SFA Oxford

THE PALLADIUM STANDARD

September 2020

THE PALLADIUM STANDARD

September 2020

Issue 13

Designed and typeset by Francesca Price

CONTENTS

TPS COLLECTION: AGENDA-SETTING COMMENTARY

The Palladium Standard was first published in September 2016, following the successful launch of The Platinum Standard in May 2014

One-half review, one-half preview, The Palladium Standard comprises analytical commentary on those issues we believe will set the PGM agenda for the year ahead

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

FOREWORD – HARD CHOICES

Foreword – Hard choices

"Life is a constant oscillation between the sharp horns of dilemmas"
(H.L. Mencken)

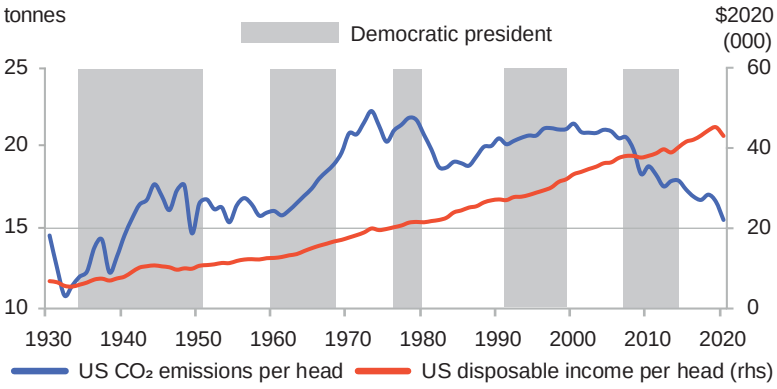
It's not clear whether a position on the horns of dilemmas or astride the fence is more painful. This edition of The Palladium Standard aims to ease your discomfort, for it's a guide through three 'historic' decisions that are directly ahead or in progress: the US presidential election; how (as much as whether) to integrate ethics into the PGM business; and how the enablers of a cleaner, hydrogen-powered future – the miners of minor PGMs – can signal the required environmental, social and governance virtues.

Oxford Economics (OE) agrees that the November US presidential election is 'the most important in history'. And the choice appears polar. Covid-19 has put the brakes on 'divisive' President Trump's remaining electoral impetus – the economy. So 'unifier' Joe Biden would appear to be a dead cert: predicted to win 60% of the popular vote and 318 votes in the Electoral College (versus Trump's 220, i.e. almost exactly reversing the 2016 shock defeat of Hillary Clinton). But OE is clear that this prediction is based solely on economic criteria; in other words, it omits to take into account the vagaries of the American voting public. It also assumes an average turnout and that this can even be measured, amicably, when the vote goes postal.

On the face of it, this 'historic' choice doesn't mean much more than a 'hanging chad' for PGMs. OE notes that Biden would spend more greenbacks on 'green' causes (good for PGMs). And his version of US budget-busting may be more growth-friendly than Trump's, which comes with a trade policy brake (also good for PGMs). However, that might mean marginally higher US interest rates and a slightly stronger dollar (bad for PGMs). In fact, the US is going to 'enjoy' bigger government, more 'free stuff', and 'funny money' (zero-ish interest rates) that might turn sour whoever is elected. Hobson's choice, then. Either way, couldn't this be the best environment imaginable for all precious metals as investment 'safe spaces'?

If, as OE expects, Trump suffers the worst defeat of an incumbent since Herbert Hoover in 1932, this might signal a return almost to the carbon footprint of the 1930s.

CO_2 prohibition now agreed



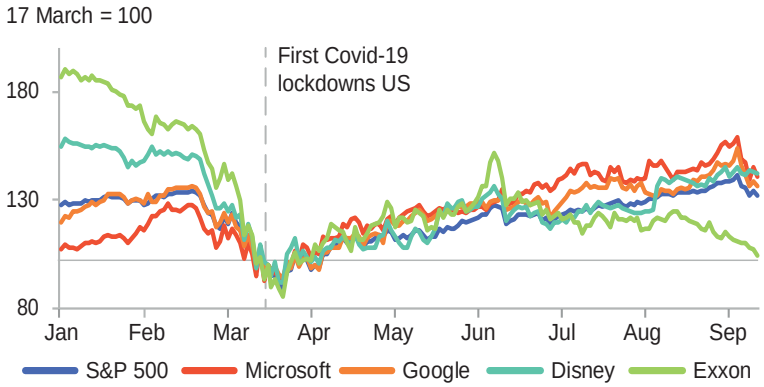
Source: Ourworldindata/EIA (CO_2), St Louis Fed database/Statista (real income)

Democrat presidents (FDR, Kennedy/Johnson) were responsible for the two surges in US emissions during the last century. That CO_2 emissions per head collapsed this century, even as real incomes rose, does indeed suggest that America can 'have it all'. But that's only if the switch to smarter energy (from coal to natural gas so far) gets even cleverer – towards, say, green hydrogen. Public money does not appear to be an object, but brand image might well be.

As Aisling Hubert notes ('PGMs are crucial for a green future provided they can attract sustainable finance'), the PGM business was conceived and nurtured in simpler times, when the dirt under a miner's fingernails, profitably dug, was the only virtue that needed to be signalled. Now PGM mining must pass broader, ethical tests to attract funding – the criteria of environment, social and governance: ESG. And while the suspicion at the back of (not just) miners' minds might be that this is just a fad, the post-pandemic zeitgeist suggests this is likely to be an ongoing challenge for industry.

Over $30 trillion is now invested by ESG funds (more than even US debt, Messrs Trump and Biden please note). And throughout the pandemic, the top ESG stocks (Microsoft, Disney and Google in the chart) have proved more than immunisation for portfolios (compare fossil-ised Exxon).

'ESG' portfolio vaccine



Source: Yahoo Finance. Note: shares in 2020 indexed to start of US lockdowns.

PGM mining in both South Africa and Russia faces governance ('G') challenges, with these countries ranking 70th and 137th out of 180 in a global corruption index. In South Africa, arguably, the 'S' – well-documented social issues in ESG – is the most challenging. The 'E' hurdle, coal dependency, is being straddled by relaxing laws on energy generation and drawing on South Africa's abundant renewable energy resources. In Russia, the 'E' seems the most pressing, especially in the light of Nornickel's recent diesel spillage in the Arctic tundra. However, the company has quickly adapted to international best practice; its heavy new infrastructure investment means it is well on the way to slashing SO_2 emissions.

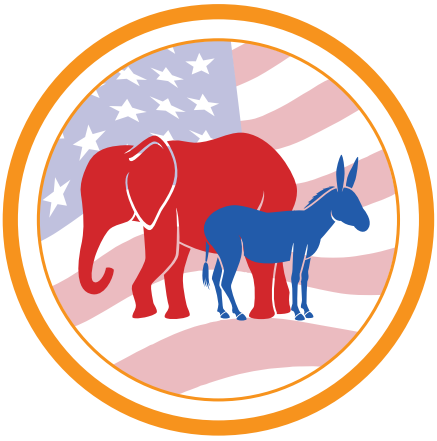
In summary, 'cleaning up their act' wouldn't seem to be too much of a culture shock for the miners of metals that help to clean up the world, would it?

Stephen Forrest, Alex Biddle and Jenny Watts ('Minor to major: key metals for the hydrogen economy') don't think so. Flaunting the green credentials of platinum and rhodium (autocatalysts) and particularly ruthenium and iridium – the linchpins of 'green' hydrogen production and fuel cells – would admit PGM to the best 'clubs': ESG funding, indices and maybe even high society.

Formerly an afterthought, minor PGMs, seen as by-products with few end-uses and of tiny stature (iridium about 300 koz, ruthenium and rhodium 1,000 koz against palladium's 6,000+ koz), now find themselves front and centre in the dash to cleaner transport and energy. South Africa – and overwhelmingly the UG2 Reef – has the near monopoly on these keys to the green economy; leverage enhanced because recycling the 'minors' is unfeasible and/or uneconomic.

Currently, the bulk of hydrogen is produced from fossil fuels, not by iridium-facilitated electrolysis, so it is not really 'green' at all. Surely the provenance of clean energy can only make hydrogen a more attractive proposition? The time has come for these PGMs to move from minor to major.

THE 2020 US PRESIDENTIAL ELECTION WILL BE ONE FOR THE RECORD BOOKS



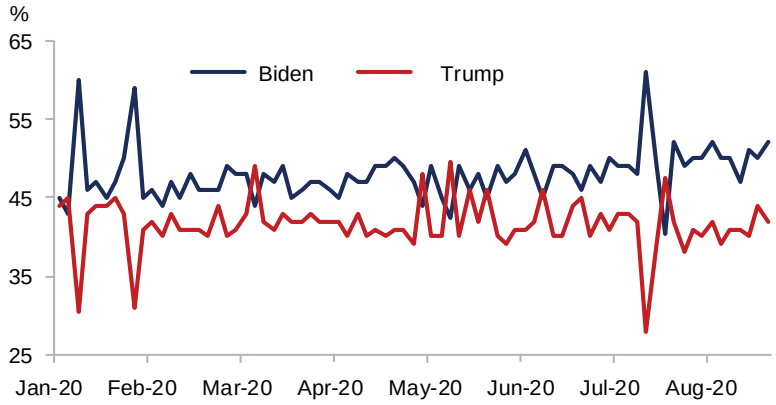
The 2020 US presidential election will be one for the record books

Oren Klachkin, Lead US Economist, Oxford Economics

Pundits always say, "*This is the most important election in history*." This time, it really seems to be the case. Political polarisation has grown more entrenched since President Donald Trump's 2016 victory and the coronavirus pandemic has left the economy grappling with the worst downturn since the Great Depression. President Trump has lost the one major success he could tout – the strength of the economy – but he relishes a fight and looks eager to hit the campaign trail. Democratic presidential nominee and former Vice President Joe Biden has painted himself as the "anti-Trump", and polling suggests he is holding on to a lead, but Trump has already shown he can beat the odds.

President Trump no longer has the economy as a success

US: Polling for General Election



Source: Oxford Economics, YouGov

The virus's shadow will hang over the election

The coronavirus crisis looks set to cast a dark cloud over the economy heading into November. The drop in economic activity has been swift, with H1'20 GDP falling at the third-fastest pace in the past century – behind only WW2's demobilisation and the Great Depression. The concurrent labour market collapse has been breathtaking, and while some job losses were recouped in May, June and July, about 13 million Americans remain unemployed today compared to before the pandemic. Plus, Oxford Economics' US National Recovery Tracker shows the economic rebound has been treading water since mid-June.

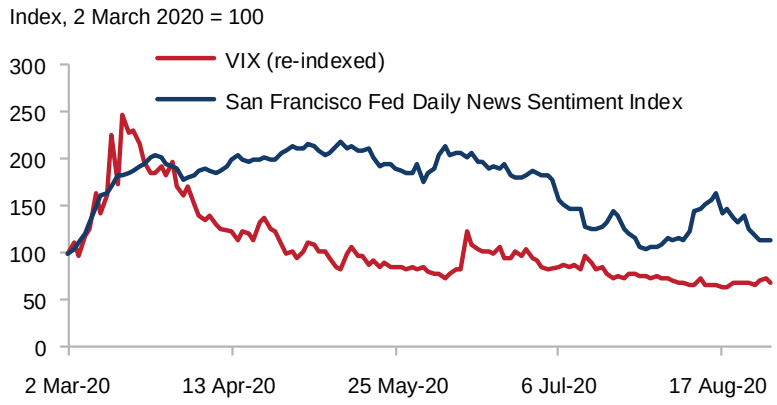
Coronavirus caused record-breaking levels of unemployment

Automobile sales, meanwhile, declined precipitously at the onset of the pandemic, but are recovering at a strong pace, supported by increased demand due to virus fear and lower interest rates. Whether automobile sales will maintain an upward trajectory after the election depends on the shape of the economic recovery going forward as well as how the next US administration handles the ongoing virus threat. The health and economic crises are inextricably linked, and a self-sustaining, robust economic recovery will not be ensured until the virus threat is brought under control.

The virus needs to be under control to allow a robust recovery

To be sure, the stock market has recovered all its pandemic-related losses, and financial market volatility has subsided greatly. This is largely thanks to the very robust policy response, particularly monetary policy. However, while financial market uncertainty has fallen considerably since the pandemic's onset, uncertainty on Main Street remains elevated. Millions of Americans, of all political persuasions, are still out of work. With the next fiscal relief package likely to be smaller than the initial one, the level of economic caution and uncertainty will be significant among US voters heading into the election.

US: Financial market vs. Main Street uncertainty



Source: SFA (Oxford), Bloomberg

Financial markets have recovered but the real economy still needs fiscal support

The coronavirus means President Trump is unlikely to win re-election

A fragile economy means the model predicts a Trump loss...

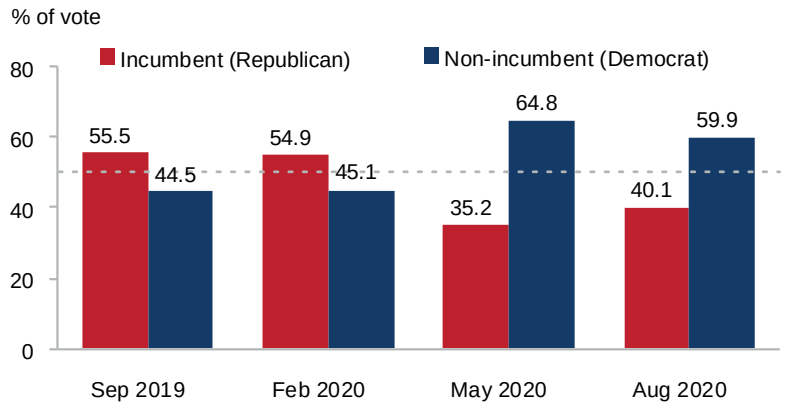
A suite of models and scenario forecasts developed by Oxford Economics can provide guidance on possible election outcomes, given the extremely uncertain environment and fragile economic recovery. In short, the models forecast that Trump will lose his re-election bid.

...potentially the worst since Herbert Hoover

With the economy likely to still be suffering from the traumatic fallout of the coronavirus-induced recession, Oxford Economics' National Election Model shows Trump earning only 40% of the popular vote and Biden capturing 60%. With an unemployment rate above 10%, real per capita incomes (excluding government transfers) falling at roughly a 4% year-on-year rate, and subdued inflation in Q3'20, Trump would suffer the worst incumbent performance since President Herbert Hoover.

This is a sharp change from our February, pre-coronavirus forecast when we projected that a roughly 2% GDP growth environment would secure Trump 55% of the popular vote. Notably, our current prediction is marginally more positive compared to that in May, when we expected Trump to win only 35% of the popular vote. This is because the economy has performed marginally better than expectations – though not enough to alter the election forecast.

US: Election model predictions over time



Source: Oxford Economics

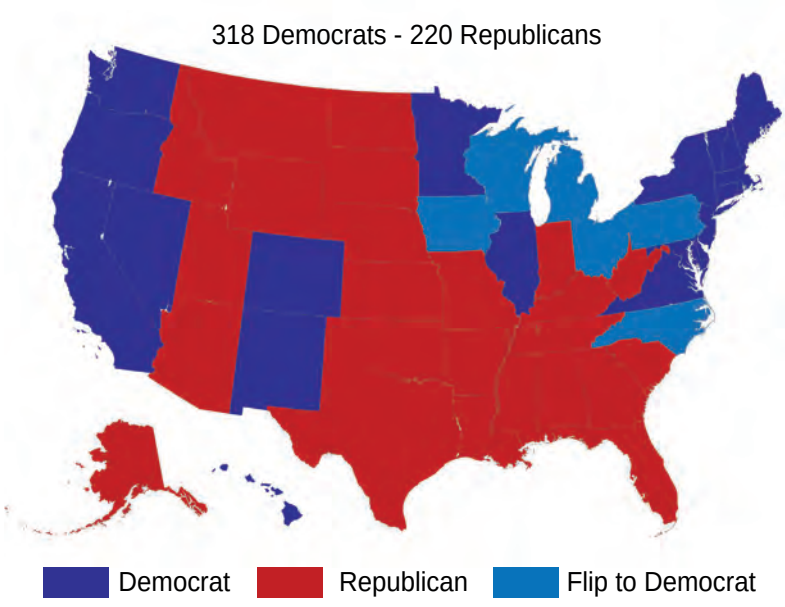
Oxford Economics' state-based Election Model, which forecasts Electoral College outcomes, predicts Trump will lose, with 220 votes to Biden's 318. Assuming average historical voter turnout, several swing states are slated to flip back to the Democrats after going Republican in 2016. These states are Iowa, Wisconsin, Michigan, Ohio, Pennsylvania and North Carolina, which collectively will push 85 electoral votes over to the Democrats.

Swing states could turn Democrat

One of the more interesting aspects of the 2020 election is that the Midwest and Southern states are anticipated to vote for Trump, even though they have underperformed the rest of the country from an economic perspective during his first term. Well before the coronavirus crisis, Trump's policies forced these states to grapple with several headwinds, particularly slower global growth and the US-China trade war. Additionally, many states in these regions have been caught in the coronavirus's summer resurgence, which has dealt a blow to their nascent recoveries. The model predicts states dominated by services-based activity – located mainly in the Northeast and on the West coast – will vote for Biden.

States with services based economies will vote for Biden

US: 2020 presidential election – Electoral College forecast



Source: Oxford Economics

Important caveats are attached to this prediction, namely that it assumes historical turnout patterns. Additionally, we do not consider non-economic factors such as candidate background, likeability, or policy leanings. And, perhaps most importantly, the models cannot control for the pandemic's multi-faceted shocks.

The model can't consider all variables

What happens if President Trump were to win re-election?

Trump's campaign has released few concrete details of policies the incumbent will pursue if he wins. Even if Trump does prove victorious, Republicans need to maintain their Senate majority and retake the House of Representatives to be able to push through major legislation – a scenario to which Oxford Economics attaches a low probability. Absent this, Trump can only implement policies via other methods, such as regulatory changes and executive action.

If Trump wins, policy implementation through congress looks difficult...

One area where the president is very keen to make progress – and where the executive branch does not need cooperation from Congress – is trade. Looking past fiscal policy over his first term, trade is one of the other areas where Trump has had an impact. Should he win, he is likely to want to shift attention back to trade, with a particular focus on China, in order to bring jobs back to the US, as a potential reprisal for the coronavirus and to constrain China's sphere of influence.

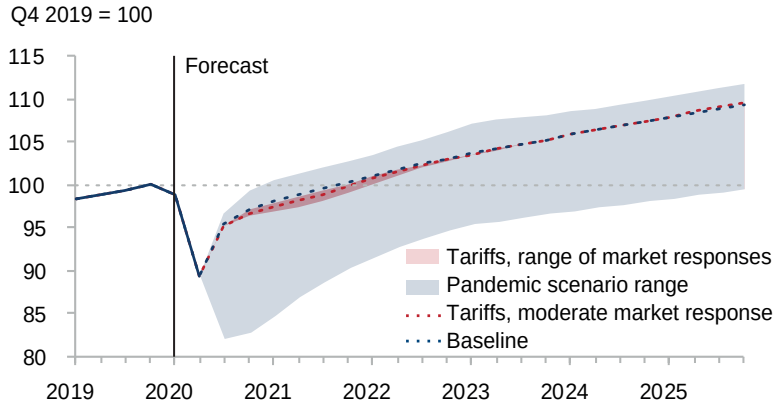
...which could mean more executive orders and a renewed focus on trade...

Oxford Economics estimates that the cost to GDP growth from imposing all previously threatened tariffs – which would push the average levy on Chinese imports to a multi-decade high of 27.6% – ranges from 0.2%-1%. A key variable is the financial market response: a strong negative reaction can hit spending via wealth effects. A mild reaction – slightly worse than a sustained version of the market reaction to Peter Navarro's July remarks on the US-China trade deal – would pose only a mild drag on the economy.

...but higher tariffs would be a drag on the economy

However, in a downside scenario of a large financial market shock, in which equities retrace March lows, the hit to 2021 GDP growth could offset up to half of the Fed's 2020 growth stimulus. In such a scenario, the 10-year US Treasury yield could be lower by 5bps-10bps relative to the baseline forecast by the end of 2021. The US dollar would appreciate only mildly, roughly 0.2% on a broad, trade-weighted basis through the end of next year.

US: GDP under different scenarios



Source: Oxford Economics, Haver Analytics

How Joe Biden's policies might change the economic landscape

On the other side, Democratic nominee Biden's policy platform says he intends to spend around $7 trillion over 10 years. The bulk of his initiatives would focus on tackling long-standing issues regarding climate and infrastructure, education, healthcare, racial inequality, housing and Social Security. Regarding taxes, Biden plans a large package of increases that would raise $4.7 trillion over 10 years relative to the Oxford Economics baseline. Importantly, Biden's plans would also reverse key components of the Trump tax cuts passed in 2017, with the brunt of higher individual taxes borne by upper-income households. Biden also plans to undo some of the central components of the tax cuts on the corporate side, namely raising the business tax rate to 28%. Notably, if he wins, Biden's environmentally friendly policy stance means automobile manufacturers will likely have to adhere to stricter pollution standards than under Trump, supporting demand for metals such as palladium and rhodium.

Biden's environmentally friendly policy stance suggests stricter pollution standards are possible

Automakers might need more palladium and rhodium

Oxford Economics estimates these topline tax and spending proposals would deliver a mild net boost to annual GDP growth over the course of Biden's term. The stronger economic environment would push up the 10-year US Treasury yield as both growth and inflation strengthen, while firmer economic activity would raise corporate profitability and support higher equity prices.

The growth impulse from Biden's collection of fiscal policy changes may lead the Fed to start normalising monetary policy sooner than markets currently expect, though the Fed would take care not to tighten policy too quickly to avoid plunging the economy back into a downturn. Stronger economic activity and higher interest rates would spur the US dollar to appreciate mildly, partially offset by the subsequent improvement in the global economy that would draw some capital flows towards other advanced and emerging economies.

Importantly, the Democrats need to control the House and Senate to advance most of Biden's agenda. While they may increase their majority in the House and could possibly gain a simple majority in the Senate, they are unlikely to hold the 60 seats necessary for a filibuster-proof Senate majority. The likelihood that Biden would be able to implement his planned fiscal policies is therefore fairly low.

The Democrats need to control Congress to advance Biden's agenda

On the trade front, Biden is unlikely to match Trump's aggressive approach, but the Biden platform is certainly less liberal compared to other recent Democratic administrations. Biden is likely to take a less direct and aggressive approach to trade, using such policies as government procurement programmes that give preference to US firms. Importantly, even if Biden brings no further tariff escalation, unwinding current levies may require lengthy negotiations, and academic research shows tariffs tend to take a long time to undo. No matter who occupies the White House next year, a swift return to previous trade relations with China, or other key trading partners for that matter, looks unlikely. Delinking with global supply chains could support the re-shoring of automobile manufacturers during the next administration's term and strengthen domestic demand for the metals used in the production process.

Trade normalisation looks unlikely

Now it is up to America's voters

The US is entering the final stages of an unprecedented presidential election cycle, as the two candidates campaign for the country's highest public office amid an ongoing pandemic that has plunged the economy into a momentous recession. Trump will argue that the country and economy were doing very well until the coronavirus hit and that the pandemic is not his fault. Biden will stress that he is a unifier, that he can better manage the country out of the health crisis, and that his policies will bolster the economy's long-term prospects.

Unprecedented = uncertainty?

With the start of early voting only weeks away, the final decision about which direction the country will take is in voters' hands.

PGMs ARE CRUCIAL FOR A GREEN FUTURE PROVIDED THEY CAN ATTRACT SUSTAINABLE FINANCE

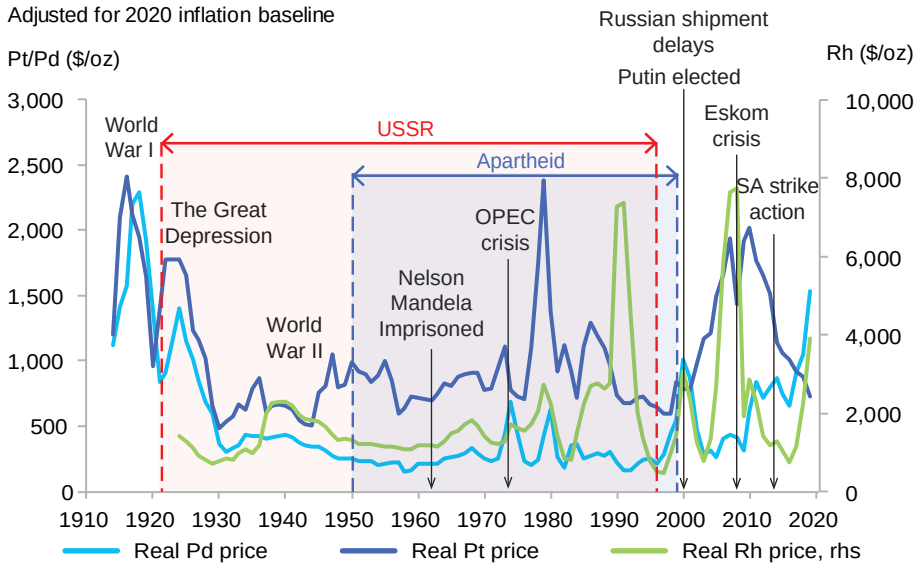
PGMs are crucial for a green future provided they can attract sustainable finance

Aisling Hubert, Mining and ESG Analyst, SFA (Oxford)

The global platinum-group metals (PGM) industry has persisted for the past century, against a backdrop of political upheaval and technological revolution. Today, the unique chemical and physical properties of PGMs mean they are ideal for the many modern specialist technologies needed for a sustainable future, such as automotive catalytic converters, electronic components, chemical catalysts and hydrogen fuel cells.

PGMs are the 'catalyst' for a sustainable future

Pt, Pd & Rh prices, 1913-2020



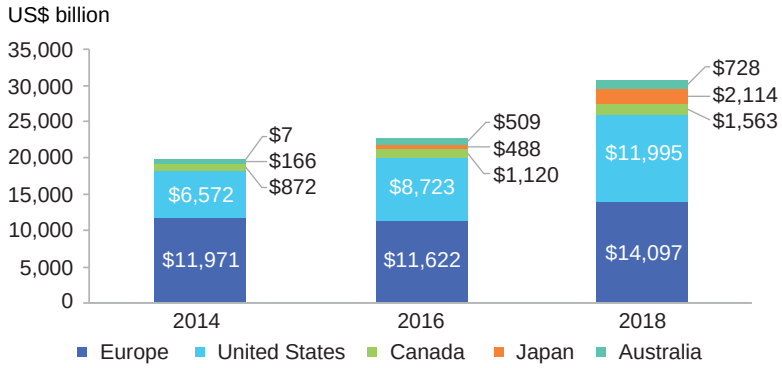
Source: SFA (Oxford)

The PGM industry has experienced the challenges of globalisation, political transformation and social expectations since it was developed in the vastly different cultural and political landscape of the early 20th century. The ability of the sector to react to new challenges and opportunities and the adaptability of its key players have been tested to extremes. New issues are now rising to the fore, as global sensibilities and investor priorities demand transparency and sustainability alongside a healthy return on investment. With the need to maintain profitability and mission creep concerns, the focus must be on the scope of the PGM industry to be a force for good, providing employment and assisting in the global push for green energy whilst simultaneously making the financial case for environmental, social and governance (ESG) excellence.

PGM producers must balance new ESG expectations and shareholder returns

Recently, ESG factors in both public and business spheres have been in the spotlight. Far from simply paying lip service to more sustainable, ethical investments, international investor habits have highlighted the swift flow of capital into high-ESG performance assets. Funds employing one or more methods of responsible investment have been seen to grow by 34% from 2016 to 2018, to a total value of $30.7 trillion.

Growth of global sustainable investment funds over time

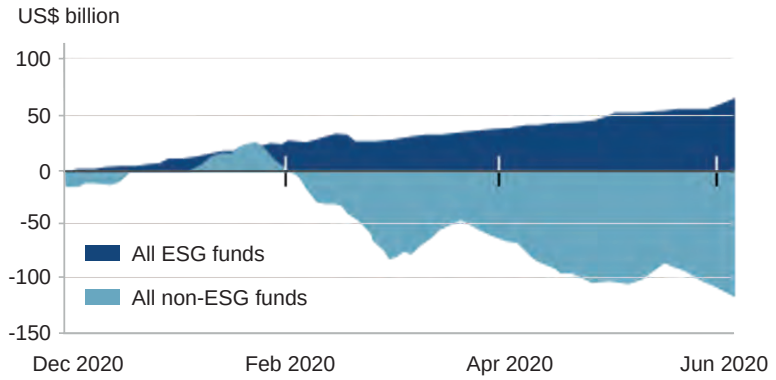


Source: Sustainable Investment Review (2018)

Perhaps even more telling is the performance of ESG assets throughout the initial shocks of the Covid-19-induced global economic crisis. In contrast to the capital outflows from non-ESG assets, ESG funds have shown relative buoyancy amidst the chaos, including under-exposure to the oil industry which suffered catastrophically in the spring of 2020, and over-exposure to 'future-proofed' clean energy and technology solutions which are now being incorporated into Covid recovery plans. This appears to demonstrate that weathering crises seems an inherent trait of funds constructed with environmental and social risk mitigation as a priority.

ESG investment has proved to be a crisis hedge

Cumulative capital flows for ESG and non-ESG funds



Source: Goldman Sachs (August 2020)

PGMs are intrinsically linked to future green technology plans, and significant opportunity exists for the sector with new end-uses such as hybrid vehicle autocatalysts and hydrogen fuel cell technology for industry and transport. However, in order to access these new financial pastures, producers must be proactive in shaking off the old image of extraction as an exploitative, polluting activity and embrace the new global sensibilities of transparency, accountability and stakeholder integration.

An industry accustomed to political and economic revolution

Global reserves are concentrated in just a handful of countries, with South Africa and Russia accounting for the vast majority at 91% and 6%, respectively. Modern industrial extraction of PGMs began with the discovery of the Bushveld Igneous Complex in South Africa and its associated reefs over several decades from 1897-1924. In Russia, the Taimyr Peninsular deposits were uncovered around the same time, marking the transition from the reliance on Ural placer deposits to hard-rock operations, with large-scale mining commencing in 1935. At this time, both countries operated under vastly different political and economic systems than those in place today. In South Africa, colonialism was deepening ethnic divisions regarding work, ownership and legal freedoms, paving the way for subsequent deep segregation under apartheid. In Russia, exploitation of the Taimyr Peninsula deposits began a decade after the establishment of the Soviet Union during a period of intense national industrialisation and the mass exodus of rural, pastoral and agrarian communities to cities, due to the seizure of land by the state.

The PGM industry was conceived and nurtured in a very different political environment

Since then, PGM mining has developed into a sophisticated global industry, with cutting-edge technological innovations creating increasingly efficient resource extraction, all the more necessary as PGM mine grades gradually declined. However, new challenges have arisen as awareness of the environmental costs of rapid globalisation and industrialisation is growing through the use of increasingly high-resolution Earth monitoring techniques. Additionally, and perhaps more noticeably, discord surrounding power and ownership persists, at both societal and administrative levels, as social licence to operate is now considered the number one risk to mining operations (source: EY, 2019).

PGM miners are faced by legacy problems and future challenges

The financial implications of this new zeitgeist are clear as increased ESG scrutiny is now impacting companies' profitability and traditionally prosperous companies are lagging behind. A healthy dose of introspection is required for the sector to rethink its place in future global infrastructure and industry and how to present its total value proposition to shareholders and local communities, and the wider implications for the PGM supply chain.

South Africa: Social challenges persist against the backdrop of national energy crisis

Some of the core social challenges facing the South African PGM industry can be traced back to the apartheid-era systems of pervasive dependence on migrant labour. The socio-economic fissure between migrant workers and the more settled workforce, often along ethnographic lines, has delineated the gulf between settled and unsettled community prosperity. Often a single salary supports one or more families, thus heightening economic insecurity for women in mining communities and in the rural homelands of migrant families. Against the backdrop of global economic insecurity and rampant unemployment, internal pressures can come to a head, as was seen in the tragic events of 2012-2014 . Alongside these localised problems, South Africa has battled with systemic issues and the country now ranks 70th in the global corruption index (source: Transparency International, 2019).

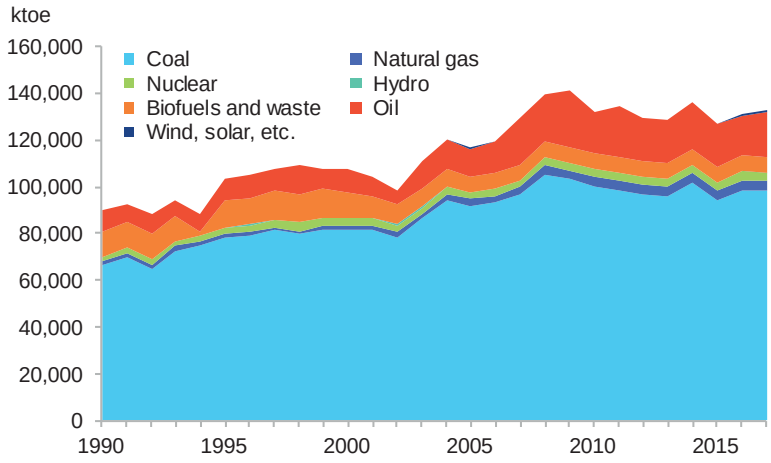
In South Africa, it's the 'S' in ESG that is the most challenging

New social challenges are now looming, as mechanisation and technological innovation reshape traditional mining methods and widespread workforce upskilling will be required to keep pace with the changes and reduced labour requirements. Employers must be prepared to meet these new challenges head-on and work proactively to ensure their employees' relevancy in the future.

The country's reliance on pollutant-heavy coal to produce electricity for the unreliable and overstretched national power grid presents specific problems. Although not unique to the PGM industry in South Africa, the failing electricity supply remains one of the major risks to the national economy and barriers to investment. With South Africa providing the lion's share of PGM output worldwide, a national problem is effectively a sector problem.

Coal dependency has energy instability and pollution by-products

Total primary energy supply (TPES) by source, South Africa 1990-2017



Source: International Energy Agency (2019)

South Africa: International accountability and relaxing legislation will drive producer energy innovation

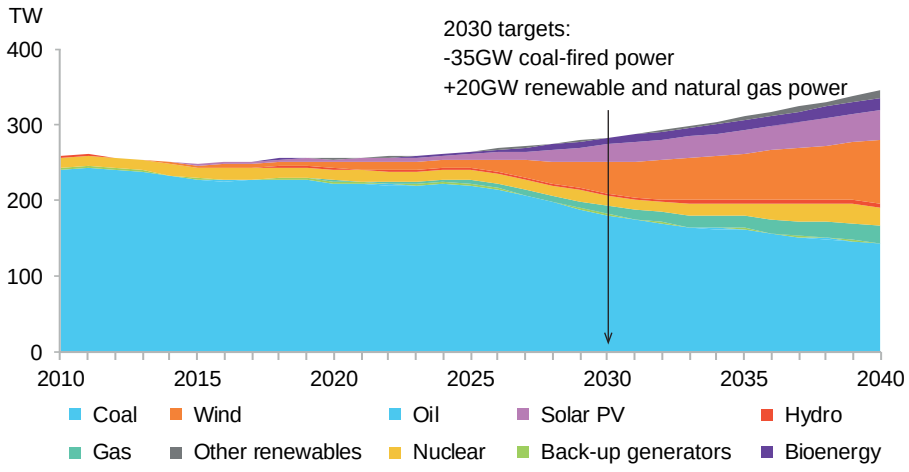
Nonetheless, there are signs of improvement and reconciliation across the sector. Despite reliance on coal, PGM miners have managed to reduce average greenhouse gas emissions by 32%, largely due to a reduction in electricity consumption since 2014, a credit to the producers as the national energy crisis poses a near-insurmountable obstacle. In addition, the chronic instability of the power grid has prompted, for the first time, the government to indicate its support for some level of energy self-sufficiency, as stated by the Mineral Resources and Energy Minister, Gwede Mantashe, at Cape Town's Mining Indaba conference in early 2020. Since the event, steps have been taken to relax the laws requiring licensing and permitting of energy generation and distribution projects.

Relaxation of legislation promises more energy stability

Additional pressure on South Africa to clean up its act comes from its subscription to the UNFCC's Paris Agreement which will see the country held to account over its environmental policies. Commitments have been made to reduce the country's CO_2 emissions over the next few decades, pledging an emissions peak between 2020 and 2025, and then allowing them to plateau as the country overhauls its infrastructure and legislation before a committed reduction from 2035 onwards. In October 2019, the country put forward its Integrated Resource Plan (IRP) for energy generation out to 2030, defining the shift away from coal dependency which in 2017 made up 88% of the country's energy needs. The aim is to reduce this to 59%, with energy from renewable sources rising to 25%. The definition of these national goals and growing support from government entities have made pioneering producer projects possible, including Anglo American's hydrogen fuel cell-powered mining truck and Impala Platinum's integration of 'green' hydrogen fuel cell technology at its refineries.

The Paris Climate Accord is prodding a reduction in greenhouse gas emissions

South Africa electricity generation by source in the Stated Policies Scenario, 2010-2040



Source: International Energy Agency (2019)

With its abundant sources of potential renewable energy, especially solar and wind power, South Africa is ideally positioned to become a leading participant in the global push for green hydrogen viability for fuel cell usage. However, sustained momentum and governmental initiatives in clean energy solutions will be needed if current climate goals are to be met.

South Africa is rich in renewable energy potential, so could be a major player in clean hydrogen production for fuel cells

In terms of social reforms, South Africa has some way to go, both along the platinum belt and in the country as a whole. Although grassroots efforts from activists and recent initiatives from producers such as Sibanye-Stillwater's Honour, Engage, Create initiative are meaningful beginnings, there is much room for improvement at a national level as inequality and poverty remain core societal issues.

Russia: Recent rapid modernisation but climate-sensitive Arctic tundra may pose future challenges

Russia is the other major contributor to global PGM production via the mining behemoth Nornickel. Emerging from the country's transition from state control to free market, Nornickel has remained a bastion of industry within the country and has witnessed the metamorphosis of a nation, adapting to keep pace with modern international market standards, though not without both internal and external hurdles.

Russian mining has had to quickly adapt to international best practice

Since its debut on the global stage in the early 2000s, Nornickel has battled to modernise its 20th century infrastructure legacy. In the past decade, these outdated systems tarnished the company's reputation as unprecedented levels of sulphur dioxide (SO_2) emissions led to the decimation of fragile tundra ecosystems, with acid rain from the Kola MMC Division operations extending as far as neighbouring Norway and Finland.

The Russian ores are situated in one of the world's most fragile ecosystems, with the Arctic tundra expected to experience the effects of rising global temperatures. This poses a threat not only to the highly specialised flora and fauna of the region but also to industry, as thawing permafrost threatens the foundations of the cities and mines. This prompted the establishment of a long-term permafrost monitoring programme at Norilsk, after 21,000 tonnes of diesel was spilled into rivers and subsoil near Norilsk in May 2020 as a consequence of thaw-related subsidence beneath a fuel tank.

Perhaps the environment is Russian PGM producers' greatest ESG challenge

Within the company, core governance challenges remain, as discord amongst the largest shareholders impedes a unified corporate strategy. The difference of opinion regarding the company's long-term investments, at the cost of high-paying dividends, has seen company initiatives flounder, including the recent Arctic Palladium project scheduled to have begun in 2020. It is expected that a difference of opinion will continue to play out as the economic strength, which has buoyed the company's performance in recent years, diminishes in the wake of the Covid-19 pandemic.

Like South Africa, Russia also faces challenges at a national level, with the country ranking 137th out of 180 countries according to the global corruption index (source: Transparency International, 2019). This is alongside foreign policy that is often prohibitive to international investment.

Russia: Grand environmental plans herald further progress and employee wellbeing is industry-leading

Nornickel has outlined ambitious measures to overhaul the environmental impact of the company. In 2016, company CEO Vladimir Potanin announced that $1.7 billion had been earmarked for production chain modernisation, alongside aims to slash SO_2 emissions in Siberia by 75% before 2023 and reduce SO_2 in the Kola Peninsula by half. In 2019, the company's sustainability strategy was updated, the timeline pushed out to 2030 and a commitment to new company goals set in place, such as supporting the global shift to clean mobility and green modernisation of the facilities on the Taimyr and Kola Peninsulas. Recently it was announced that the highly inefficient geriatric smelters of the Kola Peninsula, centred on the town of Nikel, will be shut down by the end of 2020 with an expected drop in SO_2 emissions of 33% and resulting in the redeployment or retirement of a total of 600 smelter workers. Nornickel's latest targets are for a reduction in SO_2 emissions of 85% at Kola MMC by 2021 and of 90% at the Polar Division by 2025, compared to the base year of 2015.

New infrastructure makes emission reduction goals feasible

After having been one of the worst single point source contributors to global pollution, Nornickel's multi-phase approach in overhauling its aged infrastructure has been highly effective in reducing harmful SO_2 emissions. Although pollutants remain the main challenge for the company, other performance indicators such as lost time injury frequency rate (LTIFR) and fatalities have also been improving, and in 2019 the company was named Russia's Best Employer by Forbes. Of the major producing regions, Russia leads the pack in terms of workforce gender equality, with women accounting for 27% of the total workforce, 53% of white-collar employees and 24% of management.

Nornickel's progress on safety and gender equality now recognised

Most of the upgrades have been completed during times of economic prosperity, but it is likely that the company will be able to sustain momentum during and beyond the Covid-19 pandemic disruption to global economies, although tightened purse strings may lead to disagreement over shareholder priorities.

Russia benefits from a wider variety of energy sources than South Africa. Despite natural gas, coal and oil dominating the energy mix, the country also has greater capacity for nuclear and renewable energy. Russia is also a subscriber to the UNFCC's Paris Agreement, pledging to cut greenhouse gas emissions in a global effort to limit the effects of climate change this century.

Russia is better placed than South Africa to lower CO_2 from mining

PGMs have a future in clean-air technology but profitability depends on proving green credentials

PGMs are central to future clean energy solutions as an essential component in the production of green hydrogen for fuel cell use and their persistence in both internal combustion engine (ICE) and hybrid autocatalysts, alongside medical and electronic uses. The social and environmental value proposition of PGM extraction is clear, but the industry has specific challenges unique to each PGM producing area due to the social and environmental constraints in the respective regions.

'Soft' ESG strategies, as well as 'hard' mining economics, will unlock the rapidly growing ESG investment funds

Aside from the two major producing countries outlined in this report, it is also worth mentioning other regions which require specific consideration in terms of their social and environmental approach. Examples which provide opportunities for excellent ESG stewardship as well as specific sensitivities include the Stillwater complex in Montana situated on the edge of a national forest and a stone's throw from Yellowstone National Park, and the immense hydroelectric capacity of Zimbabwean extraction amidst social unrest.

Although the movement towards requiring responsible companies to meet ESG criteria has been swift, it would be unwise to consider this a transient trend. As modern sensibilities shape the young investors of the future, it will become increasingly critical for companies to wrestle with these new, intangible challenges or risk being left behind as evolving investor expectations force the industry to adapt once more.

Joining the dots

between EVs and critical battery metals

The ultimate 'must have' investor's guide for new participants and seasoned players in battery metals

Beresford Clarke, Director of Research: *"With these three key battery commodities at, or near, the bottom of their price cycle, there is significant strategic and commercial value to be gained from taking a 360° perspective on their markets, 'joining the dots' on how EV uptake is developing around the globe and how individual supply chains for these metals are evolving"*

In this report, SFA (Oxford), with its proven record of in-depth analytical excellence, acting as a trusted adviser across the value chain, provides definitive answers to the following questions

- What does long-term EV battery demand mean for critical battery cathode materials?
- What are the drivers for EV battery demand?
- Where is EV battery demand growth coming from in the short, medium and long term?
- Who are the major EV battery suppliers in each region?
- What are the demand risks from EVs for the critical battery materials?
- Who are the major lithium producers? Who are their clients?
- Who are the major nickel producers? Who are their clients?
- Who are the major cobalt producers? Who are their clients?
- What are the preferred product forms, for the three key metals, in EV batteries?
- To what extent is the EV battery supply chain vertically integrated?
- What is the possibility of further integration in the future?
- When will battery metal prices incentivise new mine supply?
- Where will new mine supply come from?
- What is the lead time for new projects to come online?
- What role will EV battery recycling play in future supply?

For further information or to receive your copy of Joining the dots between EVs and critical battery metals, please contact David Mobbs at **dmobbs@sfa-oxford.com.**

Seven reasons why you need this report

1. **Supply of critical battery materials needs rebalancing to match the ambitions of the EV sector.** Cobalt, lithium and nickel supply needs to be 9x, 7x, and 3x (respectively) higher than projected to fulfil market requirements by 2040.

2. **A comprehensive 'joining the dots' approach** used to extrapolate regional supply and demand for each critical battery material, forming the report basis, and analytical integrity.

3. Detailed examinations of the drivers of EV uptake, battery technology evolution and **automotive battery demand levels out to 2040.**

4. The report is a unique guide through the rise of EVs, battery technology developments, critical parts of the value chain including process flowsheets and technologies, the labyrinth of battery raw material flows from mine to market and **deep insight into the key derivatives of battery metals.**

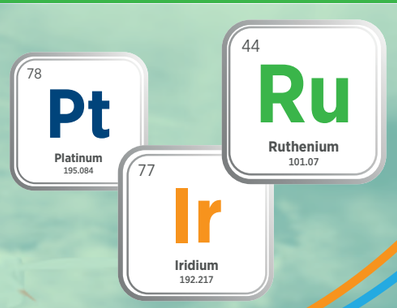
5. It provides a **comprehensive overview of current and prospective lithium, nickel and cobalt producers**, mapped and analysed, with market balances out to 2040, and quantification of metal supply and demand by region, plus an examination of the commercial landscape showing the relationship between producers and end-users.

6. **'Equilateral thinking'** and comparative analysis across the metals by using the same macroeconomic parameters from Oxford Economics and LMC Automotive for forecasting trends on a like-for-like basis.

7. **Over 450 pages of detailed analysis**, commentary and charts enabled by our long history of supplying OEMs with comprehensive analytics of the automotive supply chain, coupled with extensive consulting experience.

The hydrogen economy

Creating an integrated sustainable energy revolution



PGMs have the catalytic effectiveness and well-proven durability for demanding industrial and automotive applications

Platinum-based PEM electrolysis has the high power density needed for energy storage

The next 10 years will be a critical period for establishing a competitively-priced clean hydrogen supply

Government targets for the decarbonisation of transport have widened the opportunity for new platinum demand

The hydrogen industry is gaining momentum from unprecedented political and economic support

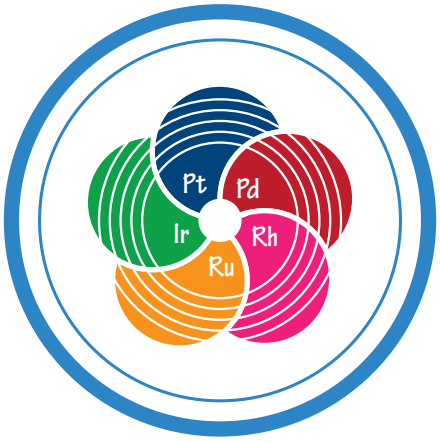
Platinum and iridium are intrinsic to the production of green hydrogen; hydrogen needs PGMs and PGMs need hydrogen

Decarbonisation of industry and transport is vital to avoid global warming

Hydrogen is the most reliable renewable energy source, and 'green' hydrogen production can offset CO_2 emissions in many sectors

Interest in hydrogen as a source of clean energy is growing globally, with applications in land transport, heavy industry, aviation and shipping

MINOR-TO-MAJOR: KEY METALS FOR THE HYDROGEN ECONOMY



Minor-to-major: key metals for the hydrogen economy

Stephen A. Forrest, Alex Biddle, Dr. Jenny Watts and Aisling Hubert, SFA (Oxford)

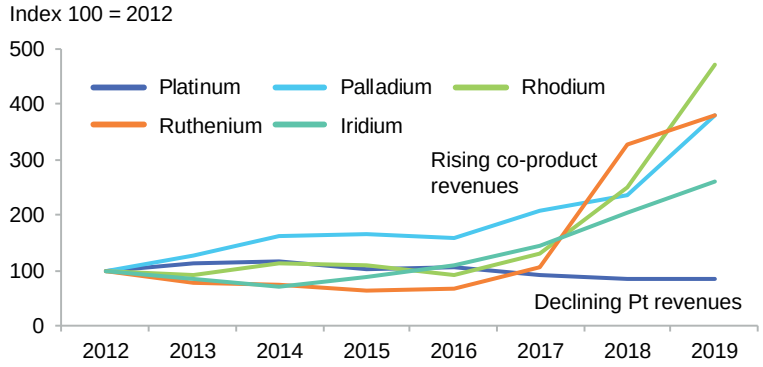
Strategic minor metals increasingly add more value to PGM mines

SFA (Oxford) believes that the elevation of minor metals (rhodium, ruthenium and iridium) as contributors to mine revenue is likely to become a progressively key strategic factor for South African mine investment in the future.

Indeed, historical reflections on price were based typically on the rarity of these minor metals. There was a limited number of 'new' end-uses (despite considerable stocks with producers) and their adoption was also curtailed by the small scale of the markets. More recently, minor metal revenues from South Africa have been increasing sharply, leaving platinum in the dust, with miners taking greater interest in promoting end-uses for the minor metals since they are increasingly reliant on them to generate profits.

Revenue from minor metals has been increasing in recent years

South African 5E revenue



Source: SFA (Oxford). Note: ZAR real 2020 revenues presented.

Market development initiatives have historically been rare for minor metals, unlike those for platinum. Furthermore, the inelastic flow of these co-product metals, save for the occasional metallurgical delay or mine stoppage from industrial action, offered minor metal markets little concussion and price lift. After flat-lining for six years (2012 to 2018), rhodium demand could be seen as the exception owing to increasing loadings in autocatalysts to limit levels of NO_x emissions in vehicles, particularly in China.

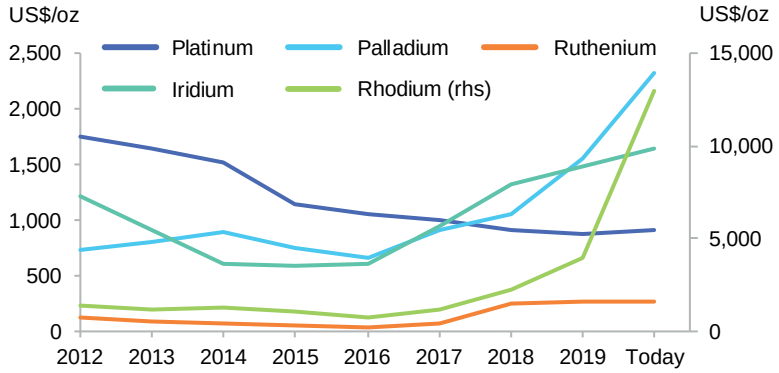
Market development initiatives have been rare for minor metals

Notwithstanding the historical context, the next round of value extraction to be marked up and drilled will need to have bold and clear directional lines painted on the rockface. SFA has been busy over the last 12 months examining the long-term availability of these minor metals for industrial end-uses. Specifically, the obtainability of rhodium, needed in autocatalysts to meet stricter standards for NO_x emissions, and the readiness of ruthenium and iridium supply for use as key ingredients in fuel cells and electrolysers for the future hydrogen economy. Stemming from this work, SFA has included this article on the availability of iridium, ruthenium and rhodium in this edition of The Palladium Standard.

Ruthenium and iridium are key ingredients for the hydrogen economy

In real terms, today's rhodium, iridium and ruthenium prices are up 801%, 36% and 114% respectively to $13,000/oz, $1,645/oz and $270/oz since the beginning of 2012. The palladium price has risen by 220% to $2,324/oz, while that of platinum is down 48% to $906/oz.

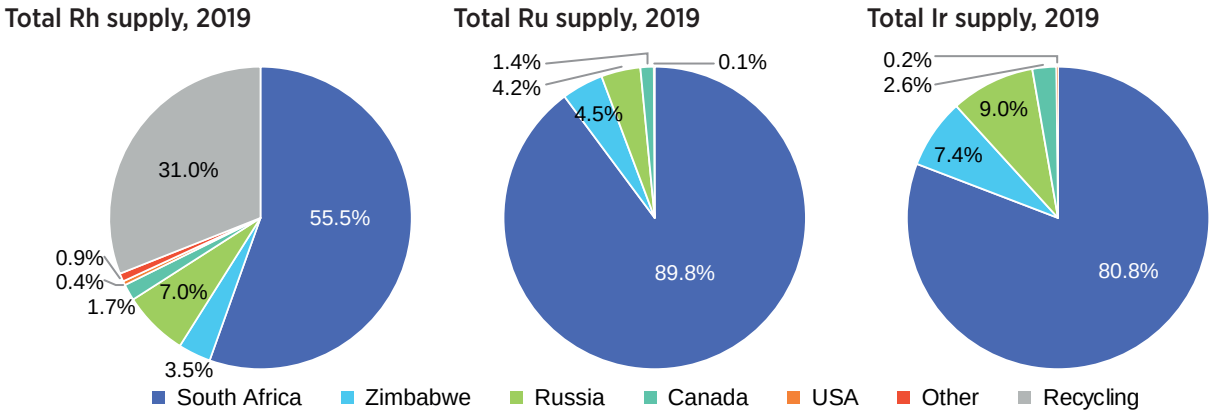
PGM prices 2012-present, real 2020



Source: SFA (Oxford). Note: Prices shown in 2020 real terms.

Minor metals are heavily South African centric

Primary rhodium, ruthenium and iridium supply is almost entirely derived from South Africa, with the country accounting for 81%, 90% and 81% of global mine production respectively and 55% of total rhodium supply, including open-loop recycling.



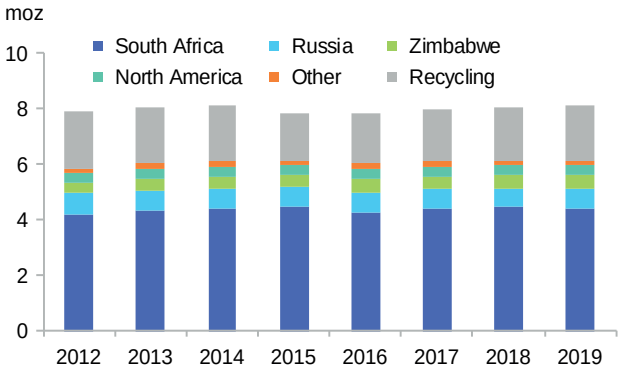
Source: SFA (Oxford). Note: 2019 production shown. Open-loop recycling for ruthenium and iridium is not recorded.

The following charts detail the regional share of production for platinum, palladium, rhodium, ruthenium and iridium, and total 5E including recycling. Importantly, the recycling of platinum, palladium and rhodium is a well-established industry since autocatalysts are easily recovered from scrapped vehicles in large quantities and contain a high concentration of these metals, making recovering them economically viable (especially given the price of these metals). In contrast, the open-loop recycling industry in ruthenium and iridium (which is extremely opaque) is likely to involve very small volumes since many applications use a microscopic amount of metal, rendering recovery by way of recycling uneconomic, especially given the low historical prices for ruthenium and iridium.

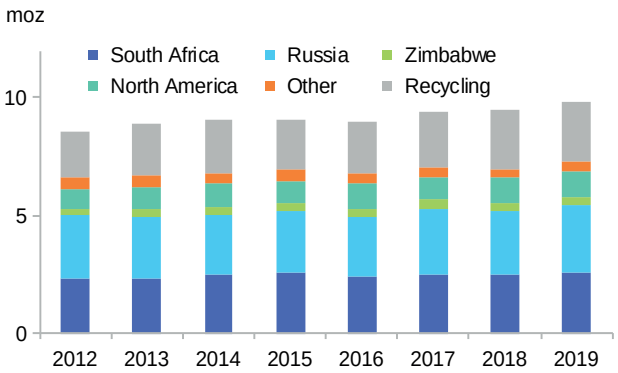
Therefore, South African PGM mining is vital in terms of the future supply of ruthenium and iridium, and rhodium despite recycling. Given the importance of these metals as key ingredients in the hydrogen economy (Ru and Ir) and in autocatalysts (Rh) in years to come, investment in new PGM supply from South Africa will be driven by the minor metals, rather than platinum.

Sources of supply for minor metals heavily weighted towards South Africa

Global platinum supply by region

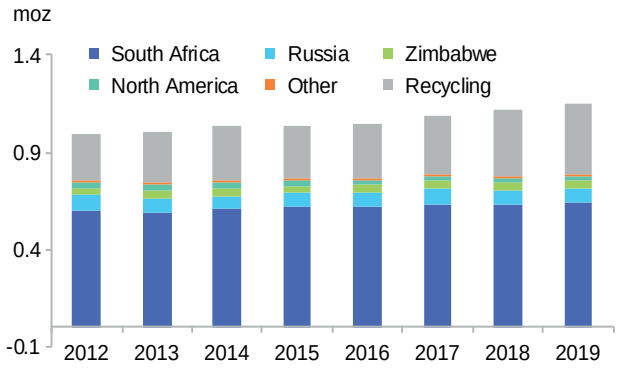


Global palladium supply by region

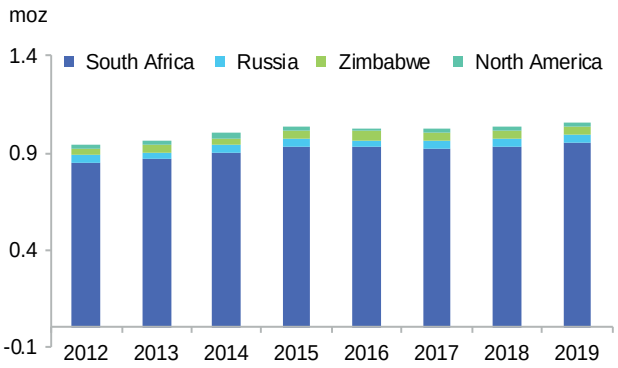


Source: SFA (Oxford)

Global rhodium supply by region

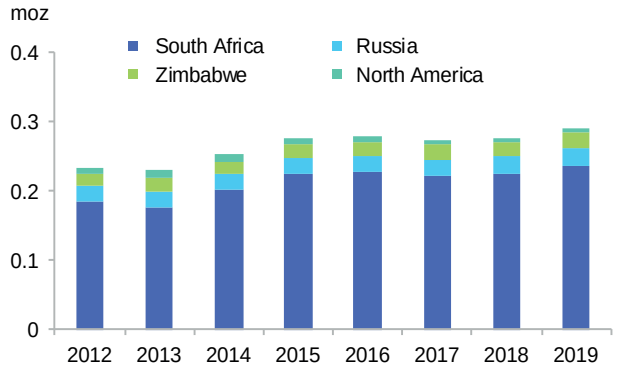


Global ruthenium supply by region

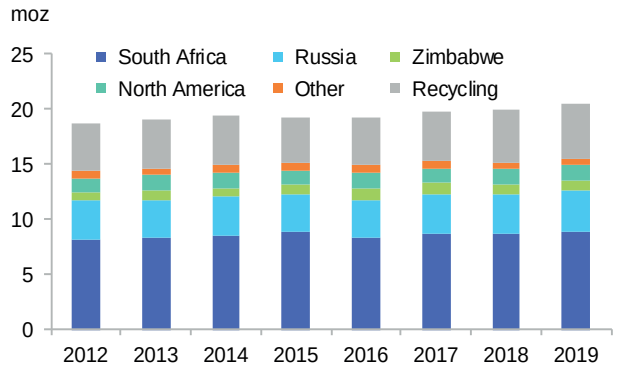


Source: SFA (Oxford). Note: Ruthenium recycling is not quantified but is believed to represent very small volumes at present.

Global iridium supply by region



Global PGM supply by region



Source: SFA (Oxford). Note: Iridium recycling is not quantified but is believed to represent very small volumes at present.

UG2 Reef holds the key to unlocking expansion in minor metal supply

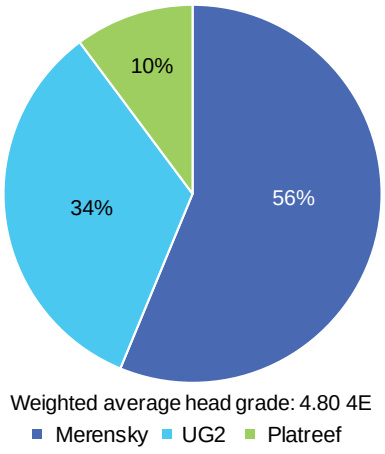
Since the mid-2000s, South African producers have increasingly focused on the extraction of ore from the UG2 Reef, as older Merensky operations deplete and newer generation shafts become deeper (higher cost). Ahead of the 2008-2009 stock market crash, a number of UG2-rich mines began operation, adding some 195 koz p.a. of rhodium production capacity during this time, but many of these mines (totalling 110 koz Rh capacity) have since been placed on care and maintenance. Consequently, there is significant production capacity that can be restarted with relatively low capital requirements and shorter lead times to production than greenfield projects.

Similarly to rhodium, the co-product consequence of replacing depleting Merensky platinum and palladium ounces with UG2 production also increased minor metal capacity as the UG2 Reef prill split is much more weighted towards ruthenium and iridium than any other PGM orebody worldwide. UG2-rich mines that started operation in the 2000s added 320 koz of ruthenium and 80 koz of iridium capacity, of which 190 koz and 45 koz respectively has since been closed. This closed capacity accounts for approximately 18.7% and 15.7% of annual production of ruthenium and iridium respectively, excluding delays to UG2 projects that were mothballed before reaching first production.

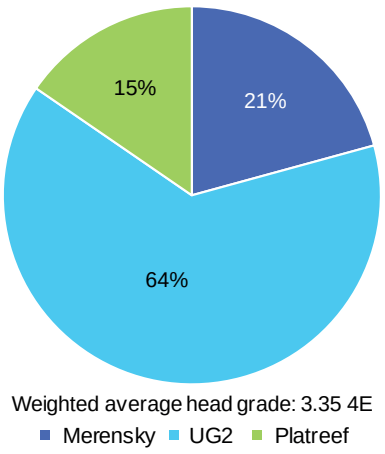
Rise in UG2 mining in 2000s increased minor metal capacity, but much of this has since been mothballed

The Merensky Reef now makes up just 21% of South Africa's output mix, from well over 50% in 2000. The UG2 Reef, meanwhile, accounts for 64% of milled production in South Africa, up from just 34% over the same period, despite capacity closures. Open-cast Platreef operations account for some 15% of output.

SA PGM mining production by reef, 2000



SA PGM mining production by reef, 2020



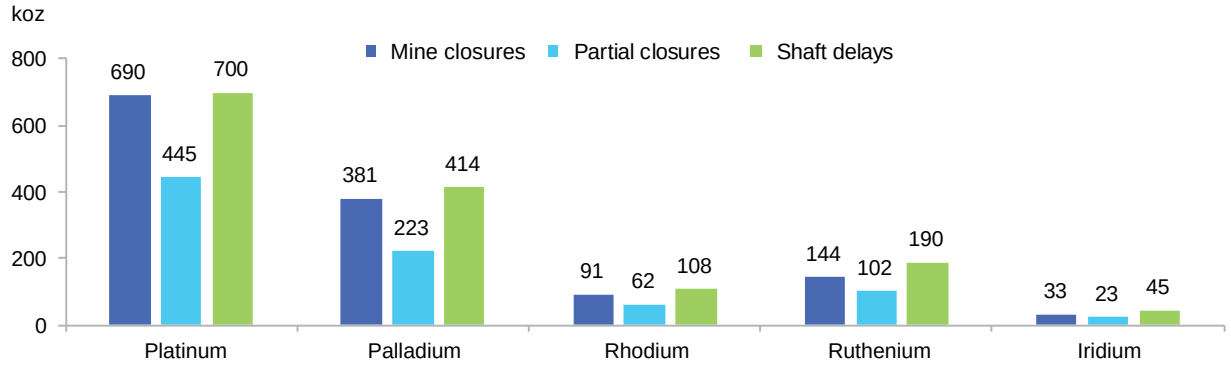
Source: SFA (Oxford). Note: Percentages based on tonnes milled.

Since the rhodium price collapsed from a peak of more than $10,000/oz in June 2008 to <$2,000/oz in 2011, and subsequently to $693/oz in 2016, there have been several PGM mine closures in South Africa as well as projects mothballed during development, most of which involved UG2-rich mines. The charts below show the extent to which this impacted minor metal production capacity.

As most of these shaft closures occurred in South Africa, the capacity currently closed as a proportion of total supply is significant for the minor metals (43% of Ru, 36% of Ir, 23% of Rh). Palladium supply is much more diverse than the other PGMs, with recycling also accounting for a high portion of supply. Consequently, closed capacity accounts for only 10% of total palladium supply in 2019.

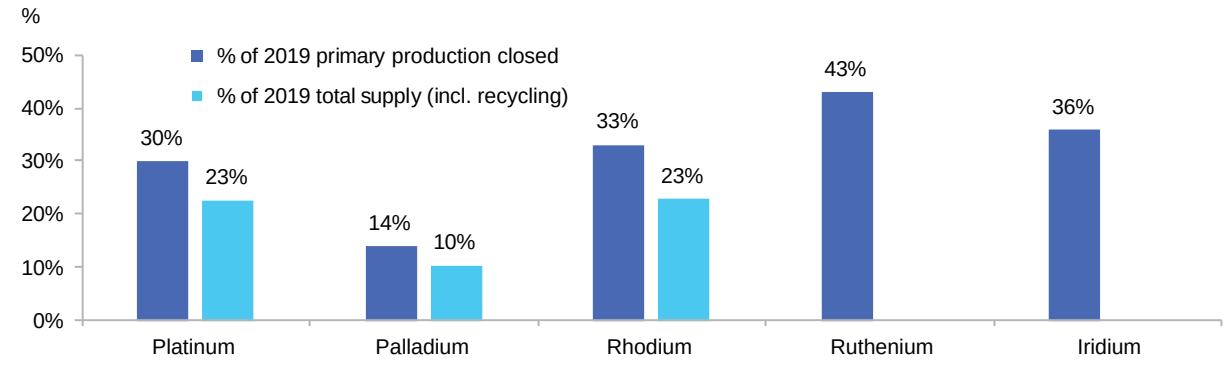
Mothballed UG2 mining capacity and projects represents a significant resource of minor metals for the future

Mothballed, existing and future PGM mining capacity since 2009



Source: SFA (Oxford)

Mothballed, existing and future PGM mining capacity since 2009

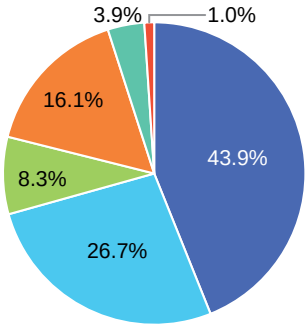


Source: SFA (Oxford). Note: Ruthenium and iridium recycling is not quantifiedd but is believed to represent very small volumes at present.

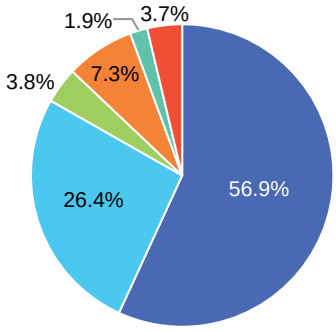
On average, the UG2 Reef contains the highest proportion of rhodium at 8.3% of a 6E PGM share (Pt, Pd, Rh, Ru, Ir, Au) versus 3.8% for Merensky and 2.9% for Platreef. The UG2 Reef also contains by far the highest proportion of ruthenium and iridium, with an average of 16.1% and 3.9% respectively. Platreef and the Massive Sulphide Zone (MSZ) in Zimbabwe contain the highest proportion of gold, 6.4% and 7.2% respectively, while Norilsk (74.0%) and Stillwater (76.5%) are heavily weighted towards palladium. In addition, Norilsk is a primary base metal producer, so has much higher base metal grades than the other PGM orebodies.

UG2 contains the highest proportion of minor metals in the basket

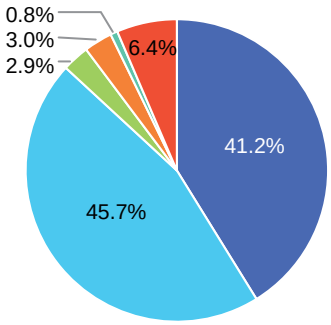
UG2 orebody 6E prill split



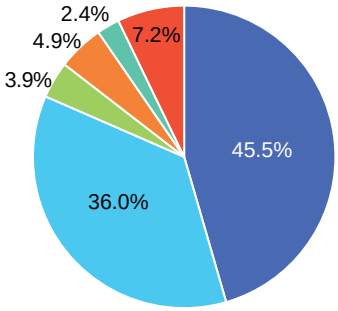
Merensky orebody 6E prill split



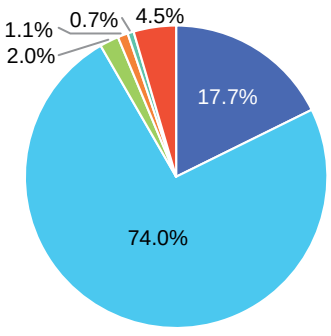
Platreef orebody 6E prill split



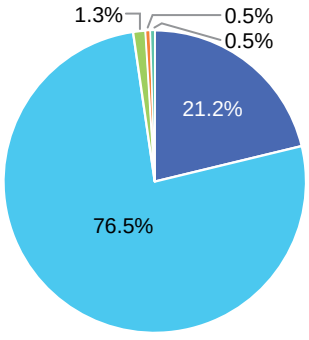
MSZ orebody 6E prill split



Russian 6E prill split



US 6E prill split



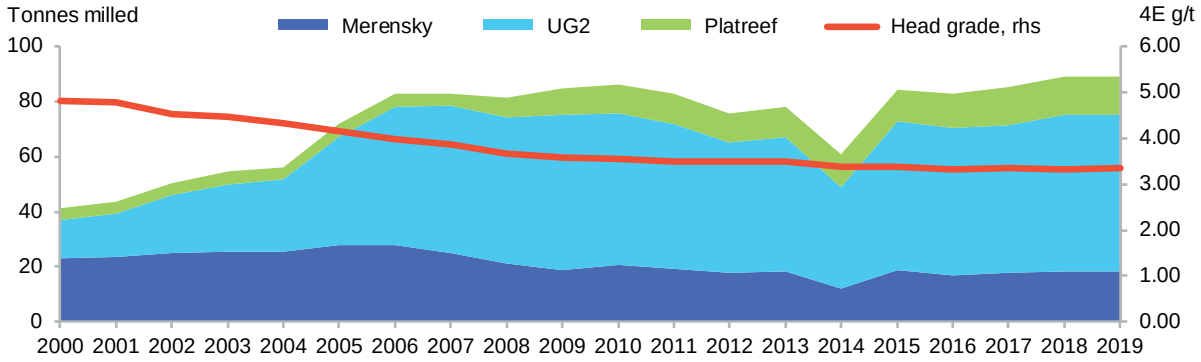
Platinum Palladium Rhodium Ruthenium Iridium Gold

Source: SFA (Oxford). Note: Numbers may not sum due to rounding.

Unlike the Merensky Reef and the wide Platreef, the UG2 Reef has a PGM grade distribution that is typically bottom-loaded, so narrow reef UG2 miners are forced to extract waste (overbreak), resulting in the dilution of head grade. As such, UG2 head grades are lower than most other PGM orebodies. Therefore, as the volume of UG2 output increased, the weighted average South African head grade declined from 4.80 4E g/t in 2000 to 3.50 4E g/t in 2013. By 2019, the average head grade in South Africa was 3.35 4E g/t.

UG2 head grades are typically lower than Merensky and Platreef

South African PGM mine production



Source: SFA (Oxford)

The disadvantage for the UG2 Reef is compounded by the relative lack of base metal by-products (nickel and copper) compared to the Merensky Reef and Platreef, which means that UG2 miners require a higher PGM basket price to mine economically. This is the reason that so much UG2 capacity was closed following the price crash in 2009. However, with rhodium now trading in excess of $10,000/oz, numerous mines and UG2 sections within mine lease areas have become economically viable.

High rhodium prices improved UG2 mining economics

The charts below compare revenues per tonne milled for the Merensky and UG2 Reefs. These show not only the impact of a lower head grade on revenue per tonne, but also a lack of diversity and the heavy reliance on rhodium (and other minor metals) in the UG2 Reef compared to the Merensky Reef.

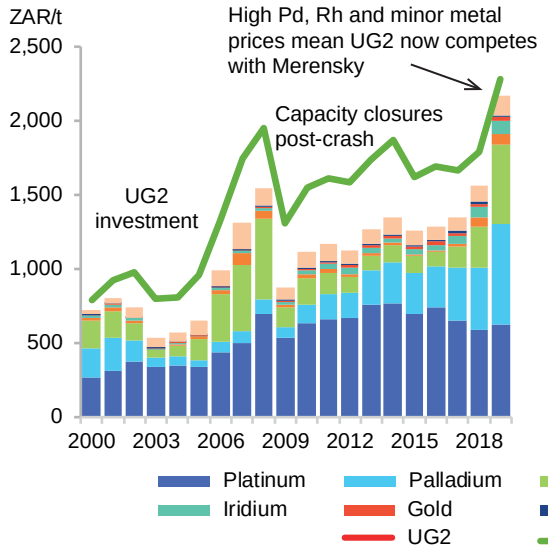
Merensky benefits from superior grade and higher proportion of base metals

In addition, the Merensky Reef contains a much higher proportion of base metals which, looking ahead, are important for the battery materials industry. Many PGM producers have invested in nickel sulphate production to add value to their base metal output and to take advantage of the growth in demand from the emerging electric vehicle market.

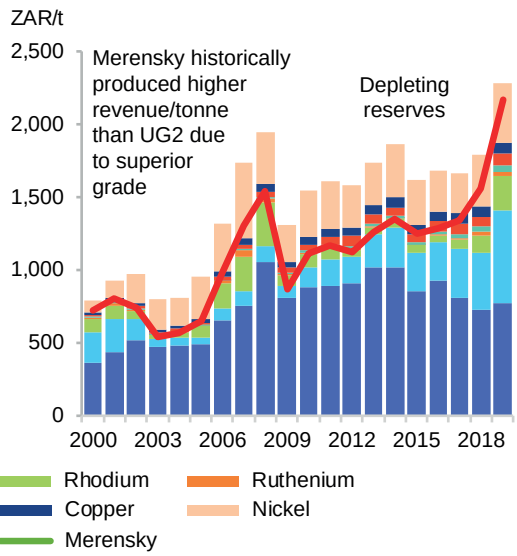
However, Merensky reserves continue to deplete, with shallow reserves almost all exhausted. Mining deeper underground to exploit future Merensky reserves will be costly, with ventilation costs one of the most significant hurdles. In contrast, many mothballed UG2 mines are relatively shallow since historically the Merensky Reef was mined in preference to the UG2 Reef given its superior grade and weighting towards platinum, which until recent years provided the largest source of revenue for South African platinum mines. Consequently, the UG2 Reef is becoming a more attractive investment proposition going forward owing to its significance for minor metal supply.

Mining the Merensky orebody is progressively more costly as shallow reserves are mined out

Merensky revenue per tonne



UG2 revenue per tonne



Source: SFA (Oxford). Note: Chrome is excluded since revenues and recoveries from UG2 tailings are highy variable depending on the contract in place and the technology applied.

Charging up shot holes to advance towards meeting new metal demand

It is now time to shine cap-lamps on the demand for the 'minor metals', ruthenium and iridium. While iridium is a 250-300 koz market, ruthenium, at around 1,000 koz, is on a par with rhodium. Attention has rarely revolved around these metals in the way it does with autocatalyst demand for platinum, palladium and rhodium, or indeed jewellery demand for platinum.

However, as the hydrogen economy becomes increasingly centre stage for governments, companies and society, so iridium and ruthenium (together with platinum) will help to catalyse the low carbon future and avert global warming. The use of iridium in some electrolysers and ruthenium in some fuel cells represents entirely new markets for these metals. Of course, loadings are still high at the moment, but there are extensive R&D efforts underway to thrift the metal content, from modifying the porosity of the substrate to improving the dispersion of the metal particles.

The hydrogen economy will drive new demand for iridium and ruthenium

The long-term growth in demand for platinum in electrolysers and fuel cells will, to some extent, offset the decline in demand from autocatalysts. Fuel cells are already building a head of steam in the rail industry and making waves in the maritime sector, thereby adding demand for platinum, ruthenium and iridium in markets with no substantial previous PGM footprint. In addition, Anglo American Platinum is working to develop an FCEV mining haul truck as part of its FutureSmart Mining™ initiative. The vehicle will be the largest hydrogen-powered mine truck to date.

These are completely new markets for ruthenium and iridium form an exciting part of the supply and demand map going forward. Designing for recyclability of the PGMs is also key to the sustainability of these technologies.

A platinum-ruthenium catalyst is used in a fuel cell to generate electricity

Hydrogen used in a fuel cell is used to generate electricity via a chemical reaction between hydrogen and oxygen, which is then used to power the motor of a fuel cell electric vehicle (FCEV). In addition to road transportation, PGM-based fuel cells are also utilised in the production of stationary power.

Platinum (with ruthenium) is used as a catalyst for the reactions that take place, with an estimated 30-60 g of PGM per FCEV. This is approximately ten times more than traditional autocatalysts for internal combustion engines which use between 3 g and 7 g of PGM. Fuel cell uptake not only represents a potentially large demand for PGMs but also holds significant environmental potential. Using hydrogen as a form of energy can reduce dependency on fossil fuels and also benefit the environment by reducing emissions of greenhouse gases and pollutants.

FCEVs contain 10x more PGMs than internal combustion engine vehicles with an autocatalyst

Despite this, several hurdles still remain prior to widespread hydrogen fuel cell technology uptake. These include production costs, energy efficiency and lack of hydrogen fuel infrastructure. Additionally, the sourcing of hydrogen used in the cells governs whether this power source is significantly cleaner than electric alternatives.

Electrolysers are the enabling technology that helps to turn green energy, generated from abundant natural sources such as solar or wind, into storable and convenient green hydrogen fuel. Hydrogen generated in this way, via electrolysis of water, has no carbon footprint and can be used as a transport fuel and as an industrial process feedstock. Such green hydrogen must be distinguished from the vast bulk of hydrogen currently available, which is produced via processes involving fossil fuels, so with a substantial carbon footprint. These incumbent technologies are efficient and scaled, so currently compete favourably on cost grounds with newer green hydrogen.

Green hydrogen generated by the electrolysis of water using natural sources of power has no carbon footprint

Several practical electrolyser technologies have been developed over many decades, not all of which make use of PGMs, though the PGM-based technologies appear to be in the ascendancy. It is too soon to pick winners, and a strongly growing market offers opportunities for several approaches, often with a regional flavour and linked with other established industrial operations.

Environmental potential of hydrogen is a mining offset supporting investment

PGMs result in a significantly net-positive environmental impact. Annual total global production of platinum, palladium, rhodium, ruthenium, iridium and osmium is roughly 500 t. Forty per cent of PGM demand is derived from autocatalysts, with the average gasoline light-duty autocatalyst containing between 3 g and 7 g of PGMs.

PGM mining has a net-positive environmental impact owing to the use of PGMs in reducing emissions

A typical autocatalyst contains 72% primary PGMs and 28% recycled PGMs. An average 5 g of PGMs per autocatalyst will result in emissions of roughly 164 kg CO_2e and 1.26 kg SO_2 during production, according to the International Platinum Group Metals Association (IPA).

All autocatalysts result in a net total reduction in pollutant emissions, accounting for the emissions resulting from their production. For all investigated Euro 5 systems, the break-even point for emissions of CO, hydrocarbons, NO_x and particulate matter is reached after, at most, 40,000 km of driving (Source: IPA). This is the point at which the emissions created during production are offset by vehicle emission reductions.

Quantifying the long-term positive effects of PGM usage, not only in autocatalysts but also in industrial processes, medical uses and electronics, results in significant upside to PGM extraction. Increasing levels of recycling are also seeing a reduction in the environmental costs of end-use PGM implementation.

Safe, reliable mine production sequenced for the green-powered investor

Environmental, social and governance (ESG) criteria are used to assess organisations and institutions on their ethical and sustainability practices. In recent years, ESG-compatible investment vehicles have been gathering traction amongst investors of all types as public awareness of the social and environmental influences of companies grows.

ESG investment vehicles attracting attention as public awareness grows

Understanding and mitigating regulatory, political and stakeholder issues is key to longevity in the natural resource sector, and the pressures surrounding these factors are set to increase over the coming years.

Miners are at the forefront of environmental guardianship and so have considerable power to govern global environmental trajectories. In the face of growing public awareness of the impact of climate change and other environmental challenges, companies have moved to quantify their ecological externalities in an effort to increase transparency and accountability. Monitoring of greenhouse gas emissions, pollutants, tailings generation and storage, as well as water usage has led to accountability and driven innovation, as more efficient processes help compliance with industry emission standards. ESG investments are a broad category of funds which adhere to one or more of the following criteria:

Mining companies at the forefront of quantifying and reducing impacts on the environment

- Exclusionary – excludes certain companies or industries.
- Best in class – top ESG performers relative to peers.
- Green industry – green technology and sustainability-focused initiatives.
- Impact investing – investments in companies that aim to tackle specific social or environmental challenges.
- Norms-based screening – inclusion based on minimum thresholds set by organisations such as the OECD, UN, UNICEF and ILO.
- ESG integration – ESG incorporation into the financial analyses of investments.
- Corporate engagement – corporate management guided by comprehensive ESG guidelines.

ESG non-compliance results in exclusion from fast-growing sustainable funds. Sustainably managed assets represent more than 50% of total professionally managed assets in Canada, Australia and New Zealand, nearly half in Europe, 26% in the United States and 18% in Japan. Sustainable investing represents a major and fast-growing market share, with all major regions consistently showing an increase in the amount of sustainably managed investment assets year-on-year, in both absolute and relative terms.

Companies can be excluded by funds due to non-compliance with ESG

Global value of ESG-managed assets

Region	ESG-managed assets (2016) US$ (trillion)	ESG-managed assets (2018) US$ (trillion)	% change
Europe	12.0	14.1	+17%
United States	8.7	12.0	+38%
Canada	1.1	1.7	+56%
Australia/New Zealand	0.5	0.7	+42%
Japan	0.47	2.2	+360%
Total	22.8	30.7	+34%

Source: Global Sustainable Investment Review (2018). Note: Asset valuations expressed in trillions of US dollars, exchange rates for different regions are accurate to their respective years.

Organisations not compliant with ESG initiatives are likely to see exclusion from major market indices, as pressure from shareholders and public investment habits continue to bolster ESG-compliant funds.

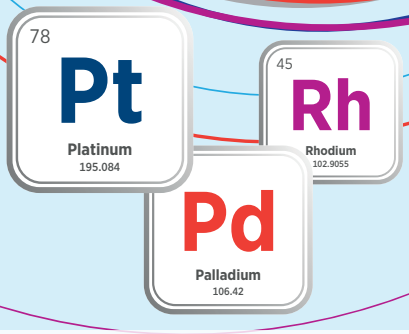
Miners must prove ESG credentials to fuel future minor metal supply

South African UG2 mining has the potential to deliver the minor metals required to fuel the future hydrogen economy, but miners need to prove their ESG credentials in order to secure investment from funds. A completely 'green' mine-to-market value chain, combined with the long-term environmental benefits of transitioning to a hydrogen economy, supports investment and PGMs already provide a hugely net-positive environmental impact via their use in autocatalysts. Therefore, improving ESG compliance and proving those credentials is the next vital step for the PGM industry in South Africa to attract investment from a rapidly emerging class of sustainable investors, with the UG2 Reef, rich in metals crucial for the hydrogen economy, front and centre. If mining companies can achieve this, the future production of minor metals can be secured.

The hydrogen economy supports investment in UG2 mining to secure future production of minor metals if ESG credentials can be proven

Long-term PGM Market Outlook

The changing nature of the PGM market out to 2030



Well-reasoned, value-adding market intelligence on the upstream and downstream chain-linkages of the PGM industry.

For further information or to register your interest for the Long-term PGM Market Outlook report, please contact David Mobbs at **dmobbs@sfa-oxford.com.**

SFA (Oxford)'s Long-Term PGM Market Outlook is an in-depth, forward-looking report on the current and long-term trends and influences acting on the global PGM markets, their sources of supply and demand, and their investment vehicles.

This report examines the changing nature of the PGM market out to 2030. It provides a **long-term sensitivity analysis of demand** with vital information needed to best gauge the impacts in the usage of palladium, platinum, and rhodium as a result of **tightening tailpipe emissions standards**, intra-metal **substitution** trends, shifts in powertrains (advances in electrification of powertrains and pure battery electric vehicles), and **recycling**. It provides an analysis of the changes in and economics of global supply, as well as **long-term production profiles**. Also included is a detailed forecast evaluation of the PGM markets (including metal prices and their influence on the jewellery, industrial, chemical, petroleum and investment sectors) out to 2030.

For companies needing an even longer-term view on the PGM markets and prices, either for strategic requirements or asset valuations, **SFA will be releasing its 2040 market outlook report in October.** Not only does this extend the view on PGM market segments and metal prices for another 10 years, but it also includes **more detail on the drivers affecting these metals over the long term**, for example the acceleration of electric vehicle use and drivers behind it, fuel cell demand light off against security of supply, recycling potential and existing mine reserve depletion, evaluation of project resources for tomorrow's demand, which will all have varying degrees of impact on each PGM. Both are hugely insightful reports depending on your business needs.

The key themes of the September 2020 issue include:

- **Covid-19 influences on supply and demand** and lasting impacts.
- **Latest developments in tailpipe emissions** standards and considerations for PGM use.
- Potential high price induced regional and global **substitution impacts on palladium demand** from using platinum in three-way catalysts.
- **The rhodium dilemma**, where to get rhodium from to meet tomorrow's needs and how might this influence metal prices.
- **Electrification of automobiles**: opportunities and threats for PGMs.
- Consideration of **environmental, social and governance** (ESG) on the platinum industry.
- The latest developments in **the hydrogen economy** and likely near-term outcomes for platinum demand.
- A detailed evaluation of **supply potential from mothballed mines and new projects** worldwide.
- **Project incentive pricing**, evolving supply mixes and end user needs.

THE PGM MARKETS IN 2020

The PGM markets in 2020

Francesca Price and Dr. Ralph Grimble, SFA (Oxford)

The palladium market

Summary

The palladium market deficit is set to narrow this year to around -145 koz, compared to the -670 koz deficit recorded in 2019. Palladium's supply base is geographically diverse and not overly concentrated in South Africa, which has provided some relief to end-users.

The palladium market deficit narrows significantly this year

All demand sectors are seeing lower metal requirements this year as consumer spending slumps (autos) and economic growth stalls (industrial). Since the automotive sector is by far the largest end-user, this results in an estimated 16% drop in total palladium demand to 8.89 moz in 2020. Gross industrial demand is predicted to contract by 12% to 1.49 moz owing to a combination of the still high palladium price continuing to force some thrifting, and lower economic growth reducing the base level of demand.

Demand is down across all sectors

The market tightness for palladium has eased somewhat as lease rates have declined and car sales have weakened. With the market set to be close to balance this year for the first time since 2009, the price is expected to soften but remain high by historical standards.

Mine supply

Global palladium production is forecast to slip by 11% to 6.44 moz this year, owing to the effect of Covid-19 lockdowns on mining operations across the world, although the impact is comparatively less than it is for platinum or rhodium owing to the geographical diversity of supply. Output from Russia, the largest global producer of palladium, has continued largely unaffected owing to the mines' remote locations, although supply is still forecast to slip by 3% to 2.77 moz this year. Nornickel had already planned to conduct necessary work at its Nadezhda smelter in 2020, which will result in a build-up of stock.

South African palladium supply is expected to fall by 24% to 1.94 moz this year as a result of the 21-day lockdown of mining in the country and a phased ramp-up, as well as a reduction in efficiencies post-lockdown due to strict operating procedures. Smelters and refineries were considered to be essential services during the lockdown, and producers were able to refine in-process stocks during the first half of the year, which slightly offset the impact of reduced mine output.

South African supply was seriously impacted by a lockdown

North American supply is predicted to decline by 6% to just under 1.0 moz. Zimbabwe's mines continued to operate throughout the lockdown and yield is forecast to remain at 385 koz.

Recycling

Secondary palladium supply is estimated to drop by 12% to 2.30 moz this year. A combination of Covid-19-related travel restrictions, business closures and reduced consumer spending means that all areas of recycling will be impacted, including autocatalysts and waste electrical and electronic equipment (WEEE).

Recycling is estimated to fall 12% this year

The contraction in refined metal output from autocatalyst recycling now appears to have been less severe than was feared, particularly in the US. In Europe, Q2 was very weak with lockdowns interrupting the scrapping of old vehicles and the collection of catalysts, but activity began to recover from mid-June once the strict lockdowns ended.

Demand

Global demand for palladium is forecast to contract by 16% to 8.89 moz this year – the lowest level since 2010. In the US, consumer sentiment is improving so a continued recovery in new light-vehicle sales is possible in the near term. However, the high number of unemployed people vastly outstrips those in previous recessions, so the risks to consumer spending and auto sales are to the downside.

Global palladium demand to drop 16%

Automotive demand

As light-vehicle sales falter during the pandemic, global autocatalyst demand is predicted to be down by 1.4 moz this year (-16%), with cuts of ~400 koz in the major markets of North America, Western Europe and the RoW as a result of the Covid-19 halt to vehicle production and sales. Remarkably, China is forecast to witness a small rise in demand in 2020 as car sales show a rapid recovery, and three-way catalyst (TWC) loadings increase in line with the continued roll-out of China 6 emissions legislation.

Automotive demand slumps by 1.4 moz

The magnitude of the demand destruction, previous peak to current trough, is similar in both the 2008-2009 financial crisis and the Covid-19 crisis, affecting just under 20% of demand. Palladium usage in light-duty gasoline autocatalysts was, and is likely to be, on a growing trend before and after both of these perturbations, though the previous recovery was quicker than that expected this time as before the financial crisis emerging market gasoline vehicle sales, especially in China, were poised for strong growth. Light-vehicle production is set to fall by more than 15 million units worldwide this year, according to the latest outlook from LMC Automotive.

Industrial demand

Industrial production is recovering after the initial blow from the pandemic but demand is still set to drop by 205 koz (-12%) to 1.49 moz this year, with the ongoing loss from thrifting in microelectronics (-85 koz) and substitution in dentistry. Despite significant expansion of purified terephthalic acid (PTA) capacity in China, chemical demand is also expected to be weakened somewhat (-20 koz) as a result of Covid-19 this year. Price and aesthetic-driven substitution to non-palladium alloys will see dental demand fall by 55 koz (-20%) in 2020.

A high palladium price is driving thrifting and substitution in industrial applications

Regionally, industrial demand for palladium is projected to shrink by double digits in almost every country this year, with the exception of China which will slip just 2% year-on-year. The largest decline is the -16% forecast in North America, where industrial production is being hampered by lower electrical demand caused by price-based thrifting and the adverse economic impact of the pandemic.

Investment

Palladium ETF holdings have continued their declining trend and are down 110 koz year-to-date at 507 koz. The majority of the outflows were in South Africa (-126 koz) and Switzerland (-13 koz), while US (+20 koz) and UK (+7 koz) funds increased slightly. After sales of 195 koz in Q1, holdings have been edging higher since April.

ETF holdings are down to 0.5 moz

The large specs' net long futures position on NYMEX collapsed from over 1 moz to less than 100 koz during the first quarter and it has subsequently moved up to only 300 koz as the price continues to trade broadly sideways at a high level.

The platinum market

The platinum market remains oversupplied by >1 moz

The platinum market is forecast to move into a greater surplus in excess of 1 moz this year (excluding investment) owing to the effects of Covid-19, with platinum demand expected to be the slowest of the PGMs to recover post-pandemic.

A record high for ETF holdings

Platinum is relatively cheap which has attracted renewed interest by investors this year. Platinum ETF holdings reached a record 3.6 moz in August, up 272 koz this year, after slipping close to 3.0 moz in April. Net platinum bar purchases by price-sensitive investors in Japan were over 200 koz in H1'20, the highest volume recorded since H1'16.

Global jewellery demand is projected to drop by 24% year-on-year to 1.60 moz in 2020, led by China where demand is expected to be down by 250 koz compared to last year. A sharp increase in platinum buying was recorded on the Shanghai Gold Exchange in H1, with demand from jewellers climbing modestly. As a result, demand in the second half of the year is likely to be lower as manufacturers draw down stocks. The wide price differential to gold and new designs for jewellery pieces have cautiously renewed interest in platinum, but there is still a great deal of uncertainty as to how quickly consumer confidence will return, and whether it will be maintained.

Autocatalyst demand is estimated to slump by 26% to 2.11 moz this year. All regions are predicted to see heavy demand destruction as a result of the Covid-19 slowdown reducing commercial vehicle sales. In Western Europe, diesel's share of the now smaller passenger car market is still edging lower despite Europe's challenging 2020-2021 CO_2 emissions target.

Industrial use falls less than jewellery or automotive demand

Industrial demand is forecast to be down by 305 koz (-16%) to 1.58 moz in 2020, 335 koz lower than the pre-Covid estimate. Oil refinery closures in Japan and the US this year are set to reduce requirements in the petroleum sector by 125 koz, along with slower capacity growth in the RoW. Meanwhile, the construction of fewer new glass fabrication facilities in Western Europe and the RoW should lessen metal buying in the glass industry (-85 koz) compared to last year. Significantly lower vehicle production is also set to weaken platinum consumption in automotive sensors and plugs, contributing to the decrease in other end-use demand by 70 koz in 2020.

Global primary platinum production is set to contract by 18% this year to 5.05 moz as a result of Covid-19 restrictions on mining operations. The unplanned shutdown of the Anglo Converter Plant earlier in the year will exaggerate South Africa's reduction in supply in 2020 (-24% to 3.39 moz). Output from Russia and North America is forecast to slip by -3% and -7% respectively, while Zimbabwe, where mines were permitted to continue operating throughout the lockdown, could witness modest growth of 2% year-on-year.

Global platinum production predicted to fall 18% in 2020

Secondary supply is expected to dip to 1.71 moz this year, with platinum jewellery recycling forecast to experience the worst decline (-21%) owing to shrinking sales in China and the low price environment, thus reducing customers' resales. Autocatalyst recycling is estimated to fall by 12% to 1.31 moz, although high palladium and rhodium prices will continue to incentivise the flow of material.

The rhodium market

The rhodium market is moving into a deeper deficit of -55 koz this year. With supply impacted more than demand from the effects of Covid-19, the deficit is wider than the -20 koz recorded in 2019. This will continue to provide support for prices in the near term.

The rhodium market deficit is expanding

Covid-19-related supply disruptions in South Africa, the source of 80% of the world's mine supply, have led to an estimated 19% reduction in global mine yield to 635 koz, which is the largest percentage decline forecast of all the PGMs this year. South African production is predicted to slump by 24% to 485 koz. Output from Russia, the world's second-largest producer, Zimbabwe and North America is forecast to be little changed. Secondary rhodium supply is projected to decline by more than 11% this year, with more significant reductions in Europe than in the US owing to the region's more widespread lockdowns.

Cuts to supply have outpaced the fall in demand

As with palladium, rhodium's main end-use is the automotive industry and with vehicle sales forecast to shrink significantly, demand is likely to be hit hard. Autocatalyst demand is projected to drop by 14% to 860 koz in 2020, although it will benefit marginally from tighter emissions standards. Higher rhodium loadings in gasoline TWCs to meet China 6 and RDE standards, and gasoline vehicles' continued high share of the recovering light-vehicle market, are driving rhodium demand in the wake of the pandemic. Higher loadings are expected to lift China's demand even in 2020, when overall consumption falls by 140 koz globally. Similarly, industrial demand is estimated to fall by 18% to 140 koz, mostly owing to weaker economic growth but also to ongoing price-induced substitution and thrifting in the glass industry.

The price outlook for the next six months

Palladium: $1,950/oz

While the palladium market is estimated to remain in deficit this year, it is a much smaller deficit than predicted pre-Covid. Palladium's geographical diversity of supply has reduced the impact somewhat on primary output, although recycling has been cut owing to lockdowns in Europe, in particular, halting the scrapping of old vehicles and collection of autocatalysts. Although catalyst loadings are still increasing, the drop in automotive production has significantly curtailed demand. Industrial demand is being retarded by the high price and the weak economy.

Mine output in South Africa is operating at 80-90% capacity and processing bottlenecks are being overcome which will lift metal availability going into Q4. Market tightness has eased, with lease rates back in single digits, and the futures curve is moving into contango. The price is therefore forecast to average $1,950/oz over the next six months.

Platinum: $900/oz

The fundamental outlook for platinum has not changed to any extent, with the market expected to be significantly oversupplied (ex. investment). Primary and secondary supply are both lower this year but demand has dropped too. Commercial vehicle sales are down and diesel's share of passenger car sales in Western Europe continues to erode. Jewellery sales have slumped owing to lockdowns and weaker consumer spending, and with many countries in recession industrial demand has also fallen.

However, platinum is still relatively cheap. The price discount to gold and palladium has kept investors interested and ETF holdings are at record levels and still climbing. In addition, the price differential to palladium raises the prospect of some substitution of palladium with platinum in gasoline autocatalysts in the US which may also be attacting investors' attention. Investors absorbed the surplus output in 2019 (1.2 moz) and they will need to keep up their purchases in Q4 to repeat that feat in 2020.

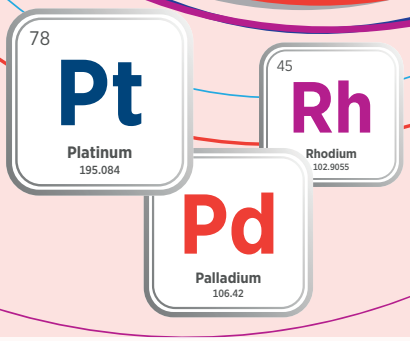
The price has rebounded to a similar level to where it was trading at the start of the year which seems high considering the fundamental outlook, but platinum is clearly receiving support at these levels, so an average of $900/oz is estimated over the next six months.

Rhodium: $9,500/oz

Rhodium supply was impacted more than platinum or palladium by the production cuts in South Africa. The rhodium market deficit is anticipated to increase slightly as supply was more impacted by the lockdowns than demand. The drop in auto sales has cut rhodium demand but the increase in loadings is providing some support. With South Africa's operations closing in on full operating capacity and processing bottlenecks being overcome, metal availability should improve going into Q4 and the price is expected to temporarily reset lower in the near term.

The PGM Radar

Market Outlook Report Q3'20



Stay up-to-date with the PGM market

To order your copy of The PGM Radar Market Outlook Report, please contact David Mobbs at **dmobbs@sfa-oxford.com.**

SFA (Oxford) is a world-renowned authority on platinum-group metals. Our understanding of the dynamics of the PGM industry is unrivalled and we have fostered relationships with the most significant PGM players across the globe, from mine sites to end-users.

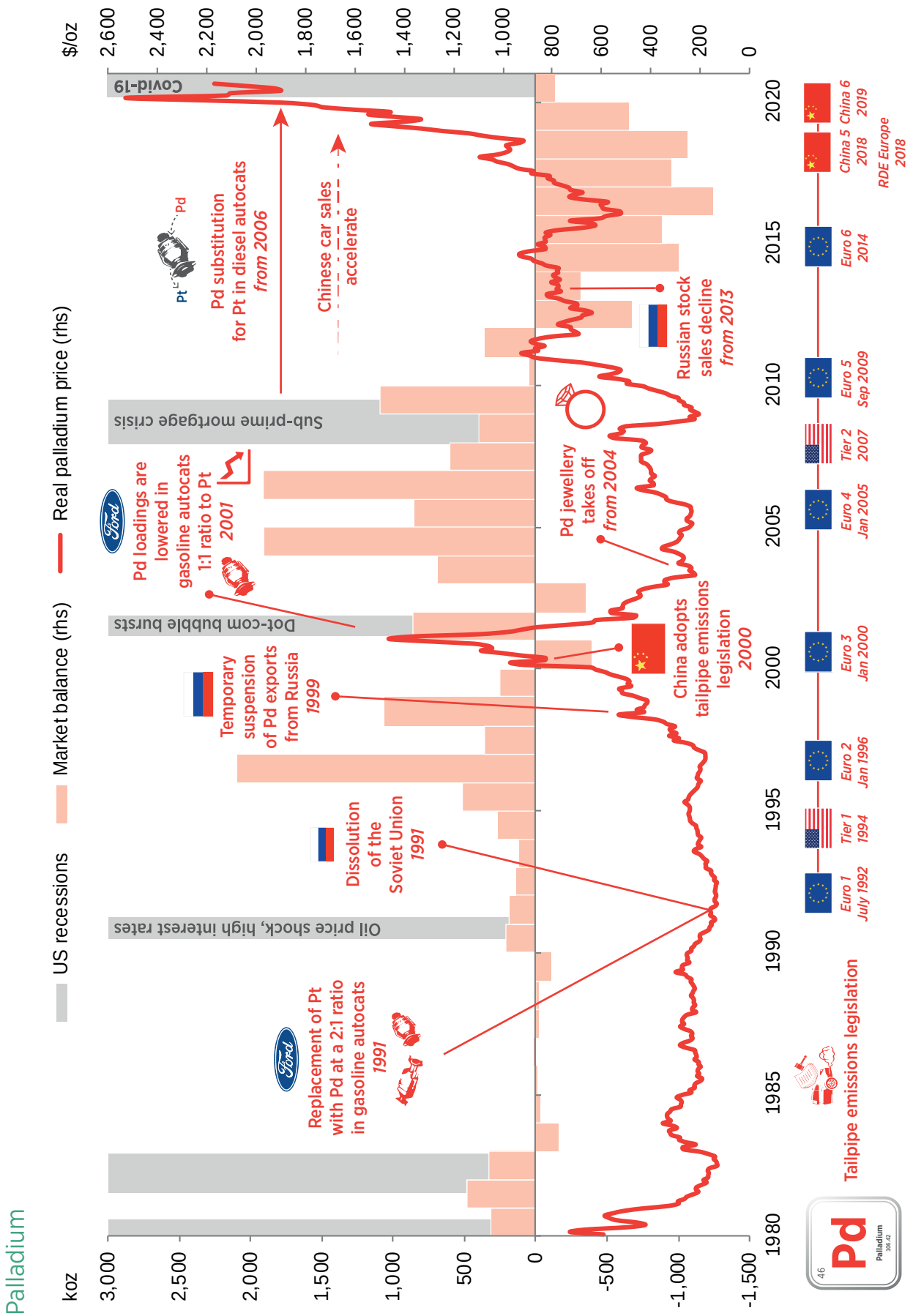
Our unique quarterly PGM Market Outlook report will provide you with SFA's hands-on, forward-looking commentary and analysis on the events and trends currently impacting PGM supply, demand and pricing, and their market implications.

Specific content for each report varies according to market events and demand developments, but is tailored to incorporate the client's specific interests in the PGM industry.

Key report features:

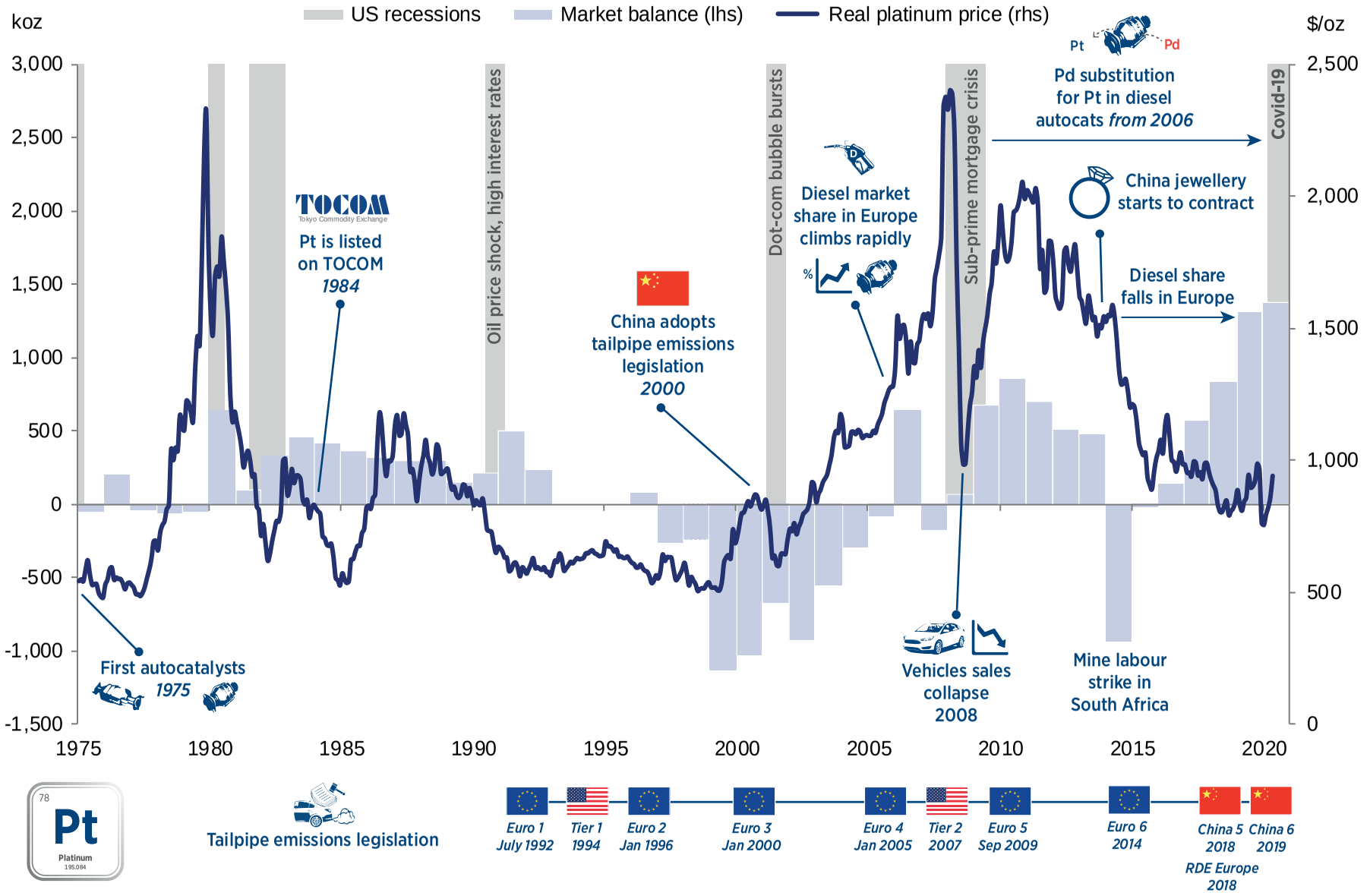
- **Macroeconomic outlook and impact on supply and demand fundamentals and technology.**
- Updates on the **present and future stability and growth of primary PGM supply and demand.**
- Tracking and reporting **relevant processes and technology developments** in the market.
- **Legislative changes in all major regions affecting emissions and environmental issues.**
- Technology shifts and **automotive powertrain developments and their impact on PGM demand.**
- Future evolution and development of **industrial technologies**, both emerging and in decline.
- **Recycling forecast** supported by an extensive database of historical autocatalyst use.
- The social, demographic and marketing aspects of the **platinum jewellery business.**
- Commentary on the **political and socio-economic risks impacting primary supply.**
- Short- and medium-term **metal pricing outlook.**

PGM PRICE HISTORY



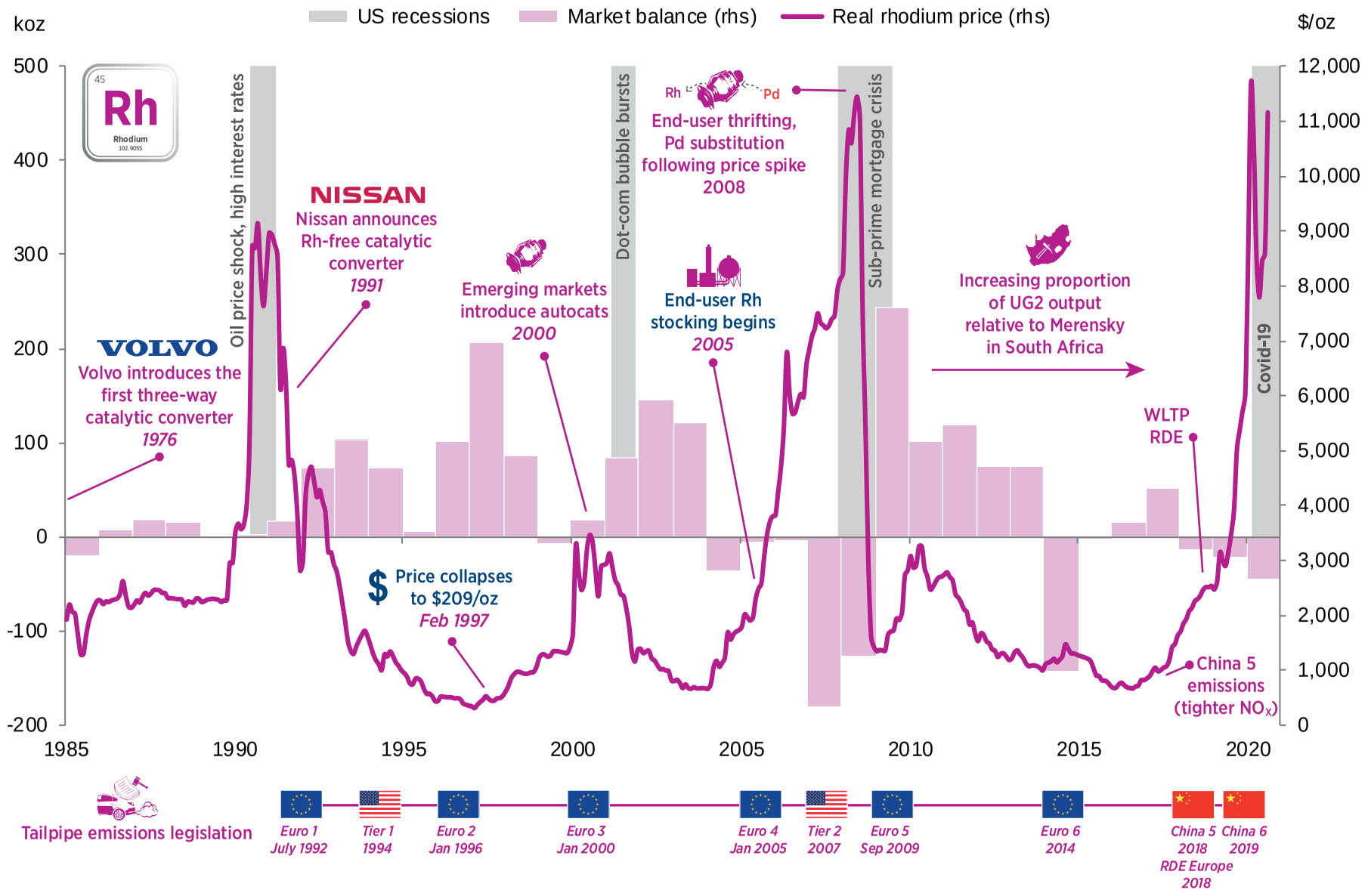
Source: SFA (Oxford), Bloomberg

Platinum

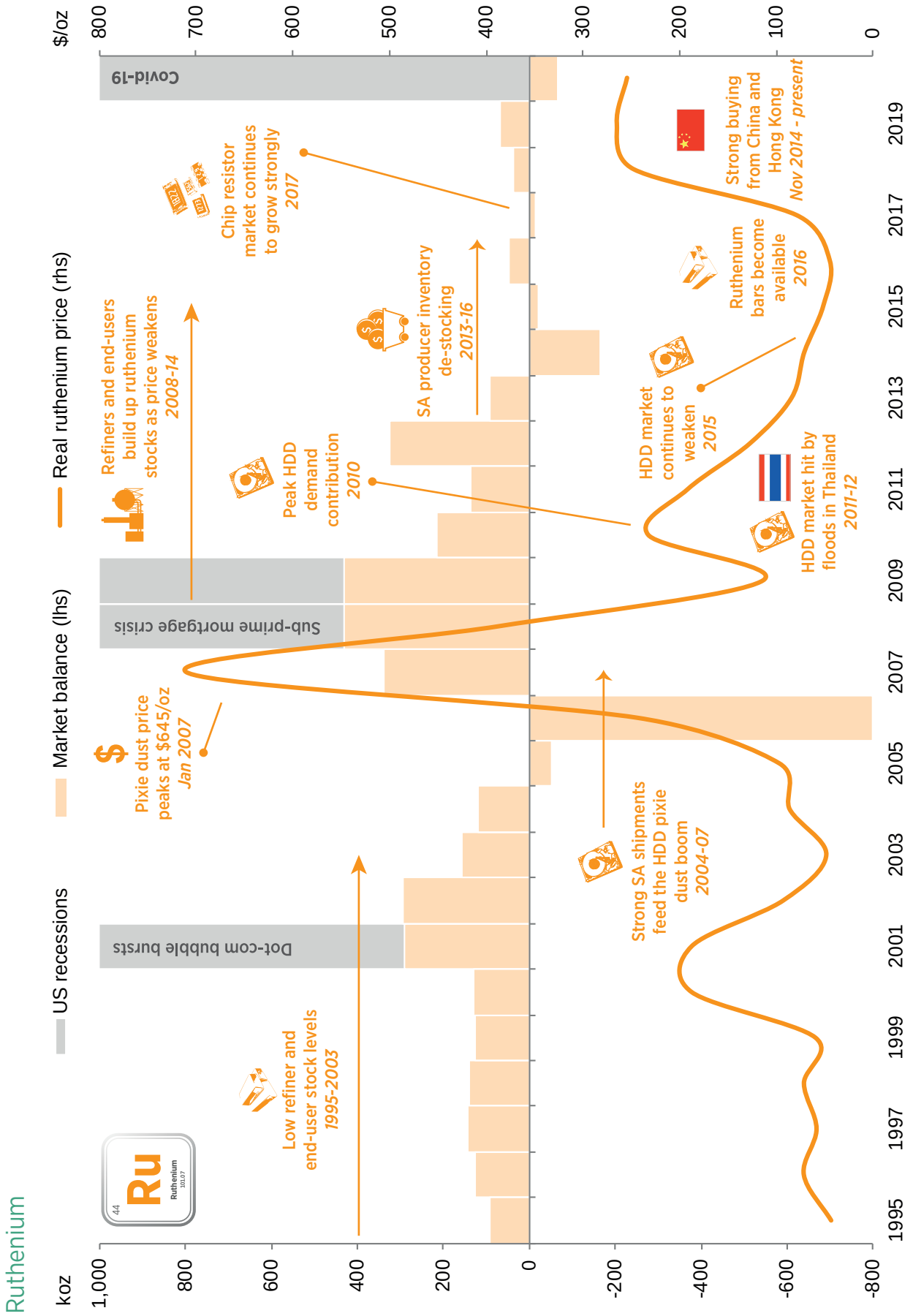


Source: SFA (Oxford), Bloomberg

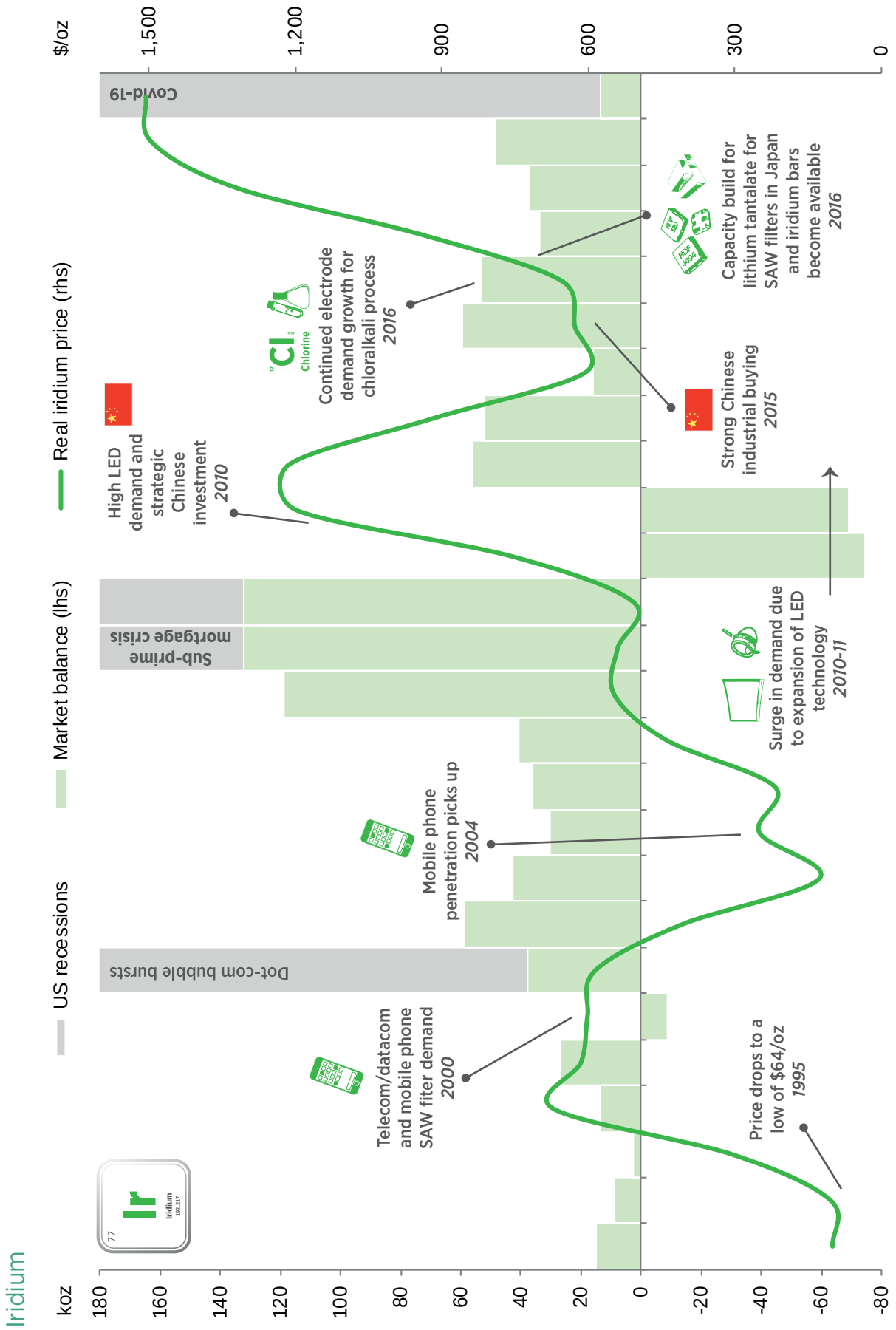
Rhodium



Source: SFA (Oxford), Bloomberg



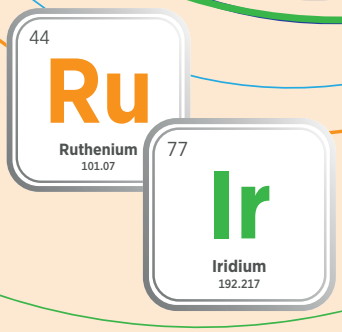
Source: SFA (Oxford), Bloomberg



Source: SFA (Oxford), Bloomberg

The Ruthenium & Iridium Markets

Quarterly Core Analysis Package Q3'20



Stay up-to-date with the market

To order your copy of The Ruthenium and Iridium Quarterly Core Analysis Package, please contact David Mobbs at **dmobbs@sfa-oxford.com.**

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

The Ruthenium and Iridium Quarterly Core Analysis Package looks at the current market and with analysis, charts and commentary provides a watching brief on the evolution of the market.

It utilises SFA's extensive knowledge and expertise in the ruthenium and iridium markets 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.

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

The Quarterly Core Analysis Package is a hands-on examination of events and trends currently impacting the ruthenium and iridium markets.

Key report features:

- Market summary
- Price outlook and drivers to 2024
- Demand trends and stock estimates
- The only S-D market balance available
- Trade flow analysis
- Supply challenges and mine economics

The **latest quarterly report** includes commentary and analysis on:

- Post-pandemic **recessionary risks to demand recovery**
- **Technology developments** in business and consumer electronics sustaining markets for Ru and Ir
- Impact of **supply disruptions** in South Africa during 2020 on output
- How **changes to the geology mined** in South Africa will affect Ir and Ru supply

APPENDIX

Palladium supply-demand balance

koz	2012	2013	2014	2015	2016	2017	2018	2019	2020f
Primary supply									
Regional									
South Africa	2,355	2,360	1,870	2,560	2,370	2,530	2,505	2,565	1,940
Russia	2,630	2,580	2,690	2,605	2,555	2,740	2,670	2,870	2,775
Zimbabwe	280	315	330	325	395	395	380	385	385
North America	895	975	1,055	995	1,065	985	1,035	1,050	985
Other	445	450	460	455	420	415	395	395	360
Total	**6,605**	**6,680**	**6,405**	**6,940**	**6,805**	**7,065**	**6,985**	**7,265**	**6,445**
Demand & recycling									
Autocatalyst									
Gross demand	6,660	7,110	7,475	7,745	8,085	8,330	8,530	8,625	7,225
Recycling	1,485	1,645	1,720	1,610	1,710	1,920	2,040	2,170	1,900
Net demand	5,175	5,465	5,755	6,135	6,375	6,410	6,490	6,455	5,325
Jewellery									
Gross demand	545	350	295	240	240	225	220	215	170
Recycling	130	145	120	80	80	70	60	55	50
Net demand	415	205	175	160	160	155	160	160	120
Industrial demand	**2,325**	**1,990**	**1,915**	**1,945**	**1,905**	**1,830**	**1,775**	**1,695**	**1,490**
Other recycling	**375**	**410**	**430**	**435**	**385**	**380**	**375**	**375**	**345**
Gross demand	**9,530**	**9,450**	**9,685**	**9,930**	**10,230**	**10,385**	**10,525**	**10,535**	**8,885**
Recycling	**1,990**	**2,200**	**2,270**	**2,125**	**2,175**	**2,370**	**2,475**	**2,600**	**2,295**
Net demand	**7,540**	**7,250**	**7,415**	**7,805**	**8,055**	**8,015**	**8,050**	**7,935**	**6,590**
Market balance									
Balance (before ETFs)	-935	-570	-1,010	-865	-1,250	-950	-1,065	-670	-145
ETFs (stock allocation)	295	-5	930	-665	-640	-375	-560	-90	
Balance after ETFs	**-1,230**	**-565**	**-1,940**	**-200**	**-610**	**-575**	**-505**	**-580**	

Source: SFA (Oxford)

Palladium demand and recycling summary

koz	2012	2013	2014	2015	2016	2017	2018	2019	2020f
Gross demand									
Autocatalyst									
North America	1,745	1,820	1,930	2,035	2,100	2,000	2,000	1,930	1,540
Western Europe	1,440	1,545	1,665	1,730	1,635	1,690	1,740	1,685	1,245
Japan	740	750	740	745	780	805	840	875	735
China	1,305	1,525	1,705	1,745	2,015	2,095	2,085	2,285	2,305
India	155	170	170	185	220	245	265	245	155
RoW	1,275	1,300	1,265	1,305	1,335	1,495	1,600	1,605	1,245
Total	**6,660**	**7,110**	**7,475**	**7,745**	**8,085**	**8,330**	**8,530**	**8,625**	**7,225**
Jewellery									
North America	45	40	35	35	35	35	35	35	30
Western Europe	80	75	60	55	55	55	55	55	40
Japan	95	65	55	50	50	50	50	50	40
China	295	145	120	75	75	60	55	50	40
RoW	30	25	25	25	25	25	25	25	20
Total	**545**	**350**	**295**	**240**	**240**	**225**	**220**	**215**	**170**
Industrial									
North America	480	410	385	400	385	365	335	310	260
Western Europe	335	290	285	290	280	270	255	240	205
Japan	565	415	425	430	405	370	345	310	265
China	405	420	385	395	405	405	415	420	410
RoW	540	455	435	430	430	420	425	415	350
Total	**2,325**	**1,990**	**1,915**	**1,945**	**1,905**	**1,830**	**1,775**	**1,695**	**1,490**
Total gross demand									
North America	2,270	2,270	2,350	2,470	2,520	2,400	2,370	2,275	1,830
Western Europe	1,855	1,910	2,010	2,075	1,970	2,015	2,050	1,980	1,490
Japan	1,400	1,230	1,220	1,225	1,235	1,225	1,235	1,235	1,040
China	2,005	2,090	2,210	2,215	2,495	2,560	2,555	2,755	2,755
RoW	2,000	1,950	1,895	1,945	2,010	2,185	2,315	2,290	1,770
Total	**9,530**	**9,450**	**9,685**	**9,930**	**10,230**	**10,385**	**10,525**	**10,535**	**8,885**
Recycling									
Autocatalyst									
North America	930	1,005	975	895	960	1,060	1,135	1,190	1,060
Western Europe	325	345	365	270	260	305	330	325	280
Japan	125	125	135	125	125	145	180	200	170
China	20	50	60	115	160	165	155	165	150
RoW	85	120	185	205	205	245	240	290	240
Total	**1,485**	**1,645**	**1,720**	**1,610**	**1,710**	**1,920**	**2,040**	**2,170**	**1,900**
Jewellery									
Japan	20	20	20	20	20	20	15	15	15
China	110	125	100	60	60	50	45	40	35
Total	**130**	**145**	**120**	**80**	**80**	**70**	**60**	**55**	**50**
WEEE									
North America	75	75	70	85	70	65	65	65	55
Western Europe	85	90	95	80	70	75	70	70	60
Japan	120	135	145	165	135	120	115	110	100
China	30	40	30	25	35	40	40	45	50
RoW	65	70	90	80	75	80	85	85	80
Total	**375**	**410**	**430**	**435**	**385**	**380**	**375**	**375**	**345**
Total recycling									
North America	1,005	1,080	1,045	980	1,030	1,125	1,200	1,255	1,115
Western Europe	410	435	460	350	330	380	400	395	340
Japan	265	280	300	310	280	285	310	325	285
China	160	215	190	200	255	255	240	250	235
RoW	150	190	275	285	280	325	325	375	320
Total	**1,990**	**2,200**	**2,270**	**2,125**	**2,175**	**2,370**	**2,475**	**2,600**	**2,295**

Source: SFA (Oxford)

Platinum supply-demand balance

koz	2012	2013	2014	2015	2016	2017	2018	2019	2020f
Primary supply									
Regional									
South Africa	4,210	4,345	3,125	4,475	4,250	4,380	4,470	4,430	3,390
Russia	780	740	740	710	715	720	665	710	690
Zimbabwe	365	405	405	405	490	480	465	460	470
North America	345	355	395	365	390	360	345	360	335
Other	180	215	200	200	185	185	180	185	160
Total	**5,880**	**6,060**	**4,865**	**6,155**	**6,030**	**6,125**	**6,125**	**6,145**	**5,045**
Demand & recycling									
Autocatalyst									
Gross demand	3,100	3,135	3,240	3,355	3,430	3,310	3,080	2,850	2,115
Recycling	1,175	1,120	1,250	1,180	1,220	1,325	1,420	1,490	1,305
Net demand	**1,925**	**2,015**	**1,990**	**2,175**	**2,210**	**1,985**	**1,660**	**1,360**	**810**
Jewellery									
Gross demand	2,750	2,945	3,000	2,840	2,505	2,460	2,245	2,095	1,600
Recycling	840	855	775	510	625	560	500	500	395
Net demand	**1,910**	**2,090**	**2,225**	**2,330**	**1,880**	**1,900**	**1,745**	**1,595**	**1,205**
Industrial demand	**1,550**	**1,495**	**1,555**	**1,685**	**1,760**	**1,645**	**1,855**	**1,885**	**1,580**
Fuel cells	**5**	**5**	**25**	**25**	**45**	**50**	**70**	**50**	**60**
Other recycling	**5**	**5**	**5**	**5**	**5**	**10**	**10**	**10**	**10**
Gross demand	**7,405**	**7,580**	**7,820**	**7,905**	**7,740**	**7,465**	**7,250**	**6,880**	**5,355**
Recycling	**2,020**	**1,980**	**2,030**	**1,695**	**1,850**	**1,895**	**1,930**	**2,000**	**1,710**
Net demand	**5,385**	**5,600**	**5,790**	**6,210**	**5,890**	**5,570**	**5,320**	**4,880**	**3,645**
Market balance									
Balance (before ETFs)	495	460	-925	-55	140	555	805	1,265	1,400
ETFs (stock allocation)	245	905	210	-240	-10	100	-240	995	
Balance after ETFs	**250**	**-445**	**-1,135**	**185**	**150**	**455**	**1,045**	**270**	

Source: SFA (Oxford)

Platinum demand and recycling summary

koz	2012	2013	2014	2015	2016	2017	2018	2019	2020f
Gross demand									
Autocatalyst									
North America	425	425	465	500	455	420	425	430	290
Western Europe	1,315	1,350	1,395	1,555	1,705	1,560	1,295	1,120	795
Japan	600	585	585	510	450	440	430	410	325
China	115	130	125	125	160	190	180	200	210
India	200	165	170	180	170	175	195	150	85
RoW	445	480	500	485	490	525	555	540	410
Total	**3,100**	**3,135**	**3,240**	**3,355**	**3,430**	**3,310**	**3,080**	**2,850**	**2,115**

Platinum demand and recycling summary (continued)

koz	2012	2013	2014	2015	2016	2017	2018	2019	2020f
Gross demand									
Jewellery									
North America	185	200	230	250	265	280	280	275	230
Western Europe	175	220	220	235	240	250	255	260	200
Japan	325	335	335	340	335	340	345	330	270
China	1,915	1,990	1,975	1,765	1,450	1,340	1,095	945	695
India	95	140	175	180	145	175	195	210	145
RoW	55	60	65	70	70	75	75	75	60
Total	**2,750**	**2,945**	**3,000**	**2,840**	**2,505**	**2,460**	**2,245**	**2,095**	**1,600**
Industrial									
North America	320	320	315	245	380	330	335	285	235
Western Europe	260	190	235	290	265	265	305	295	240
Japan	90	90	25	85	70	30	90	95	75
China	375	520	450	530	585	545	485	540	540
RoW	505	375	530	535	460	475	640	670	490
Total	**1,550**	**1,495**	**1,555**	**1,685**	**1,760**	**1,645**	**1,855**	**1,885**	**1,580**
Fuel cells									
North America	0	5	10	5	15	15	15	10	10
Western Europe	5	0	0	0	5	0	0	0	0
Japan	0	0	5	15	20	30	30	15	25
China	0	0	0	0	0	0	5	5	15
RoW	0	0	10	5	5	5	20	20	10
Total	**5**	**5**	**25**	**25**	**45**	**50**	**70**	**50**	**60**
Total gross demand									
North America	930	950	1,020	1,000	1,115	1,045	1,055	1,000	765
Western Europe	1,755	1,760	1,850	2,080	2,215	2,075	1,855	1,675	1,235
Japan	1,015	1,010	950	950	875	840	895	850	695
China	2,405	2,640	2,550	2,420	2,195	2,075	1,765	1,690	1,460
RoW	1,300	1,220	1,450	1,455	1,340	1,430	1,680	1,665	1,200
Total	**7,405**	**7,580**	**7,820**	**7,905**	**7,740**	**7,465**	**7,250**	**6,880**	**5,355**
Recycling									
Autocatalyst									
North America	575	560	560	505	535	585	640	645	570
Western Europe	405	365	465	370	400	440	465	505	435
Japan	115	95	105	95	95	100	110	110	95
China	10	20	30	55	40	40	35	40	35
RoW	70	80	90	155	150	160	170	190	170
Total	**1,175**	**1,120**	**1,250**	**1,180**	**1,220**	**1,325**	**1,420**	**1,490**	**1,305**
Jewellery									
North America	0	0	0	5	5	5	5	5	5
Western Europe	0	0	5	5	5	5	5	5	5
Japan	285	250	235	160	150	160	145	140	110
China	555	600	530	335	460	385	340	340	265
RoW	0	5	5	5	5	5	5	10	10
Total	**840**	**855**	**775**	**510**	**625**	**560**	**500**	**500**	**395**
WEEE	**5**	**5**	**5**	**5**	**5**	**10**	**10**	**10**	**10**
Total recycling									
North America	575	560	560	510	540	590	645	650	575
Western Europe	405	365	470	375	405	445	470	510	440
Japan	400	345	340	255	245	260	255	250	205
China	565	620	560	390	500	430	380	385	305
RoW	75	90	100	165	160	170	180	205	185
Total	**2,020**	**1,980**	**2,030**	**1,695**	**1,850**	**1,895**	**1,930**	**2,000**	**1,710**

Source: SFA (Oxford)

Rhodium supply-demand balance

koz	2012	2013	2014	2015	2016	2017	2018	2019	2020f
Primary supply									
Regional									
South Africa	600	590	430	620	615	635	630	635	485
Russia	75	70	75	70	70	75	75	80	80
Zimbabwe	30	35	35	35	45	45	40	40	40
North America	30	35	30	30	25	25	20	20	20
Other	10	10	10	10	10	10	10	10	10
Total	**745**	**740**	**580**	**765**	**765**	**790**	**775**	**785**	**635**
Demand & recycling									
Autocatalyst									
Gross demand	775	785	845	875	855	880	920	1,000	860
Recycling	235	260	275	260	280	295	335	350	310
Net demand	540	525	570	615	575	585	585	650	550
Industrial demand	**150**	**145**	**160**	**150**	**185**	**165**	**205**	**170**	**140**
Other recycling	**1**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Gross demand	**925**	**930**	**1,005**	**1,025**	**1,040**	**1,045**	**1,125**	**1,170**	**1,000**
Recycling	**235**	**260**	**275**	**260**	**280**	**295**	**335**	**350**	**310**
Net demand	**690**	**670**	**730**	**765**	**760**	**750**	**790**	**820**	**690**
Market balance									
Balance (before ETFs)	55	70	-150	0	5	40	-15	-35	-55
ETFs (stock allocation)	35	50	5	-5	5	-20	-50	-15	
Balance after ETFs	20	20	-155	5	0	60	35	-20	

Source: SFA (Oxford)

Rhodium demand and recycling summary

koz	2012	2013	2014	2015	2016	2017	2018	2019	2020f
Gross demand									
Autocatalyst									
North America	200	220	240	265	260	245	240	225	185
Western Europe	195	200	225	240	205	210	230	290	220
Japan	155	140	140	125	125	125	130	130	105
China	90	95	110	110	130	150	155	185	220
India	20	15	15	15	20	20	20	20	10
RoW	115	115	115	120	115	130	145	150	120
Total	**775**	**785**	**845**	**875**	**855**	**880**	**920**	**1,000**	**860**
Industrial									
North America	15	15	15	10	20	15	15	15	15
Western Europe	20	10	15	10	15	15	25	20	15
Japan	45	35	25	30	30	30	30	35	30
China	30	45	50	50	60	50	55	45	40
RoW	40	40	55	50	60	55	80	55	40
Total	**150**	**145**	**160**	**150**	**185**	**165**	**205**	**170**	**140**
Total gross demand									
North America	215	235	255	275	280	260	255	240	200
Western Europe	215	210	240	250	220	225	255	310	235
Japan	200	175	165	155	155	155	160	165	135
China	120	140	160	160	190	200	210	230	260
RoW	175	170	185	185	195	205	245	225	170
Total	**925**	**930**	**1,005**	**1,025**	**1,040**	**1,045**	**1,125**	**1,170**	**1,000**
Recycling									
Autocatalyst									
North America	145	165	160	150	160	165	180	190	165
Western Europe	60	55	60	45	50	55	60	60	55
Japan	25	25	30	30	35	35	45	45	40
China	0	5	5	10	5	5	5	5	5
RoW	5	10	20	25	30	35	45	50	45
Total	**235**	**260**	**275**	**260**	**280**	**295**	**335**	**350**	**310**

Source: SFA (Oxford)

GLOSSARY OF TERMS

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

BEV
Battery electric vehicle.

CO_2
Carbon dioxide.

Covid-19
An infectious disease caused by a newly discovered coronavirus.

ESG
Environmental, social, governance.

ETF
Exchange-traded fund.

FCEV
Fuel cell electric vehicle.

GDP
Gross domestic product.

Gross demand
A measure of intensity of use.

HDD
Hard disk drive.

ICE
Internal combustion engine.

ILO
International Labour Organization.

Integrated Resource Plan
An electricity infrastructure development plan based on least-cost electricity supply and demand balance, taking into account security of supply and the environment

IPA
International Platinum Group Metals Association.

koz
A thousand troy ounces.

LED
Light-emitting diode.

LTIFR
Lost time injury frequency rate.

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

moz
A million troy ounces.

Net demand
A measure of the theoretical requirement for new metal, i.e. net of recycling.

Net supply
Proxy supply of metal surplus to requirements.

NO_x
Nitrous oxides.

NYMEX
New York Mercantile Exchange

OECD
Organisation for Economic Co-operation and Development

oz
Troy ounce.

PGM
Platinum-group metals.

Primary supply
Mine production.

PTA
Purified terephthalic acid.

R&D
Research and development.

RDE
Real driving emissions

Secondary supply
Recycling output.

SO_2
Sulphur dioxide.

Thrifting
Using less metal in order to reduce costs.

TOCOM
Tokyo Commodity Exchange.

TWC
Three-way catalyst.

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.

UN
United Nations.

UNFCC Paris Agreement
An ageement within the United Nations Framework Convention on Climate Change to strengthen the global response to the threat of climate change.

UNICEF
United Nations Children's Fund.

WEEE
Waste electrical and electronic equipment.

4E
Platinum, palladium, rhodium and gold.

Currency symbols

ZAR	South African rand.
$	US dollar.

METHODOLOGY

Primary supply is calculated from actual mine production and excludes the sale of stock in order to provide pure production data. Stock sales are treated separately in SFA's database as movement of stocks. Therefore, state stock sales from Russia are excluded in tabulations.

Gross demand is a measure of intensity of use.

Net demand is a measure of the theoretical requirement for new metal, i.e. net of recycling.

Automotive demand is based on vehicle production data not sales.

ACKNOWLEDGEMENTS

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

In particular, we would like to acknowledge our team:

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

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

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

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

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

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

NOTES

Please note: Some tabulated data may not add up owing to rounding of individual numbers. © Published in September 2020 by SFA (Oxford) Ltd.

SFA (Oxford) Ltd
The Magdalen Centre
Robert Robinson Avenue
The Oxford Science Park
Oxford
OX4 4GA
United Kingdom

Tel: +44 1865 784366
info@sfa-oxford.com
www.sfa-oxford.com