.

The gravity of a major market surplus is expected to exert itself on the price and pull platinum lower.

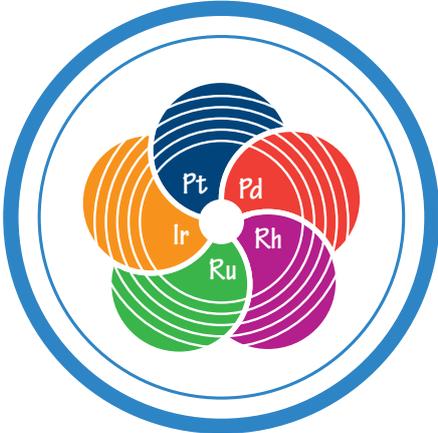
Rhodium \$4,500/oz

The rhodium price rise recently went parabolic and this is not sustainable. Tightening emissions legislation has made rhodium a strategic necessity, which seems to have set off a scramble for the metal. However, the market is projected to have a small surplus this year owing to work-in-progress stocks that are making their way through the processing pipeline. The high price is also crimping non-automotive uses and encouraging more supply from South Africa.

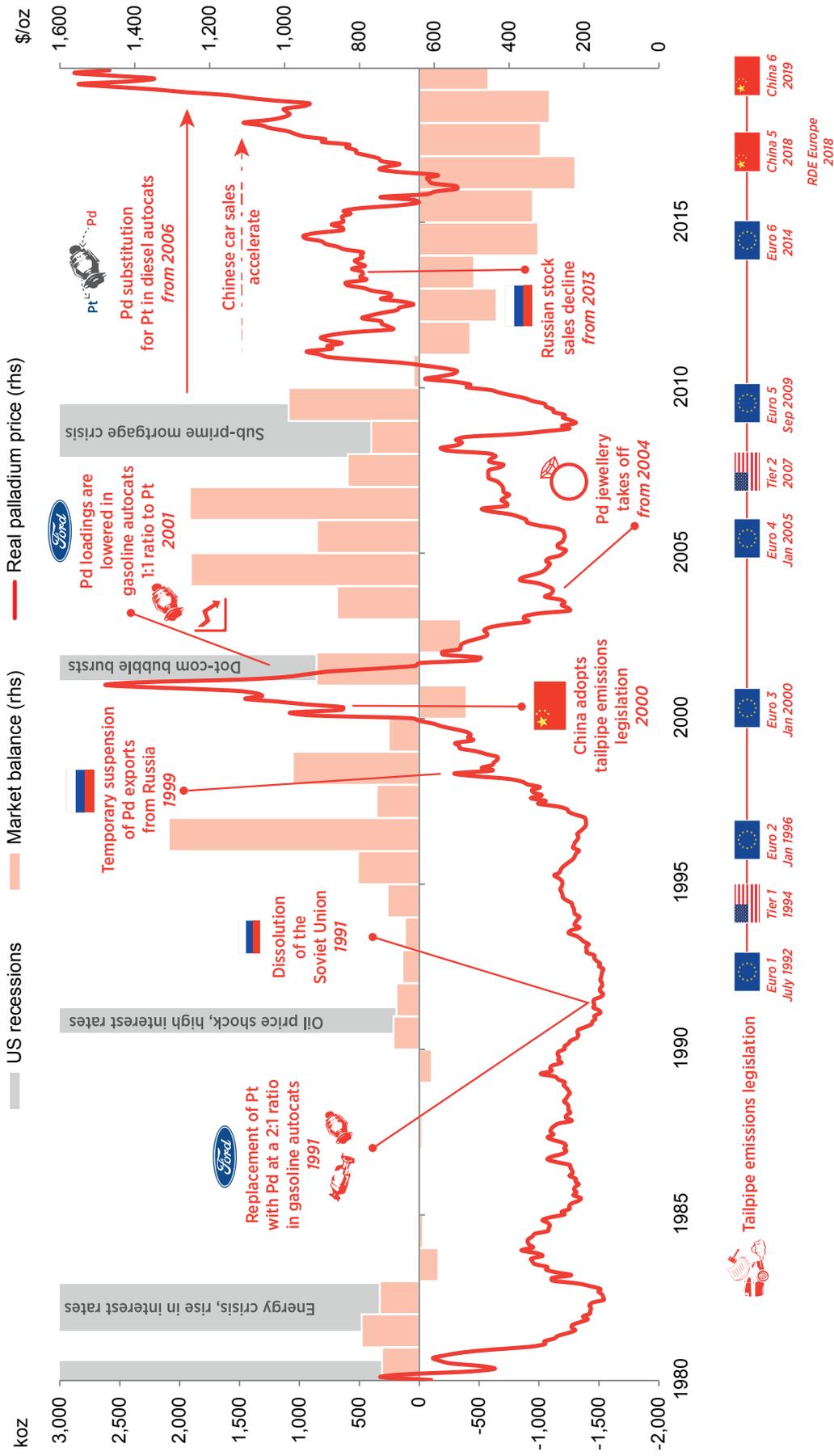
Market is tight

A reset lower is anticipated for the price in the near term, before the demand pull lifts the price again.

PGM PRICE HISTORY

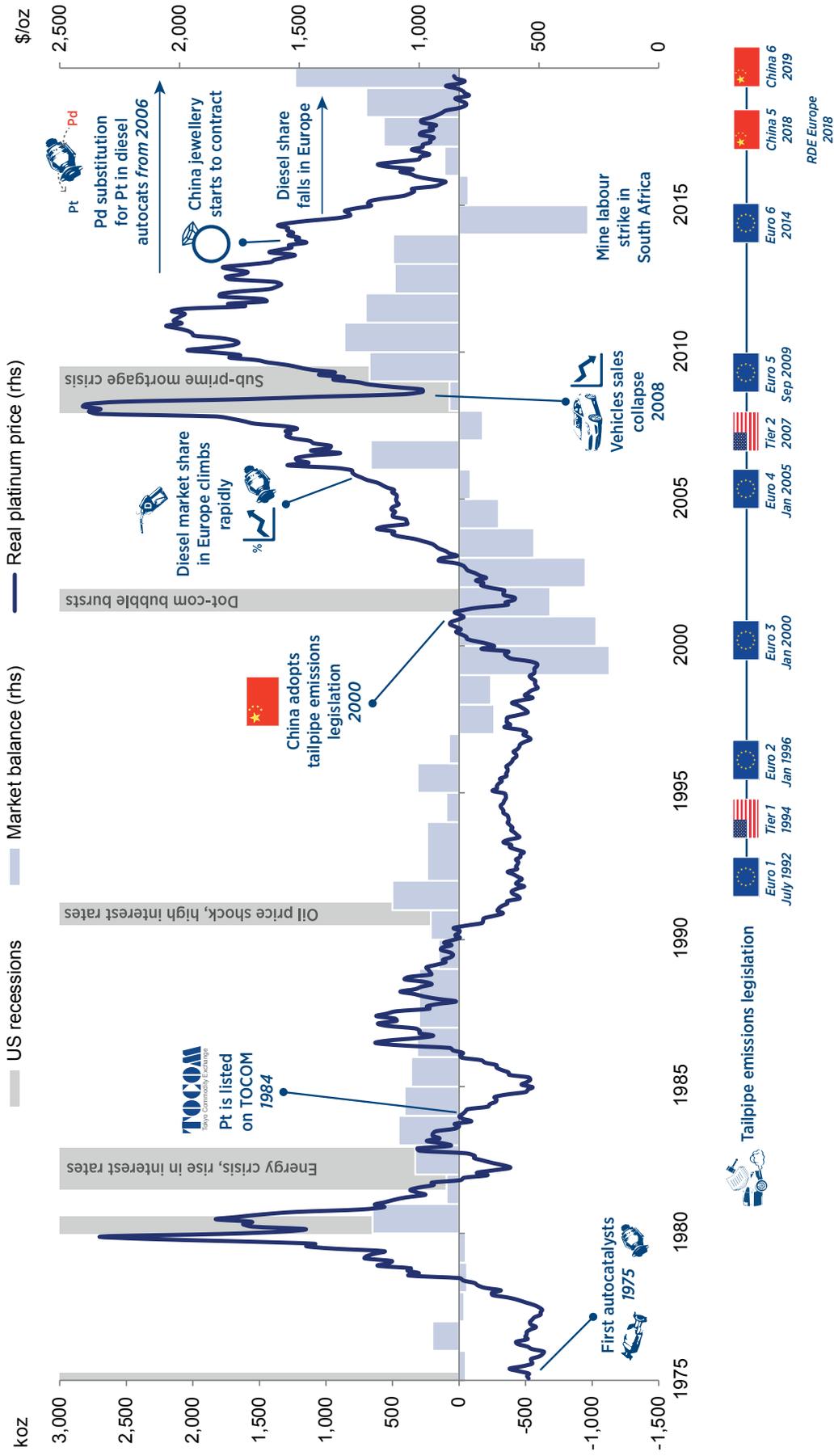


Palladium



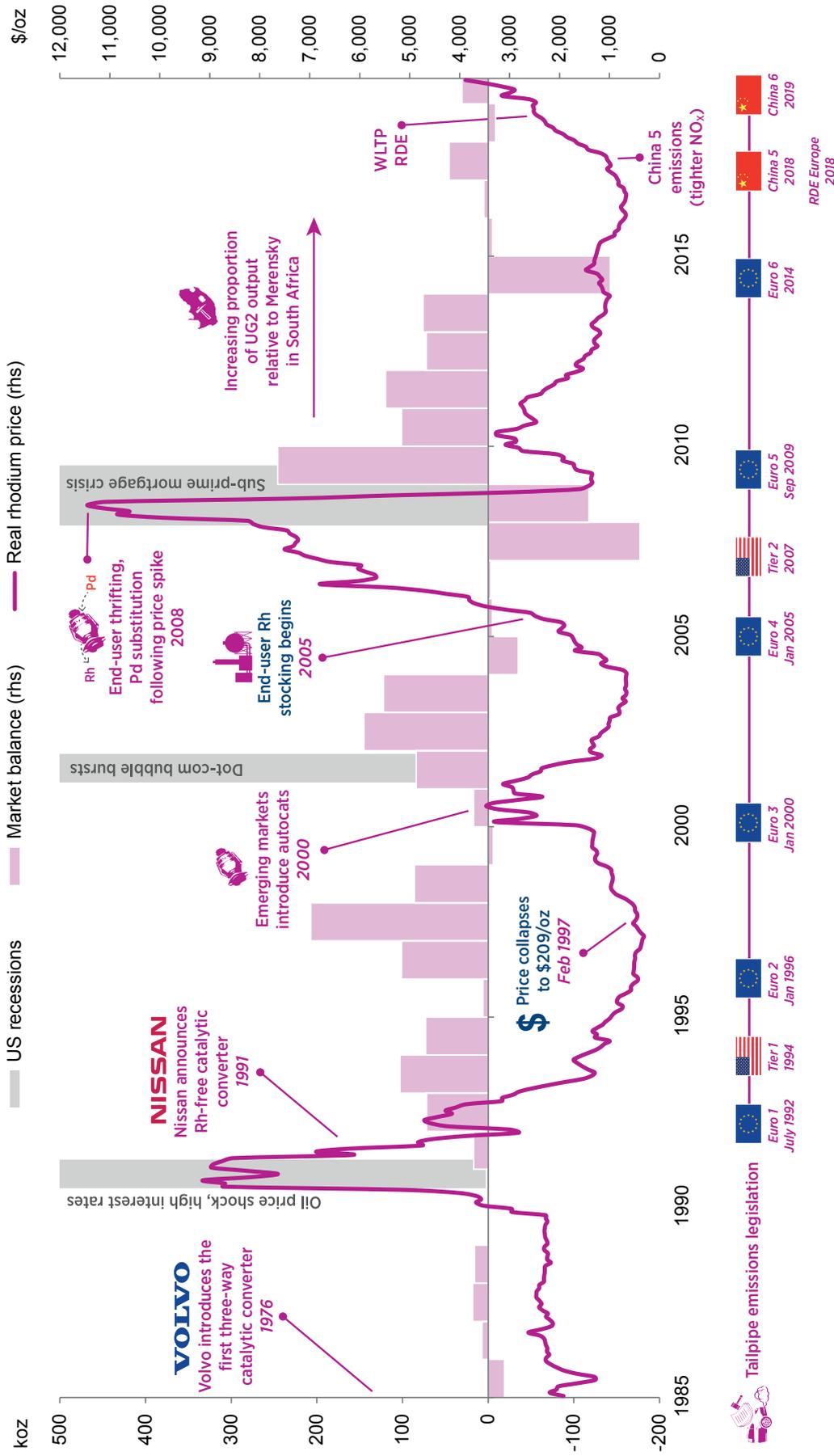
Source: SFA (Oxford)

Platinum



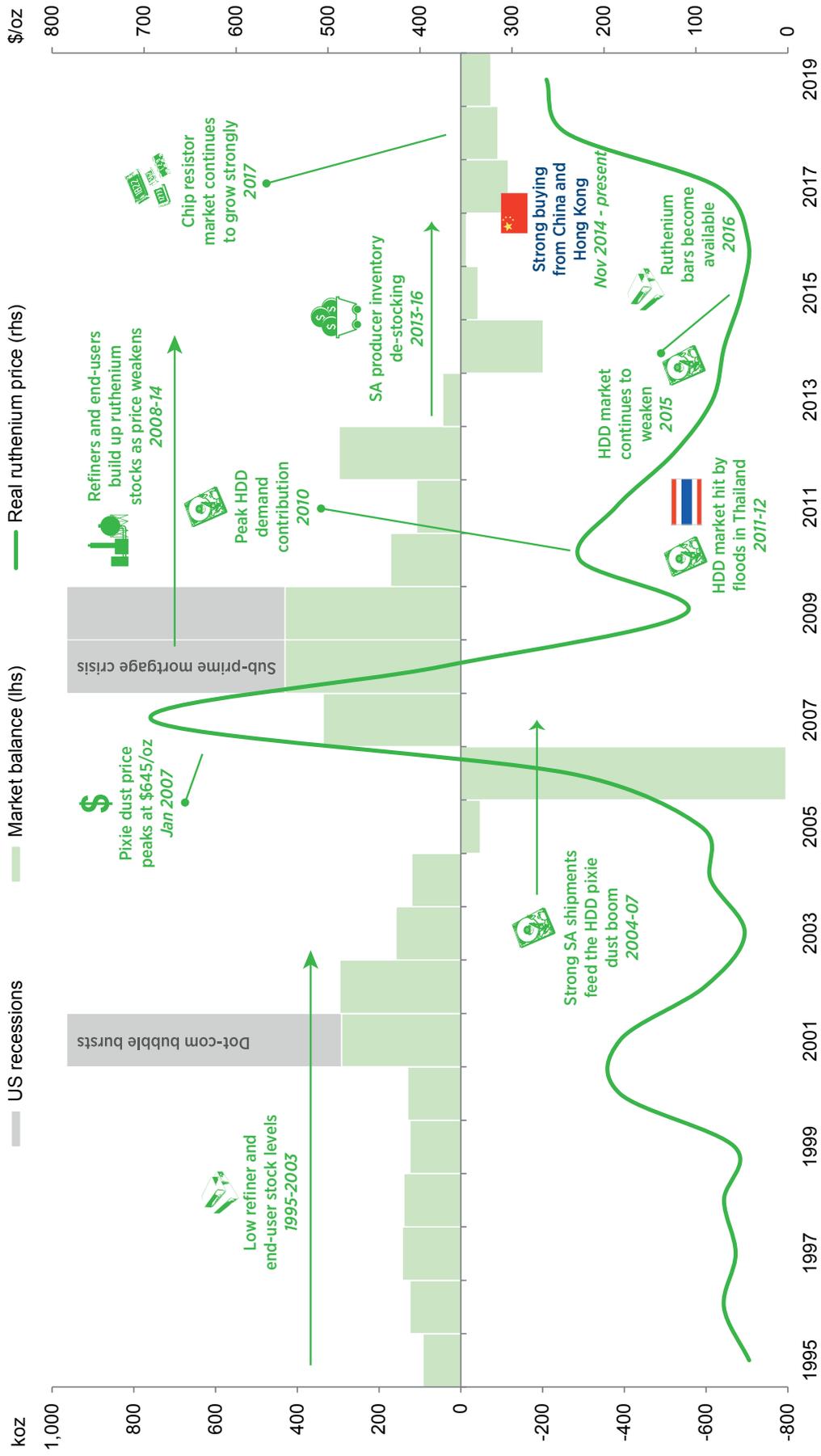
Source: SFA (Oxford)

Rhodium

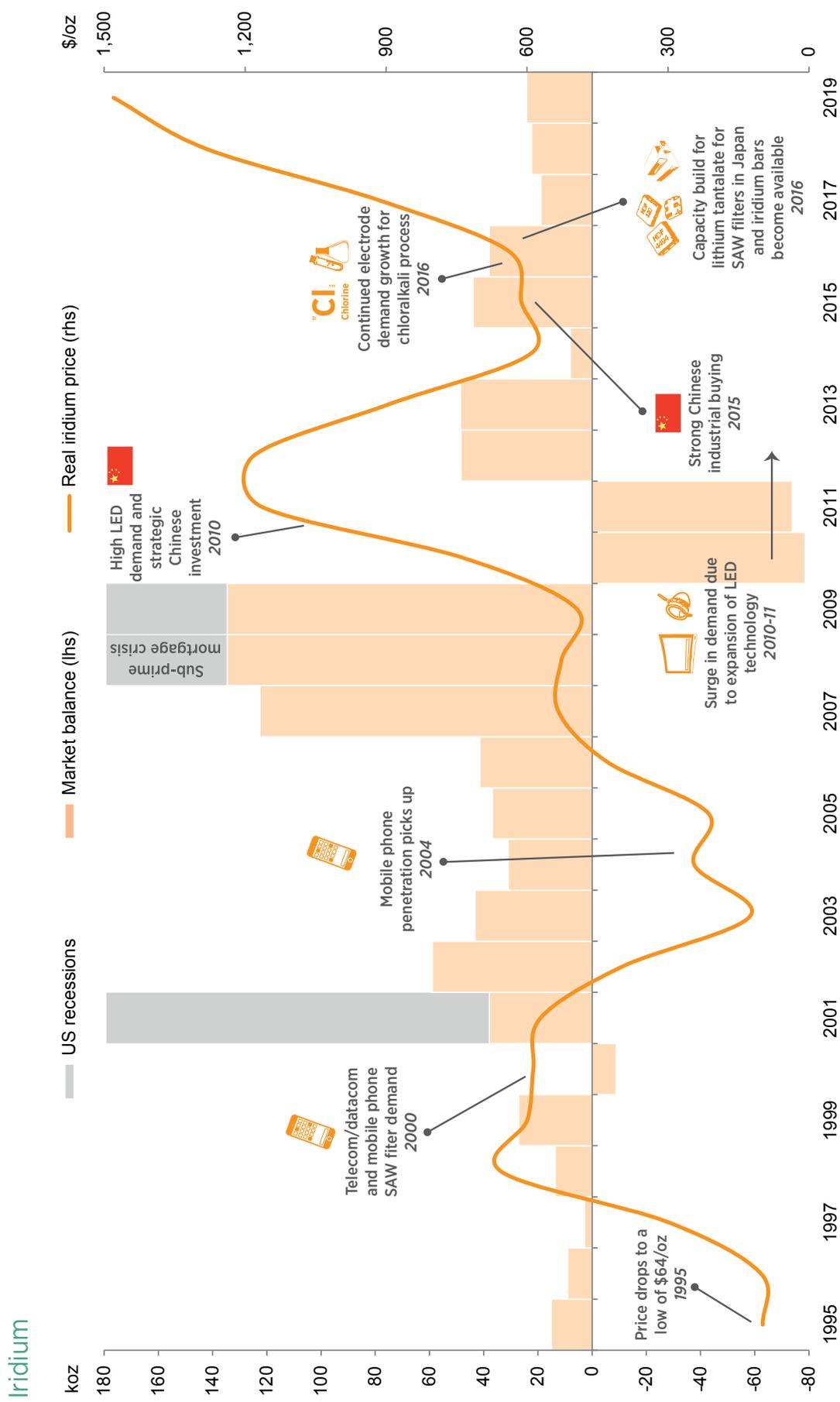


Source: SFA (Oxford)

Ruthenium



Source: SFA (Oxford)



Source: SFA (Oxford)

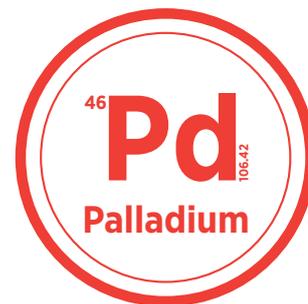
APPENDIX



Palladium supply-demand balance

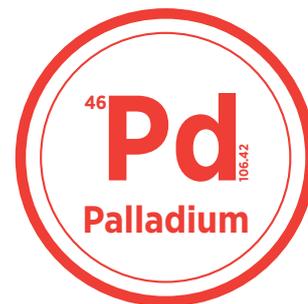
koz	2011	2012	2013	2014	2015	2016	2017	2018	2019f
Primary supply									
Regional									
South Africa	2,550	2,355	2,360	1,855	2,570	2,365	2,540	2,485	2,635
Russia	2,705	2,630	2,580	2,690	2,605	2,555	2,740	2,670	2,800
Zimbabwe	265	280	315	330	325	395	395	380	360
North America	865	895	975	1,055	995	1,065	985	1,030	1,090
Other	390	445	450	460	455	420	415	390	420
Total	6,775	6,605	6,680	6,390	6,950	6,800	7,075	6,955	7,305
Demand & recycling									
Autocatalyst									
Gross demand	6,150	6,635	7,090	7,450	7,730	8,100	8,340	8,475	8,560
Recycling	1,525	1,485	1,645	1,720	1,610	1,710	1,920	2,040	2,180
Net demand	4,625	5,150	5,445	5,730	6,120	6,390	6,420	6,435	6,380
Jewellery									
Gross demand	680	545	350	295	240	240	225	220	215
Recycling	135	130	145	120	80	80	70	60	55
Net demand	545	415	205	175	160	160	155	160	160
Industrial demand	2,465	2,325	1,985	1,915	1,945	1,920	1,845	1,775	1,720
Other recycling	370	375	410	430	435	400	380	385	385
Gross demand	9,295	9,505	9,425	9,660	9,915	10,260	10,410	10,470	10,495
Recycling	2,030	1,990	2,200	2,270	2,125	2,190	2,370	2,485	2,620
Net demand	7,265	7,515	7,225	7,390	7,790	8,070	8,040	7,985	7,875
Market balance									
Balance (before ETFs)-490	-910	-545	-1,000	-840	-1,270	-965	-1,030	-570	
ETFs (stock allocation)-530	285	-5	940	-665	-645	-375	-560		
Balance after ETFs	40	-1,195	-540	-1,940	-175	-625	-590	-470	

Source: SFA (Oxford)



Palladium demand and recycling by region

koz	2011	2012	2013	2014	2015	2016	2017	2018	2019f
Gross demand									
Autocatalyst									
North America	1,505	1,745	1,835	1,930	2,040	2,110	2,005	1,990	1,960
Western Europe	1,500	1,425	1,530	1,655	1,725	1,635	1,690	1,740	1,710
Japan	670	735	745	750	745	775	805	820	845
China	1,130	1,300	1,515	1,670	1,745	2,015	2,095	2,065	2,145
India	160	155	165	165	185	225	245	265	260
RoW	1,185	1,275	1,300	1,280	1,290	1,340	1,500	1,595	1,640
Total	6,150	6,635	7,090	7,450	7,730	8,100	8,340	8,475	8,560
Jewellery									
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	50
China	450	295	145	120	75	75	60	55	50
RoW	30	30	25	25	25	25	25	25	25
Total	680	545	350	295	240	240	225	220	215
Industrial									
North America	495	480	410	385	395	385	360	340	315
Western Europe	375	335	290	285	285	280	270	255	240
Japan	550	565	415	425	425	405	370	345	320
China	425	405	415	385	400	410	410	415	420
RoW	620	540	455	435	440	440	435	420	425
Total	2,465	2,325	1,985	1,915	1,945	1,920	1,845	1,775	1,720
Total gross demand									
North America	2,045	2,270	2,285	2,350	2,470	2,530	2,400	2,365	2,310
Western Europe	1,940	1,840	1,895	2,000	2,065	1,970	2,015	2,050	2,005
Japan	1,310	1,395	1,225	1,230	1,220	1,230	1,225	1,215	1,215
China	2,005	2,000	2,075	2,175	2,220	2,500	2,565	2,535	2,615
RoW	1,995	2,000	1,945	1,905	1,940	2,030	2,205	2,305	2,350
Total	9,295	9,505	9,425	9,660	9,915	10,260	10,410	10,470	10,495
Recycling									
Autocatalyst									
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	340
Japan	130	125	125	135	125	125	145	180	195
China	15	20	50	60	115	160	165	155	165
RoW	70	85	120	185	205	205	245	240	290
Total	1,525	1,485	1,645	1,720	1,610	1,710	1,920	2,040	2,180
Jewellery									
Japan	15	20	20	20	20	20	20	15	15
China	120	110	125	100	60	60	50	45	40
Total	135	130	145	120	80	80	70	60	55
WEEE									
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
Total	370	375	410	430	435	400	380	385	385
Total recycling									
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	415
Japan	280	265	280	300	310	280	285	315	325
China	155	160	215	190	200	255	250	240	250
RoW	135	150	190	275	285	285	325	325	375
Total	2,030	1,990	2,200	2,270	2,125	2,190	2,370	2,485	2,620



Platinum supply-demand balance

koz	2011	2012	2013	2014	2015	2016	2017	2018	2019f
Primary supply									
Regional									
South Africa	4,595	4,210	4,355	3,115	4,480	4,250	4,380	4,460	4,620
Russia	800	780	740	740	710	715	720	665	690
Zimbabwe	340	365	405	405	405	490	480	465	470
North America	375	345	355	395	365	390	360	345	390
Other	145	180	215	200	200	185	185	180	190
Total	6,255	5,880	6,070	4,855	6,160	6,030	6,125	6,115	6,360
Demand & recycling									
Autocatalyst									
Gross demand	3,090	3,125	3,120	3,270	3,370	3,435	3,300	3,095	2,980
Recycling	1,210	1,175	1,120	1,250	1,180	1,220	1,325	1,420	1,495
Net demand	1,880	1,950	2,000	2,020	2,190	2,215	1,975	1,675	1,485
Jewellery									
Gross demand	2,450	2,750	2,945	3,000	2,840	2,505	2,460	2,325	2,215
Recycling	630	840	855	775	510	625	560	505	490
Net demand	1,820	1,910	2,090	2,225	2,330	1,880	1,900	1,820	1,725
Industrial demand									
Other recycling	10	5	5	5	5	5	10	5	10
Gross demand	7,400	7,425	7,555	7,845	7,930	7,750	7,435	7,330	7,100
Recycling	1,850	2,020	1,980	2,030	1,695	1,850	1,895	1,930	1,995
Net demand	5,550	5,405	5,575	5,815	6,235	5,900	5,540	5,400	5,105
Market balance									
Balance (before ETFs)	705	475	495	-960	-75	130	585	715	1,255
ETFs (stock allocation)	175	195	905	215	-240	-10	105	-245	
Balance after ETFs	530	280	-410	-1,175	165	140	480	960	

Source: SFA (Oxford)



Platinum demand and recycling by region

koz	2011	2012	2013	2014	2015	2016	2017	2018	2019f
Gross demand									
Autocatalyst									
North America	385	425	425	465	505	460	425	450	465
Western Europe	1,495	1,340	1,350	1,440	1,550	1,705	1,555	1,295	1,185
Japan	500	600	580	590	510	455	440	420	400
China	120	115	130	120	125	165	190	185	180
India	180	200	160	160	175	165	170	190	180
RoW	410	445	475	495	505	485	520	555	570
Total	3,090	3,125	3,120	3,270	3,370	3,435	3,300	3,095	2,980
Jewellery									
North America	160	185	200	230	250	265	280	295	310
Western Europe	175	175	220	220	235	240	250	255	260
Japan	315	325	335	335	340	335	340	345	340
China	1,670	1,915	1,990	1,975	1,765	1,450	1,340	1,155	1,005
India	80	95	140	175	180	145	175	200	220
RoW	50	55	60	65	70	70	75	75	80
Total	2,450	2,750	2,945	3,000	2,840	2,505	2,460	2,325	2,215
Industrial									
North America	265	320	325	325	255	395	340	350	355
Western Europe	290	265	190	240	300	275	265	315	310
Japan	200	90	90	30	95	95	60	120	110
China	305	370	515	445	530	580	535	480	550
RoW	800	505	370	535	540	465	475	645	580
Total	1,860	1,550	1,490	1,575	1,720	1,810	1,675	1,910	1,905
Total gross demand									
North America	810	930	950	1,020	1,010	1,120	1,045	1,095	1,130
Western Europe	1,960	1,780	1,760	1,900	2,085	2,220	2,070	1,865	1,755
Japan	1,015	1,015	1,005	955	945	885	840	885	850
China	2,095	2,400	2,635	2,540	2,420	2,195	2,065	1,820	1,735
RoW	1,520	1,300	1,205	1,430	1,470	1,330	1,415	1,665	1,630
Total	7,400	7,425	7,555	7,845	7,930	7,750	7,435	7,330	7,100
Recycling									
Autocatalyst									
North America	600	575	560	560	505	535	585	640	645
Western Europe	420	405	365	465	370	400	440	465	505
Japan	115	115	95	105	95	95	100	110	115
China	5	10	20	30	55	40	40	35	40
RoW	70	70	80	90	155	150	160	170	190
Total	1,210	1,175	1,120	1,250	1,180	1,220	1,325	1,420	1,495
Jewellery									
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	145	140
China	345	555	600	530	335	460	385	345	330
RoW	0	0	5	5	5	5	5	5	10
Total	630	840	855	775	510	625	560	505	490
WEEE	10	5	5	5	5	5	10	5	10
Total recycling									
North America	600	575	560	560	510	540	590	645	650
Western Europe	420	405	365	470	375	405	445	470	510
Japan	405	400	345	340	255	245	260	255	255
China	350	565	620	560	390	500	430	380	375
RoW	75	75	90	100	165	160	170	180	205
Total	1,850	2,020	1,980	2,030	1,695	1,850	1,895	1,930	1,995



Rhodium supply-demand balance

koz	2011	2012	2013	2014	2015	2016	2017	2018	2019f
Primary supply									
Regional									
South Africa	645	600	590	425	620	615	630	630	660
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
Total	790	745	740	575	765	765	785	775	810
Demand & recycling									
Autocatalyst									
Gross demand	735	765	780	835	875	855	880	915	935
Recycling	235	235	260	275	260	280	295	335	355
Net demand	500	530	520	560	615	575	585	580	580
Industrial demand	170	150	145	160	155	185	160	210	200
Other recycling	1	1	1	2	2	2	2	2	2
Gross demand	905	915	925	995	1,030	1,040	1,040	1,125	1,135
Recycling	235	235	260	275	260	280	295	335	355
Net demand	670	680	665	720	770	760	745	790	780
Market balance									
Balance (before ETFs)	120	65	75	-145	-5	5	40	-15	30
ETFs (stock allocation)	15	35	50	5	-5	5	-20	-50	
Balance after ETFs	105	30	25	-150	0	0	60	35	

Source: SFA (Oxford)



Rhodium demand and recycling by region

koz	2011	2012	2013	2014	2015	2016	2017	2018	2019f
Gross demand									
Autocatalyst									
North America	180	200	220	240	265	260	245	240	235
Western Europe	215	190	195	220	240	205	210	230	230
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	110	115	115	115	120	115	130	145	155
Total	735	765	780	835	875	855	880	915	935
Industrial									
North America	20	15	15	15	10	20	15	15	15
Western Europe	20	20	10	15	15	15	15	25	25
Japan	45	45	35	25	30	30	30	30	35
China	40	30	45	50	50	60	50	60	60
RoW	45	40	40	55	50	60	50	80	65
Total	170	150	145	160	155	185	160	210	200
Total gross demand									
North America	200	215	235	255	275	280	260	255	250
Western Europe	235	210	205	235	255	220	225	255	255
Japan	180	195	175	165	155	155	155	155	160
China	115	120	140	155	160	190	200	215	230
RoW	175	175	170	185	185	195	200	245	240
Total	905	915	925	995	1,030	1,040	1,040	1,125	1,135
Recycling									
Autocatalyst									
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	45	45
China	0	0	5	5	10	5	5	5	5
RoW	10	5	10	20	25	30	35	45	50
Total	235	235	260	275	260	280	295	335	355

Source: SFA (Oxford)



GLOSSARY OF TERMS

AC

Alternating current, used to transmit electricity over long distances.

BEV

Battery electric vehicle.

By-products

Copper, nickel, iridium and ruthenium.

CAMs

Cathode active materials, main elements dictating cathode performance.

CFTC

Commodity Futures Trading Commission

CTMEG

Coal-to-monoethylene glycol — chemical process utilises palladium catalyst.

DRC

Democratic Republic of the Congo.

E-bus

Battery electric bus.

ETF

Exchange-traded fund.

EV(s)

Electric vehicle(s).

FTP

Federal test procedure for heavy-duty on-road vehicles.

GDP

Gross domestic product.

Gross demand

A measure of intensity of use.

HDD

Heavy-duty diesel.

koz

A thousand troy ounces.

LCE

Lithium carbonate equivalent — a industry standardised measurement for measure of lithium content.

LCO

Lithium cobalt oxide, a typical Li-ion cathode commonly used in batteries for consumer electronics.

LCV

Light commercial vehicle.

Lease rates

Fees payable for the rental of an asset.

LFP

Lithium iron phosphate — a Li-ion battery cathode commonly deployed by Chinese OEMs due to higher safety and lower cost. Displaced by NMC due to low energy density.

Li-ion

Lithium ion, a type of rechargeable battery.

LiPF₆

Lithium hexafluorophosphate — a lithium salt commonly used as an electrolyte component for Li-ion batteries.

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.

MSCI Emerging Markets Index

Morgan Stanley Capital International (MSCI) is an index to measure equity market performance across 26 emerging global markets

NCA

Nickel cobalt aluminium oxide — CAM widely used by Tesla in their BEVs.

NEV

New Energy Vehicle — China's preferred designation for zero/low emission vehicles. Currently includes BEVs, plug-in hybrids and fuel cell electric vehicles.

NMC

Nickel manganese cobalt oxide — a flexible CAM for Li-ion batteries preferred by OEMs due to its flexibility in performance (determined by the ratios of the three contained metals)

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.

NiCD

Nickel cadmium, a type of rechargeable battery

NiMH

Nickel metal hydride, a type of rechargeable battery

NMC

Nickel-manganese-cobalt (battery chemistry).

NYMEX

New York Mercantile Exchange.

OEM(s)

Original equipment manufacturer, in this context referring to the passenger car manufacturers (e.g. Volkswagen, Toyota).

OTC transactions

Over-the-counter transactions

oz

Troy ounce.

PGM(s)

Platinum-group metals.

PTA

Purified terephthalic acid — chemical synthesised using palladium catalyst.

RDE

The real-world driving emissions test.

Secondary supply

Recycling output.

SULEV

Super ultra-low emissions vehicle.

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.

WEEE

Waste electrical and electronic equipment.

WLTP

Worldwide harmonised light vehicle test procedure.

4E

Platinum, palladium, rhodium and gold.

5E

Platinum, palladium, rhodium, ruthenium and iridium.

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.

ACKNOWLEDGEMENTS

SFA (Oxford) would like to thank all those whose hard work contributed to turning what began as an ambitious idea into the finished report you now see in front of you.

In particular, we would like to acknowledge our team:

Stephen Forrest	Beresford Clarke
Dr. Ralph Grimble	Carol Lu
Jamie Underwood	Dr. Jenny Watts
Oksan Atilan	Alex Biddle
Tom Chandler	Lakshya Gupta
Francesca Price	Jordan Roberts
David Mobbs	Jo Holmes
Karen Darley	

We should also mention a team of Associate Consultants, without whom this publication would not have been possible.

A special mention should also be given to Jeremy Coombes and Andy Smith whose combined knowledge of and expertise in compiling such an ambitious PGM industry review helped to fashion a report of which we could all be thoroughly proud.

We thank Janice Hurst and Karen Darley for proofreading *The Palladium Standard* throughout its production.

Then there are our third-party data suppliers: LMC Automotive, Oxford Economics, Power Systems Research, Bloomberg, and GTIS whose data form the basis of many of the charts in this report.

Finally, to our clients and all those who have supported us throughout our time in business, we would like to dedicate this report as a mark of our gratitude for your continuing support.

Typeset by Jamie Underwood and Lakshya Gupta.

Printed by Holywell Press Ltd, Oxford.

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Please note: Some tabulated data may not add up owing to rounding of individual numbers.

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