SFA Oxford

# THE PALLADIUM STANDARD

## September 2017


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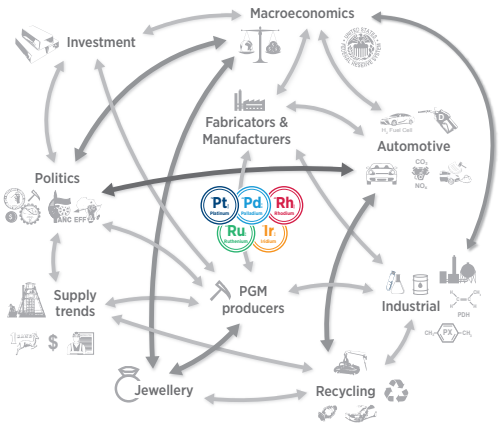
September 2017

## Celebrating 15 years of PGM market analysis






Edition 02

# CONTENTS

# FOREWORD

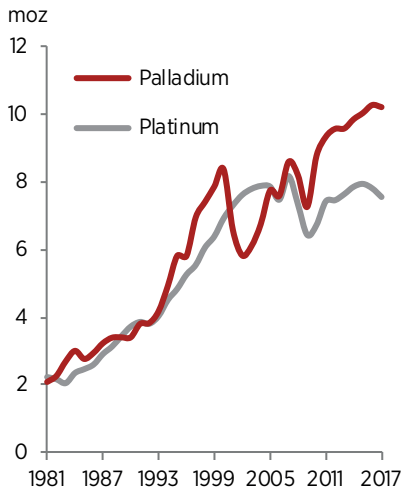
# Foreword

## Wither (sic) palladium?

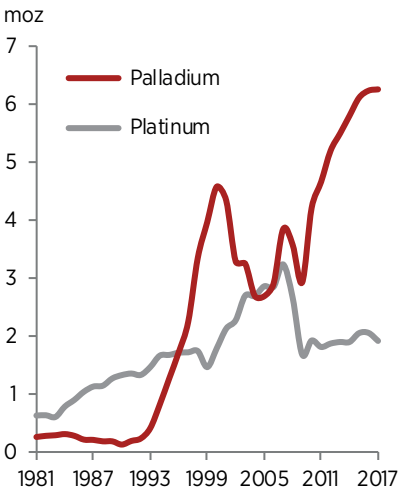
As New York hosts another Platinum Week, the question on everyone's lips concerns palladium, the protean member of the PGM family. We just can't seem to get it under control. It's lax and lugubrious one moment, hyperactive the next; disappointing, exciting and exasperating us by turns. Here is palladium trading almost at parity with platinum, a relationship not this close since the end of the last millennium. In January 2001 the palladium price shot like a firework to $1,094/oz on the fix, a premium over platinum approaching $500; six months later it was at parity again and heading for a deep discount which persisted for the next 16 years.

Is history about to repeat itself in another boom and bust sequence? Industrial demand for palladium is up by close to 30% in ten years and highly concentrated in autocatalysts — 79% of the total now from 55% a decade ago; palladium increasingly dominates over platinum and rhodium in the autocatalyst space, and sales of Russian state stocks have dried up while underlying global primary supply has hardly changed. The outcome: a market in substantial deficit for the last six years. Recycling cannot fill the gap, and visible market stocks (NYMEX, ETFs) have been decreasing at an alarming rate. What comes next is the fundamental issue addressed by Ridgefield Capital, Nornickel and SFA (Oxford) in three trenchant articles in this 2017 edition of *The Palladium Standard.*

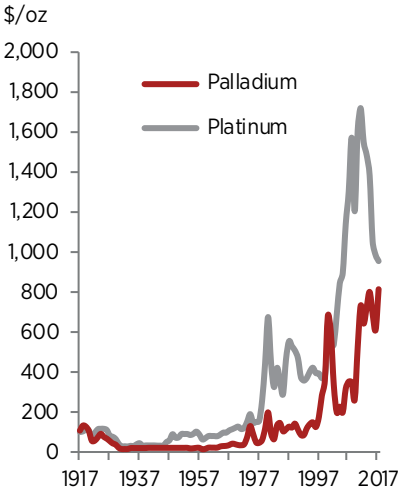
**Total demand, 1981-2017**




**Automotive demand, 1981-2017**



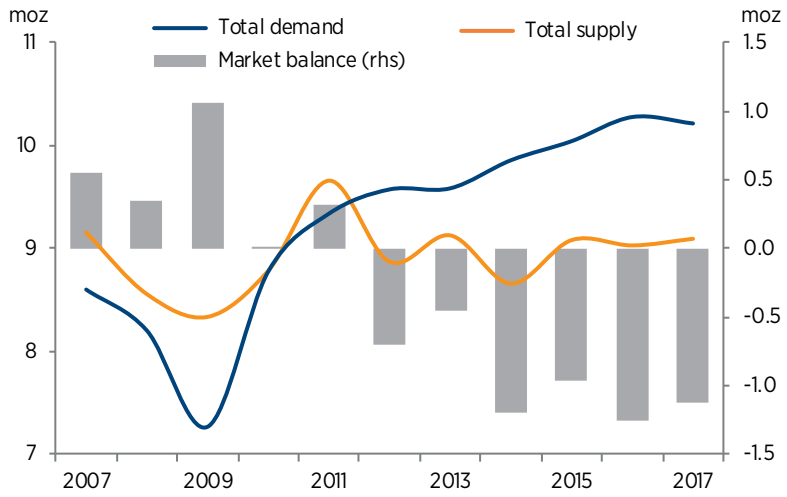

**Historical pricing, 1917-2017**




*Source: SFA (Oxford)*

The eyes of Rob Ellis at Ridgefield Capital are focused on the pressure building on the palladium price and on judging when and how it will reach its limit. He considers the potential for a repeat of the 2001 scenario, when worried auto companies bailed out of palladium, re-engineering autocatalysts to increase the proportion of platinum — temporarily, as it turned out — in the PGM mix. Since any hopes (or fears) of substitution by some magic non-precious metal formula are nothing but a chimera, the only option that's left is PGM interchangeability — leading to the question of which of the other autocatalyst PGMs would get the benefit, and when. Ellis rejects the thinking that through inertia and technical difficulties this change will not occur anytime soon, and suggests how the market will begin to signal to investors the impending peak of the palladium price rise.

**Palladium market**




*Source: SFA (Oxford). Note: Supply includes stock sales.*

What does the EV story imply for palladium demand from its main application? Beresford Clarke at SFA reminds us, in this twentieth anniversary year of Toyota's launch of the Prius hybrid passenger car, that EVs are not all (or even remotely all) about pure battery-electric power. Most of the EVs produced and sold today are hybrids of electric motors and internal combustion engines — and they need autocatalysts. As public appetite for diesel cars declines — blunted by emissions scandals and rising aftertreatment costs — fuel-efficient gasoline hybrids are fast becoming mainstream technologies for OEMs battling to meet ever tighter fuel economy targets. EVs, in the short to medium term at least, appear to promise continuity of demand for palladium-based catalytic converters.

Denis Sharypin at Nornickel presents a producer's view, observing that miners these days can less afford another palladium price soar and crash. Changing ore ratios and strengthening prices mean palladium has evolved from a by-product of platinum or nickel into a co-product which, at least in Nornickel's case, is leading the revenue charge. But although the world needs more palladium, opportunities and incentives to build new production capacity are limited. What can producers do to ease the pressure on supply and protect their margins if they can't or won't sign off on expensive expansion CAPEX? Jockeying for position in the palladium supply chain à la Northam, Sibanye and Anglo may not be enough to reassure customers, so is Nornickel's stability fund model the way to go? Or, maybe, encourage the LPPM to follow the LBMA's lead and disclose loco London holdings (but would we all get an awful fright if it did)?

All change, then, for the palladium price in the months ahead? The pointers from the past, as Ridgefield asserts, should predict the future, but our readiness to learn from them is not guaranteed. This PGM sibling is still liable to surprise us with its behaviour!

*Yours sincerely, The SFA (Oxford) team*

# THE ARGUMENT FOR PGMs — AND THE CANARY IN THE (PGM) MINE

# The argument for PGMs — and the canary in the (PGM) mine

***Rob Ellis, Ridgefield Capital***

*Twin peaks for palladium?*

In this third week of August 2017, palladium has authoritatively taken out its 16-year high of over $900/oz established three years ago in September 2014. Technically, there is nothing to suggest a price action pause in its pursuit of the metal's all-time high of $1,125/oz set back in January 2001. This, of course, begs us to revisit that time for clues as to how price action might evolve and what risks exist in liquidity and volatility.

*New summits for palladium liquidity and volatility risks*

Both risks, we would argue, are significantly higher today than 20 years ago despite the fact that the market years ago was a nascent one with a still limited history of broad speculative activity. That market was aggressively pursuing commercial hedging activity. There was a deep roster of market-makers with significant balance sheets for both commercial and price risks dedicated to the PGM space. That is one real difference to today's market. With nearly every market-maker today out of the price-risk-taking business, the appetite to deploy resources here is sharply reduced. Though the advent of ETFs and financial debt products with commodity kickers has broadened the pool of potential speculative investors and traders for the PGM space, people are apt to forget just how significant the large spec presence was 20 years ago. At one point before the spike in palladium prices, a single firm owned and allocated a billion dollars in PGMs when a billion dollars was real money. Today, despite the proliferation of ETFs, for example, that entire product line has open interest of just $1.47 billion.

*'Privatised' palladium inventory will spur price volatility*

The physical market for palladium had doubled as we entered the 1990s, but was still a mere 4 million ounces. Today it is over 10 million. Inventory which was held primarily by the government apparatus of the former Soviet Union is now held by a combination of consumers and large specs. As just noted, the number of market-makers is reduced and the aggregate volume of daily trade on exchange, exchange-cleared, and over-the-counter is severely reduced. This mélange of variables suggests a real risk to price action from volatility and liquidity.

**Implied and realised palladium volatility, 2006-2017**

*Source: Bloomberg*

The above chart of implied and realised volatility in palladium over the past 10+ years clearly reflects the general downturn in volatility that is consistent across all commodities. It also highlights the dynamic price action associated with the financial crisis in 2008. An assault on contract highs historically would be enough to drive the industry to demand a premium in implied volatility. However, though we have opened up a gap between recent realised values and current at the money (ATM) implied volatilities, their absolute valuation is not high enough to adequately assess the historical risks that accompany the definition of new metrics in absolute and relative price action.

On the fundamental side of the equation, lease rates have been tight and/or negative for months, paying the long to carry their position forward. Sponge premiums, an early warning indicator for an overheated market, remain positive or benign. Global car sales are robust even if having plateaued, and gasoline powertrains continue to gain at the expense of diesel. On the supply side, we have lost a couple of small but statistically significant producers in South Africa, where political uncertainty, trouble with cost containment, and ongoing financial viability threaten further supply cuts should basket prices remain at current levels. These variables are uniformly supportive of higher price action. Consequently, new highs should perhaps come as a mild surprise, but certainly not a shock.

*Fundamental stars aligned for a stellar palladium surprise*

However bullish both these fundamentals and the short-term price action in palladium are, they remain at odds with big picture investment flow — the dollars that are chasing tomorrow's technological breakthrough in alternative energy or new battery technologies in production and storage, the Tesla acolytes who have bought into both the car and the promise of an accelerating EV revolution, the community following FANG (Facebook/Amazon/Netflix/Google), the venture capital and private equity titans out overturning every stone in search of the next new 'thing', the follow-the-leader capital flows into passive products which mimic or leverage hot investing trends, etc. This new flow is not interested in now old-school themes, such as mining, crude oil and natural gas, retailing, and the automotive industry. **As much as advocates would like to infer otherwise, the long story in PGMs and palladium is bound irrevocably in the now old-world technology of the internal combustion gasoline and diesel engines.**

*Olde Worlde PGMs behind the New World technology curve*

It has been more than 25 years since clean air legislation and new catalysis technology launched the great growth story in PGM demand, and while there are plenty of these engines running globally whose emissions can be filtered through the addition or improvement of current catalytic converter technology, any further advances in such will likely lead us to lower loadings or away from PGM catalysts entirely. The automotive sector, at least in the form of the familiar internal combustion engine, cannot be relied upon to deliver any positive curve shifting in demand, such as we saw a couple of generations ago from catalysis based on PGMs. But the potential for some new demand could come from the fuel cell sector, where palladium catalysts are active in a number of key reactions, including the production of hydrogen fuel. Fuel cell technology fits well with many of the current air quality, energy efficiency and mobility themes driving the automotive industry, but many challenges remain before FCEVs can become mainstream.

*Scrap any idea of an auto PGM demand surge*

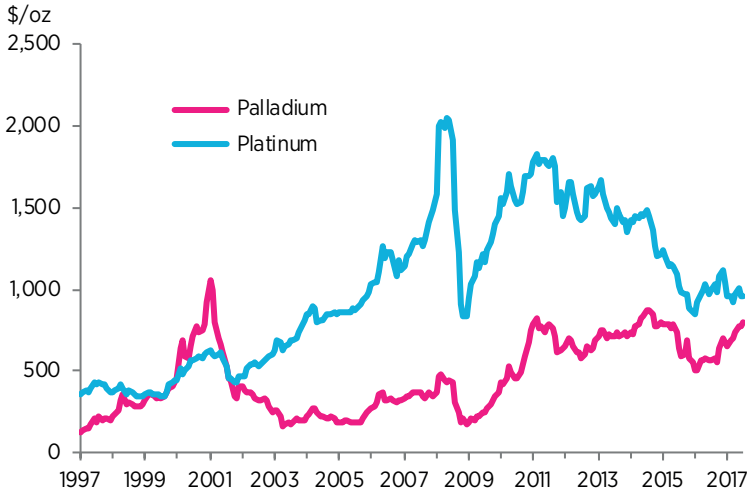
In the end, this is a commodity story dependent on the sale of current engine technology to consumers and investors who both are flirting with the technologies of tomorrow. The question, as we contemplate how high palladium can go, is will it be price or the advent of these technologies that finally takes the palladium story down. If it is price, as seems likely given the window of time demanded before the promise of an EV universe can deliver, then have we gone far enough to stimulate the rationing of demand? Have we created the stimulation of supply that the balance sheet requires? Or does the future hold an illiquid spike like those that each of the three legs of the PGM story has delivered over the course of the last two decades?

*Peak palladium: capped by price or technology?*

The picture in price action for palladium may look rosy and the fundamental back story for the metal may be strong, but that cannot belie the fact that palladium prices are by both measures expensive. And when you put them in the context of the other metals in the PGM complex they appear to be outrageously rich. Recall that it is the loading adjustments in diesel applications favouring the cheaper palladium to the detriment of platinum that has been behind the latter's poor performance. This phenomenon is, in part, the fundamental foundation for palladium's surge. But, as the chart below reminds us, this relative price performance has happened before.

*Palladium:platinum parity #2..*

**Palladium and platinum price history, 1997-2017**




*Source: SFA (Oxford), Bloomberg*

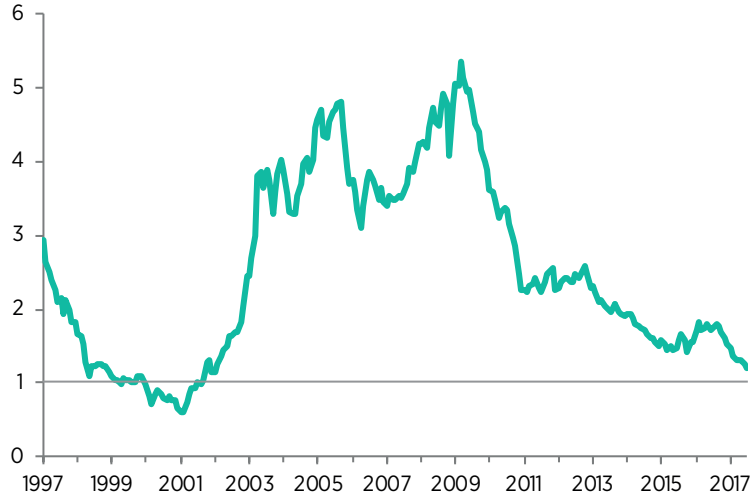
In 1998 and 1999, palladium surged to trade at 'platinum parity' for the first time. It put platinum in its rear light in 2000 and it stayed that way until peaking in a liquidity (lack of) driven surge in early 2001 at a nearly $500/oz premium. This was the first bout of price volatility to shock the automotive consumer new to the PGM balance sheet, but it would not be the last. What is instructive is that these consumers acted aggressively — by the definition of their own product timelines — to address the risks inherent in that illiquidity. In 2001, palladium was the metal with the shaky supply chain and uncertain price prospect. Platinum and rhodium supply were dominated by a South African community that was made up of predominately Western-domiciled and diversified mining companies perceived to be reliable. Palladium's Russian-heavy production and shady post-Soviet inventory management had just proved itself to be the opposite.

*..same ending?*

Palladium's current strength has not been close to producing that kind of price volatility to date, but it took three years after first reaching parity in 1998 for it to spike to those relationship highs. What is different between these two similar developments in price action is the market's all-in bias to palladium. However you measure market composition, the metrics easily support this conclusion, in objective long-short positioning by the investment and speculative components, by relative ETF flows, and in the anecdotal evidence of inventory held by the same pool of players. By the same token, the few analysts who publicly articulate their work in the PGM space uniformly identify with palladium, producing balance sheets similar to those one would find in this *Palladium Standard* published by SFA: palladium with an ongoing and significant deficit in combined primary and secondary production less demand, and both platinum and rhodium with dangerously sloppy surpluses. This was definitely not the case when palladium exploded nearly 20 years ago. It had taken a decade for the markets to embrace the potential in palladium — in both price and fundamental value — and the market was confident that substitution to the favoured and long-engineered platinum-rich catalytic solutions would quickly solve any short-term palladium tightness. Eventually, that substitution happened, driven by the dynamics of price action in palladium. Today the market rather casually believes that this history cannot repeat itself.

*More palladium bulls this time around*

**Platinum/palladium price ratio history, 1997-2017**




*Source: SFA (Oxford), Bloomberg*

*Platinum-palladium price ratio is edging closer to parity*

The most recent bottom in the platinum-palladium spread was seven years ago and platinum spent much of a five-year period at more than $1,000/oz. On a ratio or spread basis this was a significantly greater premium than that which platinum enjoyed in the 1990s, when its relatively expensive valuation led to the fundamental shift in coatings and engineering research over to palladium.

We hear constantly today from automotive sources (and palladium bulls) how slow the engineering pipeline is to address price-driven demands in changing the source or nature of commodity supply. It was this fear of platinum scarcity that first drove engineers to palladium. It was the ensuing reality that forced them back towards platinum and set the stage for its strong performance by the side of gold as that commodity soared during the go-go commodity rush in the early 2000s. That strength led to the industry engineering palladium into the solution demanded by new diesel emission standards at the expense of platinum.

So where are we now in that cycle? Have the automotive engineers learned anything about the bust-boom rotation in values to help mitigate or even anticipate that phenomenon? Conventional wisdom suggests the answer to that latter question is 'no' despite evidence gathered over the years that there are some very smart and analytical people engaged by most automotive firms in exactly this business of trying to anticipate and avoid the liquidity-driven price squeezes. For the record, we think the answer is 'yes'.

*Will the 'men in white coats' react quicker to a palladium spike this time?*

The argument that changing out the loading schematic of a catalytic converter demands the overhaul of an entire powertrain, along with a dramatic re-engineering of the assembly process and the automotive platforms its serves, is compelling. It took Ford years to introduce the simple substitution of aluminium for steel in the body of its F-Series truck line. Logically, it must take that or longer to remix the coating cocktail of a catalytic converter so it will efficiently filter emissions for particulate matter, $NO_x$ and $SO_x$, considering the myriad numbers of powertrain applications and the multiple jurisdictions covered by ever tightening air quality standards.

These engineers have had nearly 30 years of hard-earned practical experience and even more of theoretical and pragmatic research on this subject, and much of it has to have been driven by the pecuniary demands from a management paralysed by the multiple price shocks we have seen in relative valuation. For the past five years, the analysts they have hired to assure them this will not happen again and the consultants they have hired to monitor those analysts have consistently and uniformly been telling them that the palladium balance sheet is in deficit and inventories are spiralling down to crucially low levels. These same consultants have been saying, alternating between outright paranoia and benign neglect, that a significant portion of that inventory is being held by a resolute speculative element that, so long as it is rewarded with positive price action and encouraged by visibly positive fundamentals, plans to hang on to the stuff, risking the type of unstable and unpredictable price action this market segment has seen before.

*Car companies have seen the palladium 'accident' coming a long while*

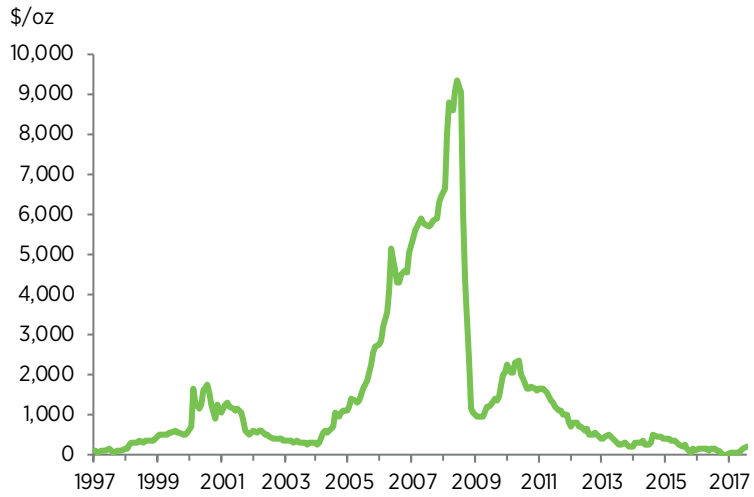
At the same time, the producing community, terrified by a fall in their basket price in local currency that is driven by the relative loss in value of platinum and rhodium, has been casting around for a solution that will restore that value. At least one major producer has offered consumers a cap on rhodium values tied to the upper end of its engineering value to catalytic converter producers. This should translate into a powerful incentive to thrift palladium even if to a less liquid substitute metal. The primary risk to such a solution would be the commercial viability of the producer but that is a marginal risk that consumers take routinely on the entire industry. There is an army of lawyers and commercial contract risk managers at the beck and call of the automotive industry: put them to work.

*Even producers got the substitution memo*

If palladium is about to live up to its long-time billing – and again, price action and fundamental signals suggest that is a real probability — then it is time to put on the optionality in metal substitution that price demands. At current valuations, this is a clarion call to buy rhodium. The consumer faced with an engineering valuation several multiples that of palladium is not acting rationally by avoiding rhodium because of liquidity risks, which the consumer can mitigate away. And this action becomes dangerously negligent when faced with the consensus view on the palladium balance sheet. Price risk managers and engineers should both have significant incentives to move towards rhodium.

*Look to rhodium as the first substitute off the PGM bench*

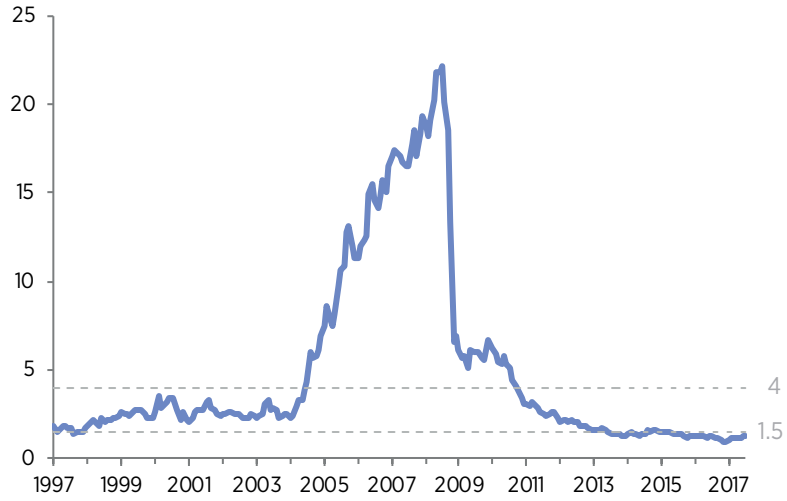
**Rhodium-platinum spread, 1997-2017**




*Source: SFA (Oxford), Bloomberg*

*Rhodium-platinum spread is currently very narrow*

**Rhodium-palladium price ratio history, 1997-2017**




*Source: SFA (Oxford), Bloomberg*

Rhodium should act now as a sort of canary in this coal mine, regardless of where palladium heads from here, as the market assesses the potential for palladium to deliver on its upside promise per the balance sheet dream we have been promised as investors for the last decade. Without a reach for rhodium by consumers who can easily deliver thrifting returns on palladium worth 1.5 to 4 times its value, can the market really accept that palladium is tightening to the point of no return? We would suggest that the answer is 'no'. If the palladium story is really any good from here, rhodium will have to ratchet higher in absolute and relative terms.

*Consumers can easily deliver thrifting returns on palladium worth 1.5-4 times rhodium's value*

Of course, the automotive sector's anticipation of balance sheet tightness or reaction to the price-driven revelation of it is not the only solution to these potential supply and demand imbalances. We can bring on marginal supply, accelerate the marketing of pipeline material, ration other demand, and encourage liquidation of inventory through price. But given the history of past balance sheet adjustments demanded by liquidity surprises, it is likely much of the market will be looking for that engineering solution to signal an end to price dislocation.

In addition to owning rhodium at the current relative value to palladium, there is a strong argument to be made for owning palladium volatility or at least upside leverage in palladium. There is, unfortunately, no good indicator that predicts when you get paid for this investment and the cost of carrying it is high, even at current implied levels of volatility. But you will get paid. Eventually.

*Bet on palladium price action getting crazier!*

# HYBRIDS: A GROWING END-USE FOR PALLADIUM

# Hybrids: A growing end-use for palladium

*Beresford Clarke, Managing Director, SFA (Oxford) Ltd*

## Toyota's bet pays off

With electric vehicles capturing the imagination of investors, the media and the public, it's easy to miss other automotive powertrain trends. In this article, I will address the silent creep of hybrids onto most automaker sales forecourts and the impacts on the palladium market. Hybrids may be a stepping stone to full electrification, but while battery-powered car infiltration remains low (~1% of light vehicle production), hybrids may be the 'magic bullet' to achieve ever stringent emissions standards over the medium term.

*Hybrids can meet medium-term emissions standards*

Hybrids are essentially two means of propulsion, i.e. combining a combustion engine with an electric motor. Keeping the combustion engine component in the powertrain means a PGM catalyst is still needed and as gasoline hybrids are most popular (by about 14x more than diesel equivalents), that means palladium currently dominates PGM loadings.

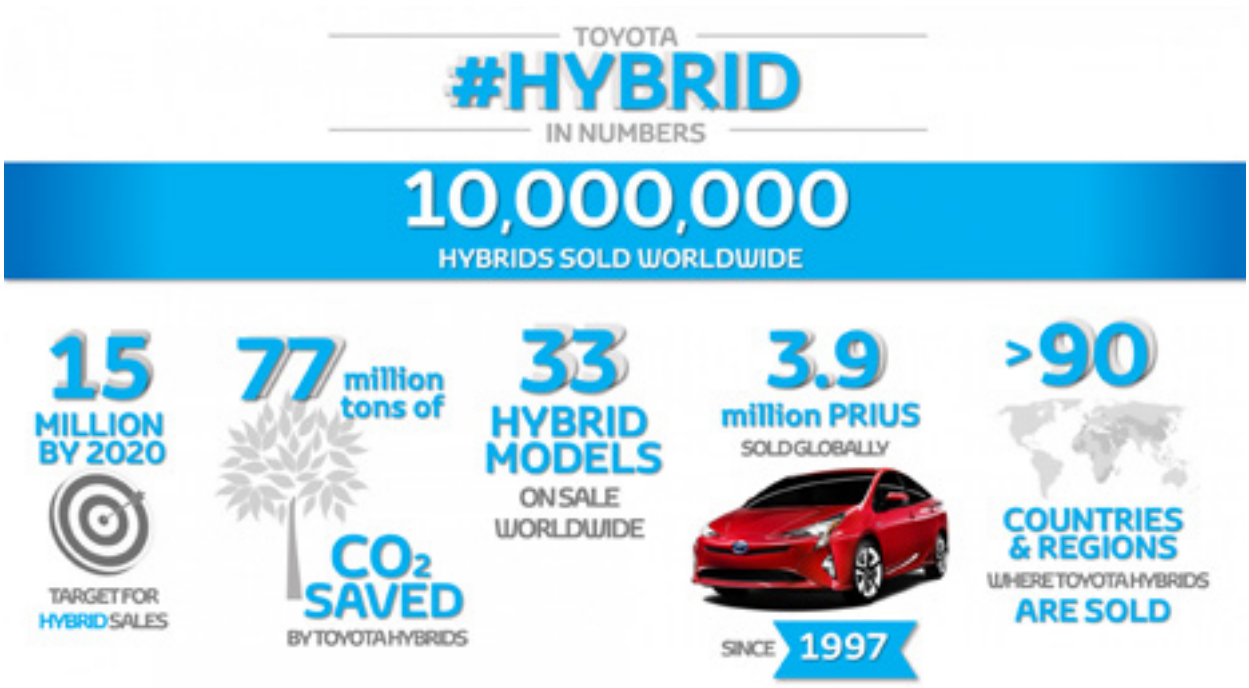
*Palladium dominates hybrid catalyst loadings*

In 1997, Toyota launched the Prius in Japan as a small sedan/saloon car with sales of close to 40,000 cumulatively by 2000. It was the first mass-produced gasoline-electric hybrid vehicle, even though the technology was first launched 100 years before. The model went on to become the iconic shape we all know in 2003 and sales accelerated, reaching a cumulative 3.9 million units this year.

*The Toyota Prius launched in 1997 was the first mass-produced hybrid*

Not long after Toyota, in 1999, Honda launched the Insight model which was the first hybrid car available in North America. Numerous other OEMs offered hybrids in the years that followed including the Ford Escape, with the first SUV hybrid. Today, most manufacturers offer a hybrid in their range.

In February 2017, Toyota announced that it has sold 10 million hybrid vehicles worldwide since the first generation Prius was introduced in 1997. That's just one manufacturer, albeit the dominant hybrid player at over 60% of the global hybrid market in 2016 and the world's largest automaker. To date just over 2 million electric cars have been sold.




*Source: Toyota*

Toyota estimates sales of 15 million hybrid units by 2020. The company currently has 33 hybrid models on sale worldwide and hybrids can be bought in more than 90 countries. For comparison, the Nissan Leaf was available in 48 countries in September 2016, though in fairness it was a later arrival and only went on sale in late 2010.

## The golden age of hybrid hypercars

Say the word 'hybrid' and everyone immediately thinks of the Prius. Hybrids don't appear to have the glamour of Tesla. However, look deeper and note that motorsport has advanced hybrid technology to bring us a new era of sportscar to the road... hypercars, the wall poster cars for any budding car enthusiast. We now have hybrid hypercar offerings from Ferrari (LaFerrari), Porsche (918) and McLaren (P1), see opposite. While hybridisation can help to make cars more efficient (the P1 manages an average of 34 mpg), the electric drive's main job is to supplement the power of the combustion engine, while also increasing safety through the provision of four-wheel drive with the addition of electric motors. The Honda/Acura NSX supercar, for example, mates a 3.5-litre twin-turbocharged V6 engine to an electric motor on the rear axle and has an additional two electric motors on the front to achieve maximum power and traction.

*Say hybrid and you think of the Prius...*

*...but 'hybrids' have spurred hypercars from Ferrari, McLaren, Porsche*

*Ferrari LaFerrari (hybrid)*


*2016 McLaren P1 GTR (hybrid)*

*Porsche 918 (hybrid)*

*Source: Automobile Magazine, Car and Driver*

Toyota is using its TS050 Hybrid LMP1 racing car to further develop hybrid road car performance, while balancing environmental benefits. Porsche used hybrid racing technology to recuperate energy from a turbine in the exhaust and regenerative braking to boost power available from the battery, while saving as much fuel as possible to avoid pitting at the World Endurance Championships. Hybrid technology is increasingly being featured in Porsche's road line-up using experience from hybrid motorsport.

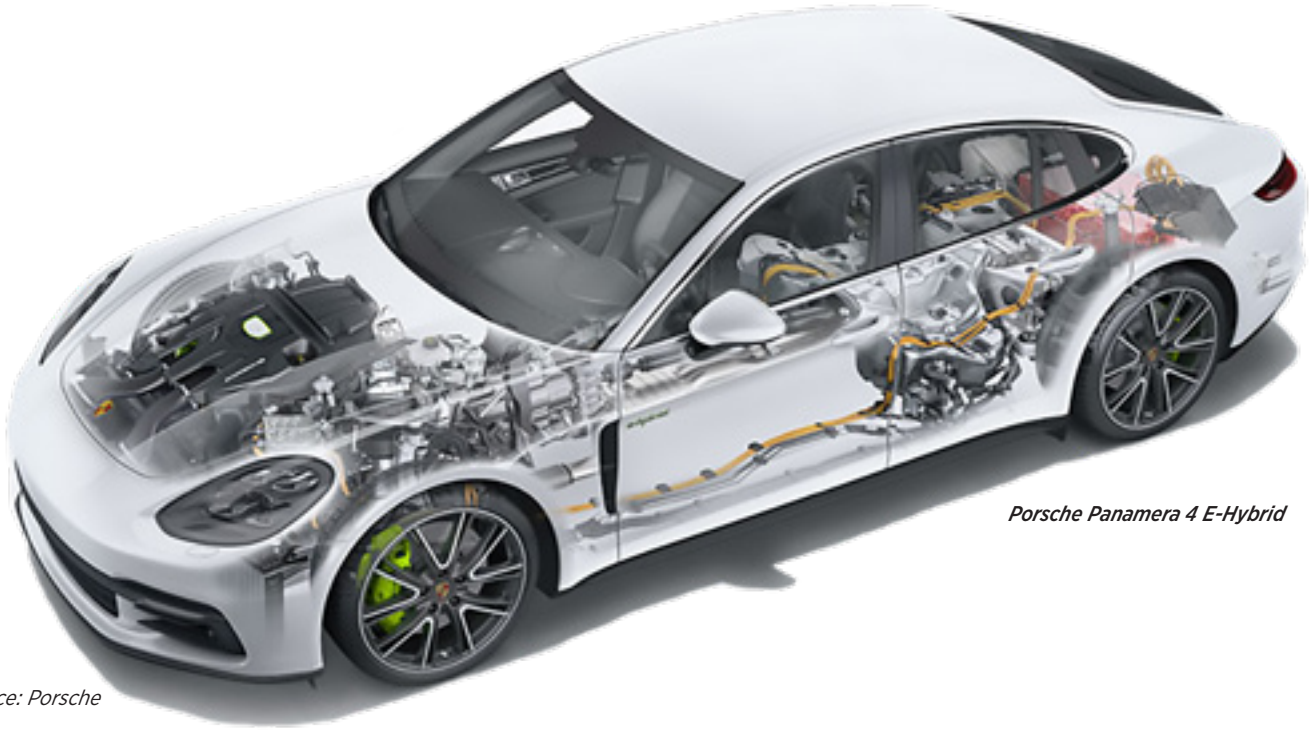

***Toyota TS050 Hybrid LMP1***

*Source: Wheelsage*

Finally, in the ultimate of motorsport, Formula 1 shifted to 'full' hybrid technology. F1 was late to hybrid technology in 2009 through the use of KERS (kinetic energy recovery system) after testing the systems during the previous two years. Mercedes' first hybrid system in 2007 weighed more than 100 kg and was less than 40% efficient. Within two years weight was cut by three-quarters and efficiency almost doubled. The rapid pace of motorsport engineering development helps to improve road cars through technological advances and innovation.

*Motorsport is accelerating the advance of hybrid technology for the road*

The change in F1 rules designed to make cars more efficient, where only 100 kg of fuel is allowed for the race distance, led to newly permissible technologies such as direct injection and hybrid systems and allowed the use of full hybrid technology (mated to smaller 1.6-litre V6 engines) three years ago. Honda and Renault fully returned to F1 in 2015 and 2016 respectively following the shift in regulations towards smaller, greener, high-tech powertrains which are more relevant and can be applied to road car products.



*Porsche Panamera 4 E-Hybrid*

*Source: Porsche*

To quote the Honda CEO, Takanobu Ito:

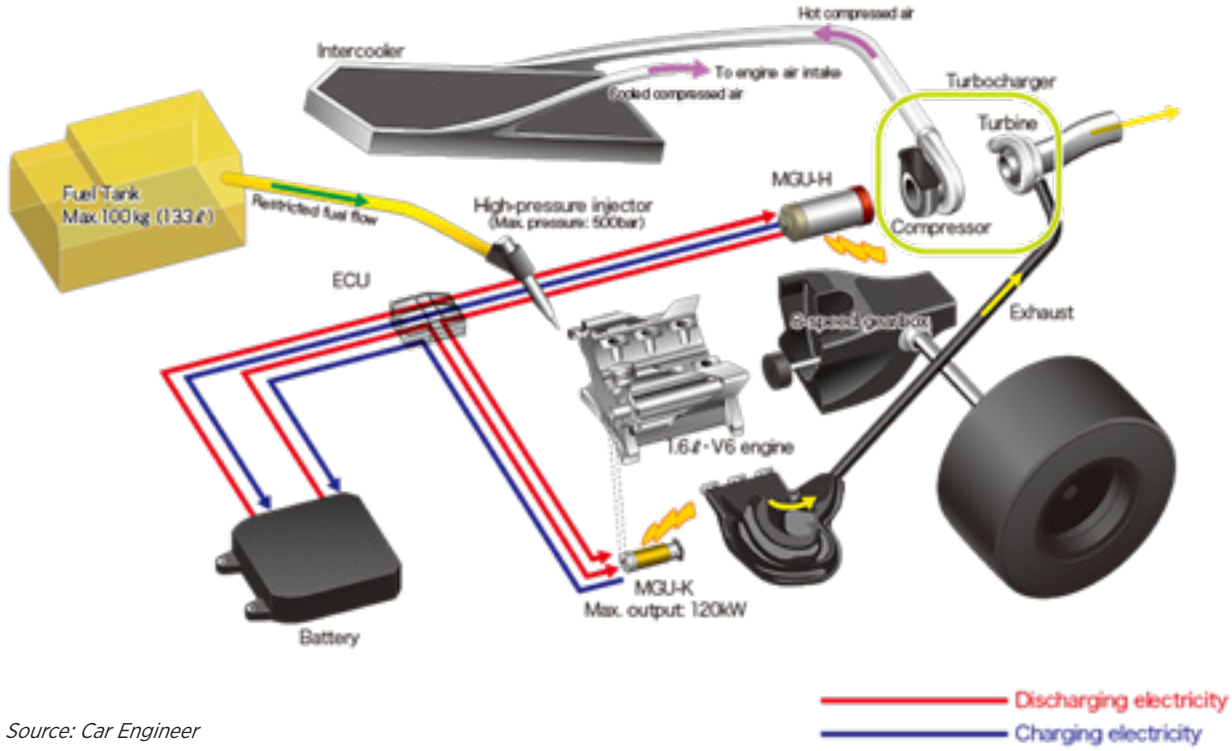
*"The new F1 regulations with their significant environmental focus will inspire even greater development of our own advanced technologies and this is central to our participation in F1."*

The 1.6-litre V6 engines, boosted by electronically assisted turbochargers, use energy recovery systems (ERS) that significantly raise the performance of current F1 cars to the equivalent 2.4-litre V8s they replaced, but use 35% less fuel. F1 cars use 160 hp electric motors directly linked to the rear axle, which when slowing down act like a dynamo to charge up the batteries in the form of kinetic energy (termed MGU-K), thereby improving fuel efficiency. Batteries are also charged using waste heat recovery from exhausts (termed MGU-H).


*Mercedes Benz F1 W05 Hybrid*

*Source: Mercedes-AMG Petronas*

**F1 hybrid powertrain schematic**

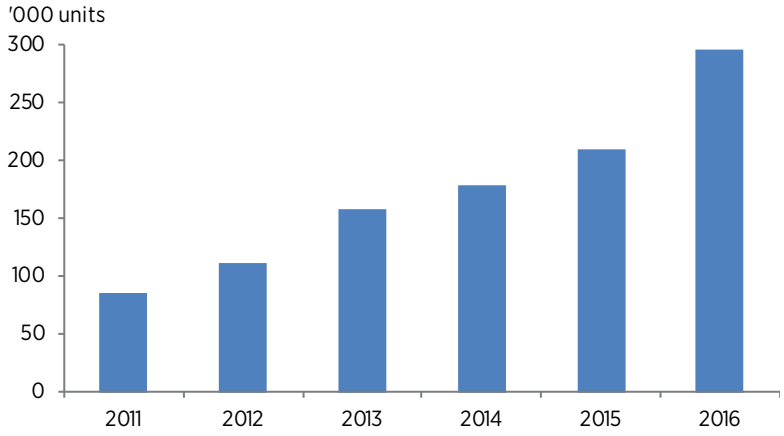



*Source: Car Engineer*

## Hybrids' inflection point?

Toyota has geared up to promote hybrids as alternatives to diesels in Europe as the company sees hybrids playing a pivotal role in the switch from diesel to electric cars. With diesels coming under fire in the region, Toyota has seen hybrid sales increasing by 41% y-o-y in 2016 (to 295,000 units) and 44% (to 208,300 units) in H1'17, albeit from a low base. In Toyota's latest model, the C-HR compact SUV, hybrids account for 80% of sales.

**Toyota Europe's hybrid vehicle sales**




*Source: Toyota Europe*

*Toyota's hybrid sales grew by 41% in 2016 and 44% in H1'17*

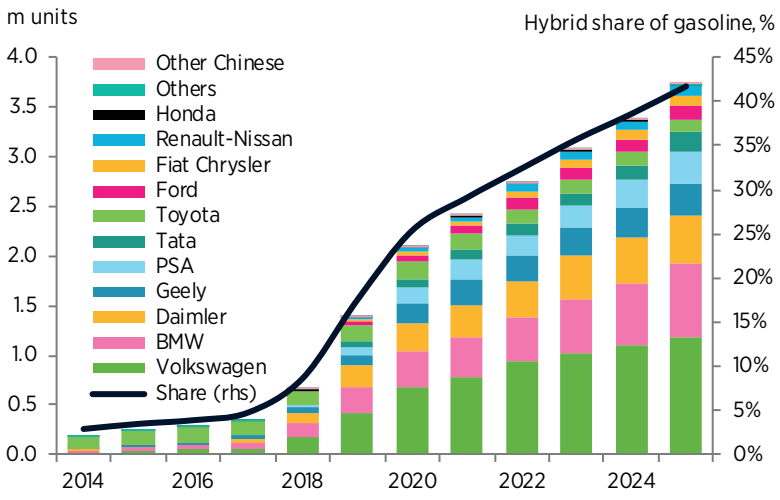
The company plans to lift its European hybrid sales to half its total sales in the region by 2020, from around a third in 2016 and 40% in the first half of 2017. In August, Toyota introduced a $4,700 discount in Germany to buyers switching from diesel cars to its hybrid models. To attract consumers, Toyota will offer more hybrid choices in its range of models. Currently, only one grade of hybrid can be chosen per model. Going forward, more power and battery options will be available.

Without diesels, car makers will find it extremely difficult to achieve fleet average $CO_2$ emission targets of 95 g/km by 2021, which may leave them with hefty financial penalties, especially those with large, heavy cars such as SUVs. The target in 2015 was 130 g/km $CO_2$ and new cars sold in 2016 achieved 118 g/km. To make the next big cut to emissions, OEMs are adding electrified vehicle options to buyers as quickly as possible. The results of which, in LMC Automotive's forecast, are quite dramatic. Where only Toyota dominated hybrid production in Europe before 2017, car makers such as VW, BMW and Daimler have suddenly become major players in the region. From fewer than 200,000 units produced in Europe, full hybrid output is expected to jump by more than ten-fold to exceed 3.3 million units by 2025 and hybrids' share of gasoline cars should hit 39%. There also appears to be a relatively smooth transition to gasoline hybrids from diesel-powered cars (see second chart). A diesel hybrid may be too expensive relative to a diesel car to buy, but a gasoline hybrid could provide most of the fuel efficiency benefits of a diesel car, particularly in traffic and built-up areas, at a similar price.

*Without diesels, car makers will find it difficult to achieve fleet average $CO_2$ targets*

*So OEMs are adding electrified vehicle options as quickly as possible, mainly hybrids*

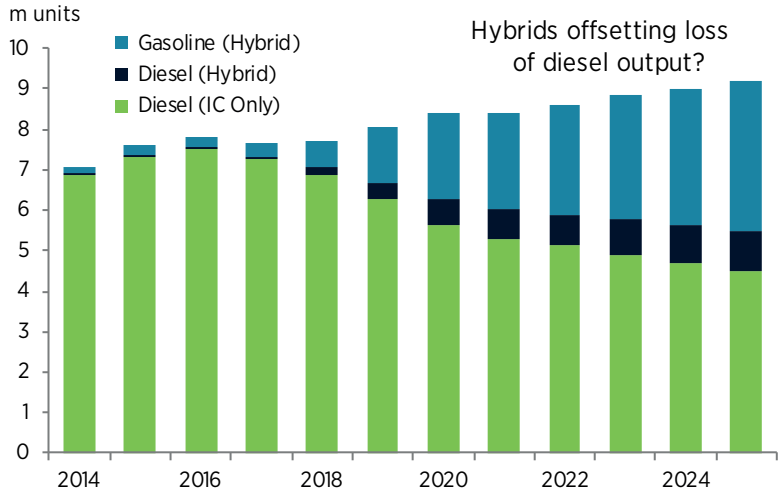
**Gasoline hybrid production: Western Europe**




*Source: LMC Automotive*

*Big car makers, Daimler, BMW, VW (Audi), are rapidly increasing hybrid output in Europe*

**Light vehicle production in Western Europe: Diesel vs. hybrids**




*Source: LMC Automotive*

*Hybrids offsetting the loss from diesel?*

## Japan builds and consumes the most hybrids

Global production of hybrid cars has grown from almost zero in 1997 to 2.5 million units in 2016. Japan is at the cutting edge of the technology with over three-quarters of all hybrids manufactured in the country.

*Hybrid car production has gone from 0 to 2.5 million units in 20 years*

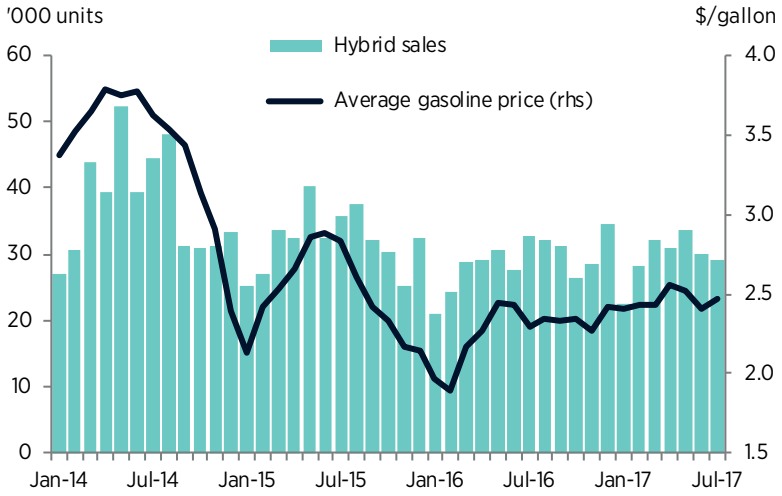
Japan is also the largest consuming country for hybrids, with 26% of all sales in 2016. Excluding Kei cars (mini vehicles with restricted size and engine displacement for tax and parking purposes), that figure jumps to 38%, according to JAMA. Also, the top selling car in Japan last year was the Toyota Prius hybrid.

In 2016, Toyota sold 1.4 million hybrids globally and should add another 100,000 units in 2017. Global sales were up 8.4% to 768,000 units in the first half. The other major Japanese hybrid manufacturer, Honda, reported 125,000 hybrid units in H1'17, up 18% y-o-y.

According to WardsAuto data, hybrid sales in the US reached 373,000 units in 2016, up 9% on the previous year. Toyota accounted for 65% of sales, followed by Ford (12%), Hyundai (5%), Honda (3%) and Chevrolet (1%). However, to date US hybrid sales have been very sensitive to gasoline prices (see chart opposite); while low gasoline prices prevail, hybrid sales growth may be limited. Going forward, however, pressure to cut $CO_2$ emissions from cars in the US could lead to an increasing preference towards hybrids, i.e. the inflection point for hybrids is yet to happen as it has in Europe and Japan.

*Pressure to cut $CO_2$ emissions from cars could lead to an increasing preference towards hybrids*

**US hybrid car sales vs. average gasoline price**




*Source: SFA (Oxford), LMC Automotive*

*Hybrid sales are very fuel price sensitive in the US*

## Future impact on palladium demand

*"Volvo cars to go all electric", Volvo Car Group, 5th July 2017*

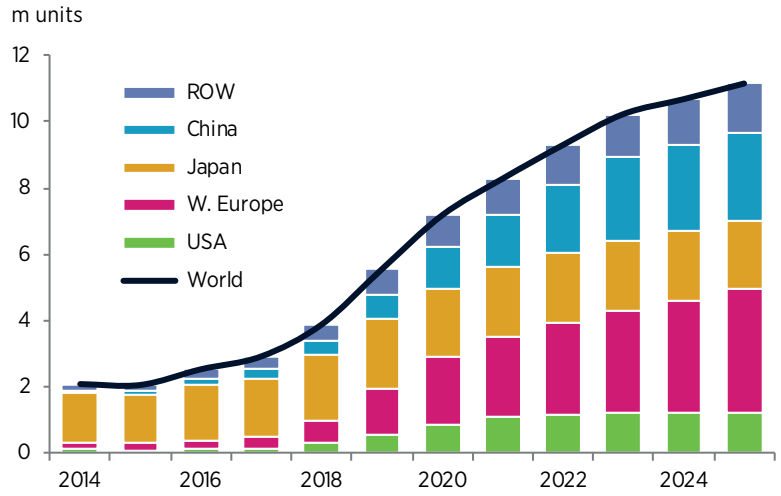
Many readers took this headline to suggest that Volvo was ditching the combustion engine, but while the company plans to launch five all-electric cars between 2019 and 2021, the remaining range will be mild, full or plug-in hybrid. The headline actually means that every Volvo launched from 2019 will have an electric motor, which can, of course, be mated to a combustion engine, as is summarised at the bottom of Volvo's press release:

*"Volvo Cars will introduce a portfolio of electrified cars across its model range, embracing fully electric cars, plug in hybrid cars and mild hybrid cars."*

*Hybrid production should exceed 12 million units next decade*

Global production of gasoline-powered light vehicles is forecast to grow close to 90 million units by 2025 and over that time hybrids are forecast to grow from 3% of gasoline vehicles to over 12%. So, from nothing 20 years ago, hybrid production could reach around 11 million units from more than 20 manufacturers. **By the end of the 2020s hybrids should comfortably exceed 12 million units, particularly if inflection points are achieved in other countries outside Europe and Japan. Over the same period pure electric cars should exceed 3 million units according to LMC Automotive**, though forecasts vary significantly with other companies forecasting significantly higher penetration of electric cars by 2025 as battery costs fall.

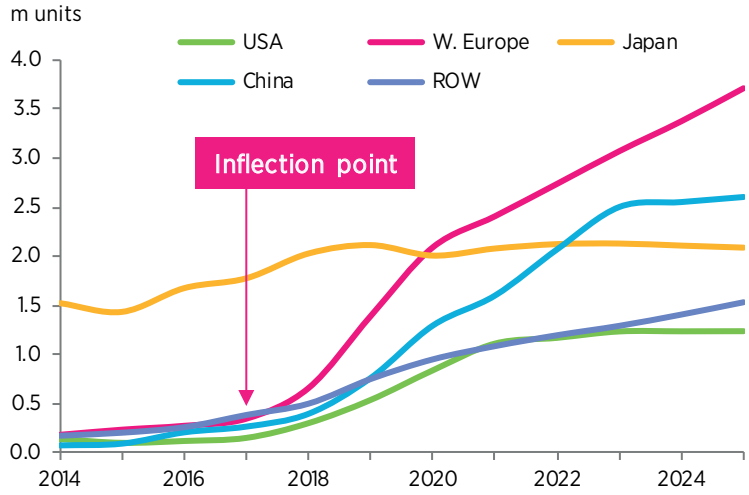
**Gasoline hybrid production: World**




*Source: LMC Automotive*

*Hybrids are going global*

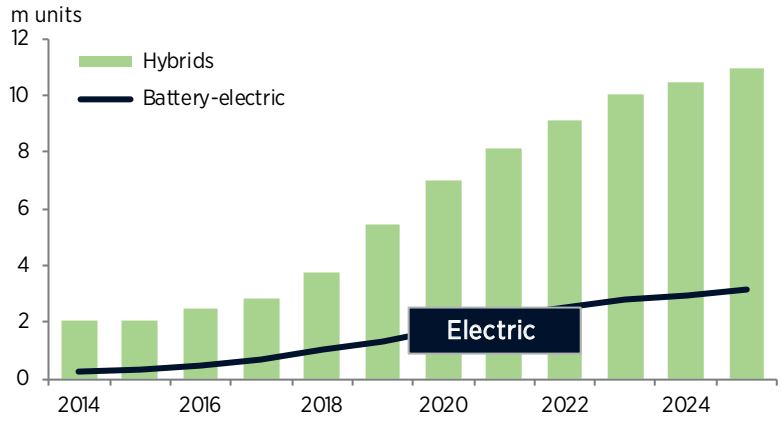
**Gasoline hybrid production by country**




*Source: LMC Automotive*

*Hybrids have reached an inflection point in Europe*

**Gasoline hybrids vs. electric vehicles**



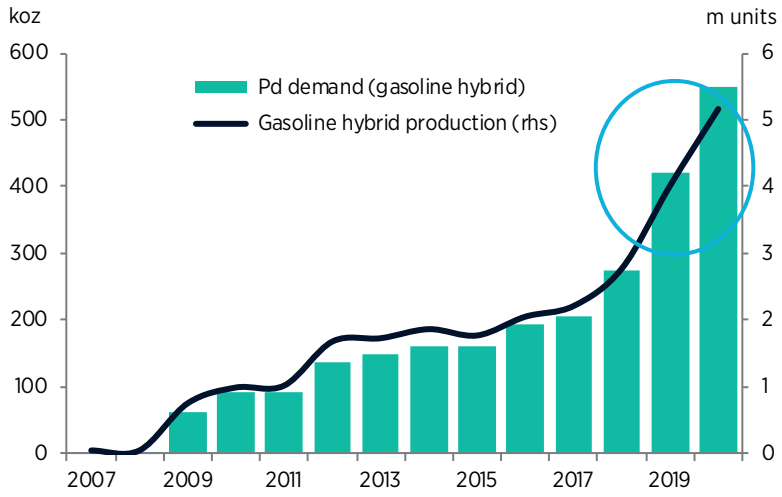

*Source: SFA (Oxford), LMC Automotive*

*Hybrids have a headstart on battery electric cars, reaching ~11 million and >3 million respectively by 2025*

This is significant for palladium, as the chart below shows — from just 200 koz of demand in hybrids today, palladium demand is set to more than double by 2020 to over half-a-million ounces and could exceed 1 million ounces by the end of the next decade.

*Palladium demand in hybrids is set to increase rapidly over the next three years...*

**Forecast palladium demand in gasoline hybrids**




*Source: SFA (Oxford), LMC Automotive*

*...potentially exceeding 1 moz in the 2020s*

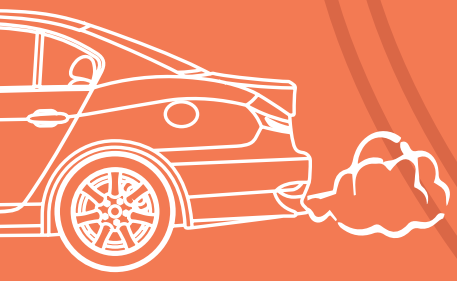
***BMW i8 (hyrbid)***

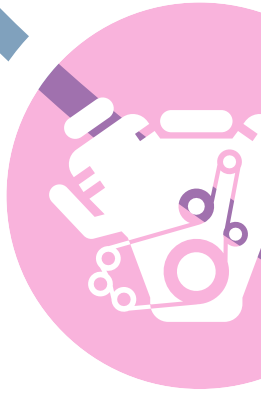
*Source: TRUECar*

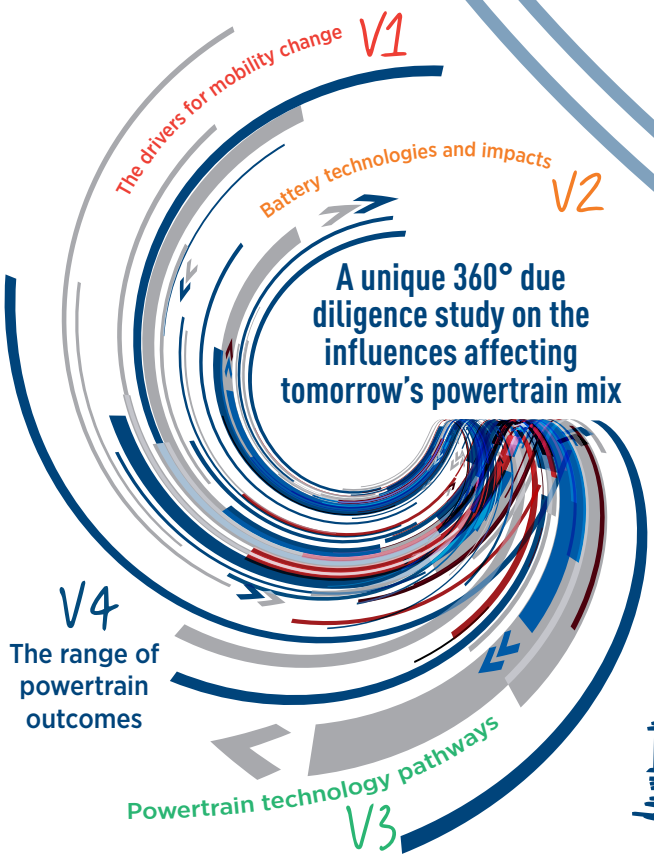
SFA Oxford

consulting analysts in tomorrow's commodities and technologies

# Future powertrains: Joining the dots to 2050








# FUTURE POWERTRAINS: JOINING THE DOTS TO 2050

A unique 360° due diligence study on the influences affecting tomorrow's powertrain mix

**SFA (Oxford) is proud to announce its ground-breaking assignment "Future powertrains: Joining the dots to 2050" study. This arose from our recognition that powertrains are changing and there is a huge amount of agenda-driven and corporate-driven material out there. We feel obliged to try to make analytical, objective sense of it all; while no-one can, in all honesty, predict the precise rate of powertrain evolution, at SFA (Oxford) we are well-placed to unpack all the influences, and provide some intellectually rigorous signposts at this momentous crossroads.**

As the future of both SFA (Oxford) and its clients is critically dependent on the powertrain pathways of tomorrow, **it is essential that we provide our clients with the best possible strategic direction**. A one-dimensional study won't cut it. We believe this problem needs to be considered through 360°, **from the megatrends of urbanisation, air quality and digitisation, to a deep-dive due diligence study on battery technology and all the degrees in between**.

"Future powertrains: Joining the dots to 2050" will **remove the 'noise' and diversely opinionated automobility sector forecasts clouding your judgements and provide the realistic powertrain scenarios** that will guide your strategic assessments. Spread across four volumes (V1-V4), **the series will answer the important questions that SFA (Oxford) is regularly asked** by its clients, covering:

- **Drivers for change: mass transit solutions vs. personal mobility (V1)**
- **What are the latest automotive battery developments and what is their impact likely to be? (V2)**
- **What are the potential pathways for powertrains? (V3)**
- **What is the range of automobility outcomes to 2025 and beyond to 2050? (V4)**

SFA (Oxford) would also be able to provide additional support to you that complements the study, in the form of a **presentation of the key findings to your Board or Exco**, thereby ensuring the Board and senior executives are fully appraised of "Future powertrains". In addition, SFA (Oxford) would be willing to **facilitate workshops** that investigate the future of powertrains and the corporate implications for you. In the future, **SFA (Oxford) will also be developing supplementary reports** that look at the implications of powertrain evolution for a range of metals. These services will be subject to your bespoke requirements and will therefore be quoted separately.

Why this report is a necessity for you:

- Obtain the most **comprehensive due diligence on tomorrow's powertrain mix**, carried out by a multi-disciplined team of analysts that understand PGMs
- Realign your business and marketing with **tomorrow's powertrain pathways** in a timely manner
- Cut through the hype and understand the **length of the internal combustion engine tail**
- Understand the **risks from potential technology** and **policy inflection** points ahead
- Discover **which commodities are the winners and losers**, and when
- Examine the **opportunities and risks** for your company

# Q&A WITH NORNICKEL ON THE FUTURE OF THE PALLADIUM MARKET

# Q&A with Nornickel on the future of the palladium market

*Denis Sharypin, Head of Market Research, Nornickel*

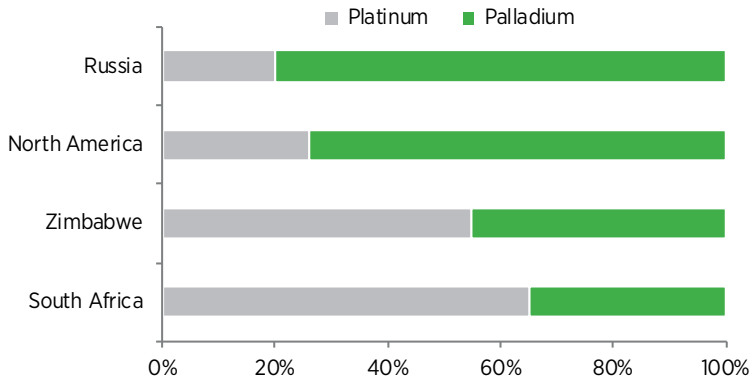
## Mine supply and recycling

### Where are the main palladium deposits located?

**Commercially viable global reserves are very limited and geographically concentrated.**

According to the latest research, most of the precious metals in the Earth's crust are the result of the impact of a cataclysmic meteorite shower on Earth shortly after the planet's core was formed. Considering its alien nature (by the way, palladium was named by W.H. Wollaston after asteroid Pallas, which was discovered in 1802), palladium is a truly precious metal. Together with platinum, it is one of the scarcest elements on Earth — even rarer than gold. Commercially viable global reserves are very limited and geographically concentrated in a few regions around the globe — primarily in Russia (Northern Siberia), South Africa (Bushveld), Zimbabwe (Great Dyke), Canada (Ontario) and the United States (Montana). The Northern Hemisphere deposits contain more palladium than platinum, while 80% of all platinum is mined in Africa. And no, we haven't added Luxembourg that strives to become a hub for some exciting asteroid mining, to the list of possible PGM projects, not just yet.

**Palladium:platinum content ratio**




*Source: Nornickel estimates*

*Russian deposits have the highest Pd:Pt ratio in the world*

## Does palladium supply come mostly as a by-product of nickel and platinum mining?

**Palladium has transformed from being a by-product of platinum and base metals production into a co-product. Palladium's share in mining companies' revenues has grown significantly since 2005.**

Nornickel (formerly Norilsk Nickel), as well as other PGM producers, mines polymetallic deposits and produces a basket of metals. Obviously, the revenue share of an individual metal within this basket depends on the metallic content and relative prices. Ten years ago, when nickel prices hit a record high and palladium prices were unjustifiably low, nickel sales generated over 60% of Nornickel's metal revenue while palladium accounted for less than 10% of it. However, with the subsequent drop in nickel prices, palladium's fundamental revaluation, and the higher share of disseminated ores with relatively higher PGM content, palladium became the largest contributor to Nornickel's revenue in H1'17, accounting for 30% of the total metal revenue (Ni — 27%, Cu — 26%). Indeed, as the new rebranded name of the company unintentionally hints, the main product for Nornickel now is neither copper, *Nor Nickel*, but PGMs, accounting for about 40% of the company's revenue. Palladium has become a fully-fledged element of Nornickel's diversified metal basket.

*Palladium was the highest revenue contributor in H1'17 at 30% and PGMs now account for 40% of Nornickel's revenue*

In Africa we see a clear trend of growing palladium share in revenues — 27% in H1'17, which happens to be equal to the current nickel share in Nornickel's revenue, vs. 7% in 2005. It is a result of a narrowing Pt:Pd price ratio and gradual redistribution of mined platinum and palladium tonnages with the shift of PGM mining from the Western Limb (Pt:Pd 2.0:1) to the Eastern Limb (1.5:1), Northern Limb (1.1:1) and Zimbabwe (1.2:1). Overall, the African Pt:Pd output ratio has shifted from 2.0:1 in 2005 to 1.7:1 in 2017. It is worth noting, however, that in view of the anticipated lower supply from the Eastern Limb following the recently announced Bokoni closure, stagnating output in Zimbabwe, and possible ramp-up of Northern Limb's greenfield projects after 2022 only, the African Pt:Pd output ratio is likely to stay at a relatively stable level for the next five years, unless significant one-region-centred shutdowns take place. It means that over that time, the revenue share of palladium in African businesses should mostly depend on relative Pt:Pd price fluctuations.

*Narrowing of the Pt:Pd price ratio and a mining shift on the Western Limb are driving greater shares of Pd revenue for producers in South Africa*

While palladium is the primary metal for Stillwater (US), output from Canada can still be regarded as a by-product of its nickel mining. Owing to lower PGM content in Canadian ores, palladium accounted for less than 10% of its revenues in 2016.

## How fast can palladium mines provide additional volumes, if the price is at or above the current levels?

**PGM mine production is not price elastic, i.e. it cannot react to higher palladium prices quickly as significant capital investments and plenty of time are needed to build or expand a mine.**

*PGM mine production is not price elastic (i.e. it cannot react to higher palladium prices quickly)*

**Nornickel's 'expansion' CAPEX allows it to keep the output profile flat. The company conducts major downstream production reconfiguration to optimise its asset portfolio, decommission obsolete capacities, modernise processing facilities, and improve efficiency and its environmental footprint.**

**A low platinum price environment results in approximately 50% of South African PGM production being unprofitable or on the edge of loss-making on a net cash cost basis, but environmental regulation and government pressure to secure employment and social order prevent mining companies from shutting down cash-burning projects.**

Major global challenges:

*Industry headwinds to grow supply*

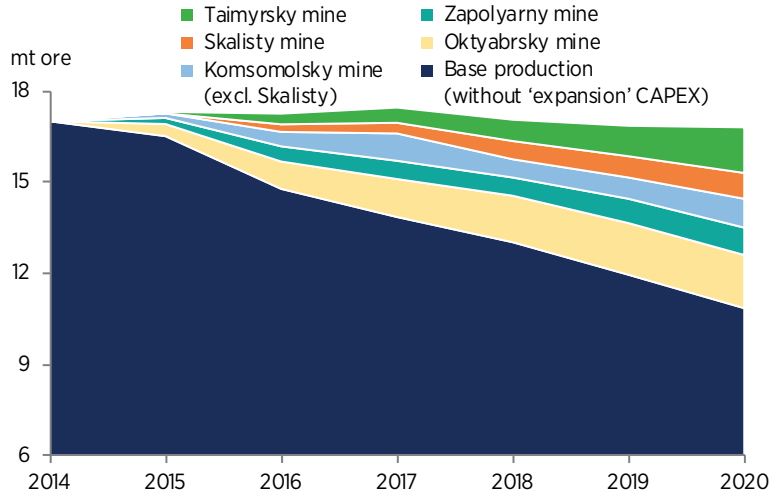
- It takes about 10 years and over US$1 bn to build a sizeable underground mine from scratch.
- Open-pit mines (mostly in South Africa or Russia) can be ramped up in 3-5 years but the polymetallic nature of sulphide ore bodies dictates building complex processing capacities and requires substantial investments and time.
- Mining is a capital-intensive business and just to maintain stable production rates continuously growing capital is required, amidst degradation of ores and their deeper occurrence. In addition, mining inflation during the life-of-mine is higher than the CPI because of rapid depletion of more accessible and higher-grade reserves. Every new tonne of extracted ore needs more energy, labour and other resources. As a result, growing expenses are needed not only to increase production volumes but also just to keep them flat.

**In Russia:**

- Since 2014, Nornickel has been conducting major downstream production reconfiguration to optimise its asset portfolio, decommission obsolete capacities, and improve efficiency. Closure of the outdated nickel plant in the city of Norilsk in August 2016 called for substantial capital investments in upgrading the Talnakh concentrator and the further expansion of Nadezhda smelter in the Polar Division, as well as upgrading and scaling up the refinery in the Kola Division (Monchegorsk refinery) by 2019. This programme is still ongoing.
- The major sulphur dioxide capturing project at Polar Division would require investment of roughly US$1.7-2 bn by 2023.
- 'Expansion' CAPEX, which in 2016 alone totalled over $400 million for Nornickel mines' development (excluding Bystrinsky greenfield copper project with no PGMs), keeps the output profile flat; without these investments, Nornickel's mine output would have decreased significantly.

*Nornickel has invested heavily in new processing infrastructure to deal with environmental legislation*

**Without 'expansion' CAPEX Nornickel production could decrease significantly**




*Source: Nornickel estimates as of 2015*

- Higher palladium prices make Nornickel's South Cluster (approximately 70% of PGM value in the metal basket) of the Polar Division more attractive for possible development (2 mtpa –> potentially up to 6 mtpa of ore, as disclosed in May 2016). This project is currently under review by the management. However, palladium prices should be sustainably high in the long-run to justify the capital investments in Talnakh Concentrator Phase 3 expansion (from currently 10.2 mt to 18.0 mt of ore p.a.) and subsequent mine development.

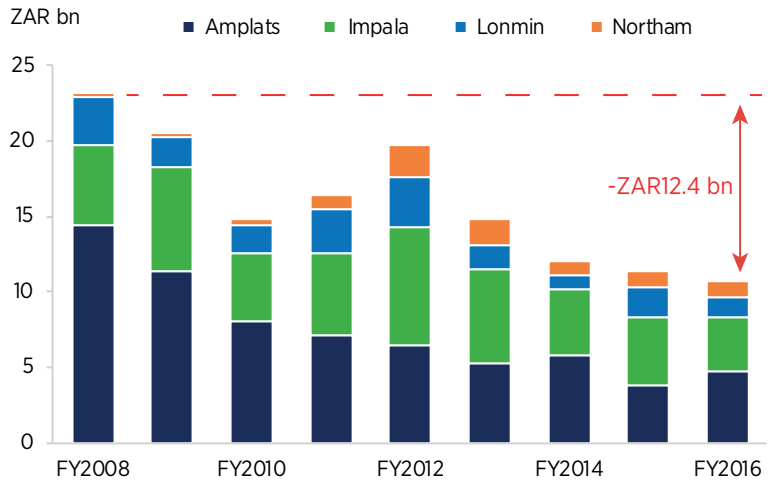
- Nornickel also owns a licence for the Maslovskoe deposit located in close proximity to the city of Norilsk (less than 10 miles), which could also be a long-term upstream option to increase PGM output. Enjoying ore resources of over 200 mt with high palladium (4.6 g/t) and platinum (1.8 g/t) content and relatively low base metals credits (less than 30% of the basket value), Maslovskoe has the potential to become the world's largest PGM mine, though no investment decisions have been made yet. This project requires the construction of an underground mine as well as additional processing facilities to address any potential bottlenecks.
- Russian Platinum's Chernogorskoe greenfield open-pit mine is under review, its launch is delayed, and construction of the concentrator has not yet started. Considering that the project is located in the Arctic region (near Norilsk), the project would face such challenges as: building processing facilities on the permafrost, operating open-pit mining at up to -65°F ultralow temperatures (note: Nornickel mines over 90% of its Polar Division ore underground), the high cost of shipping large volumes of intermediate products (concentrates or matte) via the Arctic Sea route, and achieving high payability considering that the rare mix of base and precious metals can be processed in big volumes by only a few polymetallic processors globally.

**In South Africa:**

*Marginal Pd growth forecast from South African mines*

- Over the next three years, South African annual production is expected to grow marginally, by 0.1 moz to 2.6 moz of palladium and by 0.1 moz to 4.6 moz of platinum. Along with old and loss-making shaft closures, some projects will be launched and/or expanded (Booysendal, RBPlats' Styldrift, Impala's Lease Area) to compensate closing capacities and natural attrition.
- The low platinum price environment results in approximately 50% of South African PGM production being unprofitable or on the edge of loss-making on a net cash cost basis, but environmental regulation and government pressure to secure employment and social order prevent mining companies from shutting down cash-burning projects. However, the SA PGM industry has been experiencing CAPEX shortages for an extended time. Eventually, we believe deferred CAPEX will lead to a deterioration of the production base.

**Capital expenditure**




*Source: Company reports*

*Over ZAR12 bn CAPEX cuts by FY2016 compared to FY2008*

- Overinflated workforce — demands for annual wage increases above the South African CPI.
- The growing effect of strikes through labor union unrest. Although the three-year wage deals for the majority of mines running until 2019 should limit the potential for industrial action, some stoppages cannot be entirely ruled out as producers are focusing on capital preservation, asset disposal, and rationalisation. Rivalry between unions may also destabilise labour relations in the mining sector.
- A growing risk of resource nationalism. The recently published Mining Charter, which imposes new requirements on black empowerment and additional taxes for black communities, if enforced, will likely inhibit the development of the existing and new projects in the country.
- Unstable power supply and water shortages in South Africa.
- Frequent safety stoppages.
- Lack of skilled labour.
- Further development of platinum-rich projects in South Africa is also capped by more balanced platinum market fundamentals.
- Limited base metal refining capacities in South Africa are a bottleneck for developing the Northern Limb with ores containing relatively high Ni/Cu content. Capacity expansion will lead to higher project CAPEX.

**In Zimbabwe:**

- Constant changes in legislation regulating taxation and export of revenues.
- Requirement to build smelting and refining capacities constrains business models for new projects.
- The Zimbabwean Empowerment Act, promulgated in 2008, requires the transfer of a 51% shareholding in all foreign-owned companies to indigenous Zimbabweans. In April 2016, Zimbabwe's President announced that foreign mines could retain ownership control as long as 75% of the gross value of exploited resources is retained in Zimbabwe. The President's statements clarifying the Empowerment Act have yet to be codified into law.
- Lack of skilled labour.
- The Darwendale project by a Russian consortium (Vi Holding-Rostech-VEB), after having been officially announced three years ago, is still under assessment at a very early stage of development.

*A lot of institutional and technical challenges for PGM business development in Zimbabwe*

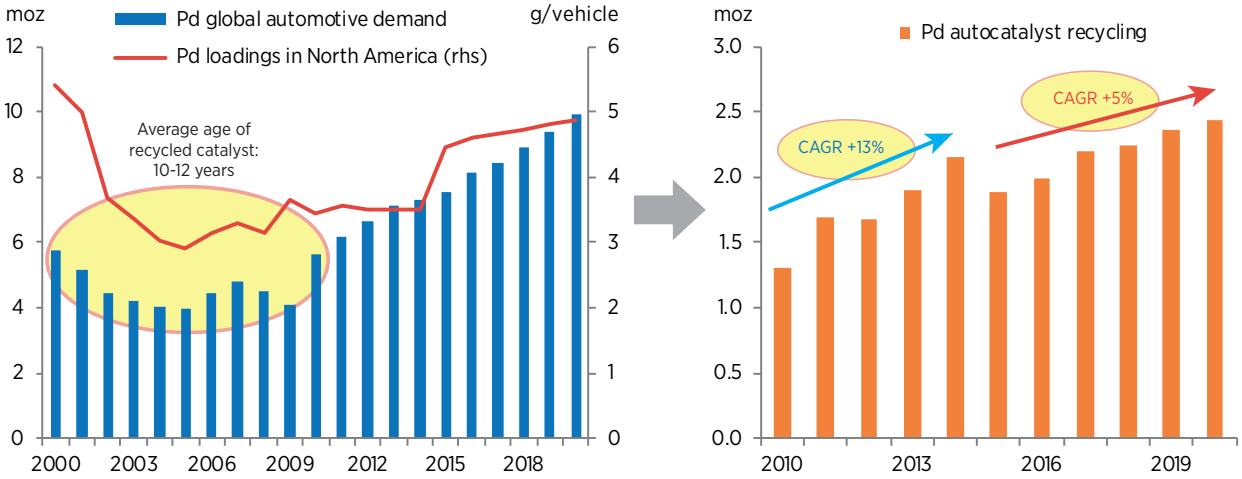
**In North America:**

- Palladium mine output in North America is going to increase by 2% to 1.1 moz, while platinum production is expected to be flat at 0.4 moz within the three-year horizon. Canadian production is estimated to be lower while US shipments are expected to grow with the development of the Blitz project.

## Can recycling cover palladium market deficits?

**Although recycling is expected to grow, it won't be able to balance the market as it lags behind the underlying palladium demand.**

**Palladium automotive demand and recycling**




*Source: Nornickel estimates*

Palladium scrap from spent autocatalysts is the only substantial source of material returning to the market: palladium supply from this source increased from 0.2 moz in 1999 to 2.2 moz in 2017, with CAGR in excess of 15%.

Following the price spike, palladium loadings decreased considerably in the early 2000s. Considering that the average lifespan of a catalytic converter, which is recycled today, is about 10-12 years, this results in lower CAGR (5-6% over the next five years) of recycled palladium volumes. This trend places additional pressure on scrap processors as more capacity and processing costs are required just to keep the volumes of payable PGM ounces flat.

*Lower Pd loadings in the last decade result in slower recycling growth*

In 2020-2025, a new wave of old vehicles will come into the recycling stream and, along with the expected increasing recovery rate due to the maturing collection structure of the used autocatalysts, this will lead to an increase in recycled palladium. However, this incremental supply alone will not be able to balance the market as it lags behind strong underlying palladium demand.

## Demand and consumption

### What are the key palladium demand drivers?

**Automotive demand is the main driver for palladium consumption as a result of tightening environmental regulations, powertrain shifts and termination of engine downsizing. In 2017, palladium consumption is expected to reach a new all-time high of 10.7 moz. By 2020, annual consumption will require another 1.3 moz of palladium.**

*Automotive Pd demand is on the increase*

Mandatory installation of catalytic converter systems has led to a dramatic reduction in emissions and an improved quality of life: pollution per vehicle has decreased approximately 100-fold compared to pre-1974 levels. Every year catalytic converters reduce the volume of global pollutants by about 80 mt, providing cleaner air and a better quality of life to residents of large cities.

Society's continuous requirement for ever-improving air quality standards dictates the continual tightening of these standards, with regards to both the degree of exhaust purification and guaranteed vehicle mileage. Emerging economies are struggling with heavy air pollution and catching up with the emission control standards of the developed world:

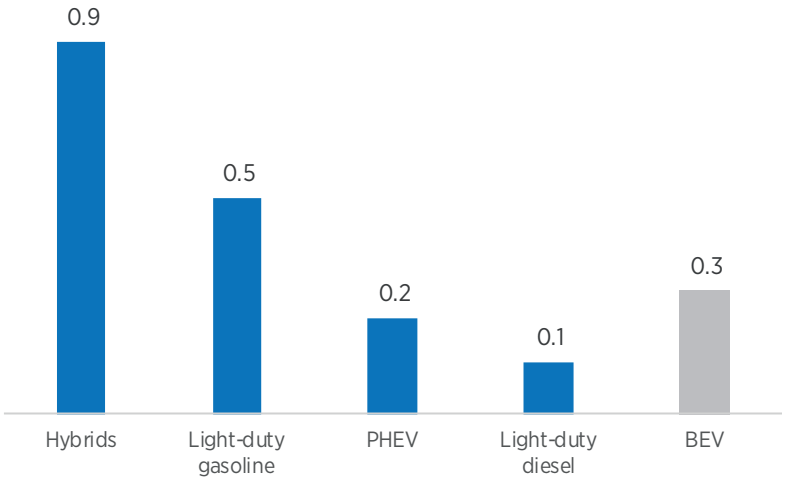
*Driven by the need for clean transport*

- **China 6 standard**, which will be implemented by steps in 2018-2023, combines best practices from both European and US regulations, and for some end-points it sets additional regulatory requirements.

*Pd-based autocatalysts continue to help meet emission standards*

- A mandatory limit on the number of particles from gasoline direct injection engines, which will require **gasoline particulate filters** (GPF, contains palladium) in Europe from September 2017.
- The introduction of **Real Driving Emission (RDE)** tests in Europe (Euro 6d-TEMP and Euro 6d) in September 2017 (partly enforced) and 2021 (fully enforced) should increase PGM loadings.
- Continuing more stringent **Tier 3** phase-in in the US from 2017 to 2025.

**Incremental average annual output by powertrain, 2016-2024, m units**




*Source: Nornickel estimates, LMC Automotive*

*Hybrids and gasoline will see the strongest powertrain growth containing Pd-based exhaust gas catalysts*

**Powertrain shifts are positive for palladium:**

- **Hybrids and gasoline engines** should drive palladium consumption. Hybridisation, involving the use of petrol engines featuring palladium-based exhaust gas catalysts, is a key trend in the development of environmentally friendly transport, with 7-10% share of hybrids in vehicle sales by 2025. This trend is positive for PGM consumption as gasoline hybrids have between 10% and 15% more PGM in their catalysts compared with conventional gasoline vehicles of the same engine size.

*Tightening environmental regulations, powertrain shifts and termination of engine downsizing drive Pd consumption*

- **Engine size:** Current low fuel prices and the growing popularity of SUVs encourage automakers to introduce vehicles (including hybrids) with higher ICE displacement. RDE tests also push automakers to increase engine sizes as ultra-small engines show good emission results during laboratory tests only, but they are not so effective in real driving. These factors put an end to the trend of engine downsizing seen in 2005-2015.

- **Anti-diesel sentiment affected consumer behaviour, resulting in a higher gasoline ratio.** By the end of H1'17, the diesel share in German light vehicles' sales fell by 9% y-o-y to 41% (lowest since 2009) while the gasoline share grew by 12% y-o-y to 56%. In France, the diesel share fell from 59% to 34% in just two years. In India, the diesel share fell from 47% to 27% in four years.

*Gasoline powertrains gaining at diesels' expense*

- **Gasoline direct injection** (23% in 2016 to 38% in 2024) is positive for palladium: cooler exhausts produce more hydrocarbons.

- **Aftertreatment extending to new areas:** e.g. non-road, marine applications.

*New markets subject to emissions legislation*

- **Limited EV penetration:** Despite strong media attention, pure electric vehicles are to stay a niche product for the next 10 years. High EV penetration will be challenged by the lack of (re)charging infrastructure, constrained CAPEX in electric grid and power generation, long charging periods, short and volatile driving ranges, poor performance in cold climates, limited supply of lithium, nickel sulphate and cobalt sulphate, which might increase battery prices, and a shorter battery life than that of the vehicle, which increases the cost of ownership. Most forecasts estimate EVs share at 3-5% of global vehicle sales by 2025. Even if the 40%+ growth seen in H1'17 could be maintained by 2025, the EVs market share would still not reach a 10% level. It is worth noting that the growing EV market is a remarkable story for the demand for nickel, which is used as a critical material in making Li-ion (or as Elon Musk called them, nickel-graphite) and other types of batteries.

*Gasoline internal combustion faces little immediate threat from battery EVs*

- **Fuel cells:** There is some renewed attention to this technology — thanks mainly to the Chinese government, which announced its plans to supply 50,000 hydrogen electric cars by 2025 and another 1 million by 2030. If these intentions are realised, the platinum offtake can be boosted by 0.3-1 moz p.a. (the current loadings per vehicle are about 30 g but there are goals to decrease this to below 10 g). Fuel-cell expansion will also have a positive impact on palladium demand as it exhibits a number of unique properties which enable its application in a myriad of hydrogen technologies. Palladium has the ability to absorb up to 900 times its own volume of hydrogen that allows the efficient use of the metal in hydrogen production, purification, storage and detection. Palladium-based alloys can also be used efficiently in certain fuel cell catalysis.

*Up to 1 moz of Pt upside if FCEVs take off in China by 2030*

*Unique absorption property of Pd in hydrogen production*

## Why is palladium not being used actively in jewellery despite its favourable characteristics?

**Palladium has everything to become a widely-used jewellery metal, except effective marketing. Palladium Global Marketing is going to address this.**

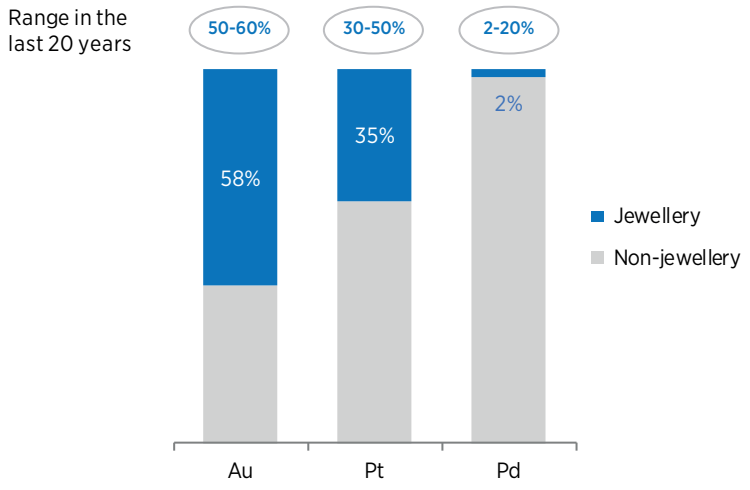
*Lack of positive identity in the jewellery market so far*

Palladium has distinctively strong physical/consumer characteristics as a jewellery material:

*Favourable Pd jewellery characteristics*

- It is a true precious metal with established hallmarking (e.g. in the UK since 2010).
- It is hypoallergenic (some patch-testing showed that palladium was less allergenic than gold).
- It does not lose whiteness in everyday wear, nor does it corrode.
- It is stronger than gold, i.e. less scratching and more secure in holding gems.
- Handling of palladium is easy because it is a soft and malleable metal.
- The surface wear is as easily and quickly removed as it is for platinum products.
- Lower density — 30% lighter than gold, 40% lighter than platinum — palladium can be used to make distinctive larger pieces of jewellery.

**Share of metals used in jewellery, %**




*Source: Nornickel estimates*

*Only 2% of Pd is used in jewellery, presenting a significant growth opportunity*

However, palladium is the least-used precious metal in jewellery. It is used as a whitening agent for white gold alloys (white gold can contain up to 15% palladium) and an additive to platinum alloys (Pt 950 can contain up to 1/20 of Pd). Also, the metal is used for manufacturing luxury watch bodies, ornaments and wedding bands, mostly in Europe and the US. Volume-wise, palladium fine jewellery fabrication was predominately a Chinese story: in the mid-2000s the industry's offtake exceeded 1 moz p.a. but recently the use of palladium in jewellery in China has decreased to below 0.1 moz p.a. owing to low awareness and the lack of active marketing.

*Most jewellery materials need marketing support*

Nornickel is the largest producer of palladium and naturally takes a leadership position to support and develop the palladium market in a number of strategic initiatives. One of the major opportunities for palladium is to enhance its jewellery credentials, and Nornickel has spent the last 18 months researching and creating a global marketing plan. Lifestyle changes make millennials open to new types of jewellery, and palladium can meet this demand. Palladium jewellery will create new business opportunities and complement platinum jewellery marketing rather than compete with it. Palladium will grow the whole jewellery market.

*New Pd jewellery marketing plan in development to complement Pt jewellery*

Nornickel has established a specialist marketing team called Palladium Global Marketing Limited (PGM), and they have developed a market strategy, based on consumer research in a number of markets across the world, which has generated some interest and support from retailers. The plan is to launch it in China and then consider expanding it globally.

*Nornickel's Palladium Global Marketing Limited to boost future Pd jewellery sales in China*

## How elastic is palladium consumption?

**Automotive — inelastic with respect to the absolute price levels but displays relative price elasticity depending on the Pd:Pt:Rh price ratios and physical availability of the metal:**

- The value of PGMs in a vehicle is less than 1% of its cost of production.
- Despite more than 40 years of cost-driven catalytic converter research, no effective alternative for the use of PGMs in neutralising emissions has ever been identified owing to the PGMs' unique catalytic properties — high reactivity in a wide range of operating temperatures, which is maintained for the lifetime of a vehicle. Autocatalyst operating conditions are extreme: temperatures in tailpipe systems can exceed 1,000°C, and uneven driving patterns result in considerable fluctuation of fumes' concentrations and gas volumes. The chemical reaction is complex and involves oxidisation and reduction of several hazardous gases while catalysts have to deliver the required performance right after the engine starts operating. Sporadic news releases announcing cheap replacement materials for palladium and platinum should be read with a big pinch of salt because comparative test conditions in a research laboratory do not necessarily reflect the real operational environment. Other materials just make it impossible to reach the emission regulation standards: the most effective base metal catalyst, for instance, would lose most of its reactivity after just several weeks of use. No-PGM selective catalytic reduction (SCR) is just one element of the converter system that also contains the palladium and platinum-rich diesel oxidation catalyst (DOC) and diesel particulate filter (DPF) that are critical for diesel vehicles' compliance with Euro 6 legislation.

*PGMs face little competition in autocatalysts*

*Hostile automotive environment and challenging emissions legislation mean only PGMs can survive*

- Further thrifting of palladium and platinum is limited, as most of the cuts have already occurred: a US passenger car contained up to 30 g of PGMs in the late 1990s while average loadings today for a light gasoline vehicle are up to 10 times lower. Loadings per vehicle can be further reduced only moderately; while the combustion process becomes more efficient, the continuous tightening of emission regulations is most likely to overcompensate any losses.

*Thrifting is inevitable, but most of the gains have been made*

- Substitution equilibrium has yet to be tested — more than 1 g of platinum (or additional volumes of rhodium) may be needed to immediately substitute 1 g of palladium. Considering the tighter environmental legislation, real driving emissions tests, engine evolution while palladium has remained the metal of choice for petrol engines for over 15 years, it is not so obvious that the Pd->Pt substitution ratio on a 1:1 weight basis proved a few years ago is immediately achieved as it would require re-engineering of the whole tailpipe system, engine performance and metal coatings which are currently optimised for palladium efficient performance. It requires investments and time.

*Some scope for substitution within the PGM triangle, but not a quick or cheap move*

- A few years ago, diesel engines required platinum loadings of at least 50%, but further reduction of sulphur in diesel fuel (wide implementation of Euro 6) has widened the interchangeability between platinum and palladium. It is worth noting that for diesels, Pd-Pt alloys are considered more efficient than single-metal catalysts, which limits the potential volumes of palladium for substitution.

*Not just about price — vital to optimise the catalyst metal to the chemical reaction in the exhaust stream*

- Catalytically, rhodium can be 4-5 times more effective than palladium, but small rhodium supply volumes (1 moz p.a.), dependency on African producers (>80% of global mine production), high price volatility (from $500-$10,000/oz over the last 10 years) and existing overexposure to the automotive sector (>80% of demand) limit palladium substitution with rhodium. It is believed that the majority of rhodium above-ground stocks have been accumulated at price levels above $2,500-$3,000/oz, but it does not necessarily mean these volumes will be offered back to the market at the same prices.

*Rhodium is a very effective catalyst, but supply limitations and price volatility restrain palladium substitution by rhodium*

**Chemical — price inelastic:**

No viable alternative exists since no other material can provide the selectivity required. Alternative materials also have lower productivity and lifespan, while idling time for catalyst replacement is economically more significant than the potential cost savings on the catalyst.

*Unique catalytic properties make Pd economically indispensable*

**Electronics — low price elasticity:**

This sector has already experienced significant losses over the past decade. Spurred by the price bubble in the early 2000s, electronics sector refurbishment in Japan resulted in dramatic irreversible substitution of palladium by base metals for the majority of their products. As a result, palladium consumption dropped from over 2 moz in 2000 to 1 moz in 2014.

*Priced out of use in less-sensitive products, but use continues where products must not fail*

Inelastic as far as multi-layer ceramic capacitors used in high-end, military or aerospace applications are concerned (approximately 50% of palladium demand in the industry). The Pd>Au price environment may incentivise palladium substitution in connectors and circuit board plating.

**Jewellery — moderately price elastic:**

The platinum history shows that high prices may also incentivise palladium jewellery demand. Current low demand for palladium can be considered as an opportunity for growth.

*Needs marketing input*

**Dental — price elastic:**

High palladium prices would accelerate substitution by alternative materials. Palladium being more expensive than gold would also result in lower consumption. The Japanese state insurance programme is likely to prevent the full elimination of palladium usage in the industry.

*Price-competitive and cosmetically attractive alternatives compete, but Japan continues to support Pd*

## China's palladium consumption has significantly exceeded imports for years, although domestic production is insignificant. Where does the metal come from?

**Official statistics on palladium imports into mainland China are likely not capturing all flows.**

Palladium consumption in China accounted for 2.4 moz in 2016. Taking into account that domestic primary production was about 100 koz, metal recycling 300 koz, official palladium net imports to mainland China 650 koz, and about 300 koz was imported in the form of palladium-based products, that leaves over 1 moz of supply with unidentified origins. This discrepancy repeats every year. Considerable Hong Kong net imports (1.5 moz in 2016) give grounds to presume that unlike platinum, a significant part of palladium imports to China is not reflected in the official trade statistics, unfortunately. This is a result of regulatory differences governing the circulation of the metal in China. Platinum imported to China through the Shanghai Gold Exchange is exempt from VAT while palladium is subject to VAT (17%) at the time of import. To avoid taxes, it is likely that large portions of palladium are shipped to mainland China, bypassing customs processing.

*Chinese Pd trade data are not accurate with up to 1 moz unidentified each year*

# Investment and above-ground stocks

## Why are palladium ingots being traded at a premium/close to parity to sponge in 2017?

**Not because sponge demand is slow, but mostly because of ingots' demand in Hong Kong and a backwardation arbitrage opportunity.**

Palladium sponge is used as a primary feed in auto and chemical catalysts (easy to dissolve), while ingots are used for investment purposes (easy to store, check the quality, and maintain the exact weight) and as a feed for making alloys in dentistry, jewellery and other applications (lower losses during melting). The cost of conversion between these forms is usually less than $5/oz.

Considering that on-ground stocks have been accumulated in the form of ingots while sponge is the preferred material for over 80% of consumption, market participants use the sponge/ingot price ratio as a proxy to follow possible physical market tightness.

*Pd sponge-ingot price ratio tracks physical market tightness, with 80% of manufacturers purchasing sponge*

Considering that underlying demand for palladium sponge by the auto industry is strong, we believe that palladium ingot premia vs. sponge are driven mainly by lower availability of ingots from stocks than it was in the past, and high physical demand for ingots in Hong Kong accompanied by a backwardation arbitrage opportunity.

## How much palladium is held in Russian state stockpiles?

**Russian governmental stocks are believed to be depleted.**

Historically, platinum was more available in the Western world than palladium (mainly produced in the USSR), and therefore platinum was a metal of choice for chemical scientists and engineers seeking a superior lever to speed up chemical processes. In the 1970s, when the first gas emission legislation was introduced in the US, an automobile catalytic converter for the gasoline engine was engineered using mostly platinum.

During the Soviet era, big volumes of palladium were accumulated in Russia. The holder of the stocks was the Ministry of Finance (Gokhran). Information regarding the size of this stockpile is classified, thus no valid data are available. It is also impossible to estimate the volume of this stock as there are no reliable data on how much palladium was consumed and recycled in the USSR.

The first palladium-rich autocatalyst was introduced only in the mid-1990s, when more palladium became available from Russia to satisfy increased industry requirements driven by further tightening of emissions legislation and expanding vehicle production.

*Gokhran stocks have depleted*

As far as we can assume, the stocks held by the Russian Ministry of Finance (Gokhran) are depleted; no deliveries have been identified by the market since 2014. During the last 30 years, the stocks from Gokhran were reallocated from Russia. Some of it filled the gap between production and consumption, and some of it was accumulated in Western vaults, mostly in Switzerland, the UK, the EU, the US, Japan and China. A part of it was also sold to the Russian Central Bank (an entity independent from the Russian Ministry of Finance) in the 1990s, which is believed to be already reflected in the estimations of above-ground stocks made by analysts.

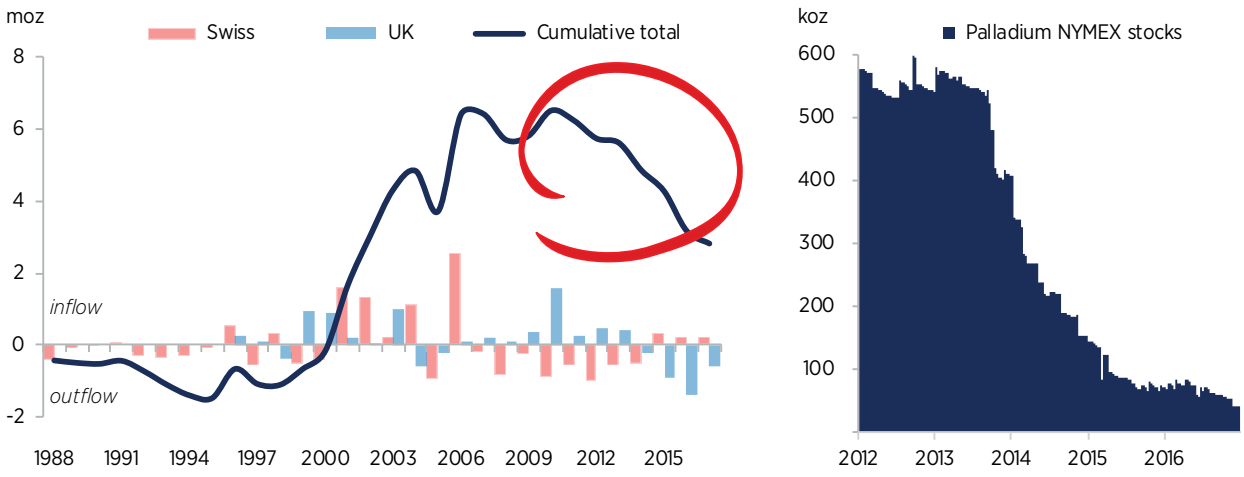
## Visible demand exceeded supply for many years. What is the source that covers the deficit? How large are palladium above-ground stocks?

**Stocks are non-transparent and all estimates are highly questionable. London and Swiss loco stocks' disclosure (as made for gold and silver stocks in London) will be very helpful. On the other hand, proxy indicators show that potentially available for consumption stocks are depleted.**

*Most above-ground Pd stock is undisclosed*

Palladium stocks in Western vaults are not officially disclosed. The only transparent stock is ETFs — 1.6 moz held globally as of the end of August 2017. Switzerland and London are considered to be the largest location of vaults that secure palladium and platinum. They are often seen as a proxy for accumulation of stocks, and a very clear trend, seen since 2010, confirms that palladium usage exceeds supply and needs stockpiles to be involved. Palladium NYMEX stock movement also reflects depletion of on-ground stocks.

**Swiss and UK palladium net trade**




*Source: Swiss Federal Customs Administration, HM Revenue & Customs, CME*

*Trade stats do not reveal vault volumes*

It is worth mentioning that the trade statistics cannot reveal the actual amount stored in the vaults:

- According to international trade rules, trade statistics reflect the origin of goods, not the previous destination. Thus, imports of Russian palladium do not necessarily show fresh supply from Russia, e.g. Soviet era metal moved from London to Zurich would be recorded as Russian imports. The metal export shows the first destination only, without information on the country of origin.

- Besides the track of palladium metal, other flows to/from a country with existing palladium refining capacities should be taken into account, e.g. scrap, compounds. These flows are recorded on a gross tonnage basis only, the palladium content is impossible to indicate.

- A 50 koz error in palladium consumption would result in ~1 moz of stock discrepancy in 20 years.

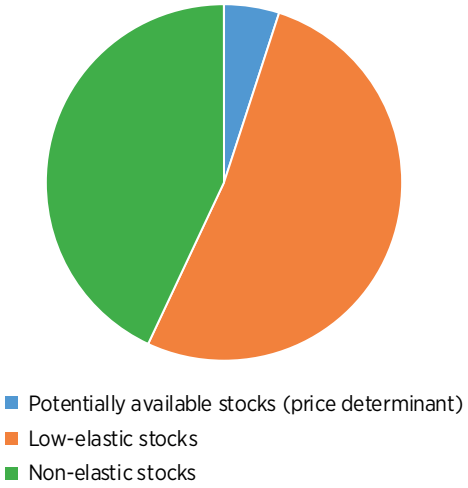
- There can be a metal flow which might not be recorded in the official trade statistics (e.g. a jeweller who transports an ingot from Switzerland in the trunk of his car without declaring it). These thin flows would result in big cumulative multi-year deviations.

*Calculating Pd stocks can result in a large error over many years*

Considering that there is no way to exactly estimate the palladium above-ground stocks using the trade statistics, we welcome the LBMA initiative to disclose loco-London gold and silver stocks and we hope that palladium and platinum stocks will also be revealed soon.

It should be mentioned that existing global stockpiles are not uniform. The holders behind them include industrial consumers, hedge funds, ETFs, trading companies and commodity exchanges. However, a substantial part of the stockpile is likely to be available — at the right price, some of the metal is tied up — in metal account deposits, industrial inventories, and partly price-elastic ETFs (despite a 16-year price record, ETFs added about 100 koz in August).

**Above-ground palladium stocks, 2017**




*Source: Nornickel estimates*

*Potentially available stocks are limited*

## What is the purpose of the Palladium Fund?

Nornickel, being a responsible market participant, launched a fund in 2016 to acquire access to non-transparent, mostly unavailable, above-ground palladium stocks, and supply additional metal volumes to industrial consumers in order to satisfy increasing metal demand and alleviate an anticipated structural supply deficit.

*Palladium Fund launched to acquire non-transparent, above-ground stocks and supply to industrial consumers*

The annual sales volumes are supposed to be limited and supplied to the industrial consumers based on market prices.

Producers' control of the bulk of the above-ground stocks would prevent a market imbalance and excessive price volatility. We believe this would provide a more stable market and, as a consequence, stimulate the long-term growth of industrial consumption.

## Is the palladium discount to platinum justified? How sustainable is the current price?

The Russian government's stock that had been compensating for the market deficit for a long time has been depleted.

*The world has consumed over 15% more palladium than was actually produced during the last 20 years.*

Automotive demand remains the strongest driver for palladium consumption, supported by sustainable global auto market growth rates, powertrain shifts, and higher metal loadings per vehicle associated with the introduction of new environmental requirements, especially in China. Increasing SUV share and transport hybridisation are viewed as new opportunities for palladium use. Pure electric vehicles' market share will be limited and they pose little threat to PGM consumption in the medium term.

The palladium futures market turned to backwardation, resulting in a spike in the lease rates. Market participants believe that backwardation is likely to continue.

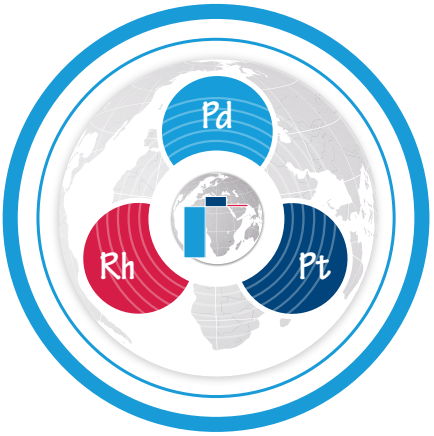
The discount of palladium to platinum is not fundamentally sustainable as palladium is a preferred metal for the automotive industry while the palladium market is in a state of structural deficit. When the first palladium-rich autocatalyst was introduced in the mid-1990s, about 2 ounces of palladium could substitute 1 ounce of platinum, fundamentally justifying the Pt:Pd price ratio of 2:1. However, with technical progress during the 2000s intensified by appreciating PGM prices, the substitution ratio between platinum and palladium for gasoline emissions reached nearly 1:1 on a weight basis. Continuing price disparity between platinum and palladium has driven the decision to load more palladium in this application and therefore it has become the dominant metal in gasoline-fired automobiles,

*Pd:Pt discount is unsustainable*

which account for ~80% of global light-vehicle production today. The market has been adjusting to a new reality, resulting in an upward shift of palladium prices. Substitution equilibrium has yet to be tested — more than 1 g of platinum (or additional volumes of rhodium) may be needed to immediately substitute 1 g of palladium. Considering the tighter environmental legislation, real driving emissions tests, engine evolution while palladium has remained the metal of choice for petrol engines for over 15 years, it is not so obvious that the Pd->Pt substitution ratio on a 1:1 weight basis proved a few years ago is immediately achievable, as it would require re-engineering of the whole tailpipe system, engine performance and metal coatings which are currently optimised for palladium efficient performance. It requires investments and time.

*Substitution equilibrium is untested as Pd prices rise*

# THE PGM MARKETS IN 2017



# The PGM markets in 2017

*Dr. Ralph Grimble and Thomas Chandler, SFA (Oxford) Ltd*

## The palladium market

**Summary**

The palladium market is set to have another year with a deficit greater than 1 moz in 2017, so the drawdown of above-ground stocks will continue.

*Deficit set to remain >1 moz*

The price has continued its recovery from the low of just under $500/oz set in early 2016, rising 40% from $673/oz at the start of this year to $942/oz at the end of August.

However, some strains developed in the market in the middle of the year as a shortage of available palladium bullion resulted in a surge in lease rates, with the price jumping over $900/oz for the first time since 2014 and subsequently climbing to the highest level since 2001.

*Price has climbed to the highest level since 2001*

Redemptions from ETFs have continued, although not at the pace seen in 2016, as some investors took profits, but a turnaround might be under way in South Africa at least, where investors have been increasing their ETF holdings in the third quarter. This could result in Q3'17 seeing the first quarterly increase in palladium ETF holdings for two years.

The investment case for palladium rests on automotive demand which now constitutes 79% of total palladium consumption, and the situation is slightly more nuanced than in the last few years as auto sales' growth expectations have been pegged back and the price has hit the highest level in 16 years.

*Automotive demand now equals 79% of total palladium consumption*

The outlook for China is for continued growth in auto sales, with changes to taxes potentially moving demand into 2017 from 2018. In Europe, the anti-diesel sentiment has benefitted gasoline cars and hence palladium, but in the US, the second-largest auto market, light vehicle sales appear to have peaked in 2016 with sales down 3% in the year to July as growth in light truck sales has not made up for a slump in passenger car sales.

*Continued growth in China's auto sales is predicted*

**Mine supply**

Primary palladium supply is expected to be 6,840 koz this year, marginally higher than in 2016, as output gains in Russia, the US and South Africa are partially offset by declines in Zimbabwe, Canada and other regions.

The persistently low platinum price combined with a strengthening rand this year have dragged the South African basket price down deep into the cost curve, several times below the 50th centile, which has forced some mine and shaft closures.

Atlatsa/AAP are closing the Bokoni mine, RBP is halting output at the South shaft UG2 operation, PTM has transitioned to a new mining method at Maseve, reducing its output, and Sedibelo has also implemented a revised mine plan at PPM. These cuts to production in South Africa are estimated to remove 50 koz of palladium output, but supply still manages to edge up 1.3% to 2,400 koz in 2017.

*Primary South African supply is forecast to increase by 1.3% this year*

Russian supply is forecast to recover to 2,680 koz, up 5.0% y-o-y, as processing higher grade material raises Nornickel's production.

US output increases 10.0% to 460 koz as North American Palladium lifts its production at Lac des Iles and Sibanye-Stillwater adds initial output from the Blitz project in Q4'17.

Unplanned maintenance by Vale at Sudbury has reduced production there, so Canadian output is projected to slip by 8.9% to 585 koz this year.

Zimbabwean production declines to a more typical level of 335 koz this year after being boosted in 2016 by processing a stockpile of concentrate that had built up after a smelter outage.

**Recycling**

Palladium recycling is projected to grow by a modest 1.1% to 2,255 koz, as the contribution to secondary supply from jewellery and industrial uses slips slightly but autocatalyst recycling continues to expand.

*Autocatalyst recycling is expected to rise by 2.6% y-o-y*

The continuing growth from spent autocatalysts means 1,800 koz of palladium is expected to be recovered this year, a 2.6% rise y-o-y.

The scrap steel price has improved during the year which should support scrappage rates, and the high palladium price will encourage the flow of catalysts so recycling in the US could prove to be higher than currently anticipated.

**Demand**

Global palladium demand (excluding investment) is forecast to slip 0.6% to 10,215 koz as weaker industrial and jewellery demand, down 90 koz and 20 koz at 1,930 koz and 220 koz respectively, more than outweighs modest growth in autocatalyst usage (+65 koz).

*Demand is set to decline by 0.6% in 2017*

**Automotive demand**

Global automotive demand is expected to climb by 0.9% to 8,030 koz as growth in China, Western Europe and other regions outweighs a decline in North America.

*Automotive demand is forecast to climb by 0.9% in 2017*

The Chinese government cut the tax on small engine cars from 10% to 5% in 2015 to boost flagging sales and it was expected to return to 10% in 2017, which brought forward purchases into 2016. After slipping in the first half of 2017 sales have picked up in recent months and year-to-date through July, sales are up 0.6% y-o-y (source: China Passenger Car Association). Rather than increase the tax to 10% as anticipated, the government announced in late 2016 that it would be 7.5% for 2017 with it returning to 10% in 2018, so a similar shift in sales could occur later this year.

North American automotive palladium demand is forecast to fall by 4.9% (-105 koz) to 2,055 koz this year. In the year to July, US light vehicle sales have declined by 3.0% y-o-y, but this masks a much greater reduction in passenger car sales while light truck sales are up y-o-y.

With the contraction in diesel market share in Western Europe, automotive demand for palladium in the region has overtaken that for platinum this year by growing 2.2% to 1,600 koz.

**Industrial demand**

Palladium requirements for industrial end-uses are forecast to drop by 110 koz (-5%) to 1,935 koz in 2017, with declining demand anticipated in all regions and many key sectors. Palladium usage in dental alloys is expected to decrease by the greatest amount, falling by 50 koz (-11%) to 410 koz, largely owing to substitution to non-PGM alternatives, particularly in Japan and the US. Slower expansion of bulk chemical capacity in China is set to reduce total chemical demand by 45 koz (-8%) to 465 koz this year, while electrical demand (-20 koz to 940 koz) is likely to be eroded by device downsizing (thrifting) and further substitution away from palladium in key electrical components.

*Demand erosion in dental and electrical applications*

**Investment**

*ETF redemptions continued into 2017*

Global palladium ETF holdings have continued to decline in 2017, falling 159 koz year-to-date to leave total global ETF holdings just under 1.5 moz.

In the UK, investors have reduced their ETF holdings by 182 koz. The bulk of the decline was the result of an investment company significantly reducing its palladium exposure at the beginning of the year following the palladium price's strong run in 2016.

Swiss holdings are down 31 koz this year and in the US the metal held in ETFs has fallen by 25 koz. However, the decline has been arrested in South Africa in Q3'17 where a 4 koz contraction in the first half of the year has turned into a year-to-date gain of 80 koz.

Futures and options positions on NYMEX started the year at 1.45 moz, rose to just over 2 moz by the end of the first quarter, as the price gained 19%, but then stalled at around that level despite ongoing price appreciation. They have just hit a high for the year of 2.25 moz in late August.

## The platinum market

A collective fall in demand for autocatalysts, jewellery and many industrial end-uses is responsible for a swelling of the industrial market surplus (before investment) to an estimated 225 koz in 2017.

*Surplus market of 225 koz forecast*

Primary platinum supply is forecast to decrease by 65 koz (-1%) to 5,970 koz in 2017, largely owing to lower output from mines in Zimbabwe. South African production is predicted to fall slightly to 4,240 koz, as lost supply from mine restructuring and shaft closures is likely to be mostly offset by greater volumes from some larger Western Limb mines and chrome-PGM producing operations. Zimbabwean output is expected to decline by 45 koz (-9%) to 445 koz, while Russian supply is projected to slip by 1% to 705 koz.

*Primary supply is down by 1% in 2017*

Global demand is predicted to decline by 255 koz (-3%) to 7,560 koz in 2017, as platinum usage in autocatalysts, jewellery and multiple industrial applications contracts. Autocatalyst demand is forecast to decrease by 75 koz (-2%) to 3,360 koz, primarily owing to the erosion of diesel shares throughout Western Europe (-100 koz), while gross jewellery consumption is expected to dip by 1% to 2,590 koz as waning demand in China (-110 koz) is largely offset by growth elsewhere, predominantly in India (+60 koz).

*Demand shrinks by 3% in 2017*

*Ongoing erosion of diesel share in Western Europe*

Industrial platinum requirements are anticipated to drop by 165 koz (-9%) to 1,610 koz, mainly owing to a large contraction in demand for use in petroleum refining. Refining capacity cuts in Japan and Western Europe are likely to result in recycled metal being returned to market in 2017, while demand for new capacity in China and North America is forecast to shrink as expansion growth eases in these regions. Lower demand is also predicted for use in chemical catalysis, glass fabrication and electrical devices.

The volume of platinum recovered from recycling is projected to be down by 50 koz (-3%) to 1,815 koz this year, as a sizeable drop in platinum jewellery recycling is set to outweigh greater volumes from spent autocatalysts. Following destocking in China last year, jewellery recycling is expected to drop by 110 koz (-18%) to 515 koz, while autocatalyst recycling is forecast to increase by 60 koz (+5%) to 1,295 koz, with good scrappage volumes supported by a strong scrap steel price.

Platinum ETF product holdings were up by 110 koz for the year to 2.61 moz at the end of August. The majority of inflows have been into South Africa, with Absa and Standard Bank holdings up by 80 koz and 13 koz respectively. Holdings also grew in the US (+44 koz) and Switzerland (+21 koz) but contracted in the UK (-43 koz), partially offsetting growth elsewhere.

*Growth in South African ETF holdings*

## The rhodium market

The industrial market surplus is forecast to widen to 50 koz in 2017, mainly from weaker demand and growth in metal recovered from recycling.

Primary rhodium supply is projected to fall by 25 koz (-3%) to 740 koz this year, primarily owing to a drop in South African output (-20 koz), while production in Zimbabwe (-10 koz) is also set to decrease.

However, total demand is predicted to decline by 45 koz (-4%) to 985 koz, with reduced requirements for both autocatalysts (-20 koz) and industrial end-uses (-25 koz).

*Demand is forecast to fall by 4% in 2017*

Rhodium recovered from recycled autocatalysts is expected to increase by 10 koz (+4%), partially offsetting the fall in primary production.

## The price outlook for the next six months

**Palladium $950/oz**

*Liquidity driven*

A push to break $1,000/oz appears to be on under impetus from liquidity issues, which will most likely mean parity with platinum too.

However, this high price level is not expected to be maintained for long as palladium has become overbought, hence the $950/oz average price. The most recent revisions to autocatalyst demand have been reductions, so gross demand growth is marginally negative and the market deficit, while still large, is gradually shrinking.

US light vehicle sales are down this year despite record incentives, and a further downward revision to demand is a risk if sales continue to disappoint.

The tax reduction on small cars in China is set to be removed at the end of the year, returning the tax to its orignal 10% from 7.5%. This could shift some demand into 2017 at the expense of a slowdown in early 2018.

**Platinum $1,000/oz**

*Supply adjusted*

Manufacturers are finding ways to reduce emissions without adding excessive costs, keeping diesel viable, particularly for larger cars, which should help to stabilise demand if the clean diesel message gets heard.

Anti-diesel sentiment and the decline in diesel share in Western Europe should be in the price and recent cuts to supply in South Africa look set to tighten the market, but the recent run-up in the price to $1,000/oz has taken it into overbought territory, limiting near-term upside.

**Rhodium $1,100/oz**

*$NO_X$ control*

The rhodium market is in fundamental surplus so although production cuts in South Africa have reduced supply, demand appears to be dropping at a similar pace. That said, rhodium is seeing more interest for tighter $NO_X$ control in gasoline vehicles. The rhodium price has had a very strong run in 2017 to trade above $1,100/oz, but it is now very overbought, making further upside look limited in the near term.

# THE EXPERT WORKING FOR EXPERTS

# The expert working for experts

***Stephen Forrest, Chairman, SFA (Oxford) Ltd***

## A world authority on PGMs

SFA (Oxford) is world-renowned as both a PGM authority and supply and demand specialist. For more than 15 years, our deep understanding of PGM industry dynamics has allowed us to foster relationships with the most significant PGM players worldwide. SFA works closely alongside each client to enhance its individual business case, independently and in complete confidence.

From its beginnings as a niche business in the early 2000s, the company has established its position as one of the world's leading commodity consultancies, encompassing the entire industry value chain — supply and demand — for many of the strategic metals, particularly the PGMs.

During that time, we have closely monitored the PGM industry, understanding its numerous complexities and developing alongside it, with each of our nine dedicated consulting analysts specialising in a particular area of supply and demand, ranging from end-use authorities to supply specialists to value chain experts.

## 'Think tank'

Thanks to the team's individual and collective expertise, we are able to provide a wider and deeper range of research that extends beyond the scope of most other commodity consultancies, acting as a 'think tank' for many of our clients, focusing particularly on strategic investment ideas and opportunity capitalisation.

## Intimate relationships and unique skills

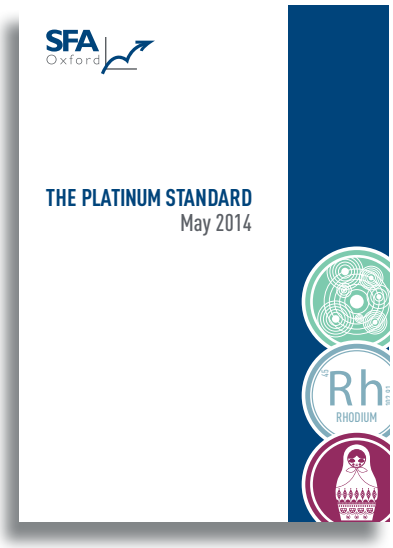
SFA's unique network of clients and associates is the catalyst that has enabled us to establish our position as the analytical link in the strategic metal value chain. This global network encompasses all the major PGM producing and consuming regions, each of which is examined and understood, their intricacies articulated plainly and coherently.

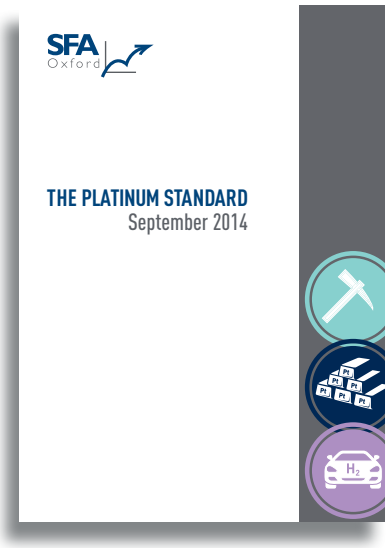
Over many years we have also acted as trusted advisors to the commodity industry's major metal producers, these relationships having been built upon our analysts' delivery of ground-breaking, granular analysis.

After 15 years, we are proud to have achieved a reach of over one trillion dollars of clientele*, delivering a greater comprehension of tomorrow.

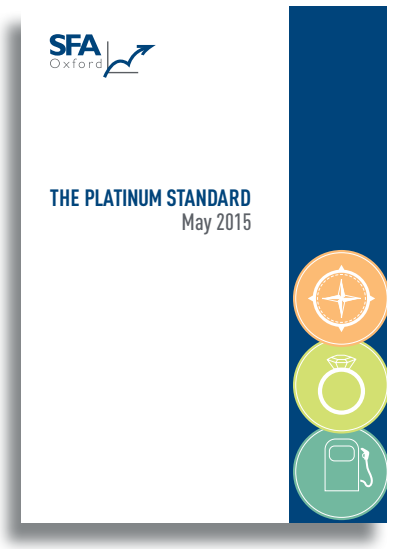

* Market capitalisation.

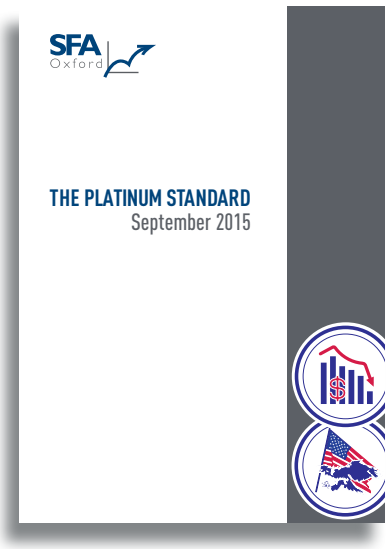
# TPS COLLECTION: AGENDA-SETTING COMMENTARY



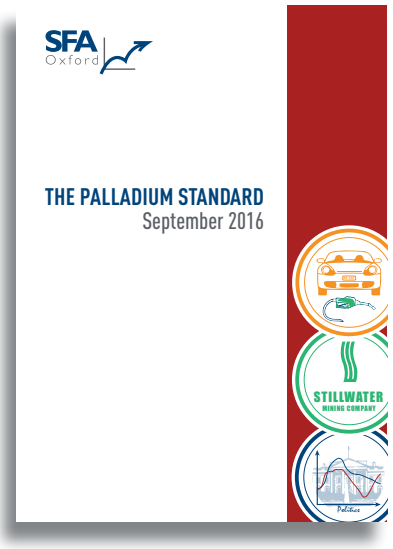



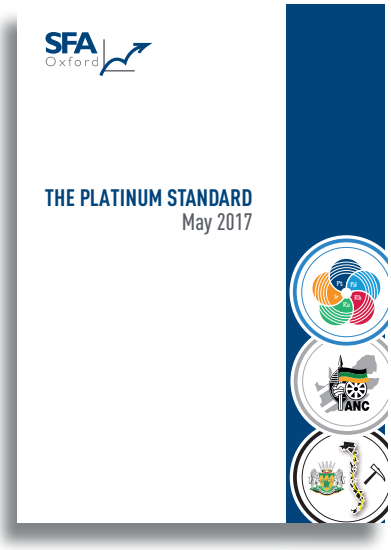

*The Palladium Standard was launched in September 2016 following the success of the The Platinum Standard*



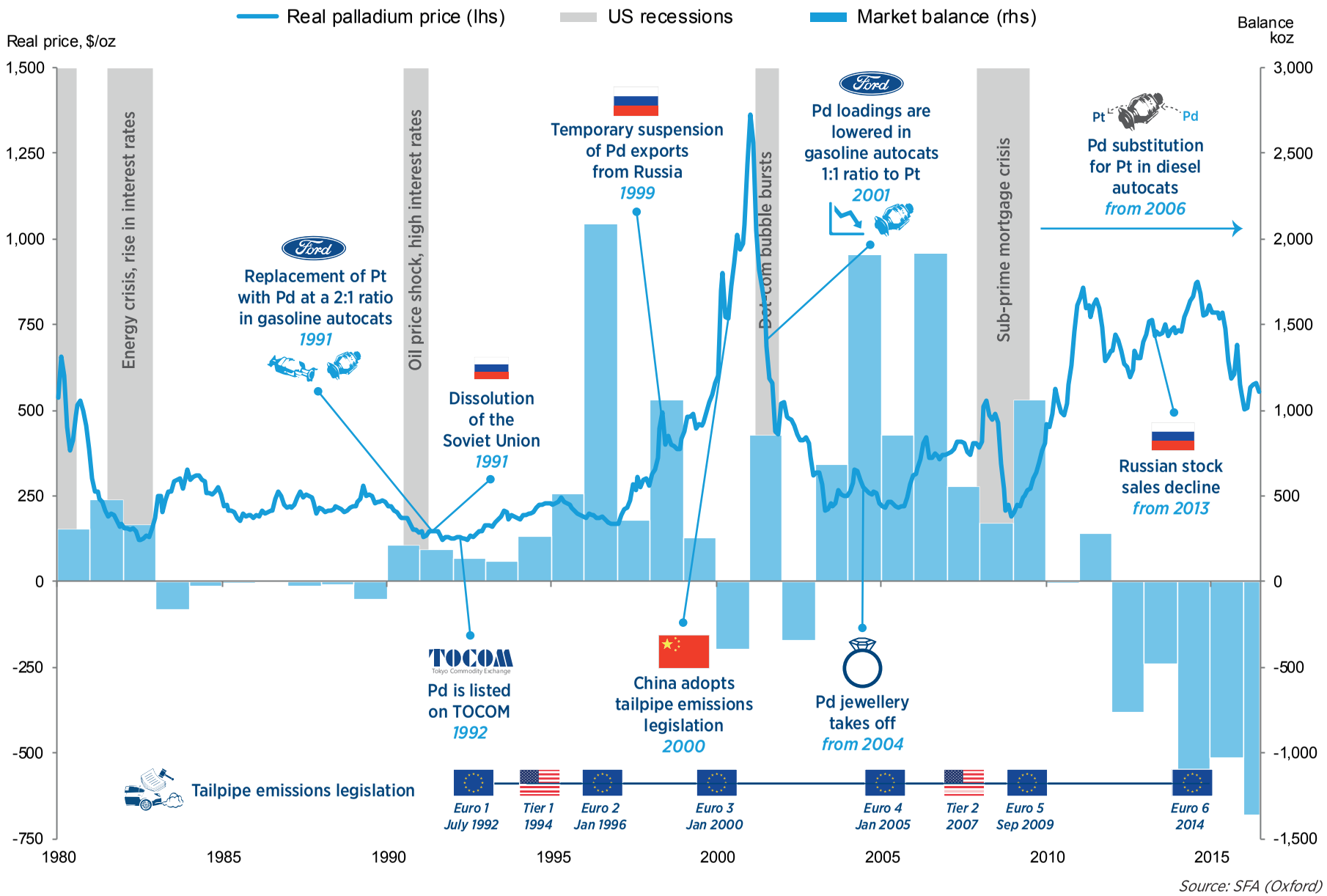

*One-half review, one-half preview, the reports comprise analytical commentary on those issues we believe will set the PGM agenda for the years ahead*

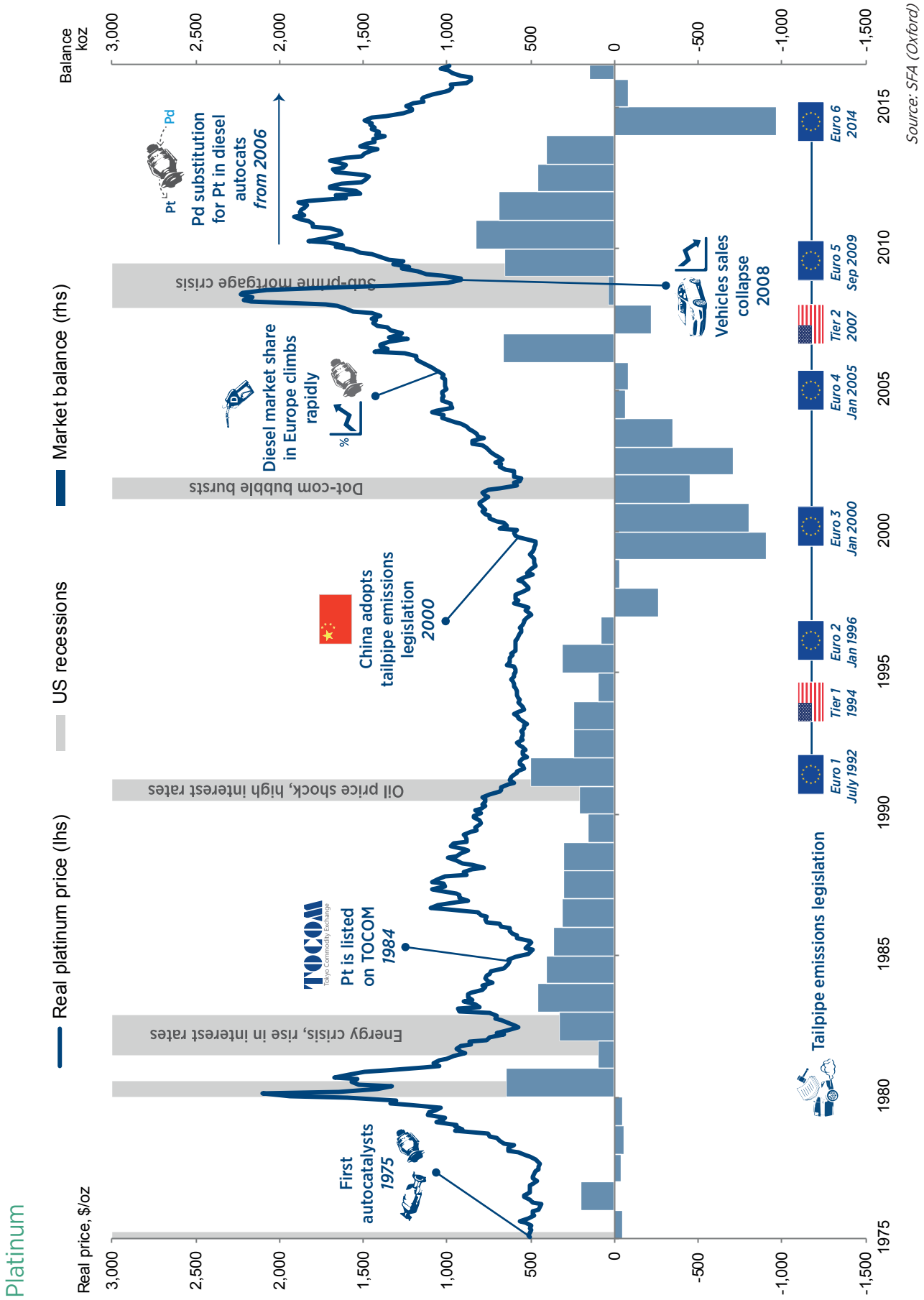



# PGM PRICE HISTORY

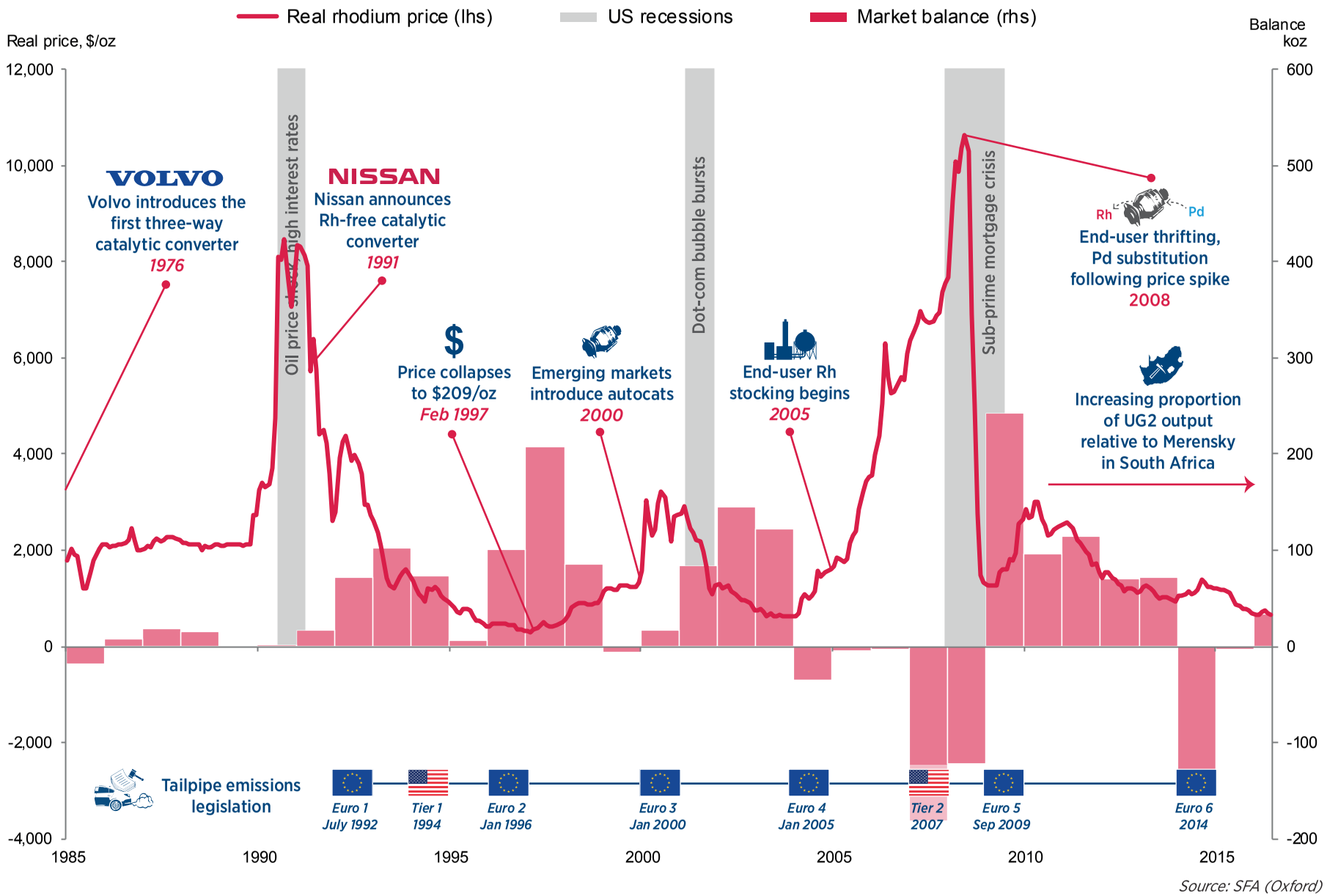
## Palladium



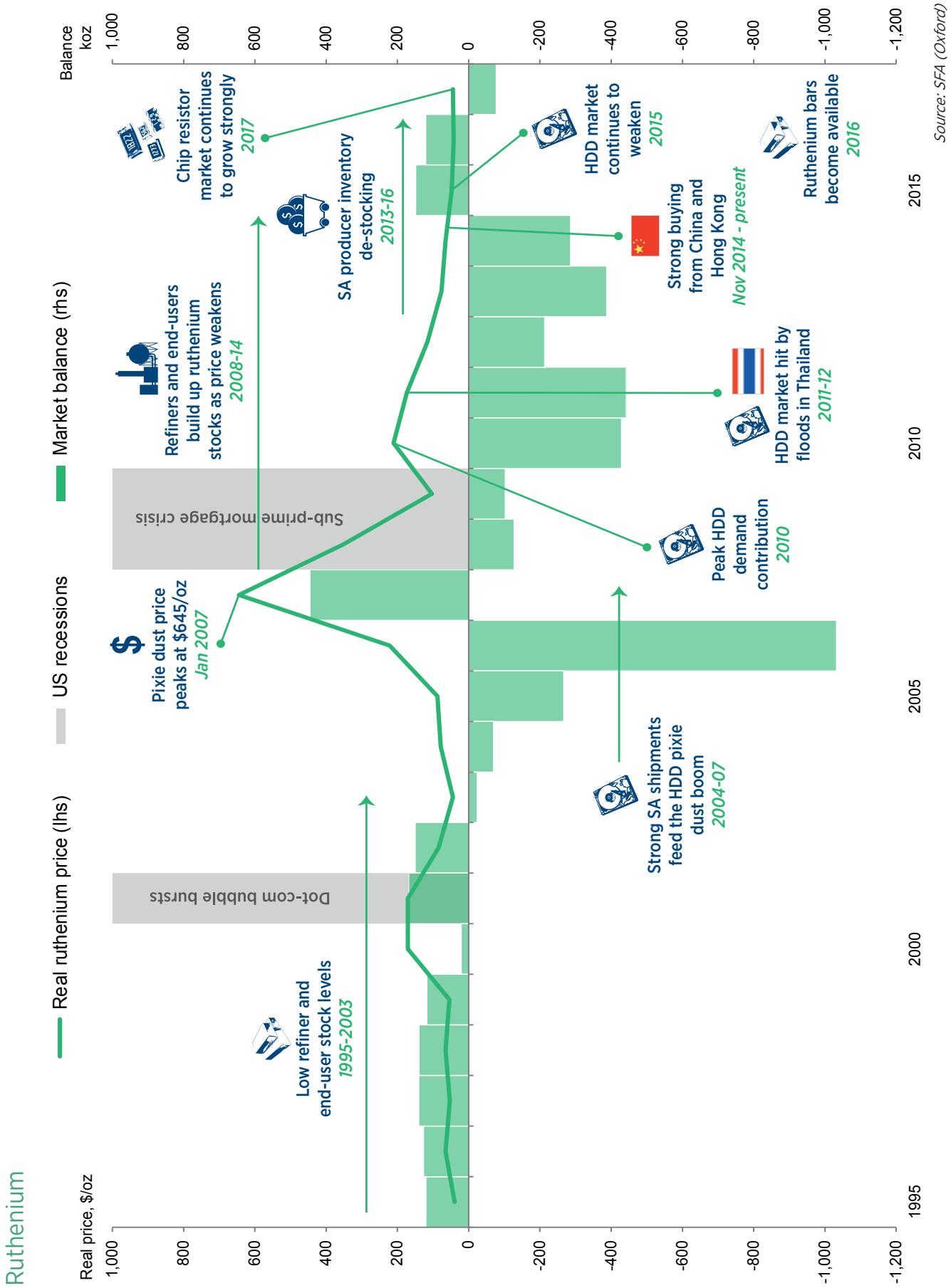

*Source: SFA (Oxford)*


Real platinum price (lhs)
US recessions
Market balance (rhs)
Real price, $/oz
Balance koz
3,000
2,500
2,000
1,500
1,000
500
0
-500
-1,000
-1,500
1975
1980
1985
1990
1995
2000
2005
2010
2015
Energy crisis, rise in interest rates
Oil price shock, high interest rates
Dot-com bubble bursts
Sub-prime mortgage crisis
First autocatalysts 1975
TOCOM
Tokyo Commodity Exchange
Pt is listed on TOCOM 1984
China adopts tailpipe emissions legislation 2000
Diesel market share in Europe climbs rapidly
Pt
Pd
Pd substitution for Pt in diesel autocats from 2006
Vehicles sales collapse 2008
Tailpipe emissions legislation
Euro 1 July 1992
Tier 1 1994
Euro 2 Jan 1996
Euro 3 Jan 2000
Euro 4 Jan 2005
Tier 2 2007
Euro 5 Sep 2009
Euro 6 2014
Source: SFA (Oxford)

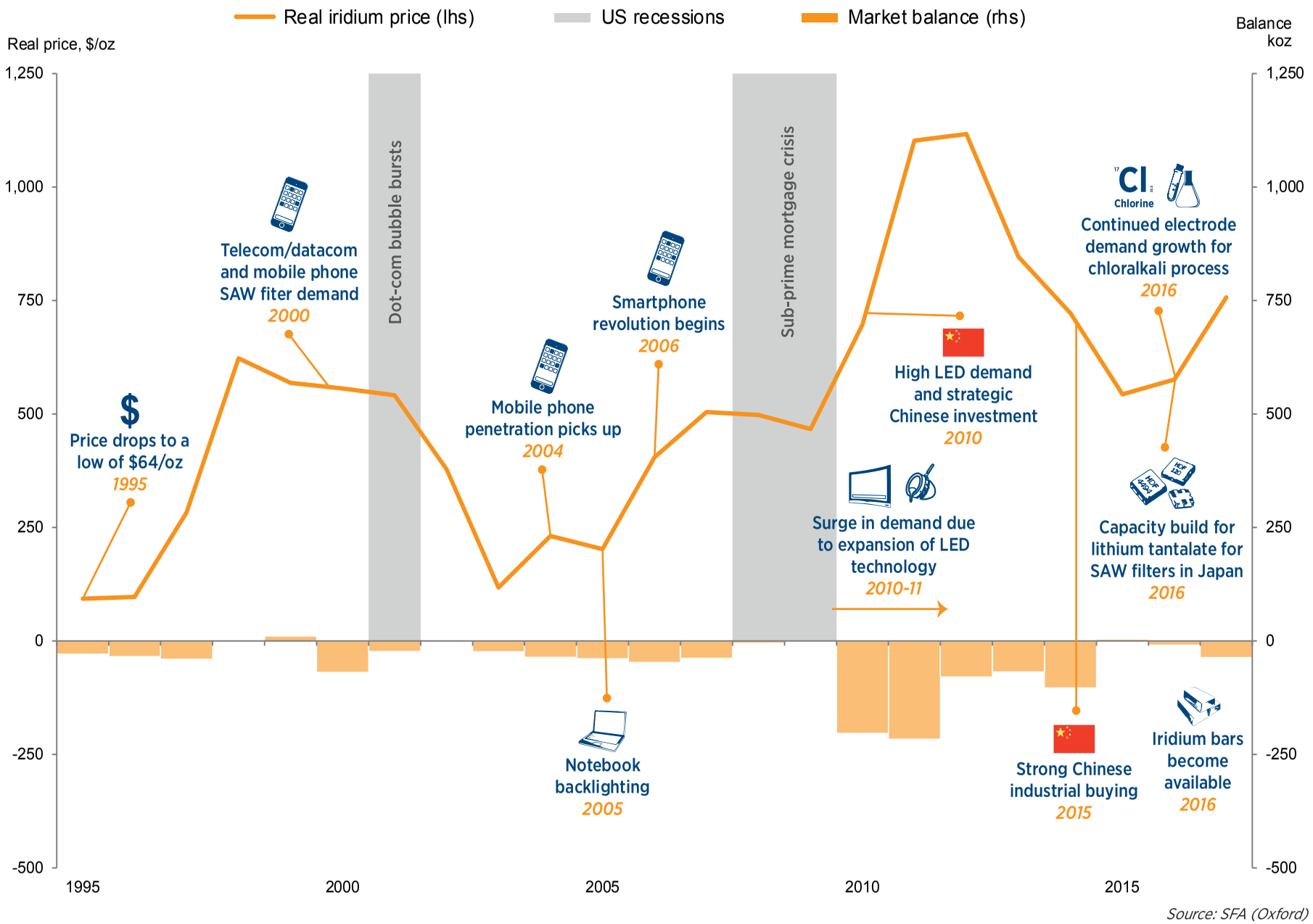
## Rhodium




*Source: SFA (Oxford)*

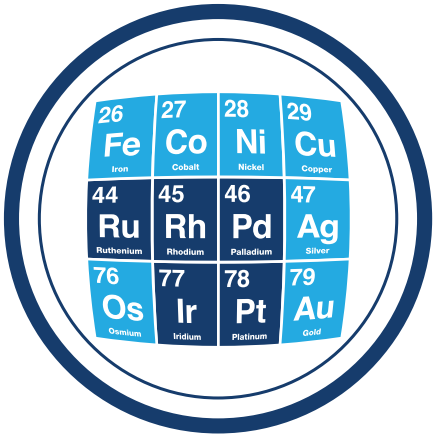

Ruthenium
Real price, $/oz
Balance koz
Real ruthenium price (lhs)
US recessions
Market balance (rhs)
1,000
800
600
400
200
0
-200
-400
-600
-800
-1,000
-1,200
1995
2000
2005
2010
2015
Dot-com bubble bursts
Sub-prime mortgage crisis
Low refiner and end-user stock levels 1995-2003
Pixie dust price peaks at $645/oz Jan 2007
Refiners and end-users build up ruthenium stocks as price weakens 2008-14
Strong SA shipments feed the HDD pixie dust boom 2004-07
SA producer inventory de-stocking 2013-16
Peak HDD demand contribution 2010
HDD market hit by floods in Thailand 2011-12
Chip resistor market continues to grow strongly 2017
HDD market continues to weaken 2015
Strong buying from China and Hong Kong Nov 2014 - present
Ruthenium bars become available 2016
Source: SFA (Oxford)

## Iridium




*Source: SFA (Oxford)*

# SFA'S REPORTS

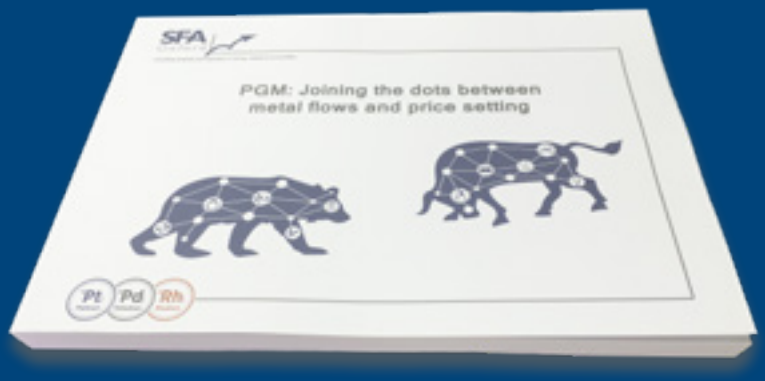


*World Trade Center Complex, New York*

# PGM: JOINING THE DOTS BETWEEN METAL FLOWS AND PRICE SETTING

## The real world of PGM pricing

*PGM: Joining the dots between metal flows and price setting* report provides answers to PGM commercial questions which we have all posed. Our report contains unrivalled insight, with over 300 pages of detailed analysis, commentary and charts providing unique exploration of the purchasing dynamics between market participants, the complexity of the associated price web and which factors drive metal prices for platinum, palladium and rhodium.




- Where is the price made and to what extent does this reflect the physical movement of metal?
- Who trades on the London 'Fix' (auction) and what is the volume of trade?
- How do the demand-side participants (automotive, jewellery, and industrial) source their metal, and how do they price it?
- How do the supply-side participants (producers and recyclers) sell their metal, and how do they price it?
- How are contracts on futures markets (NYMEX, TOCOM) priced, and to what extent does trade on these markets actually result in the physical movement of metal?
- What is the history of estimated above-ground stocks and how does this look against prices for each of the metals?
- Where do above-ground stocks sit (split by OEM, fabricator, jewellery, industrial, investor etc.), and when these stocks are being drawn down, where are these transactions taking place and how are these trades being priced?
- How can an analysis of the supply-demand balance over the last 10-20 years highlight the drivers of spot price changes for each PGM over time?
- What were the event-driven impacts on price and how did these detach the price from fundamentals? How did PGM prices react to these events compared with other commodities?
- What is the link between purchasing demand and end-use demand and its impact on price?

The report is supported by a conference call directly with the team of analysts, which follows a few days after receipt of the document. SFA is also available for a presentation to a client's Board or senior executives on the key findings, to ensure they are fully appraised of worldwide metal flows and price setting.

# PGM: SPENT AUTOCATALYST RECYCLING MAPPED AND ANALYSED


SFA has, for more than a decade, comprehensively tracked the development of PGM usage and subsequent PGM scrap generation in the autocatalyst (as well as jewellery, electrical and electronic) sector. This was enhanced by an in-depth review in 2016 of the recycling business. SFA's detailed Core Analysis Package of the full recycling sector therefore provides a client with an independent review and up-to-date analysis of the autocatalyst recycling sector.

This substantial uplift in PGM recycling intelligence and know-how has been commissioned and verified by a number of secondary PGM recyclers. SFA has unique access to, and use of, the latest data, updated on a quarterly basis directly from a primary source.

The SFA team has developed a detailed Core Analysis Package report on the autocatalyst recycling sector that incorporates our understanding of:

- The competitive landscape: a complete overview of the autocatalyst business.
- Global autocatalyst recyclers mapped.
- A review of the business models of recyclers including SWOT evaluations.
- A complete assessment of each part of the value chain including technologies employed.
- An independent view on the economics of recycling: audited value chain presented.
- Scrap steel price impact on recycling volumes and grades.
- Ceramic substrate and PGM volumes: now and in the future.
- Major risks to the recycling business ahead.

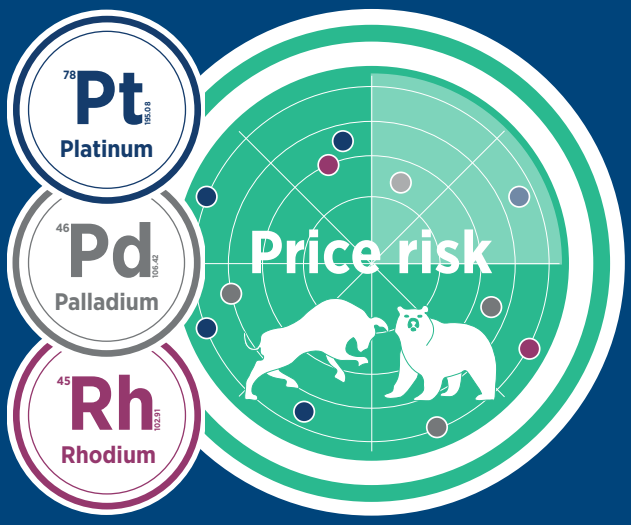
The report provides unrivalled insight with over 400 pages of detailed analysis, commentary and charts, and is supported by a conference call directly with the team of analysts. SFA is also available for a presentation to a client's Board or senior executives on the key findings to ensure they are fully appraised on this study on the spent autocatalyst recycling industry.

*Decanned spent autocatalyst ceramic*

# THE PGM RADAR

## Short- to medium-term supply, demand and price forecasting

*The PGM Radar*, a risk-focused report that details on-the-horizon price-impacting factors, is the next evolution of our Quarterly Core Analysis Package (CAP), widely considered the benchmark in regular research of the platinum, palladium and rhodium markets. The report offers a brand new suite of analytical charts and scenarios, and is an essential guide to today's PGM picture.




*Source: SFA (Oxford)*

The CAPs are provided in concise bullet-point form to facilitate rapid understanding of the incorporated analysis and selected data. Specific content for each CAP varies according to market events and demand developments, but is tailored to incorporate the client's specific interests in the PGM industry. Typically, each CAP includes:

- Macroeconomic developments on supply and demand fundamentals and technology.
- Updates and advice on the present and future stability and growth of primary platinum supply and demand.
- Comment on the political and socio-economic risks impacting primary platinum supply in politically sensitive PGM-producing regions (e.g. South Africa, Zimbabwe and Russia).
- Short- and medium-term metal pricing outlook.
- Tracking and reporting relevant processes and technology developments in the market and likely impact on the sector.
- Future evolution and development of industrial technologies.
- Developments in demand/supply that impact on SFA's central case including the secondary and recycling sectors.

Each CAP report is supported by a conference call a few days after receipt of the document. Additional analysis and data arising from discussions may also be made available at that time.

# PGM: THE INDUSTRY BIANNUAL

## Long-term supply, demand and price forecasting

Strategic decision making

Board-level motivation

End-use evolution

Legislation drivers

Political risk

Recycling loops

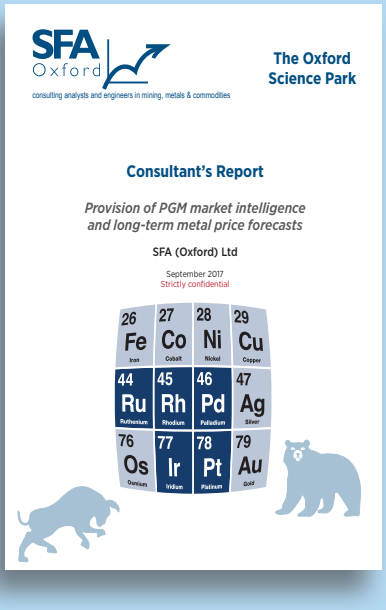
Sustainability

Expansion windows

Food chain economics

Investment appraisal

Technology pathways




*PGM: The Industry Biannual* is a highly detailed report, produced around March and September each year, and typically of about 180-200 pages

Substitution threats

Demographic shifts

Competitor analysis

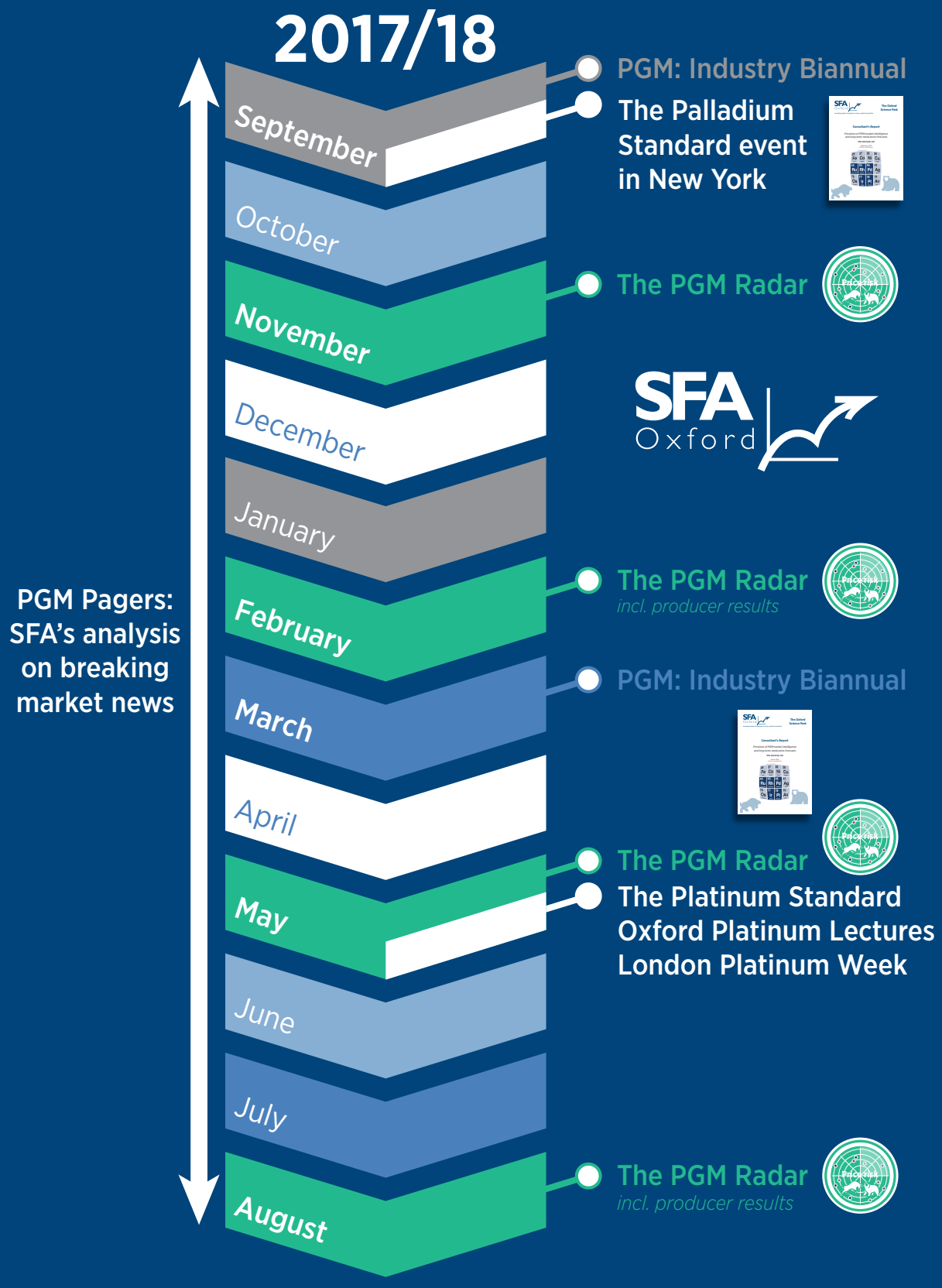
Capital raising

Scenario implications

Energy megatrends

Opportunities from innovation

# SFA'S PRINCIPAL PGM REPORTING TIMELINE



# THE RUTHENIUM MARKET

*The Ruthenium Market* report offers a robust, independent outlook for this niche strategic commodity. It provides a granular overview of the technological developments and underlying evolution of demand and end-use applications – electrical, chemical catalysis, electrochemical, and aerospace.

The main application, namely higher-density data storage (electrical demand), is covered in detail, in particular: manufacturing bases, players and regions; price and performance drivers encouraging the use of ruthenium; and threats to ruthenium at current prices (substitution, new technologies).


### Electrical demand

- Use of ruthenium in hard-disk drives (HDD)
- Technology evolution and main players
- Technology substitution threats from solid-state drives (SSD)
- Forecast memory capacity requirements and HDD manufacture
- Impact of changing technology on ruthenium demand outlook

### Electrochemical demand

- Industrial process requirements of anodes coated with PGMs
- Chloralkali products and output, growth, capacity requirements and PGM top-up requirements

### Chemical demand

- Forecast regional production of ammonia and acetic acid
- CATIVA™, KAAP™ and Grubbs catalyst technologies
- Technology evolution: growth and substitution threats
- Installed capacity versus production outlook
- Forecast demand for ruthenium from new plant capacity and top-up requirements

### New applications and potential upside

- Aerospace, environmental legislation and the economics of using ruthenium in turbine blades
- Fuel cells: technologies, outlook, potential hydrogen requirements and opportunities for ruthenium use in catalysts

### Ruthenium supply and stocks

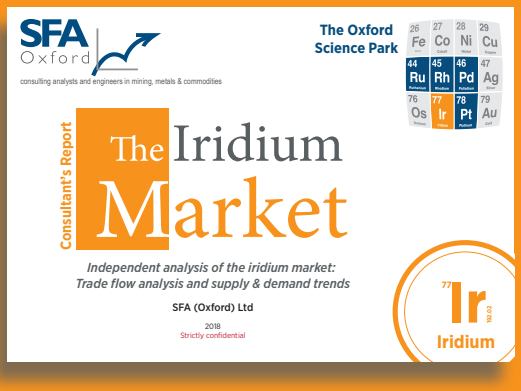
- Forecast (primary) supply, by producer and by region
- Reserve and resource depletion analysis
- Estimated stocks (stockpiles, working inventories), producers, traders and recyclers, and quantification of unrefined stock
- Stocks in weeks of demand

### Pricing of ruthenium

- Pricing trends out to 2022

# THE IRIDIUM MARKET

*The Iridium Market* report provides a short- to medium-term supply, demand and price forecast in a focused outlook for iridium end-use applications (existing and future), in particular: LEDs, biomedical, jewellery, automotive and catalysis; manufacturing and fabrication bases, players and regions; price and performance drivers encouraging the use of iridium; threats to iridium (within substrate, tooling sector) at current prices (substitution by molybdenum and tungsten etc.); new technologies; and opportunities for iridium growth in new LED applications (automotive, industrial and residential lighting, signs, etc.) and chemical demand.




## Electrical demand

- The LED market: new technology, energy efficiency, costs and market share
- Demand growth and capacity builds for LED TVs and lighting
- The iridium crucible market and the role of sapphire in LED production
- Gallium nitride (GaN) on sapphire versus GaN on silicon
- The threat of substitution from molybdenum and tungsten in high-temperature melting applications
- Iridium demand for crucibles used in LED production
- Outlook for OLED displays and potential impacts on iridium demand

## Electrochemical demand

- The chloralkali process and iridium demand
- Substitution of a mercury-based process by an iridium-based process

## Automotive demand

- Automotive demand for iridium-tipped spark plugs
- Substitution threats from molybdenum

## Chemical demand

- The CATIVA™ process and acetic acid demand, including capacity requirements

## Other demand

- Jewellery
- Medical
- Novel end-uses

## Iridium supply and stocks

- Forecast (primary) supply, by producer and by region
- Reserve and resource depletion analysis
- Industry stock levels
- Movements of stock by producers and quantification of unrefined stock
- Stocks in weeks of demand

## Pricing of iridium

- Pricing trends out to 2022

# APPENDIX

## Palladium supply-demand balance

| koz | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017f |
|---|---|---|---|---|---|---|---|---|---|
| **Primary supply** | | | | | | | | | |
| **Regional** | | | | | | | | | |
| South Africa | 2,425 | 2,590 | 2,550 | 2,355 | 2,360 | 1,855 | 2,570 | 2,370 | 2,400 |
| Russia | 2,675 | 2,720 | 2,705 | 2,630 | 2,580 | 2,690 | 2,605 | 2,555 | 2,680 |
| Zimbabwe | 180 | 225 | 265 | 280 | 315 | 330 | 325 | 395 | 335 |
| North America | 610 | 580 | 865 | 895 | 975 | 1,055 | 995 | 1,065 | 1,050 |
| Other | 0 | 300 | 390 | 445 | 450 | 460 | 455 | 420 | 375 |
| **Total** | **5,890** | **6,415** | **6,775** | **6,605** | **6,680** | **6,390** | **6,950** | **6,805** | **6,840** |
| **Demand & recycling** | | | | | | | | | |
| **Autocatalyst** | | | | | | | | | |
| Gross demand | 4,090 | 5,615 | 6,195 | 6,690 | 7,145 | 7,530 | 7,740 | 7,995 | 8,070 |
| Recycling | 1,155 | 1,395 | 1,525 | 1,485 | 1,645 | 1,720 | 1,630 | 1,750 | 1,800 |
| Net demand | 2,935 | 4,220 | 4,670 | 5,205 | 5,550 | 5,810 | 6,110 | 6,245 | 6,270 |
| **Jewellery** | | | | | | | | | |
| Gross demand | 775 | 695 | 680 | 545 | 350 | 295 | 240 | 240 | 215 |
| Recycling | 0 | 100 | 135 | 130 | 145 | 120 | 80 | 80 | 60 |
| Net demand | 775 | 595 | 545 | 415 | 205 | 175 | 160 | 160 | 155 |
| **Industrial demand** | 2,400 | 2,465 | 2,465 | 2,325 | 2,085 | 2,035 | 2,060 | 2,045 | 1,935 |
| **Other recycling** | 350 | 405 | 370 | 375 | 410 | 430 | 435 | 400 | 400 |
| **Gross demand** | 7,265 | 8,775 | 9,340 | 9,560 | 9,580 | 9,860 | 10,040 | 10,280 | 10,220 |
| **Recycling** | 1,505 | 1,900 | 2,030 | 1,990 | 2,200 | 2,270 | 2,145 | 2,230 | 2,260 |
| **Net demand** | **5,760** | **6,875** | **7,310** | **7,570** | **7,380** | **7,590** | **7,895** | **8,050** | **7,960** |
| **Market balance** | | | | | | | | | |
| Balance (before ETFs) | 130 | -460 | -535 | -965 | -700 | -1,200 | -945 | -1,245 | -1,120 |
| ETFs (stock allocation) | 505 | 1,085 | -535 | 285 | 0 | 940 | -670 | -640 | |
| **Balance after ETFs** | **-375** | **-1,545** | **0** | **-1,250** | **-700** | **-2,140** | **-275** | **-605** | |

*Source: SFA (Oxford)*

## Palladium demand and recycling summary


| koz | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017f |
|---|---|---|---|---|---|---|---|---|---|
| **Gross demand** | | | | | | | | | |
| **Autocatalyst** | | | | | | | | | |
| North America | 1,005 | 1,310 | 1,505 | 1,745 | 1,835 | 1,970 | 2,090 | 2,170 | 2,065 |
| Western Europe | 920 | 1,280 | 1,500 | 1,425 | 1,530 | 1,650 | 1,705 | 1,585 | 1,620 |
| Japan | 600 | 810 | 670 | 735 | 745 | 745 | 750 | 785 | 790 |
| China | 705 | 1,010 | 1,130 | 1,300 | 1,515 | 1,665 | 1,735 | 1,995 | 2,045 |
| India | 105 | 150 | 160 | 155 | 165 | 165 | 180 | 220 | 240 |
| RoW | 755 | 1,055 | 1,230 | 1,330 | 1,355 | 1,335 | 1,280 | 1,240 | 1,310 |
| **Total** | **4,090** | **5,615** | **6,195** | **6,690** | **7,145** | **7,530** | **7,740** | **7,995** | **8,070** |
| **Jewellery** | | | | | | | | | |
| North America | 60 | 65 | 45 | 45 | 40 | 35 | 35 | 35 | 35 |
| Western Europe | 50 | 65 | 65 | 80 | 75 | 60 | 55 | 55 | 55 |
| Japan | 80 | 85 | 90 | 95 | 65 | 55 | 50 | 50 | 50 |
| China | 560 | 450 | 450 | 295 | 145 | 120 | 75 | 75 | 50 |
| RoW | 25 | 30 | 30 | 30 | 25 | 25 | 25 | 25 | 25 |
| **Total** | **775** | **695** | **680** | **545** | **350** | **295** | **240** | **240** | **215** |
| **Industrial** | | | | | | | | | |
| North America | 495 | 500 | 495 | 480 | 425 | 405 | 415 | 410 | 385 |
| Western Europe | 365 | 410 | 375 | 335 | 305 | 305 | 305 | 300 | 285 |
| Japan | 595 | 575 | 550 | 565 | 420 | 435 | 440 | 430 | 400 |
| China | 420 | 435 | 425 | 405 | 455 | 430 | 435 | 440 | 415 |
| RoW | 525 | 545 | 620 | 540 | 480 | 460 | 465 | 465 | 450 |
| **Total** | **2,400** | **2,465** | **2,465** | **2,325** | **2,085** | **2,035** | **2,060** | **2,045** | **1,935** |
| **Total gross demand** | | | | | | | | | |
| North America | 1,560 | 1,875 | 2,045 | 2,270 | 2,300 | 2,410 | 2,540 | 2,615 | 2,485 |
| Western Europe | 1,335 | 1,755 | 1,940 | 1,840 | 1,910 | 2,015 | 2,065 | 1,940 | 1,960 |
| Japan | 1,275 | 1,470 | 1,310 | 1,395 | 1,230 | 1,235 | 1,240 | 1,265 | 1,240 |
| China | 1,685 | 1,895 | 2,005 | 2,000 | 2,115 | 2,215 | 2,245 | 2,510 | 2,510 |
| RoW | 1,410 | 1,780 | 2,040 | 2,055 | 2,025 | 1,985 | 1,950 | 1,950 | 2,025 |
| **Total** | **7,265** | **8,775** | **9,340** | **9,560** | **9,580** | **9,860** | **10,040** | **10,280** | **10,220** |
| **Recycling** | | | | | | | | | |
| **Autocatalyst** | | | | | | | | | |
| North America | 890 | 975 | 975 | 930 | 1,005 | 975 | 895 | 960 | 950 |
| Western Europe | 135 | 205 | 335 | 325 | 345 | 365 | 325 | 315 | 340 |
| Japan | 100 | 175 | 130 | 125 | 125 | 135 | 125 | 125 | 145 |
| China | 0 | 0 | 15 | 20 | 50 | 60 | 115 | 160 | 160 |
| RoW | 30 | 40 | 70 | 85 | 120 | 185 | 170 | 190 | 205 |
| **Total** | **1,155** | **1,395** | **1,525** | **1,485** | **1,645** | **1,720** | **1,630** | **1,750** | **1,800** |
| **Jewellery** | | | | | | | | | |
| Japan | 0 | 10 | 15 | 20 | 20 | 20 | 20 | 20 | 20 |
| China | 0 | 90 | 120 | 110 | 125 | 100 | 60 | 60 | 40 |
| **Total** | **0** | **100** | **135** | **130** | **145** | **120** | **80** | **80** | **60** |
| **WEEE** | | | | | | | | | |
| North America | 85 | 80 | 70 | 75 | 75 | 70 | 85 | 75 | 70 |
| Western Europe | 75 | 115 | 80 | 85 | 90 | 95 | 80 | 75 | 80 |
| Japan | 115 | 130 | 135 | 120 | 135 | 145 | 165 | 135 | 125 |
| China | 25 | 25 | 20 | 30 | 40 | 30 | 25 | 35 | 40 |
| RoW | 50 | 55 | 65 | 65 | 70 | 90 | 80 | 80 | 85 |
| **Total** | **350** | **405** | **370** | **375** | **410** | **430** | **435** | **400** | **400** |
| **Total recycling** | | | | | | | | | |
| North America | 975 | 1,055 | 1,045 | 1,005 | 1,080 | 1,045 | 980 | 1,035 | 1,020 |
| Western Europe | 210 | 320 | 415 | 410 | 435 | 460 | 405 | 390 | 420 |
| Japan | 215 | 315 | 280 | 265 | 280 | 300 | 310 | 280 | 290 |
| China | 25 | 115 | 155 | 160 | 215 | 190 | 200 | 255 | 240 |
| RoW | 80 | 95 | 135 | 150 | 190 | 275 | 250 | 270 | 290 |
| **Total** | **1,505** | **1,900** | **2,030** | **1,990** | **2,200** | **2,270** | **2,145** | **2,230** | **2,260** |

*Source: SFA (Oxford)*

## Platinum supply-demand balance


| koz | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017f |
|---|---|---|---|---|---|---|---|---|---|
| **Primary supply** | | | | | | | | | |
| **Regionl** | | | | | | | | | |
| South Africa | 4,550 | 4,725 | 4,595 | 4,200 | 4,355 | 3,115 | 4,465 | 4,255 | 4,240 |
| Russia | 775 | 790 | 800 | 780 | 740 | 740 | 715 | 715 | 705 |
| Zimbabwe | 230 | 280 | 340 | 365 | 405 | 405 | 405 | 490 | 445 |
| North America | 275 | 200 | 375 | 345 | 355 | 400 | 385 | 395 | 405 |
| Other | 0 | 120 | 145 | 180 | 215 | 220 | 180 | 180 | 175 |
| **Total** | **5,830** | **6,115** | **6,255** | **5,870** | **6,070** | **4,880** | **6,150** | **6,035** | **5,970** |
| **Demand & recycling** | | | | | | | | | |
| **Autocatalyst** | | | | | | | | | |
| Gross demand | 2,525 | 2,925 | 3,130 | 3,175 | 3,180 | 3,310 | 3,385 | 3,435 | 3,360 |
| Recycling | 835 | 955 | 1,210 | 1,175 | 1,120 | 1,255 | 1,190 | 1,235 | 1,295 |
| Net demand | 1,690 | 1,970 | 1,920 | 2,000 | 2,060 | 2,055 | 2,195 | 2,200 | 2,065 |
| **Jewellery** | | | | | | | | | |
| Gross demand | 2,680 | 2,170 | 2,450 | 2,760 | 2,945 | 3,000 | 2,880 | 2,605 | 2,590 |
| Recycling | 415 | 475 | 630 | 840 | 855 | 775 | 515 | 625 | 515 |
| Net demand | 2,265 | 1,695 | 1,820 | 1,920 | 2,090 | 2,225 | 2,365 | 1,980 | 2,075 |
| **Industrial demand** | 1,235 | 1,635 | 1,850 | 1,530 | 1,520 | 1,545 | 1,670 | 1,775 | 1,610 |
| **Other recycling** | 15 | 10 | 10 | 5 | 5 | 5 | 5 | 5 | 5 |
| **Gross demand** | 6,440 | 6,730 | 7,430 | 7,465 | 7,645 | 7,855 | 7,935 | 7,815 | 7,560 |
| **Recycling** | 1,265 | 1,440 | 1,850 | 2,020 | 1,980 | 2,035 | 1,710 | 1,865 | 1,815 |
| **Net demand** | **5,175** | **5,290** | **5,580** | **5,445** | **5,665** | **5,820** | **6,225** | **5,950** | **5,745** |
| **Market balance** | | | | | | | | | |
| Balance (before ETFs) | 655 | 825 | 675 | 425 | 405 | -940 | -75 | 85 | 225 |
| ETFs (stock allocation) | 385 | 575 | 175 | 200 | 905 | 215 | -240 | -10 | |
| **Balance after ETFs** | **270** | **250** | **500** | **225** | **-500** | **-1,155** | **165** | **95** | |

*Source: SFA (Oxford)*

## Platinum demand and recycling summary

| koz | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017f |
|---|---|---|---|---|---|---|---|---|---|
| **Gross demand** | | | | | | | | | |
| **Autocatalyst** | | | | | | | | | |
| North America | 335 | 390 | 385 | 425 | 425 | 465 | 470 | 425 | 415 |
| Western Europe | 1,290 | 1,335 | 1,495 | 1,340 | 1,360 | 1,450 | 1,555 | 1,645 | 1,545 |
| Japan | 315 | 480 | 500 | 600 | 580 | 590 | 525 | 485 | 465 |
| China | 95 | 135 | 120 | 115 | 130 | 125 | 130 | 170 | 175 |
| India | 100 | 145 | 180 | 200 | 160 | 160 | 175 | 165 | 180 |
| RoW | 390 | 440 | 450 | 495 | 525 | 520 | 530 | 545 | 580 |
| **Total** | **2,525** | **2,925** | **3,130** | **3,175** | **3,180** | **3,310** | **3,385** | **3,435** | **3,360** |
| **Jewellery** | | | | | | | | | |
| North America | 140 | 160 | 160 | 185 | 200 | 230 | 250 | 265 | 275 |
| Western Europe | 185 | 180 | 175 | 175 | 220 | 220 | 235 | 240 | 250 |
| Japan | 430 | 370 | 315 | 325 | 335 | 335 | 340 | 335 | 340 |
| China | 1,860 | 1,370 | 1,670 | 1,915 | 1,990 | 1,975 | 1,765 | 1,450 | 1,340 |
| India | 40 | 50 | 80 | 105 | 140 | 175 | 220 | 245 | 305 |
| RoW | 25 | 40 | 50 | 55 | 60 | 65 | 70 | 70 | 80 |
| **Total** | **2,680** | **2,170** | **2,450** | **2,760** | **2,945** | **3,000** | **2,880** | **2,605** | **2,590** |
| **Industrial** | | | | | | | | | |
| North America | 205 | 265 | 265 | 320 | 320 | 320 | 260 | 390 | 340 |
| Western Europe | 275 | 285 | 280 | 250 | 170 | 230 | 305 | 265 | 250 |
| Japan | 130 | 140 | 200 | 90 | 90 | 30 | 95 | 95 | 25 |
| China | 125 | 390 | 310 | 375 | 520 | 450 | 540 | 585 | 500 |
| RoW | 500 | 555 | 795 | 495 | 420 | 515 | 470 | 440 | 495 |
| **Total** | **1,235** | **1,635** | **1,850** | **1,530** | **1,520** | **1,545** | **1,670** | **1,775** | **1,610** |
| **Total gross demand** | | | | | | | | | |
| North America | 680 | 815 | 810 | 930 | 945 | 1,015 | 980 | 1,080 | 1,030 |
| Western Europe | 1,750 | 1,800 | 1,950 | 1,765 | 1,750 | 1,900 | 2,095 | 2,150 | 2,045 |
| Japan | 875 | 990 | 1,015 | 1,015 | 1,005 | 955 | 960 | 915 | 830 |
| China | 2,080 | 1,895 | 2,100 | 2,405 | 2,640 | 2,550 | 2,435 | 2,205 | 2,015 |
| RoW | 1,055 | 1,230 | 1,555 | 1,350 | 1,305 | 1,435 | 1,465 | 1,465 | 1,640 |
| **Total** | **6,440** | **6,730** | **7,430** | **7,465** | **7,645** | **7,855** | **7,935** | **7,815** | **7,560** |
| **Recycling** | | | | | | | | | |
| **Autocatalyst** | | | | | | | | | |
| North America | 550 | 580 | 600 | 575 | 560 | 560 | 505 | 535 | 560 |
| Western Europe | 135 | 195 | 420 | 405 | 365 | 470 | 450 | 480 | 510 |
| Japan | 110 | 145 | 115 | 115 | 95 | 105 | 95 | 90 | 95 |
| China | 0 | 0 | 5 | 10 | 20 | 30 | 55 | 40 | 40 |
| RoW | 40 | 35 | 70 | 70 | 80 | 90 | 85 | 90 | 90 |
| **Total** | **835** | **955** | **1,210** | **1,175** | **1,120** | **1,255** | **1,190** | **1,235** | **1,295** |
| **Jewellery** | | | | | | | | | |
| North America | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 |
| Western Europe | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 |
| Japan | 130 | 150 | 285 | 285 | 250 | 235 | 160 | 150 | 165 |
| China | 285 | 325 | 345 | 555 | 600 | 530 | 340 | 460 | 335 |
| RoW | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 5 |
| **Total** | **415** | **475** | **630** | **840** | **855** | **775** | **515** | **625** | **515** |
| **WEEE** | **15** | **10** | **10** | **5** | **5** | **5** | **5** | **5** | **5** |
| **Total recycling** | | | | | | | | | |
| North America | 555 | 580 | 600 | 575 | 560 | 565 | 515 | 540 | 565 |
| Western Europe | 135 | 200 | 425 | 405 | 365 | 475 | 455 | 485 | 515 |
| Japan | 245 | 295 | 400 | 400 | 345 | 340 | 255 | 240 | 260 |
| China | 285 | 325 | 355 | 570 | 620 | 560 | 395 | 500 | 375 |
| RoW | 45 | 40 | 70 | 70 | 90 | 95 | 90 | 100 | 100 |
| **Total** | **1,265** | **1,440** | **1,850** | **2,020** | **1,980** | **2,035** | **1,710** | **1,865** | **1,815** |

*Source: SFA (Oxford)*

## Rhodium supply-demand balance

| koz | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017f |
|---|---|---|---|---|---|---|---|---|---|
| **Primary supply** | | | | | | | | | |
| **Regional** | | | | | | | | | |
| South Africa | 660 | 650 | 645 | 600 | 590 | 425 | 620 | 615 | 595 |
| Russia | 75 | 75 | 75 | 75 | 70 | 75 | 70 | 70 | 75 |
| Zimbabwe | 20 | 25 | 30 | 30 | 35 | 35 | 35 | 45 | 35 |
| North America | 20 | 15 | 30 | 30 | 35 | 30 | 30 | 25 | 25 |
| Other | 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| **Total** | **775** | **775** | **790** | **745** | **740** | **575** | **765** | **765** | **740** |
| **Demand & recycling** | | | | | | | | | |
| **Autocatalyst** | | | | | | | | | |
| Gross demand | 585 | 730 | 740 | 770 | 785 | 835 | 860 | 840 | 820 |
| Recycling | 170 | 220 | 235 | 235 | 260 | 275 | 270 | 285 | 295 |
| Net demand | 415 | 510 | 505 | 535 | 525 | 560 | 590 | 555 | 525 |
| **Industrial demand** | 105 | 175 | 170 | 150 | 150 | 175 | 180 | 190 | 165 |
| **Other recycling** | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| **Gross demand** | 690 | 905 | 910 | 920 | 935 | 1,010 | 1,040 | 1,030 | 985 |
| **Recycling** | 175 | 220 | 235 | 235 | 260 | 275 | 270 | 285 | 295 |
| **Net demand** | **515** | **685** | **675** | **685** | **675** | **735** | **770** | **745** | **690** |
| **Market balance** | | | | | | | | | |
| Balance (before ETFs) | 260 | 90 | 115 | 60 | 65 | -160 | -5 | 20 | 50 |
| ETFs (stock allocation) | | | 15 | 35 | 50 | 5 | -5 | 5 | |
| **Balance after ETFs** | | | **100** | **25** | **15** | **-165** | **0** | **15** | |

*Source: SFA (Oxford)*

## Rhodium demand and recycling summary

| koz | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017f |
|---|---|---|---|---|---|---|---|---|---|
| **Gross demand** | | | | | | | | | |
| **Autocatalyst** | | | | | | | | | |
| North America | 150 | 180 | 180 | 200 | 220 | 235 | 255 | 255 | 240 |
| Western Europe | 190 | 200 | 215 | 190 | 195 | 220 | 235 | 200 | 195 |
| Japan | 115 | 165 | 135 | 150 | 140 | 140 | 125 | 125 | 120 |
| China | 45 | 70 | 75 | 90 | 95 | 105 | 110 | 130 | 130 |
| India | 10 | 15 | 20 | 20 | 15 | 15 | 15 | 20 | 20 |
| RoW | 75 | 100 | 115 | 120 | 120 | 120 | 120 | 110 | 115 |
| **Total** | **585** | **730** | **740** | **770** | **785** | **835** | **860** | **840** | **820** |
| **Industrial** | | | | | | | | | |
| North America | 10 | 15 | 20 | 15 | 15 | 15 | 15 | 20 | 15 |
| Western Europe | 15 | 25 | 20 | 20 | 10 | 15 | 15 | 15 | 15 |
| Japan | 35 | 45 | 45 | 45 | 35 | 30 | 35 | 30 | 30 |
| China | 20 | 40 | 40 | 30 | 45 | 55 | 55 | 65 | 50 |
| RoW | 25 | 50 | 45 | 40 | 45 | 60 | 60 | 60 | 55 |
| **Total** | **105** | **175** | **170** | **150** | **150** | **175** | **180** | **190** | **165** |
| **Total gross demand** | | | | | | | | | |
| North America | 160 | 195 | 200 | 215 | 235 | 250 | 270 | 275 | 255 |
| Western Europe | 205 | 225 | 235 | 210 | 205 | 235 | 250 | 215 | 210 |
| Japan | 150 | 210 | 180 | 195 | 175 | 170 | 160 | 155 | 150 |
| China | 65 | 110 | 115 | 120 | 140 | 160 | 165 | 195 | 180 |
| RoW | 110 | 165 | 180 | 180 | 180 | 195 | 195 | 190 | 190 |
| **Total** | **690** | **905** | **910** | **920** | **935** | **1,010** | **1,040** | **1,030** | **985** |
| **Recycling** | | | | | | | | | |
| **Autocatalyst** | | | | | | | | | |
| North America | 125 | 160 | 140 | 145 | 165 | 160 | 150 | 160 | 165 |
| Western Europe | 20 | 30 | 60 | 60 | 55 | 60 | 60 | 60 | 65 |
| Japan | 20 | 25 | 25 | 25 | 25 | 30 | 30 | 35 | 35 |
| China | 0 | 0 | 0 | 0 | 5 | 5 | 10 | 5 | 5 |
| RoW | 5 | 5 | 10 | 5 | 10 | 20 | 20 | 25 | 25 |
| **Total** | **170** | **220** | **235** | **235** | **260** | **275** | **270** | **285** | **295** |

*Source: SFA (Oxford)*

# GLOSSARY OF TERMS

**Basket price**

Collective revenue of metals divided by 4E oz.

**By-products**

Copper, nickel, iridium and ruthenium.

**CAGR**

Compound annual growth rate.

**ETF**

Exchange-traded fund.

**EV, EVs**

Electric vehicle(s).

**FCEVs**

Fuel cell electric vehicles.

**Gross demand**

A measure of intensity of use.

**HDV**

Heavy-duty vehicle.

**koz**

A thousand troy ounces.

**LCV**

Light commercial vehicle.

**Lease rates**

Fees payable for the rental of an asset.

**LBMA**

London Bullion Market Association.

**LPPM**

London Platinum and Palladium Market (UK).

**MLCCs**

Multi-layered ceramic capacitors.

**Moody's**

The bond credit rating business of Moody's Corporation.

**mt**

Million tonnes.

**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.

**NYMEX**

New York Mercantile Exchange.

**OEMs**

Original equipment manufacturers.

**oz**

Troy ounce.

**PGMs**

Platinum-group metals.

**Price elastic**

Susceptible to changes in price.

**Primary supply**

Mine production.

**Producer sales**

Mine output plus inventory sold to market.

**RDE tests**

Real-world driving emissions tests.

**SAW filters**

Surface acoustic wave filters; increasingly ubiquitous electronic components found in wireless communications equipment, often use iridium crucibles to make lithium tantalate and lithium niobate for SAW filters.

**Secondary supply**

Recycling output.

**SUV**

Sports utility vehicle.

**S&P 500**

Standard & Poor's 500 Index is an index of the largest 500 US companies by market capitalisation.

**TOCOM**

Tokyo Commodity Exchange.

**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.

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# NOTES

## Disclaimer, copyright, and intellectual property



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

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