

THE PALLADIUM STANDARD

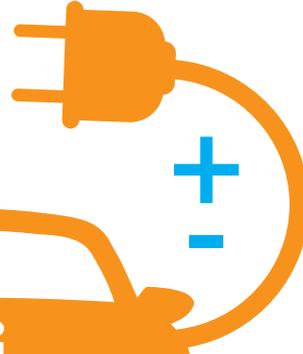
September 2018



One vehicle dataset, three metal forecasts

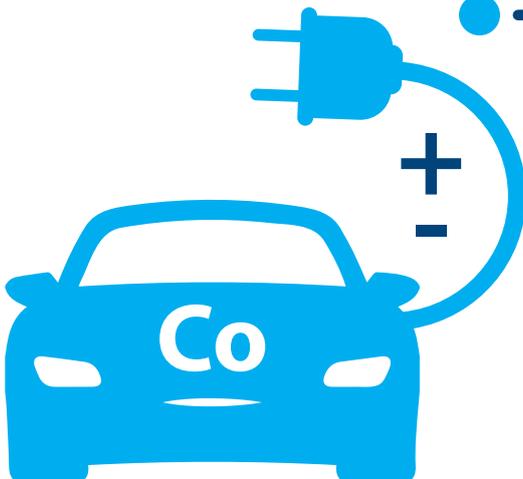
In this unique package, SFA (Oxford) takes you on a journey from today's powertrains (mostly ICE) to the powertrains of the future (BEVs, EREVs, hybrid, plug-in and fuel cell vehicles) and assesses the impact on key metals.

Equilateral Thinking

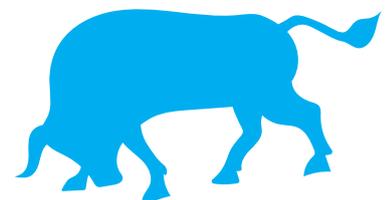


Regularly conducting in-depth lithium market studies for automotive and battery manufacturing clients since 2009

Due diligence assignments in the DRC and involvement in the cobalt industry go back ten years



Recognised world authority on PGMs



For more information on equilateral thinking on PGM, Cobalt and Lithium, please contact MD, Beresford Clarke.

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September 2018

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FOREWORD

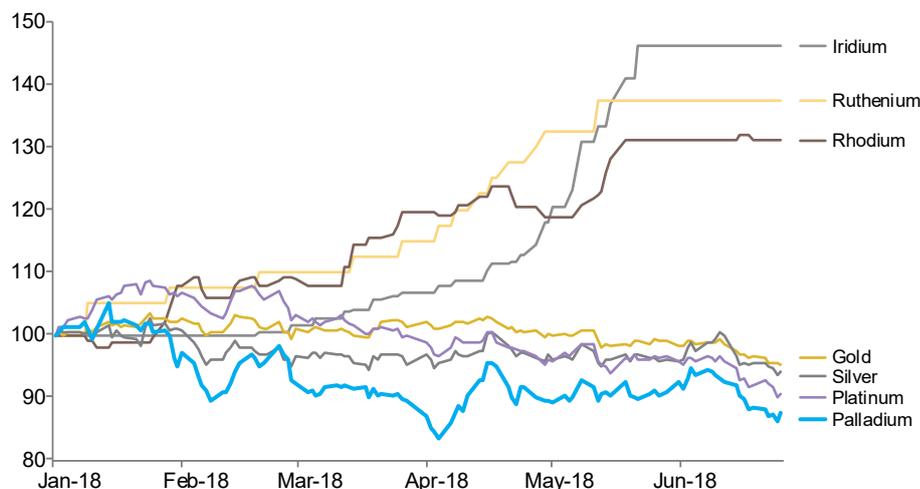


Foreword

Is palladium oversold?

As this year's worst performing precious metal, palladium's two-year price climb to an all-time peak of \$1,100/oz in mid-January 2018 now looks to be firmly in the past. In August prices traded back below \$900/oz. Based on market fundamentals (800 koz deficit in 2018), the palladium price should be well poised to build on \$1,100/oz and yet... it hasn't. So why is this?

Indexed precious metal price performance H1'18



Source: SFA (Oxford)

At \$950/oz (the current price as of 31 August) the palladium price is still relatively high, and so it makes sense that investors have taken profits and brought the price down 13% from its peak this year.

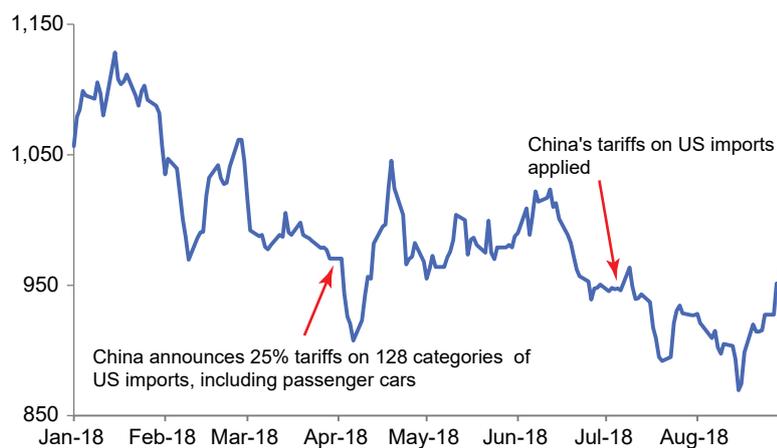
To forecast the palladium price, it is vital to understand whether investors are simply taking a pause after achieving a long sought-after milestone (\$1,000/oz) or if they believe the investment case for the metal is over.

In the first article of this edition of *The Palladium Standard*, Andy Smith speculates that uncertainty about palladium demand is an underlying cause for the metal's poor performance. Escalating trade tensions between the US and China, the world's two largest economies, with heavy implications for the passenger car market, have done little to inspire investor confidence. With palladium's high exposure to automotive end-use (81% market share), China's targeting of \$10 billion worth of passenger car imports from the US understandably causes alarm bells to ring; when the tariffs were first announced back in April, the palladium price dropped by almost 5% in just two days.

The Palladium Standard

Thorough analysis of the ensuing fallout, however, reveals (in the worst case) a 4% decline in palladium demand by 2020 – that’s an absolute reduction of ~200 koz over the next two years. While certainly significant, for a metal in annual deficit of 800 koz, this will do little to swing the market into surplus. In fact, this downside could be entirely offset by potential demand creation in Europe, due to the demonisation of diesel and the resulting switch to palladium-rich gasoline or gasoline-hybrid cars. It is unsurprising, then, that the palladium price recovered rather quickly from the news and hardly moved when the tariffs were actually implemented (on 6 July).

Palladium price in 2018 (USD/oz)



Source: SFA (Oxford)

If sensationalist events do not explain palladium’s poor ledger this year, perhaps it is down to the high risk that comes with exposure to a single end-use – especially if the twin pillars of industrial demand growth (the US and China) are showing signs of slowing.

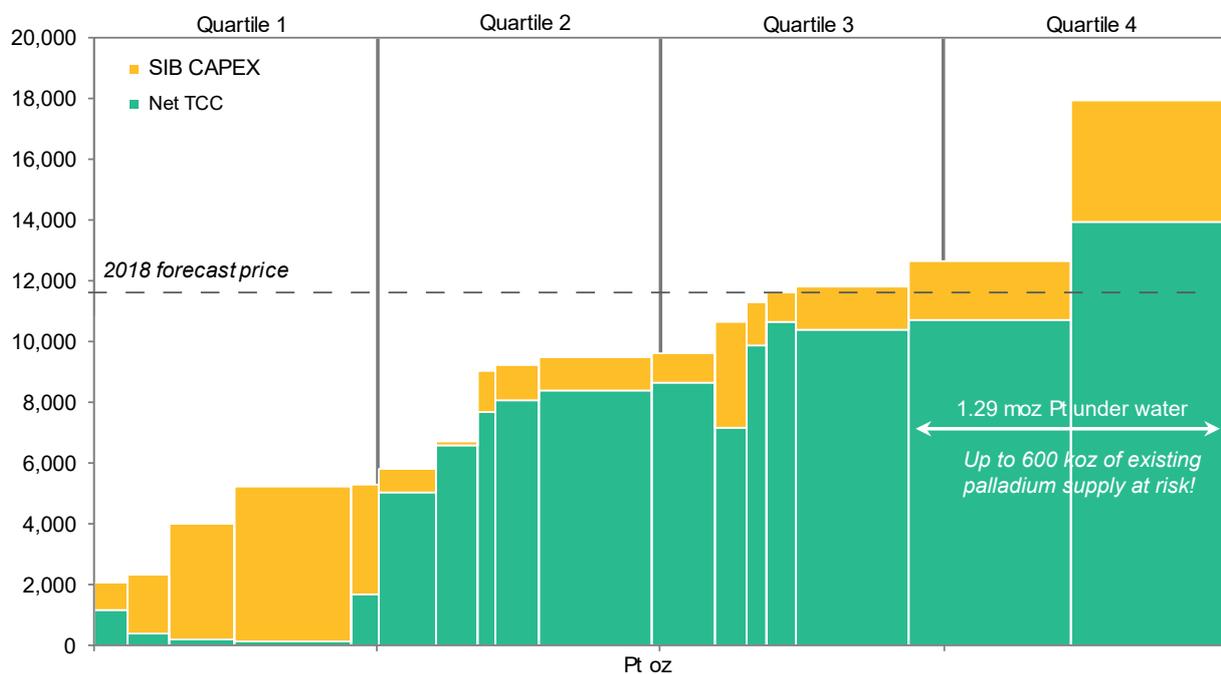
In the second article, Beresford Clarke discusses the threat to the internal combustion engine coming from electric propulsion, in the form of both pure battery power and hybrids (mild and plug-in). Undoubtedly, there is currently significant promotion of electrified vehicles. However, while year-on-year sales growth looks impressive as a percentage, the lower absolute number of units means that there are major challenges facing the next generation of powertrains before electric chargers become standard in our homes.

In the long term, the downside for palladium is certainly much greater than the upside for cobalt and lithium, due to the PGM’s heavy reliance on automotive end-use... but in the short to medium term, demand for gasoline cars (including gasoline-hybrids) is going to grow industrial palladium demand, at least through to 2028. Even in our ‘EV bull’ scenario, the palladium market is only just in balance by 2030 – indicating the severity of the supply deficit and the long period before electric vehicles are expected to displace the internal combustion engine.

So, with palladium demand looking to expand in an already deficit market, one would be correct in assuming that supply would increase going forward. Indeed, most new PGM projects (new mines and expansions) are palladium-rich – Waterberg (65%) and Ivanplats (52%) are both potential future projects that could add over 600 koz of palladium annually when completed.

However, owing to today’s low platinum price inducing mine closures in South Africa, there is a significant risk to existing palladium supply. In 2018, up to 600 koz of palladium will be supplied (as a by-product) from loss-making platinum mines in South Africa... in 2019 that number could increase to over 1 moz at current price forecasts.

Net total cash costs, 2018f (ZAR/Pt oz)



Source: SFA (Oxford)

Clearly then, there has been a decoupling between what the market fundamentals indicate the palladium price should be doing (appreciating) and what the price is actually doing (taking a pause). When the world’s largest palladium producer has to rely on 350 koz of stock sales in the first half of the year, arguably to mitigate price volatility and avoid similarly dire consequences to those witnessed in 2001, the palladium market is demonstrably tight.

With that, we circle back to our original question: why is palladium cheap today? Perhaps today’s price is discounted based on palladium’s future fallout. Or maybe, investors view palladium as an exception to the fundamental economics of supply and demand. More likely, though, is that traders are taking a pause, basking in their profits, before (once again) putting their foot on the gas as soon as gasoline (and gasoline-hybrid) car sales return to firm growth.

**PGMs – CASUALTIES OF
A US-CHINA TRADE WAR?**



PGMs – casualties of a US-China trade war?

Andy Smith, Precious Metals Consultant

“Today is the first day of the war with China”

Ray Dalio, founder of Bridgewater (world's biggest hedge fund),
6th July 2018

When one of the biggest active investors declares a trade war has begun, you'd better duck, right? And since, as industry advocates have long trumpeted, 'PGMs are used in almost everything we consume', anything that hurts trade must wound PGMs, yes? Probably.

PGMs are used in almost everything

We first examine the long-term 'casus belli' for the trade friction — important because it turns out that the world has likely been 'over-trading' in many ways. This was bound to end, whether under this US President or the next or the next. The growth aspirations of an over-traded world will have to be pared back to a reality few seem willing to contemplate. Hence the 'macro' of what trade frictions are signalling is more hurtful to PGMs than the 'micro' of the measures themselves.

The world has been over trading

And working out the 'micro' of the measures for PGMs is to chase a moving, slippery and shrinking target. PGMs are undoubtedly collaterally damaged, but estimating to what extent depends on the calibre of microscope one can bring to bear on myriad end-use categories at risk. It also depends on whether the 'war' is a shooting or a phoney one, 'over by Christmas'. Worst-case scenarios are (all too) easily painted, once a wet finger is introduced to a rule of thumb. Plugging an 'official', maybe even a plausible one into our end-use models suggests a worst-case demand hit in just autos (but likely in other industrial uses too) of 3-4% by 2020 across the main PGMs.

PGM collateral damage of 3-4% demand by 2020 (worst case)

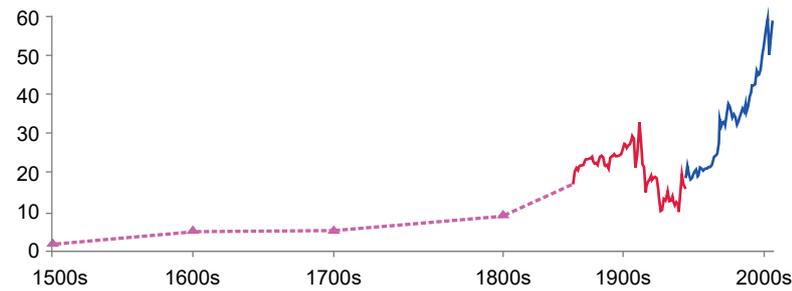
Trade 'surplus'

Arguably we are witnessing 'Peak Globalisation'. We've passed from diminishing into negative returns from complexity in economic activity. We've hit 'max' goodwill/trust for counterparties. Esoteric arguments made by the economic textbooks for the 'gains from trade', for winners being able (somehow) to compensate losers seemed unarguable when trade was less than 20% of global GDP. Now we're at 60%. At the climax of the last golden age of globalisation, just before World War I, 30% proved unsustainable, peaceably. In this sense, cometh the era, cometh the man; if there wasn't a President Trump to point out or tweet about these risks, we'd have to invent one.

We've reached peak globalisation...

Over-trading #1

Share of world trade in global GDP, %

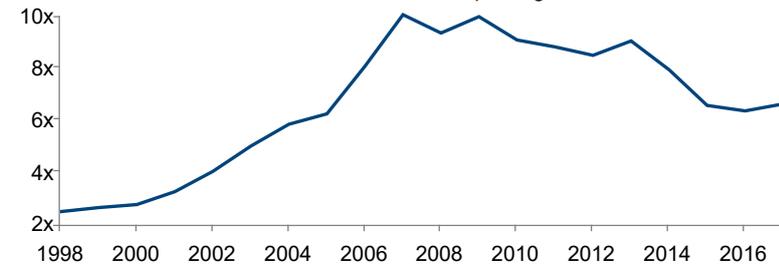


Source: SFA (Oxford), OurWorldinData.org (based on three databases)

If this were a stock market or a commodity price, we'd not hesitate to call it a 'bubble'. Nor if it were what Warren Buffett called "financial weapons of mass destruction" – over-the-counter, OTC derivatives. Which burst in 2008.

Over-trading #2

Notional 'over the counter' derivatives as a multiple of global GDP



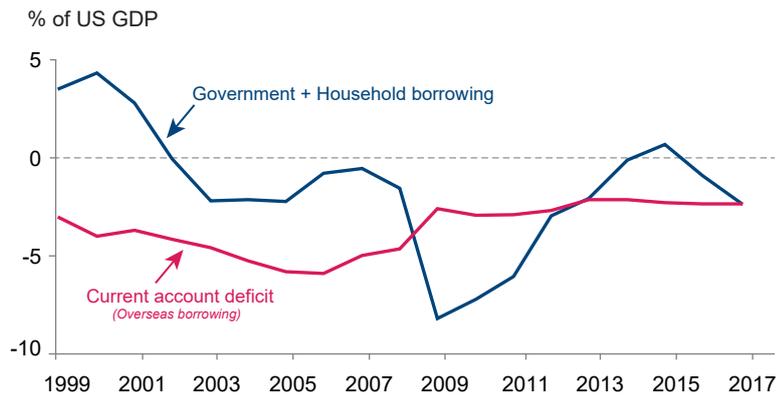
Source: SFA (Oxford), BIS, IMF

Growth as we knew it, artificially juiced by 'free' trade and 'free for all' derivatives, is over. Reduce forecast PGM (and almost all commodity) demand growth, accordingly.

...reduce PGM demand forecasts accordingly

The US itself has 'over-traded' for decades. Government and households have lived beyond their means all this century – borrowing overseas, running up the tab of current account deficits, becomes an accounting certainty. So, unless Washington and 'Joe Public' start living within their means, there'll always be a trade deficit. There's nothing 'unfair' about that. So far President Trump's direction of travel, a fiscally-pumped dash for growth, is in precisely the opposite direction. Scapegoating 'trade' will remain as enduring as the Constitution.

Trade crisis until 'Make America Solvent Again'

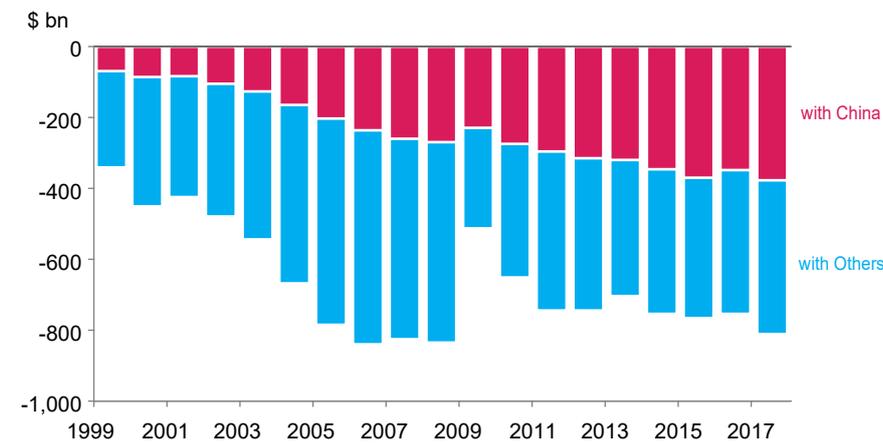


Source: SFA (Oxford), BIS, IMF

'Better' still, politically, if you can point a finger at one target in particular. China, by its success, has made it easy for the US to make trade 'personal', so an election issue.

How much trade is too much?

China (rising) owns a (static) US trade deficit



Source: SFA (Oxford), derived from US Bureau of Economic Analysis

If you were trying to be charitable, you'd probably see merit in Washington's claims that the trade re-set is about 'security'. At some point, exposure to a dominant trading partner becomes too risky. At, say, 25% of your imports, or 50% of your trade deficit?

Exposure to a dominant trading partner becomes too risky

'Red' lines for any US President?



Source: SFA (Oxford), derived from US Bureau of Economic Analysis

Phoney war, so far

So far tariffs are actually in place on \$34 billion of US and Chinese exports. That's a 25% potential price rise on all of 0.2% and 0.3% of GDP respectively. Nuclear this isn't, yet. But heavier artillery is being prepared...

"Trade war" has been limited so far but things are escalating

Tit for Tariff

	US on China	China on US	Googletrends USA 'trade war'
March 23	Steel/aluminium tariffs imposed		47
April 2		New tariffs 128 categories	83
3	1333 categories; intent +25%		83
4		133 categories; intent	83
5	Trump threatens tariffs on \$100 bn		83
May			
June 15	818 categories, \$34 bn, tariffs +25% July 6 284 categories, \$16 bn 'later'		37
16		545 categories, \$34 bn, tariffs + 25% July 6, \$16 bn 'later'	37
18	Trump wants another \$200 bn identified for +10%; threat + \$200 bn more		37
July 6	Tariffs announced June 15 begin	Tariffs announced June 15 begin	62
10	List of categories of \$200 bn to be liable to 10% tariffs		79
August 1	Looking at raising proposed 10% to 25% on the \$200 bn		41

Source: SFA (Oxford), Googletrends USA

...and the ordinary, 'Googling' Americans and Chinese have taken note/ fright.

(Trade) war talk

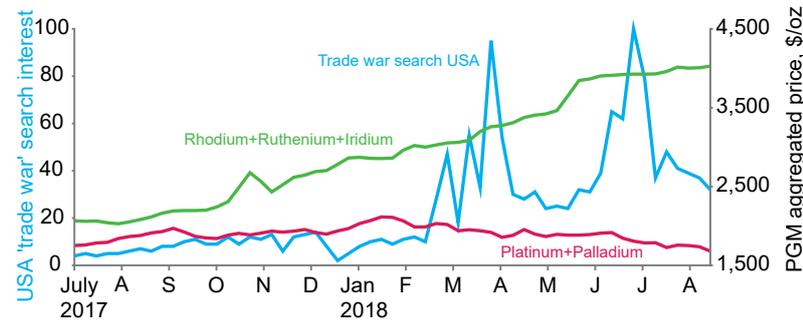
Googletrends search interest relative to maximum 100



Source: SFA (Oxford), Googletrends USA

Coincidentally (?), 'major' and 'minor' PGM prices parted ways as trade war drums beat more loudly. 'Minor' PGMs are no more vital/ irreplaceable than 'major' PGMs, and there is little evidence of precautionary stock building. Perhaps the relatively tiny exposure of iridium and ruthenium (low single digit %) to what is anticipated to be the worst-hit PGM end-use, autos, explains part of the outperformance of the 'minors' under fire?

Trade war talk sorts PGM chaff from wheat?



Source: SFA (Oxford), Bloomberg, Googletrends USA

Major PGMs hit worst

Also supporting the hope this will 'all be over by Christmas' is the US Trade Representative's report of 3rd April. This outlined 'Section 301' action on Chinese goods and actually revealed considerable deliberation if not method in President Trump's 'madness'. In particular, the criteria used to determine which categories of Chinese exports made the list of 1300+ to be charged an extra 25% tariff were extremely focussed:

- Products that "benefit from" (Subsidies? Regulatory blind eye?) China's 'Made in China 2025' policy were in the cross-hairs, i.e. scatterguns were neither targeted nor used.
- Removed from the list were products "likely to cause disruption to the US economy" or those likely "subject to legal or administration constraints" (where the courts might complicate matters), i.e. a 'do as little harm as possible' credo.
- Remaining products were then ranked "according to the likely impact on consumers" looking at "alternative country sources for each product", i.e., 'do as little harm as possible', again.
- Only products with the "lowest consumer impact" made the list, i.e. ...you get the picture.

The US has been extremely selective with their selection of tariffs

In any case, casualties will be minimised in a tariff war. For a tariff is not an embargo. There are several ways extra tariffs could be 'worked around' to minimise macro and micro 'harm' (and so ricochets to PGMs). For example:

- Central banks can be leaned upon to delay interest rate rises, or encourage a currency devaluation.
- Companies could swallow whole or in part the tariff rise.
- Products subject to extra tariffs could see a change in location to non/lower-tariffed countries. (There are reports that this is already happening for some Chinese goods.)

Of course, these are no grounds for standing 'at ease'. As noted, the arc of 'trading' history is bending towards a shooting war, sometime. We may dodge this bullet, not the next. And as MarketWatch's Caroline Baum observes: "Trump has been consistent on one, and only one, issue since at least the 1980s. And that's trade." Besides, the sheer imbalance in trade – China exports to the US four times (\$500+ billion) what the US sends to China – means that pretty early in these exchanges China must go beyond trade tit for tat, raising its retaliation to, for example, selling US bonds, or worse. Furthermore, if Republicans retain Congress in November's election all (slim) hope of Congressional restraint on the President will be gone.

China's exports to the US are four times greater than vice-versa

Trade War: Boom or Bust?



Trade – the ‘only thing’ Trump is consistent on

China has to do more than hit US imports, worth ‘only’ \$130 bn vs \$500 bn Chinese sales to US

Republicans retain Congress in November mid-terms: legality of President’s tariffs unchallenged

Trump flip-flops

Trump removes trade threat as concession to Chinese help in an imminent (?) North Korea deal

Republicans lose Congress in November mid-terms: Congress challenges legality of President’s tariffs

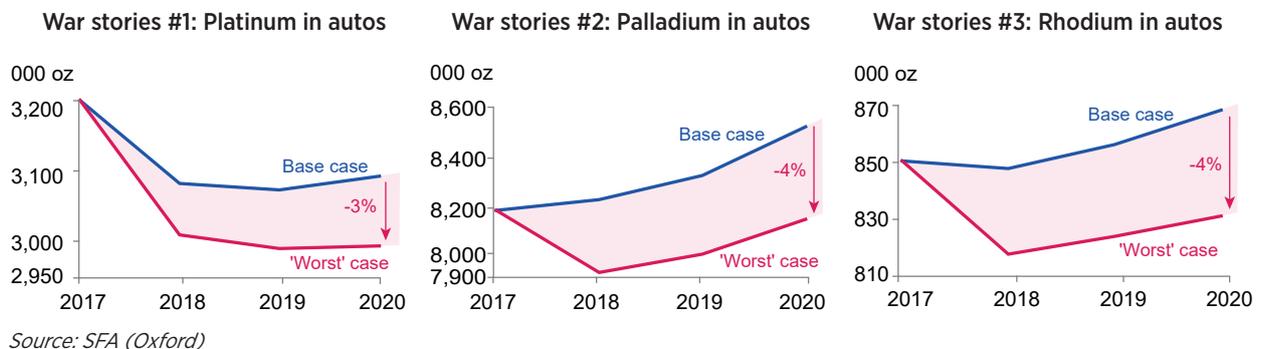
Estimating PGM casualties

The direct impact of extra ‘narrow, bilateral’ tariffs – i.e. roughly where we are at the moment – is “small”, according to Mark Carney, Governor of the Bank of England. So some form of model-based magnification, and considerable imagination, is therefore required before measurable damage can be simulated. The worst the Bank of England can envisage (at this stage) is an extra 10% tariff between the US and all its trading partners. The body count peaks after three years in which uncertainty rises, ‘financial conditions’ tighten (central banks don’t ease policy to accommodate the higher inflation), and a trade war escalation is expected. US GDP is left 5% lower, global GDP 2.5% lower.

Worst case: global GDP hit by 2.5%

In this ‘official’ worst case – the Full Trump? – we estimate that PGM demand in just the auto sector might drop 3-4%, with similar falls likely in other industrial end-use sectors.

Lower auto sector sales impacts PGMs



The Palladium Standard

As the lists of goods threatened with the imposition of tariffs are a 'work in progress' in both Washington and Beijing, fine-detail input-output analysis probably has a limited shelf life. So another, more useful way of gauging which PGM end-use sectors might ultimately be at risk is to examine a detailed breakdown of Chinese and American exports to one another for 'PGM exposure'. Our first pass and probably conservative estimate is that 37% of Chinese exports to the US and 43% of US exports to China are certainly or probably significant PGM users.

'PGMs are used in almost everything'

PGMs in the cross-fire

Chinese exports to US with PGM 'exposure'	\$ million	US exports to China with PGM 'exposure'	\$ million
(41050) Cell phones and other household goods, n.e.c.	70,360	(22090) Civilian aircraft engines, equipment and parts	16,265
(21300) Computers	45,515	(30000) Passenger cars, new and used	10,211
(20005) Electronic apparatus	14,081	(21320) Semiconductors	6,077
(41200) Televisions and video equipment	10,656	(21180) Industrial machines, other	5,447
(21180) Industrial machines, other	10,585	(21610) Medicinal equipment	3,453
(23120) Semiconductors	9,595	(12550) Chemicals-other	2,984
(12540) Chemicals – organic	5,305	(20005) Electric apparatus	2,317
(21000) Industrial engines	5,093	(12540) Chemicals – organic	2,297
(21610) Medical equipment	4,763	(11130) Natural gas liquids	2,007
(41310) Jewellery	2,107	(41050) Cell phones and other household goods, n.e.c.	1,825
(30000) Passenger cars, new and used	1,576	(21300) Computers	950
(12530) Chemicals – inorganic	1,481	(12530) Chemicals – inorganic	609
(12510) Chemicals – fertilisers	1,435	(12270) Precious metals, other	374
(12550) Chemicals – other, n.e.c.	1,069	(20100) Trucks, buses and special purpose vehicles	250
(21600) Laboratory testing instruments	987	(41310) Jewellery, etc.	215
(22010) Parts–civilian aircraft	600	(12510) Chemicals – fertilisers	196
(10020) Petroleum products, other	597	(21030) Excavating machinery	191
(41100) Motorcycles and parts	569	(41200) Televisions and video equipment	78
(30100) Trucks, buses and special purpose vehicles	500	(21500) Business machines and equipment	73
(14280) Other precious metals	85	(41210) Stereo equipment, etc.	67
(41220) Recorded media	36	(22100) Railway transportation equipment	58
(50010) Other military equipment	24	(41100) Pleasure boats and motors	51
(10300) Nuclear fuel materials	20	(11300) Nuclear fuel materials	41
(22210) Commercial vessels, other	17	(22210) Commercial vessels, other	4
(22000) Civilian aircraft	16	(50050) Tanks, artillery, missiles, rocks, guns and ammunition	1
(50000) Military aircraft and parts	13	(22200) Vessels, excluding scrap	0
PGM certain	165,178	PGM certain	39,484
PGM probable	21,908	PGM probable	16,556
All Chinese imports to US	505,470	All US exports to China	129,894

Source: SFA (Oxford). The figures in brackets are five-digit standard industrial classification, n.e.c. = not elsewhere classified.

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Perhaps the final word might go to Patrick Buchanan, “America’s leading populist conservative” (his *Suicide of a Superpower* maintains), at least before Donald Trump. Buchanan is a long-time isolationist (‘America First’) and protectionist. He concludes that “free trade has been the policy of powers that put consumption before production, today before tomorrow.” But isn’t this demonstrably (gratification instantaneously, please) ‘The American Way’? And if that’s right, how long can President Trump diverge from it?

**ELECTRIC SHOCK?
THE 'ELECTRIFIED' METALS
TRILOGY: PALLADIUM,
LITHIUM AND COBALT**



Electric shock? The ‘electrified’ metals trilogy: palladium, lithium and cobalt

Beresford Clarke, Managing Director, SFA (Oxford) Ltd

Background

SFA (Oxford) has recently completed very long-term market outlooks for critical commodities for tomorrow’s powertrains, from mild hybrids to electric cars. The studies help SFA to examine whether palladium’s glory days are numbered from the replacement of combustion engines by electric motors, whether there is enough cobalt to satisfy the needs of battery manufacturers going forward, and just what are the dynamics of the emerging lithium market.

Is cobalt the new palladium? The challenges of securing palladium from Russia in the past led to a major price spike in the early 2000s, when Russia accounted for over half of the world’s palladium supply. Fast forward to 2017 and we mirror another extreme concentration of supply, with the Democratic Republic of the Congo (DRC) providing almost two-thirds of the world’s cobalt.

*Is cobalt the new
palladium?
(supply security)*

The analysis of the three metal markets used exactly the same input parameters for macroeconomics, car sales and powertrain splits, so a like-for-like comparison could be achieved.

SFA is known for its reputation in PGMs, but what about lithium and cobalt? Well, SFA has been working behind the scenes in the lithium and cobalt markets for over 10 years, helping companies with asset valuations and investment appraisals, including on-site due diligence studies in the DRC, and has been aiding decision-making through the provision of independent commodity market intelligence and price forecasting to end-users.

The supply dynamics for these metals vary significantly

The concentration of primary cobalt supply is of greatest concern to battery fabricators and OEM car manufacturers alike. Last year the DRC accounted for an enormous 64% of the world's cobalt supply, while the next largest contributors, Australia and Cuba, accounted for only 4% each.

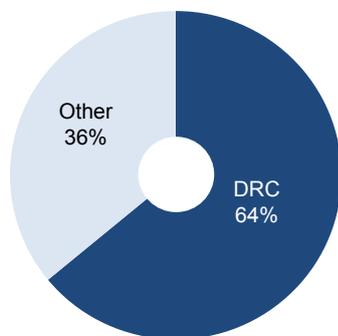
Two thirds (and rising) of the world's cobalt comes from the DRC

Political unrest, corruption, sudden changes to regulations and taxation can rapidly impact the supply of metals from the DRC. The DRC is also one of the most challenging countries with which to do business and ranks 182 out of 190 in the World Bank Doing Business 2018 Index. Furthermore, the highlighting by Amnesty International of human rights abuses related to the use of child labour at artisanal mines in the DRC has led cobalt users to map supply chains to ensure responsible sourcing of materials.

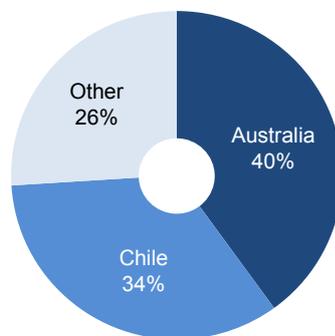
Nearly all cobalt is produced as a by-product of other metals, namely copper and nickel. There is just one primary cobalt mine, Bou-Azzer in Morocco, which accounts for just 1% of global supply. Therefore, much of the world's future cobalt supply will also be heavily reliant on prevailing copper and nickel prices.

Geographic split of electrified metals supply, 2017

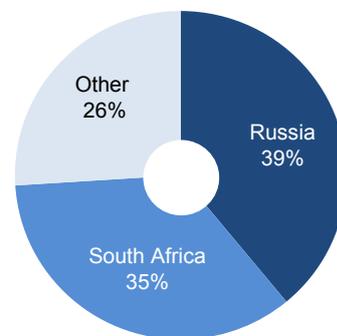
Cobalt



Lithium



Palladium



Source: SFA (Oxford)

In contrast to cobalt, primary lithium production is geographically more diverse and far more politically stable, with Australia and Chile providing just over a third of supply each, while the next biggest (and growing) supplier is Argentina at a sixth of world supply. The rest comes from mines in the remaining continents of North America, Africa, Europe and Asia.

Lithium supply is geographically diverse

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The rapid growth of consumer electronics, such as smartphones and tablets, and, more recently, electric cars has lifted prices of lithium to re-incentivise more expensive hard-rock mining, which suffered in the late 1990s and early 2000s with the commercialisation of cheaper brine extraction from the high Andes in South America.

Russia, at 39%, was the largest supplier of palladium from mines in 2017, followed closely by South Africa at 35%. Like cobalt, almost all palladium supply is derived as a by-product of other metals. In this case, nickel (Russia) and platinum (South Africa). Two primary palladium mines exist in North America – Stillwater and North American Palladium – which collectively account for 11% of global mine production.

Russia is the largest supplier of mined palladium

However, increased recycling of end-of-life catalytic converters and electronics has created an alternative, and geographically diverse, source of palladium supply, which has helped to encourage car companies to use the metal. Palladium recycling now accounts for 25% of global output.

Recycling accounts for 25% of total palladium supply

Key to the future sustainability of the cobalt market will be the recycling of old batteries, which currently accounts for only 6% of global supply. Meanwhile, despite being called ‘lithium-ion batteries’, the lithium content is actually less than 5% of complete battery packs and recovery is currently cost prohibitive.

Recycling of cobalt and lithium is virtually non-existent

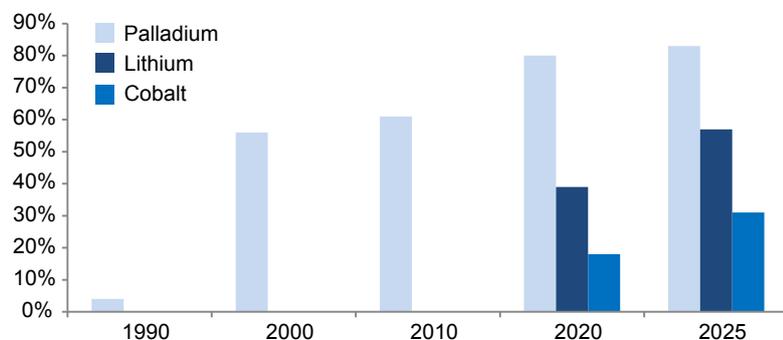
Palladium has everything to lose and lithium and cobalt everything to gain

Automotive end-use accounts for the highest concentration of demand for palladium at 81%, while, despite receiving considerable media coverage, automotive battery demand accounts for only 9% of cobalt and 20% of lithium consumption.

Over four-fifths of palladium used in autocatalysts

The rise of automotive commodities, new and old

Automotive demand as a percentage of total demand



Source: SFA (Oxford)

The Palladium Standard

This suggests that palladium has much to lose and cobalt and lithium have a great deal to gain from the evolution of powertrains, particularly with an increasing shift towards electric cars. However, cobalt is not used in all batteries and where it is used, in nickel-manganese-cobalt (NMC) and nickel-cobalt-aluminium oxide (NCA) batteries, there are long-term efforts to substitute out as much cobalt as possible for nickel, though the use of cobalt will still be significant, particularly as electric cars are gaining in popularity.

Long-term efforts to substitute cobalt

Electric vehicle uptake timing is critical

In terms of the market for electrified metals going forward, the evolution of powertrains and the inflection point for electric car uptake will dictate relative performances.

The continuous use of palladium in cars began in the early 1990s when car makers began substituting palladium for platinum in gasoline catalytic converters. Since then the emergence and rapid growth of China's auto sales, and peak sales in the USA, have helped to lift the use of palladium to record levels, with global demand, including all applications, exceeding 10 million ounces for the first time a few years ago.

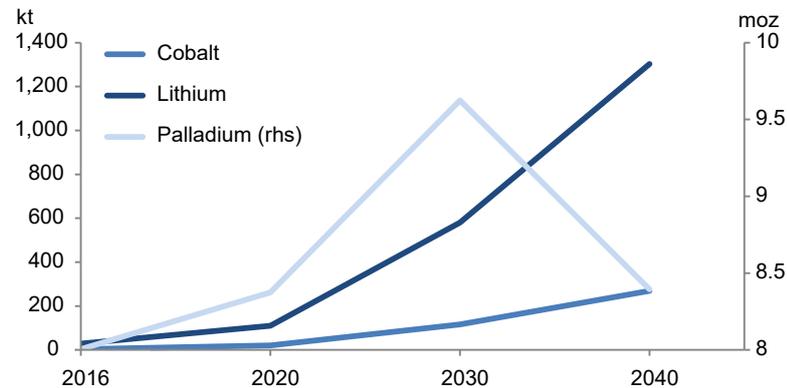
The use of lithium-ion batteries, and therefore lithium and cobalt, stepped up significantly from 2007 with the mass commercialisation of smartphones, while tablets and laptops also added demand. Cobalt use in consumer electronics was negligible in the late 1990s, but hit almost 40 kt in 2015 (boosting total demand by 80%), while the use of lithium (measured as lithium carbonate equivalent (LCE) for like-for-like measurement of lithium chemical demand) has stabilised at around 40 kt of LCE, with stronger sales of smartphones offsetting a reduction in tablet and laptop sales.

The commercialisation of electric vehicles from 2010 has led to a rapid increase in the use of lithium and cobalt, albeit from a very low base. Total electric vehicle demand for lithium grew by a third in 2017 compared to 2016 and now amounts to 40 kt of LCE (20% of demand), of which half is used in battery electric cars with the remainder in plug-in hybrids, electric buses and bikes. Meanwhile, cobalt demand in electric vehicles doubled in 2017, primarily owing to changes to China's EV subsidy rules forcing a shift to higher cobalt content in batteries (from lithium-iron-phosphate (LFP) to NMC).

Rapid increase in lithium and cobalt demand since 2010

Electrified metals outlook

Automotive demand outlook for electrified metals



Source: SFA (Oxford)

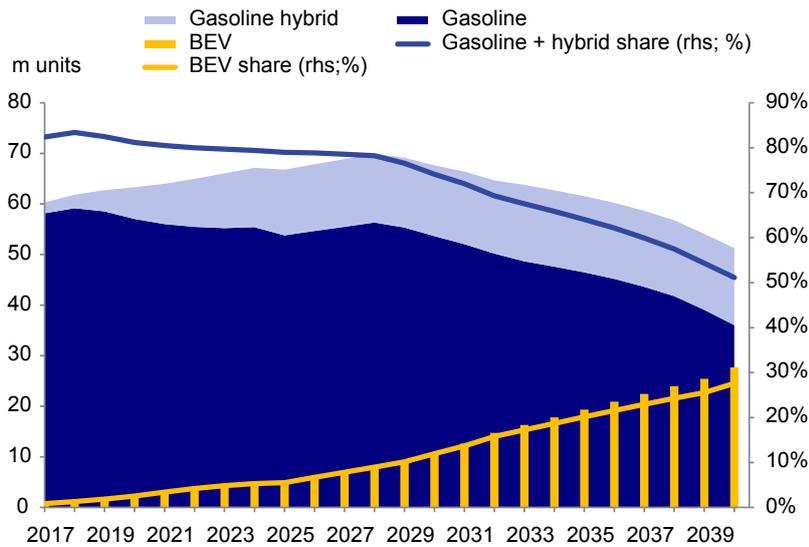
Palladium yet to peak

As per SFA's base case, palladium is set to have another 10 years of demand growth in autocatalysts, with a peak in demand likely to arrive prior to 2030. Nonetheless, demand will still be significantly higher in 2030 compared to today's levels. This assumes a rise to nearly 30 million battery electric vehicles (BEVs) produced every year by 2040. Even if the number of BEVs rises by 50% over the period, as shown in some forecasts, it still will not quite kill the palladium 'goose' by 2030.

Another 10 years of demand growth for palladium

In Europe, diesel passenger cars' share of the market will continue to fall away and gasoline or hybrids will gain share. The US is set to shift to BEVs more slowly than most mature markets, with hybrids and plug-in hybrids (with gasoline engines) gaining share over engine-only variants. Meanwhile, in most emerging markets gasoline will continue to dominate. In China, it appears more than likely that sales of electric vehicles and hybrids will grow at similar rates, even though hybrids have been slower to take off compared to other countries. The number of gasoline-powered passenger cars, including hybrids, is still expected to be millions of units higher than current levels in China, which leaves BEVs room to grow to millions as well.

Passenger car production: Gasoline vs. BEV



Source: SFA (Oxford), LMC Automotive

What does this mean for palladium? Well, as the palladium market is already in structural deficit, the prospect of growing automotive requirements over the next 10 years could well mean another price rally is in prospect, with \$1,500/oz the next target. However, current historically high palladium prices are motivating mine expansions and new PGM projects with richer palladium contents, which may reach the market in the 2020s. Autocatalyst recycling in China also has the potential to be significant in future. So higher supply from primary and secondary sources may dampen palladium prices over the long term, but, as is always the case with the PGM markets, we are more than likely going to see a price spike beforehand while a structural deficit exists.

Higher palladium prices in prospect

Positive long-term prospects for lithium and cobalt

At present, fewer than a million BEVs are manufactured each year, which is less than 1% of vehicles produced worldwide. Nonetheless, the BEV market grew at close to 50% in 2017. Whatever your outlook for BEVs over the next 10 years, sales of them are more than likely going to be in the millions. Therefore, the considerable amount of cobalt (even considering substitution) required in every BEV indicates multiples of today's demand in future.

To put the volume of cobalt in context with palladium requirements, there is more than 1,000 times more cobalt in a BEV than there is palladium in a gasoline car, and the palladium market is currently just over three times larger than the cobalt market. So any meaningful increase in the number of BEVs produced will have a major impact on the cobalt market. Of the four metals, cobalt is the most sensitive to changes in BEV market share (see the chart overleaf); a 5% increase in BEV share would lead to a 14% rise in cobalt automotive demand,

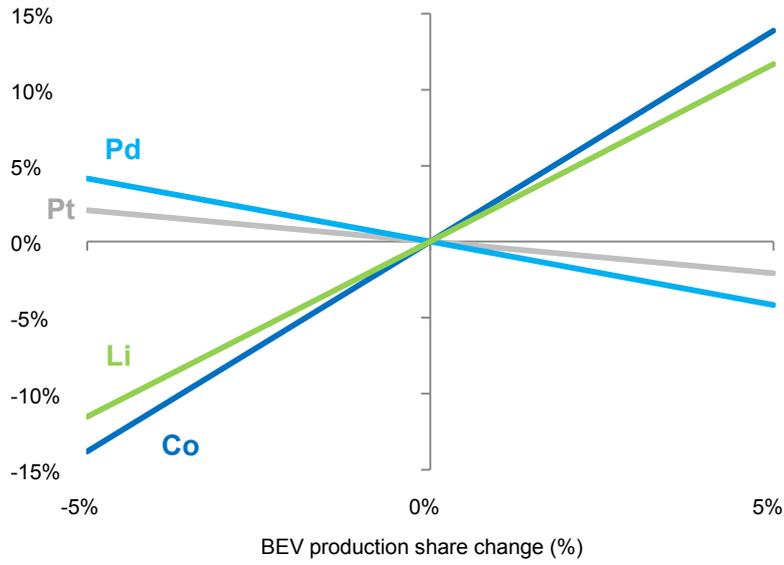
There is 1,000 times more cobalt in a BEV than palladium in a gasoline car

The Palladium Standard

while for lithium, which has a larger demand base, the same share rise would lead to a 12% increase in demand. For palladium, growth of 5% in BEV share would cut demand by 4.2%, while for platinum, which is more heavily used in commercial vehicles, the share increase would lead to a 2.1% drop in usage.

Automotive demand sensitivities

BEV LV share
(Demand change %)



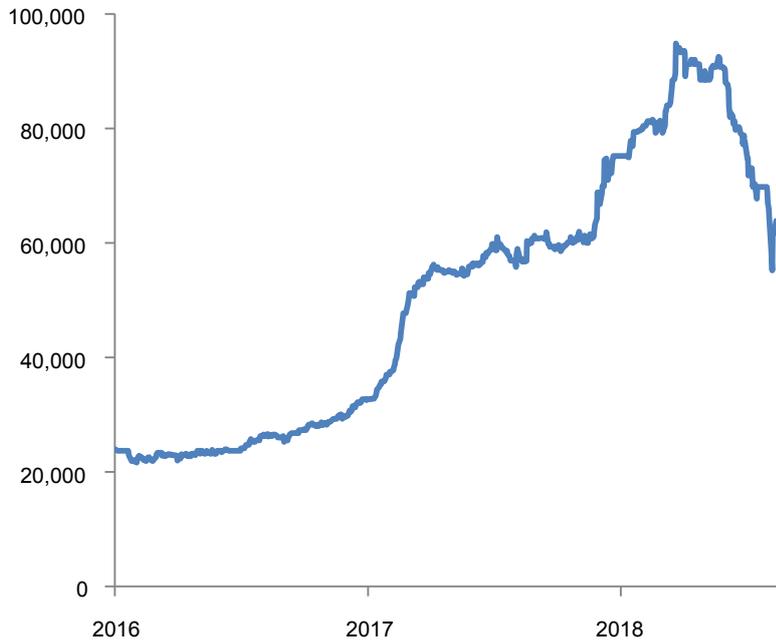
Source: SFA (Oxford)

Currently, large investments in mines in the DRC and short-term overproduction of batteries have impacted cobalt prices for the short to medium term, but over the long term a highly concentrated supply base and demand growth from BEVs are set to provide a platform for higher cobalt prices, as we have seen in the recent past.

Short-term overproduction of batteries hit cobalt and lithium prices

Recent price performance of battery electric commodities

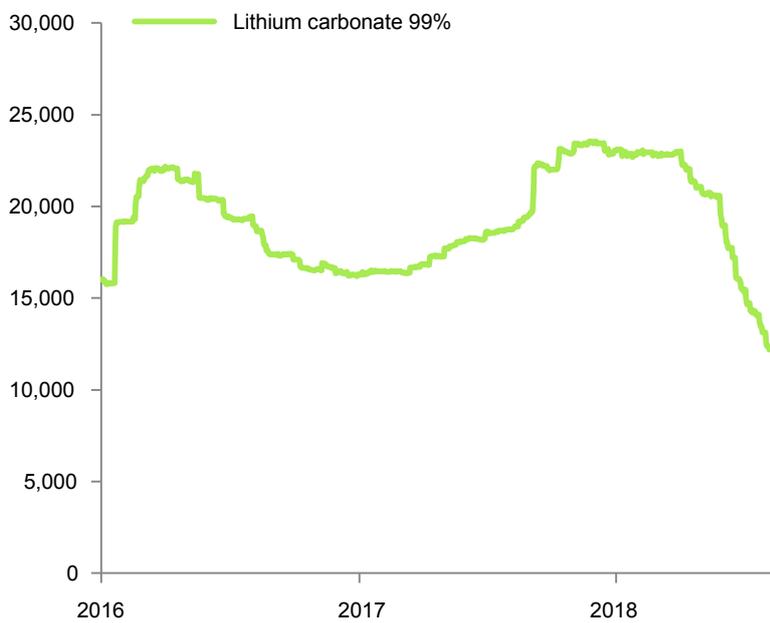
Cobalt price
\$/t



Source: SFA (Oxford), Bloomberg

Lithium price

Asia, \$/t



Source: SFA (Oxford), Bloomberg

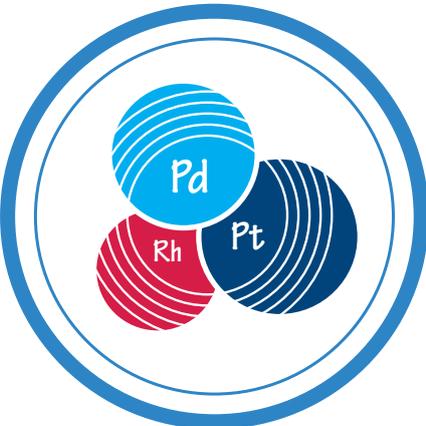
There is sufficient lithium supply to meet demand for the next few years and there are enough global resources to meet future requirements. In addition, there are numerous expansions and projects in the pipeline. With growing demand from BEVs, there is the potential to create an enlarged mining and extraction industry with an annual output multiple times bigger than today's production.

The Palladium Standard

However, over the medium term the inflection point for BEVs could catch the lithium extraction industry off guard, because of the complex chemistry of brine extraction and/or the need for chemical conversion plants for hard-rock mining, and the long lead times to full production. Also, it is worth bearing in mind that the market cannot rely on major contributions from battery recycling, so the lithium market could shift into meaningful deficit in future. Prices could therefore be significantly higher than current levels.

Solid prospects for both lithium and cobalt over the medium to long term

**THE PGM MARKETS
IN 2018**



The PGM markets in 2018

Beresford Clarke and Dr. Ralph Grimble, SFA (Oxford) Ltd

The palladium market

Summary

With the price of palladium having reached a high of over \$1,100/oz in January, and since periodically dropping below \$900/oz in July and August, it suggests market sentiment has weakened as the year has progressed.

Industrial palladium demand still strong

However, lease rates are still elevated and traders are reporting ongoing strong demand from industrial buyers, so while many investors appear to have sold off their palladium holdings, the underlying fundamentals of the market remain firm. This is confirmed by the continuing wide structural deficit in the palladium market of over 800 koz for 2018.

Nonetheless, total gross demand is growing at a much slower rate relative to that of recent history (just 0.4% year-on-year in 2018), so the investment case has certainly softened. Meanwhile, the deficit is not narrowing as supply looks set to remain flat in 2018 relative to 2017.

Demand is growing at a slower rate

In the last few years, ETF redemptions of over 2 moz have been an important source of supply to the palladium market. However, ETF holdings are now below 1 moz and back to mid-2009 levels. Looking ahead, much of the palladium market shortfall will need to be met from more opaque sources and if investors pile back into ETFs, metal prices will more than likely rally once again.

ETFs have been critical in meeting market demand - what if investors start buying again?

Mine supply

A 1.5% dip in supply to 6.98 moz is forecast for 2018. Supply from Russia is set to normalise at 2.68 moz in 2018 after the temporary increase to 2.74 moz that was recorded in 2017. This was due to the upgrading of Nornickel's processing chain from concentrating through to refining in 2016 that included closing old infrastructure (e.g. the nickel plant) and expanding other infrastructure (e.g. the Talnakh concentrator), which led to improved performance across the pipeline and higher recoveries in 2017. Nornickel also managed to process some of its pipeline backlog from 2016 last year, so it exceeded production guidance overall.

Slight dip in mine supply forecast for 2018

Output from South Africa is set to drop by close to 100 koz (including a 25 koz adjustment for normal production outages), impacted by the closure of Bokoni mine during last year.

Recycling

Recycling has become a critical source of supply for the market and is projected to reach a substantial 2.5 moz in 2018 (almost a quarter of demand), growing 5.9% year-on-year. The main contributor to growth is the recycling of automobile catalytic converters (82%), which are forecast to provide a 7.5% increase in palladium supply to 2.07 moz. The ongoing recovery in scrap steel prices continues to motivate end-of-life car dismantling at salvage yards, while higher average palladium (and rhodium) prices have helped to mobilise catalytic converter collection and supply.

Recycling supply grows to a quarter of demand

Demand

Global demand for palladium is forecast to remain flat at 10.3 moz in 2018. Autocatalyst demand is set to rise 1.5% to 8.3 moz, lifting the share of total demand to 81%. Industrial and jewellery end-uses are set to fall 3.8% and 4.4% respectively, thereby offsetting growth in autocatalyst demand.

Flat demand in 2018

Automotive demand

Despite increasing sales of electric vehicles, global automotive demand for palladium is still growing, adding 125 koz in 2018 to 8.3 moz, a rise of 1.5% year-on-year. However, this pales in comparison to the rampant growth of 400-500 koz p.a. between 2011 and 2013 when car sales in China were climbing by millions of units a year and US car sales were recovering from the financial crisis.

Automotive demand is growing but at a slower rate

Sales in the US peaked in 2016 at 17.5 million units and have been falling steadily since (17.1 million units projected for 2018), while in China car sales are set to increase by just 1.5% to 29 million units in 2018. Overall palladium demand for the two countries is projected to rise by half a percent to 4.1 moz (equivalent to 50% of global automotive demand).

Demand remains strong in Europe, where palladium is benefitting from the switch from diesel to gasoline car sales. Platinum demand there is set to fall by over 200 koz, but palladium requirements are forecast to be relatively steady at just shy of 1.7 moz in 2018.

Industrial demand

Ongoing capacity growth in the chemical sector in China, which has been stimulated by the government's 'Made in China 2025' initiative, continues to elevate palladium demand. There have been several coal-to-monoethylene glycol (CTMEG) projects commissioned in 2018. However, this is slightly offset by the various other palladium-catalysed chemical processes approaching self-sufficiency for the country, particularly purified terephthalic acid (PTA) production, thereby reducing the number of new plants required compared to last year.

The Palladium Standard

However, high palladium prices continue to impact demand in other regions and end-uses, leaving total industrial consumption down by an estimated 3.8% to 1.78 moz in 2018, which continues the steady erosion of demand since peaking at just over 2.6 moz before the financial crisis.

High palladium prices impact other end uses

Investment

Palladium ETF holdings have now dropped below 1 moz, having fallen by over 250 koz so far this year, which is more than the 220 koz lost by the same time last year. Outflows were seen in all regions, with the largest sales from South African (-102 koz) and US (-92 koz) holders.

ETF holdings are now down by two-thirds on mid-2015 levels of 3 moz, although it appeared that the level of outflows had slowed in 2017 at 409 koz, compared to 643 koz the previous year and 666 koz the year before that.

Futures and options positions on NYMEX show total short positions on NYMEX jumped to 1 moz in mid-2018, almost shifting the market net short. Long positions have collapsed by almost two-thirds to just 1.2 moz, leaving palladium slightly net long (0.2 moz), the lowest level since 2003.

ETF holdings now below 1 moz

The platinum market

The fortunes of the platinum market have weakened considerably since the publication of the last edition of *The Palladium Standard* in September 2017. Expectations for supply have increased, while demand has decreased. The year-end surplus (excluding investment) was significantly wider than forecast for 2017 at 530 koz, and is estimated to slip further to 555 koz in 2018.

Expectations for demand have decreased

Demand last grew in 2015 when the market was last in deficit (134 koz) and has fallen every year since. Both mainstays of demand, autos and jewellery, have contracted, led by the sharp drop in Chinese platinum jewellery purchasing and the Volkswagen diesel emissions scandal.

However, while jewellery purchasing in China is falling by a slower rate this year compared to 2017 (at -6% vs. -8%), the decline of platinum demand in autocatalysts is falling faster at -6.3% in 2018 against -3.5% in 2017. A recovery in the jewellery sector is underway in China but this is benefitting gold. The turnaround for platinum has not happened yet. Platinum jewellery still has an instore price premium to gold, taking account of higher manufacturing costs, but the market price for platinum is actually lower than gold. Consequently, customers receive less back when they come to trade in a platinum piece compared to an equivalent gold piece of the same weight. At this point in time, gold could therefore be seen as a better store of value.

Western Europe's autocatalyst demand is forecast to fall by 15% to 1.33 moz in 2018, which is well below the recent 'Euro 6' peak of 1.7 moz in 2016, and almost a million ounces down on the pre-financial crisis levels.

Western Europe demand forecast to fall 15% in 2018

Mine supply, meanwhile, is projected to be back to 2016 levels of just over 6 moz for 2018, a drop of 100 koz on 2017. Bokoni was producing 105 koz p.a. in 2015 and 2016, so the closure of this mine in 2017 is part of the impact on supply. Include Maseve mine (previously owned and operated by Platinum Group Metals) and lower production from Lonmin and much of the year-on-year drop is accounted for.

Platinum recycling is forecast to remain flat at 1.9 moz year-on-year in 2018, as growth in autocatalyst recycling (due to higher palladium, rhodium and scrap steel prices) is offset by a reduction in jewellery recycling caused by lower consumer demand.

With platinum prices falling below \$800/oz in August, physical investments have remained remarkably resilient. ETF holdings have declined by only 70 koz in 2018, leaving global holdings at 2.53 moz. The same cannot be said for the futures market, however, with speculators on NYMEX building record short positions of 2.55 moz.

The rhodium market

The market is set to be tighter in 2018 relative to last year, with the surplus likely to halve to 28 koz. Rhodium demand is forecast to rise by 2.9% this year with steady consumption growth in the established markets, but strong growth in the emerging markets (+8.9%/+15 koz, excluding China and India). This is primarily due to a strong pick-up in requirements for glass production, which are projected to increase by 44% to 76 koz, including mainly new glass fibre plants in Turkey and India, as well as in the US and Western Europe.

Tighter rhodium market in 2018

Automotive demand is set to continue to rise, but by just 1% in 2018 as China's strong growth in 2017 takes a pause this year.

Primary supply is forecast to fall by 5.1% (-40 koz) to 745 koz, because the closures and cutbacks that are happening in South Africa are primarily impacting production from the rhodium-rich UG2 Reef ore body. Meanwhile, recycling from autocatalysts is forecast to expand by 45 koz to 340 koz, which more than counters the decline in global mine supply.

Primary supply down 5.1% (year on year)

Liquidation of rhodium ETF holdings continued into 2018 with a 37% drop to just 44 koz from the start of the year to the end of August. This is significantly down on the peak holdings of more than 130 koz in 2014.

The price outlook for the next six months

Palladium: \$980/oz

The fundamentals are good, but not quite as strong as they were as total demand growth has slowed. Automotive demand is still growing, although US auto sales are expected to be marginally lower this year, and other industrial uses are seeing weaker demand. However, the deficit remains large and the market is still tight, with lease rates rising to double-digit levels again in August. ETF outflows have helped to fill the deficit, but with ETF holdings at less than 1 moz there is only so much longer this can continue.

Market still tight

The palladium price has rebounded strongly in August and reached a resistance level, so may consolidate its gains before advancing further.

Platinum: \$855/oz

Further supply cuts have been announced in South Africa, but the latest round will not impact the market in the near term.

Meanwhile, demand is falling faster than supply. Chinese platinum jewellery demand has yet to stabilise, although the rate of decline has eased. Diesel market share in Western Europe has continued to shrink, particularly in the two largest markets, Germany and the UK, where the media have remained resolutely anti-diesel.

This has seen the price trade below \$800/oz to the lowest level since 2008. However, sentiment is very bearish with speculative futures positioning at a record net short, so near term the price is expected to recover.

Near-term prices are expected to recover

Rhodium: \$2,430/oz

Demand growth and supply cuts have brought the rhodium market close to balance. Industrial demand has been boosted by glass capacity expansions, while automotive demand is also edging higher.

The rhodium price has continued its strong upward trend in 2018 and pullbacks have been shallow. The market remains tight with elevated lease rates, so despite being overbought rhodium is expected to continue its steady advance.

Steady price advance expected

The Ruthenium Quarterly – Q3'18

Stay up-to-date with the ruthenium market

SFA (Oxford) is the only company in the world that has derived ruthenium mine production and developed detailed demand modelling of all major end-uses to provide an authoritative view of the current and future ruthenium market.

The Ruthenium Quarterly looks at the current market and provides analysis, charts and commentary to provide a watching brief on the evolution of the market.

It utilises SFA's extensive knowledge and expertise in the ruthenium industry and provides an independent review. It gives an overview of the changing technological developments and highlights the underlying evolution of demand and end-use applications.

The report offers insights, commercial knowledge, and estimates of stocks, including the working inventories and risk positions existing with producers and traders.

The Ruthenium Quarterly is a hands-on examination of events and trends currently impacting on the ruthenium market.

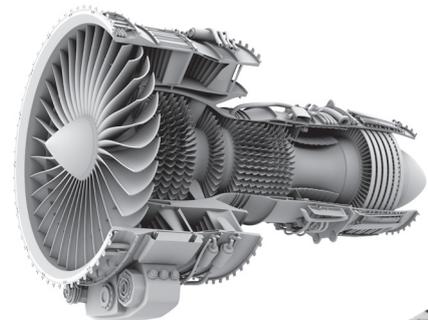


Key report features:

- **Market summary**
- **Price outlook and drivers to 2022**
- **Demand trends and stock estimates**
- **The only supply-demand market balance available**
- **Trade-flow analysis**
- **Materials for new energy applications**
- **Supply challenges and mine economics**

The **latest 26-page quarterly report** includes commentary and analysis on:

- Assessment of the **risks to ruthenium supply if overall South African PGM output is cut**
- **Chemical sector**, especially in China, which is buying metal to meet capacity growth
- **Additional refining capacity to meet demand from current and future electronics applications**
- **Meeting the needs for clean water** which is a global megatrend; ruthenium applications include seawater and brine electrochlorination



The Iridium Quarterly – Q3'18

Stay up-to-date with the iridium market

SFA (Oxford) is the only company in the world that has derived iridium mine production and developed detailed demand modelling of all major end-uses to provide an authoritative view of the current and future iridium market.

The Iridium Quarterly looks at the current market and provides analysis, charts and commentary to provide a watching brief on the evolution of the market.

It utilises SFA's extensive knowledge and expertise in the iridium industry and provides an independent review. It gives an overview of the changing technological developments and highlights the underlying evolution of demand and end-use applications.

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The Iridium Quarterly is a hands-on examination of events and trends currently impacting on the iridium market.



Key report features:

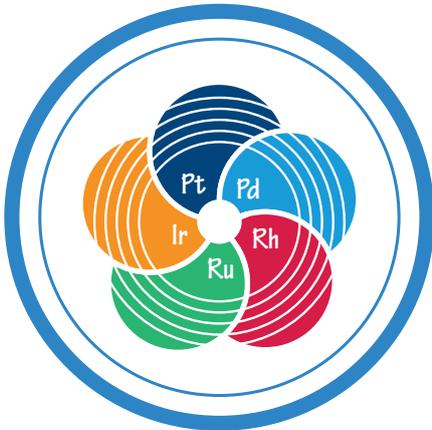
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- **Materials for new energy applications**
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The **latest 20-page quarterly report** includes commentary and analysis on:

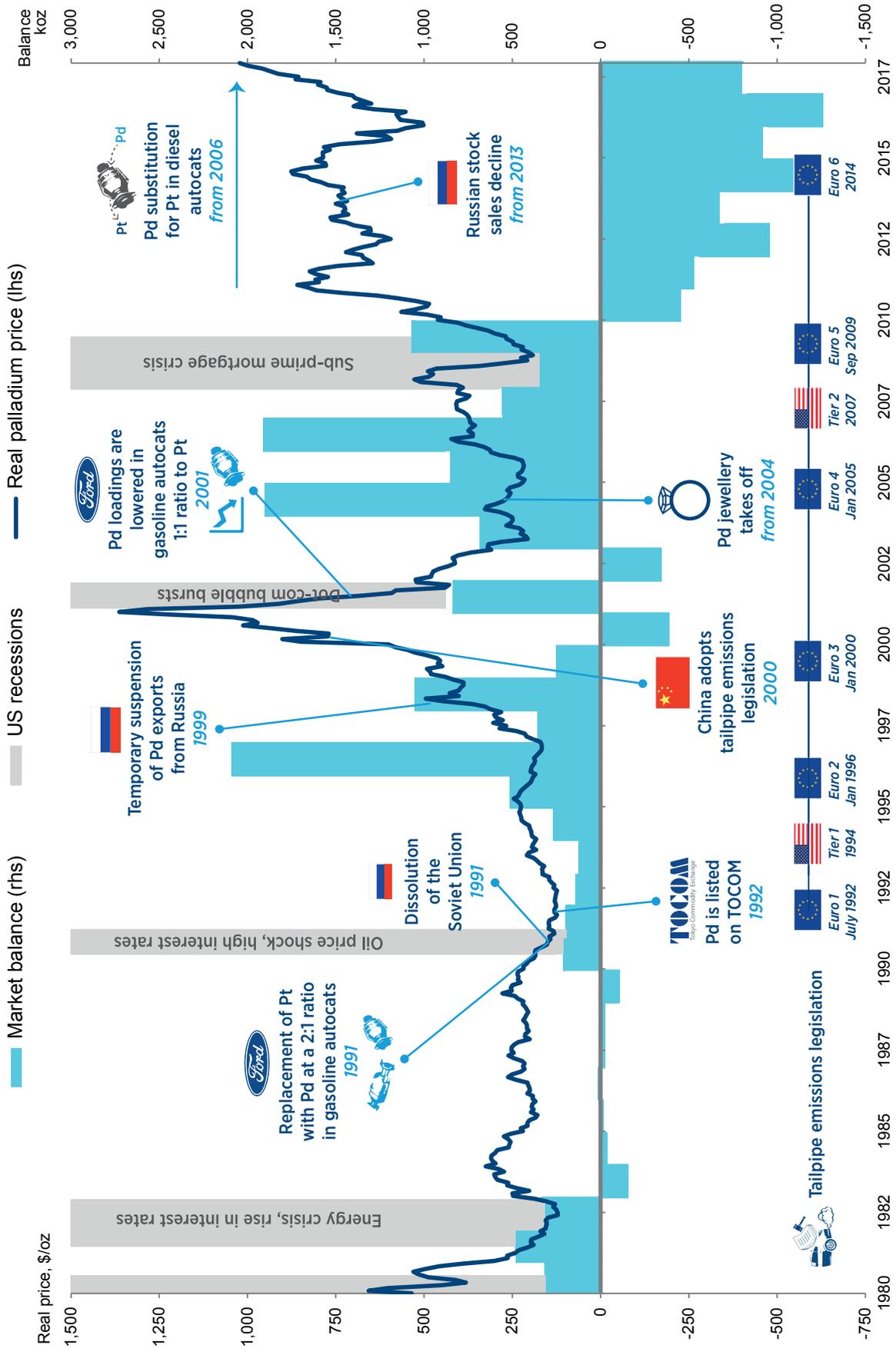
- Assessment of the **risks to iridium supply if overall South African PGM output is cut**
- Mainstay **crucible demand which remains strong** into future despite short term overcapacity
- **Dimensionally stable anodes market** that is increasingly diverse, with growth in water treatment market



PGM PRICE HISTORY

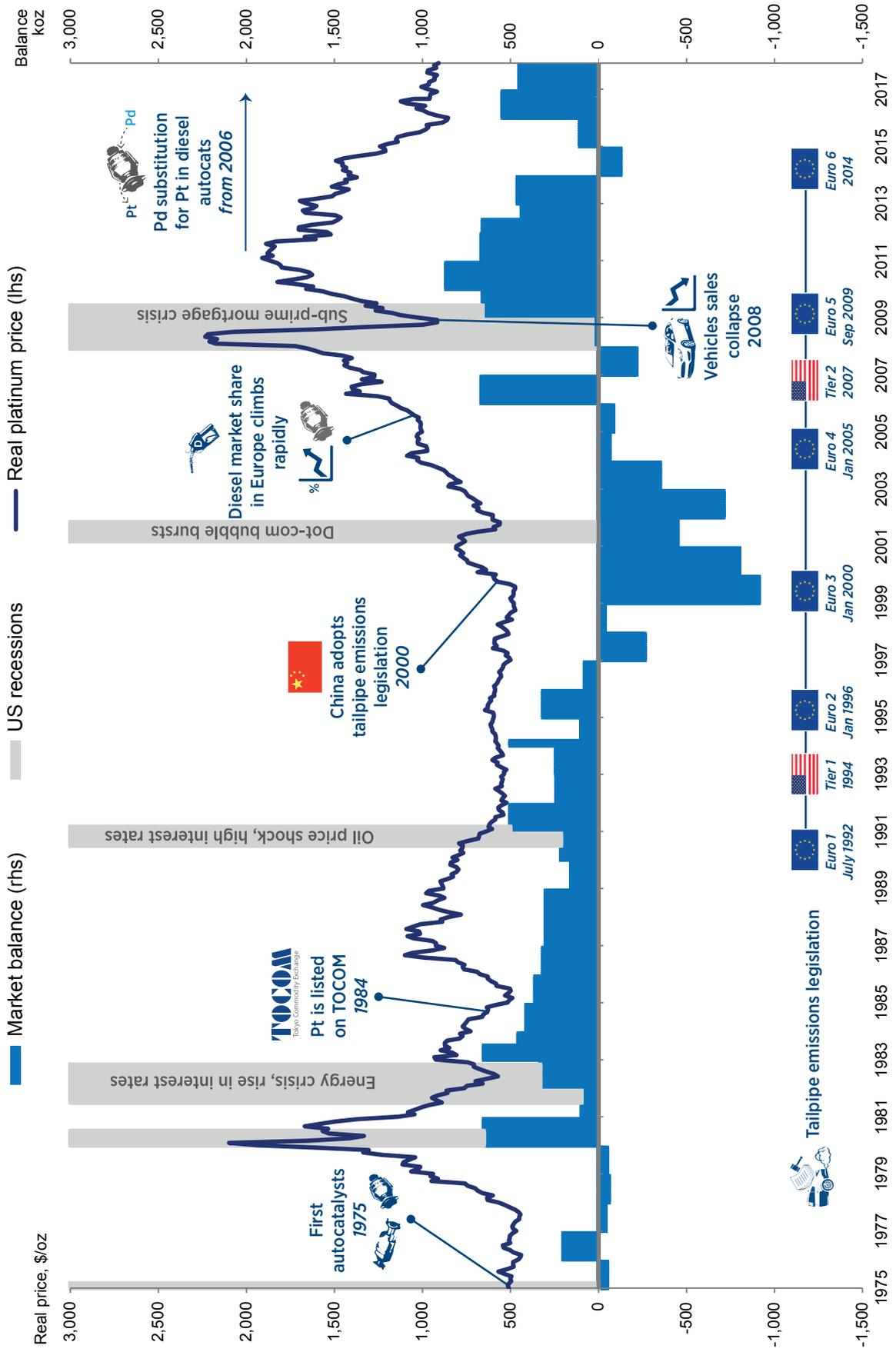


Palladium



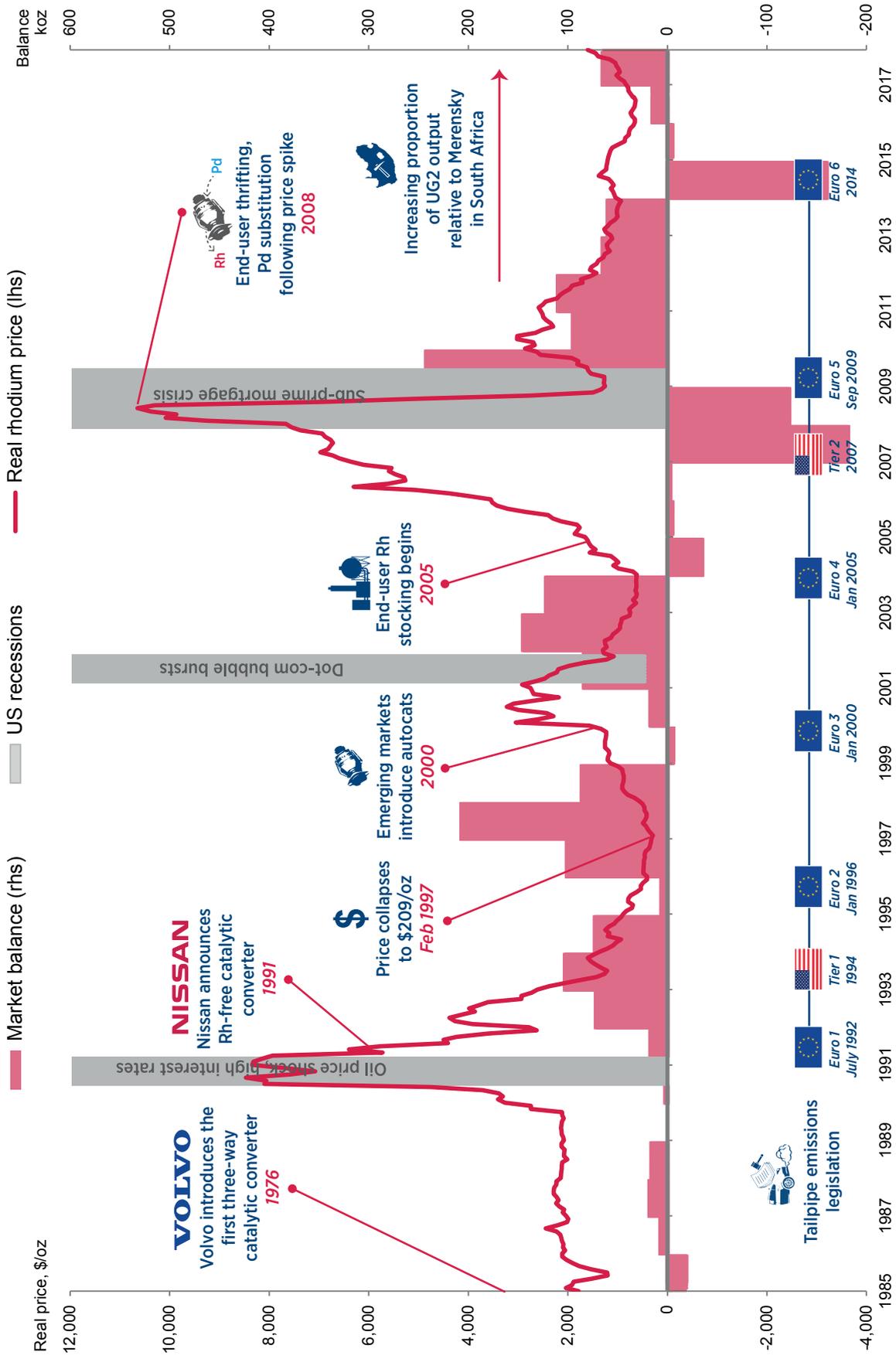
Source: SFA (Oxford)

Platinum



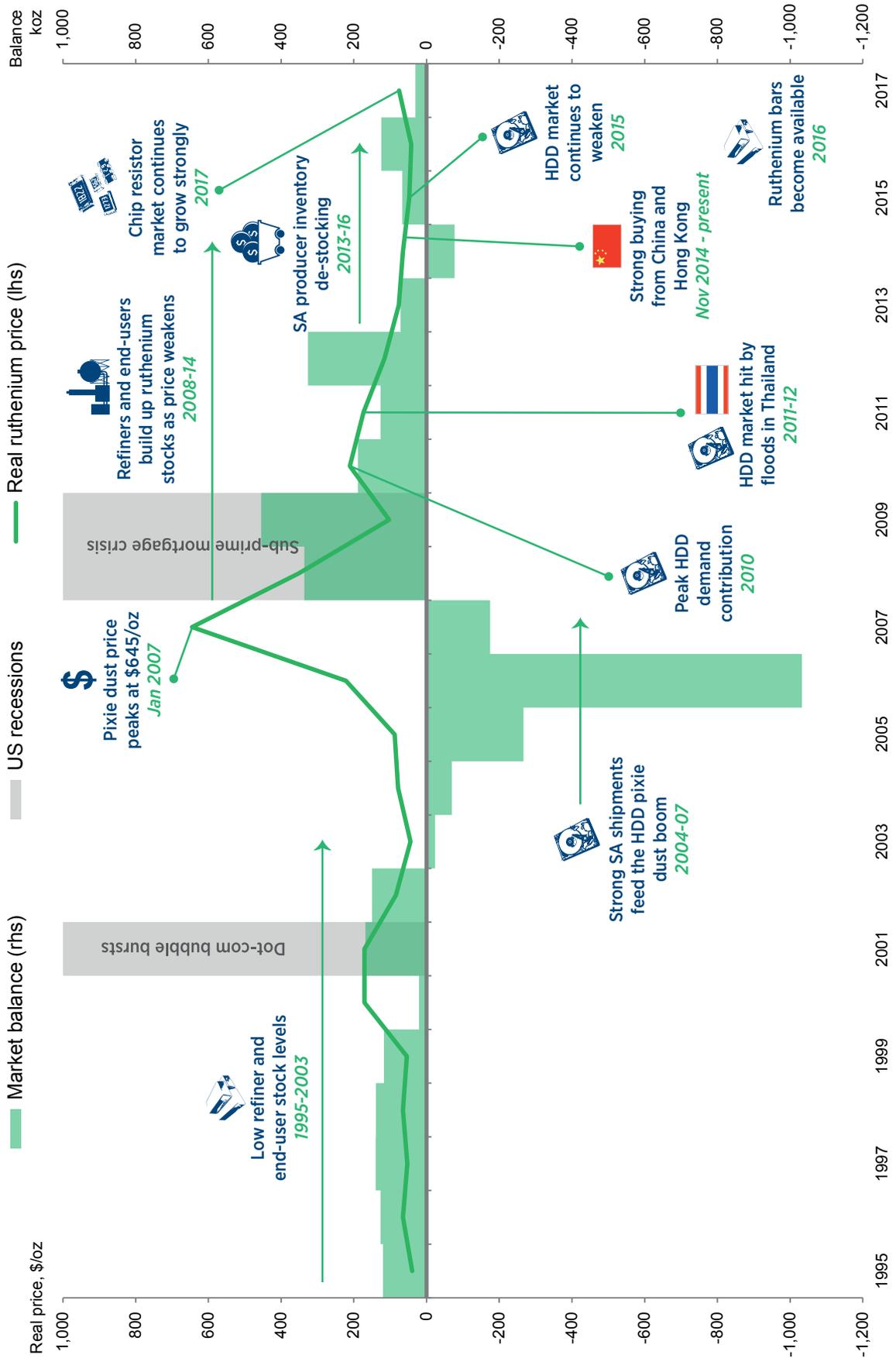
Source: SFA (Oxford)

Rhodium



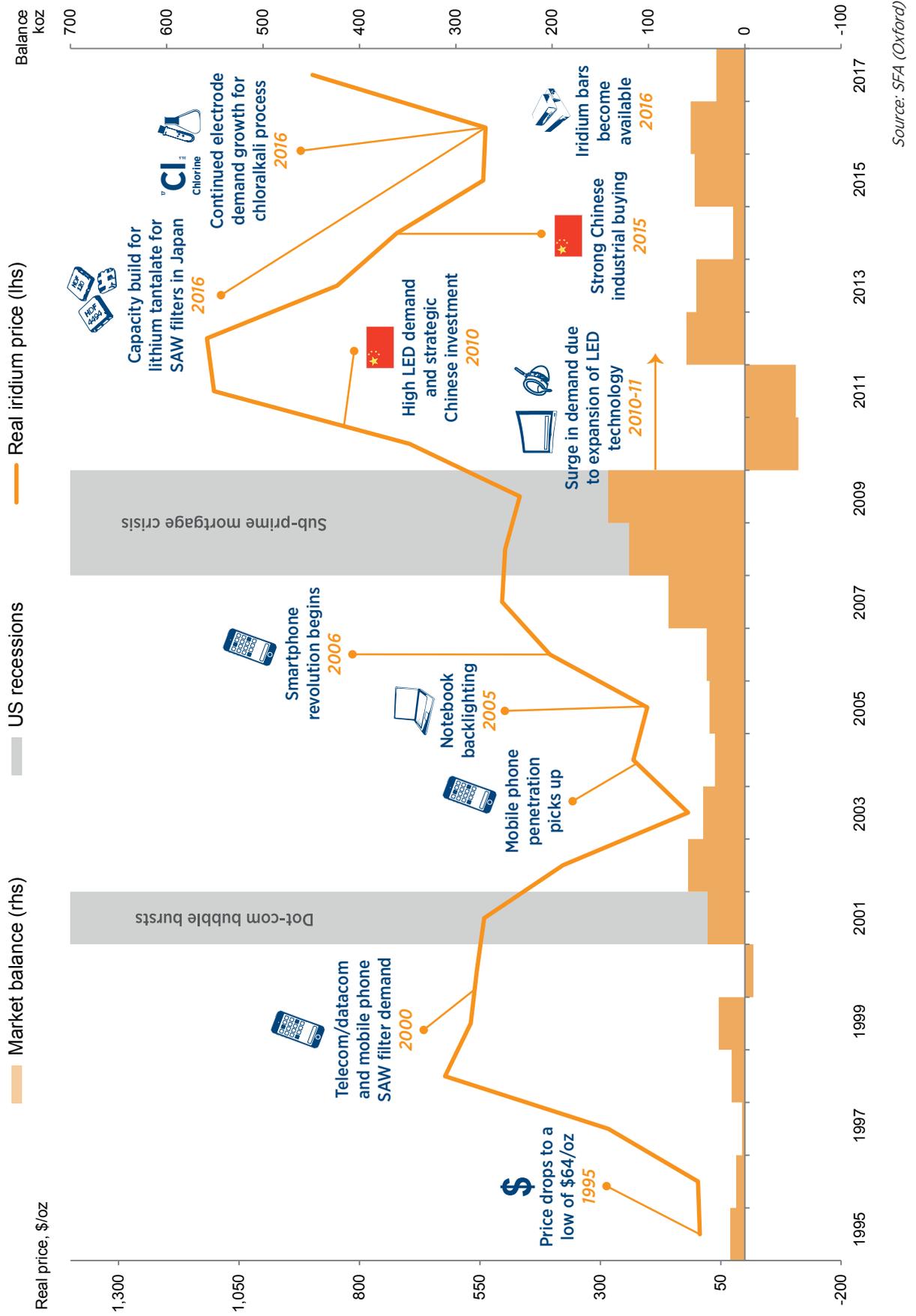
Source: SFA (Oxford)

Ruthenium



Source: SFA (Oxford)

Iridium



APPENDIX



Palladium supply-demand balance

koz	2010	2011	2012	2013	2014	2015	2016	2017	2018f
Primary supply									
Regional									
South Africa	2,590	2,550	2,355	2,360	1,855	2,570	2,370	2,545	2,450
Russia	2,720	2,705	2,630	2,580	2,690	2,605	2,555	2,740	2,680
Zimbabwe	225	265	280	315	330	325	395	395	365
North America	580	865	895	975	1,055	995	1,065	985	1,070
Other	300	390	445	450	460	455	420	415	410
Total	6,415	6,775	6,605	6,680	6,390	6,950	6,805	7,080	6,975
Demand & recycling									
Autocatalyst									
Gross demand	5,615	6,175	6,665	7,110	7,495	7,715	8,020	8,190	8,315
Recycling	1,395	1,525	1,485	1,645	1,720	1,610	1,710	1,920	2,065
Net demand	4,220	4,650	5,180	5,465	5,775	6,105	6,310	6,270	6,250
Jewellery									
Gross demand	695	680	545	350	295	240	240	225	215
Recycling	100	135	130	145	120	80	80	70	60
Net demand	595	545	415	205	175	160	160	155	155
Industrial demand	2,465	2,465	2,325	2,065	1,940	1,995	1,955	1,850	1,780
Other recycling	405	370	375	410	430	435	400	380	385
Gross demand	8,775	9,320	9,535	9,525	9,730	9,950	10,215	10,265	10,310
Recycling	1,900	2,030	1,990	2,200	2,270	2,125	2,190	2,370	2,510
Net demand	6,875	7,290	7,545	7,325	7,460	7,825	8,025	7,895	7,800
Market balance									
Balance (before ETFs)	-460	-515	-940	-645	-1,070	-875	-1,220	-815	-825
ETFs (stock allocation)	1,090	-530	285	-5	940	-665	-645	-410	
Balance after ETFs	-1,550	15	-1,225	-640	-2,010	-210	-575	-405	

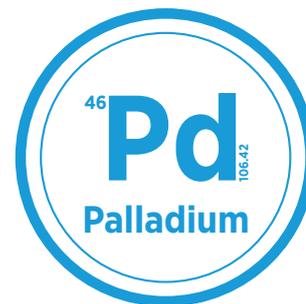
Source: SFA (Oxford)



Palladium demand & recycling by region

koz	2010	2011	2012	2013	2014	2015	2016	2017	2018f
Gross demand									
Autocatalyst									
North America	1,310	1,495	1,735	1,825	1,955	2,060	2,135	2,030	2,070
Western Europe	1,280	1,490	1,410	1,510	1,635	1,705	1,615	1,670	1,695
Japan	810	670	735	740	745	745	775	805	805
China	1,010	1,130	1,300	1,515	1,670	1,740	2,010	2,085	2,065
India	150	160	155	165	165	185	225	245	275
RoW	1,055	1,230	1,330	1,355	1,325	1,280	1,260	1,355	1,405
Total	5,615	6,175	6,665	7,110	7,495	7,715	8,020	8,190	8,315
Jewellery									
North America	65	45	45	40	35	35	35	35	35
Western Europe	65	65	80	75	60	55	55	55	55
Japan	85	90	95	65	55	50	50	50	45
China	450	450	295	145	120	75	75	60	55
RoW	30	30	30	25	25	25	25	25	25
Total	695	680	545	350	295	240	240	225	215
Industrial									
North America	500	495	480	420	390	405	400	365	345
Western Europe	410	375	335	305	290	295	290	270	260
Japan	575	550	565	420	425	430	415	375	355
China	435	425	405	445	395	415	410	405	400
RoW	545	620	540	475	440	450	440	435	420
Total	2,465	2,465	2,325	2,065	1,940	1,995	1,955	1,850	1,780
Total gross demand									
North America	1,875	2,035	2,260	2,285	2,380	2,500	2,570	2,430	2,450
Western Europe	1,755	1,930	1,825	1,890	1,985	2,055	1,960	1,995	2,010
Japan	1,470	1,310	1,395	1,225	1,225	1,225	1,240	1,230	1,205
China	1,895	2,005	2,000	2,105	2,185	2,230	2,495	2,550	2,520
RoW	1,780	2,040	2,055	2,020	1,955	1,940	1,950	2,060	2,125
Total	8,775	9,320	9,535	9,525	9,730	9,950	10,215	10,265	10,310
Recycling									
Autocatalyst									
North America	975	975	930	1,005	975	895	960	1,060	1,110
Western Europe	205	335	325	345	365	270	260	305	360
Japan	175	130	125	125	135	125	125	145	165
China	0	15	20	50	60	115	160	165	140
RoW	40	70	85	120	185	205	205	245	290
Total	1,395	1,525	1,485	1,645	1,720	1,610	1,710	1,920	2,065
Jewellery									
Japan	10	15	20	20	20	20	20	20	15
China	90	120	110	125	100	60	60	50	45
Total	100	135	130	145	120	80	80	70	60
WEEE									
North America	80	70	75	75	70	85	75	70	65
Western Europe	115	80	85	90	95	80	75	75	75
Japan	130	135	120	135	145	165	135	120	120
China	25	20	30	40	30	25	35	35	40
RoW	55	65	65	70	90	80	80	80	85
Total	405	370	375	410	430	435	400	380	385
Total recycling									
North America	1,055	1,045	1,005	1,080	1,045	980	1,035	1,130	1,175
Western Europe	320	415	410	435	460	350	335	380	435
Japan	315	280	265	280	300	310	280	285	300
China	115	155	160	215	190	200	255	250	225
RoW	95	135	150	190	275	285	285	325	375
Total	1,900	2,030	1,990	2,200	2,270	2,125	2,190	2,370	2,510

Source: SFA (Oxford)



Platinum supply-demand balance

koz	2010	2011	2012	2013	2014	2015	2016	2017	2018f
Primary supply									
Regional									
South Africa	4,730	4,595	4,210	4,355	3,115	4,465	4,255	4,385	4,335
Russia	790	800	780	740	740	715	715	720	680
Zimbabwe	280	340	365	405	405	405	490	480	460
North America	200	375	345	355	400	385	395	365	365
Other	120	145	180	215	220	180	180	190	185
Total	6,120	6,255	5,880	6,070	4,880	6,150	6,035	6,140	6,025
Demand & recycling									
Autocatalyst									
Gross demand	2,925	3,130	3,175	3,170	3,310	3,380	3,460	3,340	3,130
Recycling	955	1,210	1,175	1,120	1,255	1,185	1,210	1,325	1,385
Net demand	1,970	1,920	2,000	2,050	2,055	2,195	2,250	2,015	1,745
Jewellery									
Gross demand	2,170	2,450	2,750	2,945	3,000	2,840	2,505	2,460	2,445
Recycling	475	630	840	855	775	515	625	560	505
Net demand	1,695	1,820	1,910	2,090	2,225	2,325	1,880	1,900	1,940
Industrial demand									
Industrial demand	1,640	1,860	1,540	1,485	1,565	1,770	1,785	1,700	1,790
Other recycling									
Other recycling	10	10	5	5	5	5	5	5	5
Gross demand									
Gross demand	6,735	7,440	7,465	7,600	7,875	7,990	7,750	7,500	7,365
Recycling									
Recycling	1,440	1,850	2,020	1,980	2,035	1,705	1,840	1,890	1,895
Net demand									
Net demand	5,295	5,590	5,445	5,620	5,840	6,285	5,910	5,610	5,470
Market balance									
Balance (before ETFs)	825	665	435	450	-960	-135	125	530	555
ETFs (stock allocation)	575	175	195	905	215	-240	-10	105	
Balance after ETFs	250	490	240	-455	-1,175	105	135	425	

Source: SFA (Oxford)



Platinum demand & recycling by region

koz	2010	2011	2012	2013	2014	2015	2016	2017	2018f
Gross demand									
Autocatalyst									
North America	390	385	425	425	465	490	445	415	435
Western Europe	1,335	1,495	1,340	1,350	1,440	1,550	1,705	1,560	1,330
Japan	480	500	600	580	590	510	455	450	425
China	135	120	115	130	120	125	165	200	180
India	145	180	200	160	160	175	165	165	190
RoW	440	450	495	525	535	530	525	550	570
	2,925	3,130	3,175	3,170	3,310	3,380	3,460	3,340	3,130
Jewellery									
North America	160	160	185	200	230	250	265	280	300
Western Europe	180	175	175	220	220	235	240	250	260
Japan	370	315	325	335	335	340	335	340	350
China	1,370	1,670	1,915	1,990	1,975	1,765	1,450	1,340	1,260
India	50	80	95	140	175	180	145	175	200
RoW	40	50	55	60	65	70	70	75	75
	2,170	2,450	2,750	2,945	3,000	2,840	2,505	2,460	2,445
Industrial									
North America	265	265	320	325	325	265	395	345	350
Western Europe	295	290	260	190	240	315	275	285	295
Japan	145	200	90	90	30	95	95	60	130
China	390	305	370	515	445	545	570	535	475
RoW	545	800	500	365	525	550	450	475	540
	1,640	1,860	1,540	1,485	1,565	1,770	1,785	1,700	1,790
Total gross demand									
North America	815	810	930	950	1,020	1,005	1,105	1,040	1,085
Western Europe	1,810	1,960	1,775	1,760	1,900	2,100	2,220	2,095	1,885
Japan	995	1,015	1,015	1,005	955	945	885	850	905
China	1,895	2,095	2,400	2,635	2,540	2,435	2,185	2,075	1,915
RoW	1,220	1,560	1,345	1,250	1,460	1,505	1,355	1,440	1,575
	6,735	7,440	7,465	7,600	7,875	7,990	7,750	7,500	7,365
Recycling									
Autocatalyst									
North America	580	600	575	560	560	510	530	585	615
Western Europe	195	420	405	365	465	370	395	440	465
Japan	145	115	115	95	105	95	95	100	105
China	0	5	10	20	30	55	40	40	30
RoW	35	70	70	80	95	155	150	160	170
	955	1,210	1,175	1,120	1,255	1,185	1,210	1,325	1,385
Jewellery									
North America	0	0	0	0	0	5	5	5	5
Western Europe	0	0	0	0	5	5	5	5	5
Japan	150	285	285	250	235	160	150	160	130
China	325	345	555	600	530	340	460	385	360
RoW	0	0	0	5	5	5	5	5	5
	475	630	840	855	775	515	625	560	505
WEEE									
	10	10	5						
Total recycling									
North America	585	600	575	560	560	515	535	590	620
Western Europe	195	420	405	365	470	375	400	445	470
Japan	295	405	400	345	340	255	245	260	235
China	325	350	565	620	560	395	500	425	390
RoW	40	75	75	90	105	165	160	170	180
	1,440	1,850	2,020	1,980	2,035	1,705	1,840	1,890	1,895

Source: SFA (Oxford)



Rhodium supply-demand balance

koz	2010	2011	2012	2013	2014	2015	2016	2017	2018f
Primary supply									
Regional									
South Africa	650	645	600	590	425	620	615	630	600
Russia	75	75	75	70	75	70	70	75	75
Zimbabwe	25	30	30	35	35	35	45	45	40
North America	15	30	30	35	30	30	25	25	20
Other	10	10	10	10	10	10	10	10	10
Total	775	790	745	740	575	765	765	785	745
Demand & recycling									
Autocatalyst									
Gross demand	730	740	770	785	835	865	840	850	850
Recycling	220	235	235	260	275	260	280	295	340
Net demand	510	505	535	525	560	605	560	555	510
Industrial demand	175	170	150	150	180	175	195	175	205
Other recycling	1	1	1	1	2	2	2	2	2
Gross demand	905	910	920	935	1,015	1,040	1,035	1,025	1,055
Recycling	220	235	235	260	275	260	280	295	340
Net demand	685	675	685	675	740	780	755	730	715
Market balance									
Balance (before ETFs)	90	115	60	65	-165	-15	10	55	30
ETFs (stock allocation)			35	50	5	-5	5	-20	
Balance after ETFs			25	15	-170	-10	5	75	

Source: SFA (Oxford)



Rhodium demand & recycling by region

koz	2010	2011	2012	2013	2014	2015	2016	2017	2018f
Gross demand									
Autocatalyst									
North America	180	180	200	220	235	255	250	235	240
Western Europe	200	215	190	195	220	240	205	205	200
Japan	165	135	150	140	140	125	125	125	120
China	70	75	90	95	105	110	130	150	155
India	15	20	20	15	15	15	20	20	20
RoW	100	115	120	120	120	120	110	115	115
	730	740	770	785	835	865	840	850	850
Industrial									
North America	15	20	15	15	15	15	20	15	15
Western Europe	25	20	20	10	20	15	15	15	25
Japan	45	45	45	35	30	35	30	30	35
China	40	40	30	45	55	55	65	55	55
RoW	50	45	40	45	60	55	65	60	75
	175	170	150	150	180	175	195	175	205
Total gross demand									
North America	195	200	215	235	250	270	270	250	255
Western Europe	225	235	210	205	240	255	220	220	225
Japan	210	180	195	175	170	160	155	155	155
China	110	115	120	140	160	165	195	205	210
RoW	165	180	180	180	195	190	195	195	210
	905	910	920	935	1,015	1,040	1,035	1,025	1,055
Recycling									
Autocatalyst									
North America	160	140	145	165	160	150	160	165	180
Western Europe	30	60	60	55	60	45	50	55	70
Japan	25	25	25	25	30	30	35	35	40
China	0	0	0	5	5	10	5	5	5
RoW	5	10	5	10	20	25	30	35	45
	220	235	235	260	275	260	280	295	340

Source: SFA (Oxford)



GLOSSARY OF TERMS

BEV(s)

Battery electric vehicle(s).

By-products

Copper, nickel, iridium and ruthenium.

CTMEG

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

DRC

Democratic Republic of the Congo.

ETF

Exchange-traded fund.

EV(s)

Electric vehicle(s).

GDP

Gross domestic product.

Gross demand

A measure of intensity of use.

koz

A thousand troy ounces.

LCE

Lithium carbonate equivalent – unit used to measure intensity of lithium use.

LCV

Light commercial vehicle.

Lease rates

Fees payable for the rental of an asset.

LFP

Lithium-iron-phosphate (battery chemistry).

Merensky Reef

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

moz

A million troy ounces.

NCA

Nickel-cobalt-aluminium oxide (battery chemistry).

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.

NMC

Nickel-manganese-cobalt (battery chemistry).

NYMEX

New York Mercantile Exchange.

OEM(s)

Original equipment manufacturer(s).

oz

Troy ounce.

PGMs

Platinum-group metals.

PTA

Purified terephthalic acid – chemical synthesised using palladium catalyst.

Secondary supply

Recycling output.

TOCOM

Tokyo Commodity Exchange.

UG2 Reef

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

WEEE

Waste electrical and electronic equipment.

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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