SFA Oxford

THE PLATINUM STANDARD

May 2022

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Issue 17

Designed and typeset by Daniel Croft.

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Thank you

Dear Colleagues,

As I step down from the position of Executive Chairman of SFA (Oxford), the company I founded 20 years ago, and 'hand over the baton' of running the company to Henk de Hoop as the new CEO, I would like to take this opportunity to reflect on the considerable achievements of the 'first leg of the SFA relay'.

There are numerous reasons to be extremely proud of all that I and the SFA team have achieved in just two decades. Over those years, the SFA 'brand' has become internationally recognised as the leading authoritative and trusted voice in the PGM industry.

The seeds of a significant augmentation to SFA's focus were first sown in 2008-9. An established client, Toyota Tsusho (trading/ procurement arm of Toyota Motor Company), had long valued SFA's in-depth methodologies for PGM analysis and approached us to see if this research could be applied to battery materials, initially lithium. BASF, soon after acquiring Engelhard, also asked SFA to use its proficiency to investigate the rare earths, plus indium. In 2018, SFA published the comprehensive, 900-page Future Powertrains report – a deep dive into all aspects of future automobility.

SFA's expertise and diligence in producing in-depth, illuminating and value-adding reports, information and support for our clients across the value chain ensured that we established a broad base of long-standing, loyal clients.

I will be left with many wonderful memories, from establishing the business in my home study to leading SFA to its elevated position as a world-renowned consultancy in the PGM industry. My thoughts will also remain with the sheer brilliance of the SFA analysts and highly skilled associates. In future, I believe SFA will not only be the 'go-to' company in the PGM industry, but also become a leading authority in green energy know-how and consulting.

SFA Oxford

It is with great pleasure that I can reflect on my role as host of the annual Oxford Platinum Lectures which are always attended by the 'great and good' of our industry. We were honoured to have included the King of the Royal Bafokeng Nation among our esteemed delegates.

I will look back with particular pleasure on the extensive international travel to mines and clients that was regrettably interrupted by the pandemic. As in many companies, the pandemic caused disruption, with the majority of the team working from home, but this did not affect the quality and delivery of our work. It was important that despite being geographically separated, we remained as a cohesive unit. It is with pleasure that I can reflect that staff retention has been high – goodwill is paramount.

Thank you to our shareholder, Sibanye-Stillwater, for allowing me to continue to steer the SFA (Oxford) ship, guiding, mentoring and encouraging individual team members to develop their skills and performance. I greatly value the achievements of SFA's global recognition, its share-ownership scheme, and the courage in sacrificing financial gains to invest more in battery materials and hydrogen metals' research after I began the journey as a sole shareholder many years ago.

As I look forward to embracing the next chapter of my life and the new horizons and experiences it will bring, there are several aspects that I will miss – especially the team, our shareholder, and our clients. I have enjoyed the responsibility of being a highly regarded voice in the PGM space and an ambassador for the South African platinum industry, able to stimulate discussion and business.

Now that I am no longer at the helm, I am sure Henk will quickly adjust to the loss of my 'compass' and the knowledge and wisdom that was built up over 42 years in the PGM industry, particularly in keeping abreast of current events and attuned to business and market early warnings and whispers.

Finally, and vitally, my unlimited love and thanks to my wife, Elaine, for her continuing support over so many years and for being there in all those moments of challenge and need. I am ever yours and ever grateful.

Farewell to you all, and I wish the SFA team and all our clients the very best for the future.

Best wishes,

TPS COLLECTION: AGENDA-SETTING COMMENTARY

The Platinum Standard was first launched in May 2014

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

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

FOREWORD – NEW BEGINNINGS

Foreword – New beginnings

It never rains, but it pours

After two years of pandemic-related disruption, the world today finds itself confronting many more critical pressures. The Russian invasion of Ukraine, soaring energy costs, ratcheting up of concerns about climate change, meeting commitments to achieve a zero-carbon economy, and growing pressure on industries from institutional investors and governments to improve their ESG credentials, are all present issues capturing our attention. On the horizon are demographic changes which have yet to be felt but are likely to result in deep disturbance of existing socio-economic patterns and, for the worse, PGM demand. Metaphorically, only Biblical Egypt had more plagues than this.

In particular, the war in Ukraine is driving up the prices of commodities and forcing a rethink amongst many nations on the need for materials and energy independence, sharpening their focus on the circularity of materials and on the generation of power without reliance on imported energy. And clean power, at that – perhaps enhancing the chances of meeting the carbon neutrality targets which so many countries agreed at COP26, with the potential spin-off benefits for platinum in producing green hydrogen from renewable electricity and using it in fuel cells.

To overcome these serious challenges will take determination and resilience on the part of governments and industrial companies alike. PGM miners and refiners take their responsibilities towards the environment very seriously, and some of the ways in which the platinum industry is facing up to these challenges are explored in articles within this year's edition of The Platinum Standard.

Emphasis is shifting in PGM supply

On tackling materials issues, Marius Vigener of Heraeus writes in his article 'Best in class recycling expertise in China' about the refinery soon to begin construction near Shanghai in a joint venture with BASF. China is a PGM market out of balance with the rest of the world: its current PGM recycling volume is far lower than elsewhere as a percentage of its PGM use. Yet China is the world's largest vehicle market and thus the fastest-growing source of spent autocatalysts for recycling. This new plant dedicated to secondary refining in China will capture much of this scrap feed, meeting modern environmental requirements while reducing the carbon footprint of the local supply chain. More importantly, and maybe informatively for other nations, it will increase the circularity of PGM supply within China, advancing the country's independence in sourcing these materials.

Alex Mhembere of Zimplats, together with Adelle Coetzee and Tsakani Mthombeni of Implats, pinpoint a change of direction in Southern African PGM mining with opportunities for sustainable, predictable and responsible supply in their article 'Zimplats comes of age'. The focus of growth in PGM production is moving away from the UG2 Reef towards the Northern and South Eastern Limbs of the Bushveld Complex and into Zimbabwe. With this comes a change in the content of the orebodies, leading to significant growth in base metal (nickel and copper) production. Given the continued strength in the prices of these new age metals, Zimplats can expect to offset some of the value lost if PGM demand weakens in future. Also, as the company invests in processing changes to accommodate the new mix of refined products, it has an opportunity to improve energy efficiency and the environmental impact of its supply chain, with plans for significant installation of solar power to supplement existing hydropower at the Zimplats site.

Treading on thin ICE

Finally, Al Bedwell of LMC Automotive takes a look at what might happen to demand for battery electric vehicles as a result of potential supply issues in his article, 'Roadblocks for a zero-emission light-vehicle fleet', identifying a threat to the expected dominance of BEVs which could extend demand for ICE-powered vehicles for longer than we might currently imagine. The total cost of ownership of BEVs is falling as production volumes increase, and although BEVs cost more to buy than ICE vehicles, they are cheaper to maintain and run. If the trend continues, LMC expects electric vehicles of all types to become the dominant light-vehicle transport technology within five years. The outlook for PGM demand as a result is all too obviously negative, but the costs of critical battery cathode metals are rising. The use of cobalt and nickel can be reduced by using alternative combinations of materials, but lithium remains essential for all battery technologies and its supply is not assured. Al provides reasons why supply will likely not be sufficient to meet demand, and he also suggests ways around the problem, including the use of hybrid vehicles with ICE vehicles running on carbon-neutral fuels to reduce fleet carbon emissions, giving PGM catalysts an extra lease of life.

BEST IN CLASS RECYCLING EXPERTISE IN CHINA

Best in class recycling expertise in China

BASF and Heraeus form a joint venture offering world-class precious metal recycling solutions in China

Marius Vigener, Senior Vice President Business Line Chemicals, Heraeus

Autocatalysts are one of the main areas of consumption for platinum-group metals (PGMs), accounting for around 65% of global demand. They convert toxic substances generated by automotive engines into water, CO_2 and nitrogen, thereby improving air quality and reducing harmful polluting gases. The vast majority of passenger cars currently being produced have this type of catalytic converter system.

In view of the increasing number of cars on our roads, demand for autocatalysts is growing. PGMs are used not only in traditional combustion engines but also in hybrid vehicles so, despite expanding electrification, PGM demand remains at a high level. As a result, the recycling of spent autocatalysts becomes even more important. Currently, recycling volumes for spent autocatalysts are 10-15 years behind expected levels and consequently the recycling peak is expected to occur in the second half of the next decade.

The world will not see recycled metal from today's heavily-loaded autocatalysts for a decade at least

Chinese market for recycling with strong growth

China is one of the world's major consumers of PGMs, which are used as emission and process catalysts in major industries such as the electronics, glass, chemical, petrochemical and pharmaceutical sectors. The country is also the largest market for PGMs used in autocatalysts, with more than 21 million newly-registered vehicles in 2021. China, however, has very limited natural PGM resources and consequently relies heavily on imports and recycling.

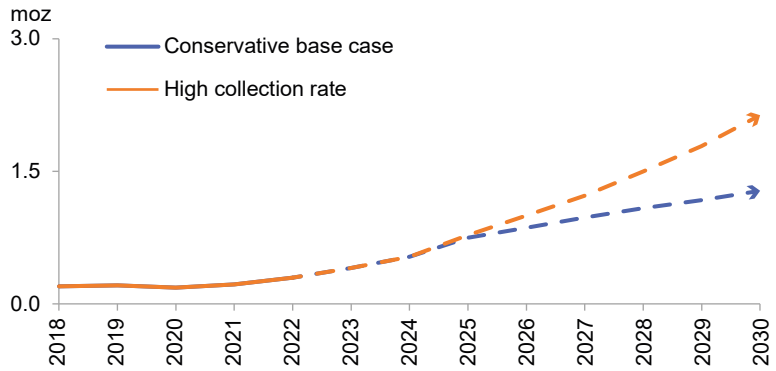
China is the leading market for PGM autocatalyst demand

China is also the fastest-growing market for the recycling of spent autocatalysts. According to SFA (Oxford), secondary PGM supply (recycling) in the country is projected to grow with a compound annual growth rate (CAGR) of 19% over the next 10 years.

Recycling is booming as metal content in scrap autocatalysts explodes

Today, global recycling covers about 29% of worldwide demand for PGMs and the trend is upwards. However, in China, this percentage is much lower, with only 10% of PGM demand being covered by recycling. This is because the Chinese market is not yet mature as local supply chains are still developing and spent automotive catalysts cannot be exported easily.

China's 3E autocatalyst recycling volumes outlook



Source: SFA (Oxford)

Improving collection rates

Recycling scrap materials, such as spent automotive catalytic converters, to recover PGMs enables a circular economy. The recovered precious metals are used to make new products for the automotive, chemical, electronics and green hydrogen industries. Furthermore, recycled metal supply is more environmentally friendly and has up to a 90% lower CO_2 footprint than primary PGM supply from mines. To ensure a local supply of recycled precious metals for China is thus an enabler for a sustainable future.

Recycled supply of precious metals is much less impactful on the environment than mining

New joint venture: BASF Heraeus Metal Resource Co., Ltd.

To recover PGMs from spent autocatalysts, BASF and Heraeus are in the process of forming a 50:50 joint venture (JV) in China. The new company will be named BASF Heraeus Metal Resource Co., Ltd. and is planned to be established southwest of Shanghai, in the city of Pinghu. The capabilities of the two companies are complementary and, with the JV, they are aiming to combine their extensive know-how in the wet chemical recycling business for the Chinese market.

The JV builds on the already strong presence of BASF and Heraeus in China. In Nanjing, Heraeus operates a large PGM recycling facility with a capacity of over 3,000 tonnes. The final recycling step for the JV will be undertaken at that facility and the output can be either fine metal or other products. For BASF, the new company will help to provide the required PGMs for its growing autocatalyst business.

Newly recycled PGMs will feed into BASF's expanding autocatalyst business

The JV allows customers to benefit from access to state-of-the-art technology for the recovery of PGMs from spent automotive catalysts in China. Moreover, the new facility incorporates sustainable and responsible practices and will partially cover its own electricity consumption with the help of photovoltaic installations, so its CO_2 footprint will be reduced and its environmental impact minimised.

BASF and Heraeus customers will be able to tap in to China's spent PGMs

Rendering of BASF and Heraeus joint venture headquarters in China

Source: BASF/Heraeus

With the formation of the JV, the two companies will participate in the fast-growing recycling market in China, thereby strengthening the circular economy. Furthermore, the country will become less dependent on imported PGMs and Chinese customers will gain access to secondary material with a lower carbon footprint.

More domestic recycled supply helps reduce Chinese clients' carbon footprint

"Through the partnership with Heraeus, we will bring best-in-class pyrometallurgy technology for the recovery of PGMs from spent autocatalysts in China and help improve resource utilisation for high-tech and other companies that use precious metals," said Tim Ingle, Senior Vice President, BASF Precious Metal Services and Recycling. "BASF's leading position in autocatalyst recycling and our combined expertise in PGMs will provide customers with a world-class circular economy solution to re-use PGMs in China."

Marius Vigener, Senior Vice President Business Line Chemicals at Heraeus Precious Metals, added: "This JV builds on our already strong presence in China within the wet-chemical recycling industry. Recycled PGMs minimise emissions and will enable our customers to reduce their CO_2 footprint. This will support China in the development of its circular economy and contribute significantly to the stability of local PGM supplies."

By adding to local PGM supply, the joint venture reduces net PGM demand for the world's largest market

Artist's impression of the planned 32,000 square metre facility

Source: BASF/Heraeus

The founding of the JV is planned to take place in Q2'22 following the approval of the relevant authorities, and merger control filing is already in progress. The new facility will cover an area of 32,000 m^2, making it the largest plant of its kind in China. Construction will begin this summer, with completion and the start of operations planned for the end of 2023.

Construction of the facility is to start this summer on what will be the largest plant of its kind in China

ZIMPLATS COMES OF AGE

Zimplats comes of age

Alex Mhembere, Chief Executive Officer, Zimplats

Adelle Coetzee, Group Executive: Metallurgy, Implats

Dr Tsakani Mthombeni, Group Executive: Sustainable Development, Implats

2022 marks the 21st year of Implats' association with Zimplats, its 87%-owned, Australian Stock Exchange-listed subsidiary. Against the backdrop of an often variable and challenging socio-economic landscape, Zimplats has an unrivalled track record of production growth, operational excellence and capital efficiency and is a cornerstone asset for the Implats Group. Increased regulatory certainty, robust economics, and the latent potential of the Zimplats Tier 1 reserve base support Implats' recent commitment to significant further investment in Zimplats' mining, concentrating, smelting, base metal refining and renewable energy capacity.

Implats has initiated a third phase of investment in growth at Zimplats

Harnessing a robust PGM cycle to deliver a more competitive, resilient portfolio

Implats' strategy seeks to leverage, strengthen, and grow its diverse asset base through increased exposure to shallow, mechanisable orebodies. The Group is using the current period of improved profitability to allocate capital to further strengthen and grow the business and, in doing so, secure its future sustainability. Implats expects to invest circa US$3.3 billion (ZAR50 billion at US$1: ZAR15) in its current five-year capital programme on mining and processing assets, across stay-in-business operations and new growth projects, including unapproved capital associated with studies underway.

Southern Africa is the world's largest source of primary PGM supply and Implats' investment in growing production, enabling beneficiation capacity and extended life-of-mine development at several of our operations, will position the region more competitively as a sustainable mine-to-market PGM producer. Sustainable, predictable, and responsible supply is key to providing comfort to current and future end-users of our precious products.

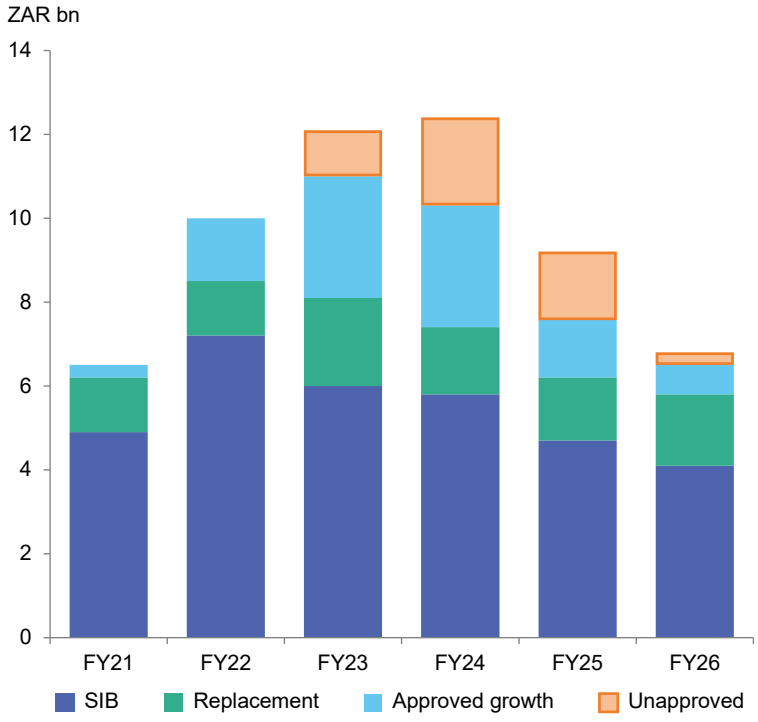
Sustainable, predictable and responsible supply is key to providing comfort to PGM end-users

Implats is advancing mining projects across operations where it has sought to capitalise on inherent mining efficiencies and flexibilities to capture quick-to-market production growth. In 2021, the Group approved and initiated expansion projects at both Zimplats and its joint venture (JV) operation with African Rainbow Minerals at Two Rivers on the Merensky Reef horizon. By 2024, these capital-efficient, brownfield expansions will deliver 260,000 6E ounces of annual production, or an additional circa 10% of mine-to-market production growth for Implats. In addition, life-of-mine extensions have been progressed at each of Impala Canada, Marula, Impala Rustenburg, and Mimosa which, collectively, result in a more sustainable and longer-life production profile.

Additionally, Implats also embarked on a series of studies aimed at delivering efficiency improvements and expansions to its processing capacity, which will accommodate the expected changes in ore mix of the Group's production profile and restore and enhance processing flexibility and optionality. Initial expansions in smelting capacity, the debottlenecking of existing base metal refining capacity and investment in renewable energy supply projects have been approved. Studies to further increase base and precious metal refining capacity and to ramp up renewable energy provision are well advanced and are captured in unapproved spend in the cumulative total.

The evolving ore mix of Implats' production requires investment in fit-for-purpose beneficiation

Implats' five-year capital programme



Source: Impala Platinum. Note: SIB = stay-in-business.

Creating capacity to cater for changing ore feeds and enable sustainable supply of PGMs

Over the recent past, it has become clear that our current installed smelting and base metal refining capacity is insufficient to create optimal processing flexibility and facilitate growth. Rising environmental awareness has also highlighted that certain currently installed technologies are sub-optimal for targeted performance in terms of energy efficiency and emissions.

The accumulation and release of increasing quantities of in-process inventory has become a regular feature of refined output from the Southern African region, and most major integrated producers have announced plans to increase near-term capital spend to address and secure optimal future performance.

Processing bottlenecks have impacted the flow of refined PGMs from South Africa

The past two decades have also seen material changes in the mix of mined ores which generate Southern Africa's PGM production. The base metals (primarily nickel and copper) produced alongside PGMs from each of Merensky, UG2, Dyke Reef and Northern Limb ores differ materially, impacting concentrate grades produced, and, as a consequence, the smelter and base metal capacity required to produce final PGMs.

An initial flurry of South African PGM growth announced in the early-2000s was premised on unlocking the potential of the largely untapped UG2 reserves across assets on both the Western and Eastern Limbs of the Bushveld Complex. These projects were planned to replace some of the existing production generated from depleting Merensky reserves, while also delivering absolute production growth.

Planned processing expansions associated with this 'millennial growth' were 'fit for purpose' and allowed for both increased milling capacity to compensate for lower in-situ grades, and smelter technology that catered for the impact of the chrome content from increased volumes of UG2 ore.

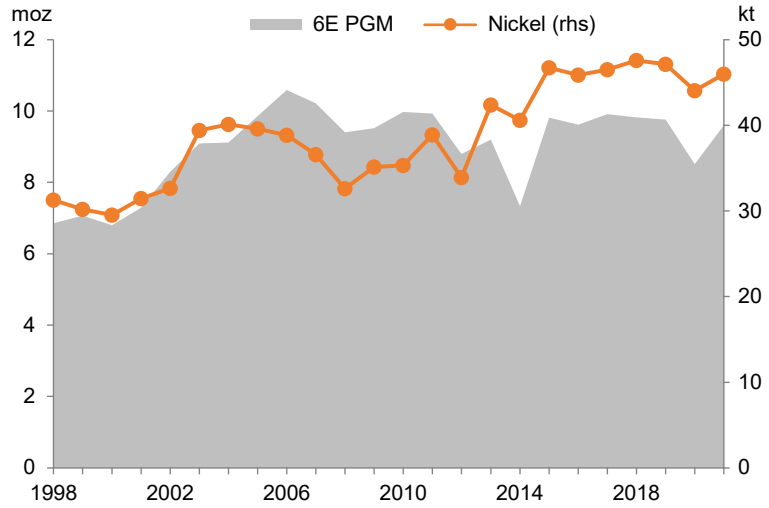
Previous industry investment in processing capacity was premised on rising contributions of chrome-rich, base metal-poor UG2 ore

PGM refining capacity was expanded for the planned growth, but limited changes were made to installed base metal refining capacity given the expected change in ore source to a predominance of UG2 which, while rich in chrome, has low absolute nickel and copper content.

Many of these UG2 replacement and growth projects were curtailed due to a decade of constrained producer margins following the global financial crisis and the rise of secondary scrap production. Instead, the key supply dynamic of Southern African PGM production has been the erosion of Western Limb volumes and the steady rise in production from the Northern and South Eastern Limb and Zimbabwean assets.

UG2 project economics were negatively impacted by low absolute rhodium and palladium pricing following the 2008 financial crash

Southern African 6E PGM output vs. nickel



Source: Impala Platinum

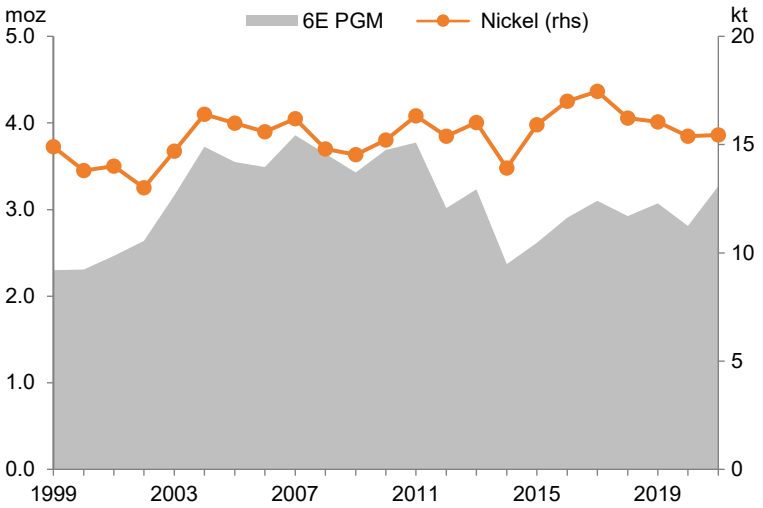
After an initial period of PGM growth outstripping associated base metal volumes, this trend has reversed, and high volumes of nickel- and copper-rich concentrates have reduced the effective capacity of smelting and base metal assets across the industry. This trend is set to continue with the Southern African project pipeline now dominated by approved and unapproved projects targeting Merensky, Northern Limb and Zimbabwean ores. Nickel and copper are universally recognised as 'future-facing metals' and provide a welcome hedge to the potential downside to PGM pricing represented by the anticipated decline in automotive demand from rising electrification of the global auto fleet.

Targeting base metal-rich PGM orebodies provides a natural revenue hedge to the threat of weaker PGM pricing in the face of rising automotive electrification

In a recent research report, analysts at RMB Morgan Stanley estimated that while Southern African PGM production could fall by circa 26% over the next two decades (2022-2042), production of nickel and copper from polymetallic orebodies, which comprise both approved and unapproved projects, could grow by more than 40% over the same period (SA Platinum Group Metals, Booming Base 5 April 2022).

While Southern African PGM production is expected to decline over the next two decades, associated base metal production will rise

Implats' 6E PGM output vs. nickel

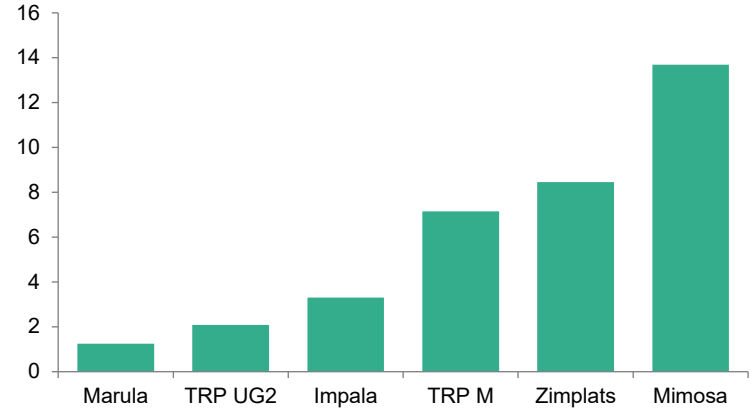


Source: Impala Platinum

At Implats, changes in the quantum and nature of third-party concentrate feeds to our Impala Refining Services (IRS) business, the cessation of a long-term autocatalyst recycling relationship and growth from our Zimbabwean assets have all led to material changes in the ratio of base metals to PGMs produced by the Group over the past two decades. Our planned growth is from assets within our portfolio that have disproportionate ratios of base metals to PGM production and this will compound any processing constraint at Implats in the medium-term.

Zimbabwean mines generate the highest ratio of base metals to PGM production in the Implats portfolio

Ratio of nickel production to PGMs at Implats' operations



Source: Impala Platinum

The ability to process and market Implats' expanding production base is considered a key competitive advantage for the Group. Moreover, the combination of present and future ore feeds and power instability in South Africa has created a constrained operating environment, with a heightened risk of metal-flow interruptions.

In addition, Implats is committed to improving both the energy efficiency and environmental impact of its value chain, and so, over the next five years, will advance the series of projects which create a flexible and robust processing asset suite with an associated reduction in Group smelting risk.

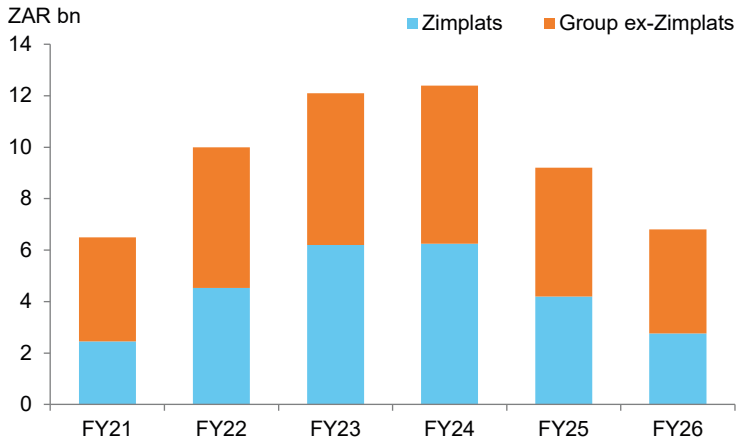
Initial projects to expand smelting capacity and debottleneck existing base metal refining have been approved and are being implemented. Studies to recommission the Zimplats base metal refinery and debottleneck the precious metal refinery circuit are nearing completion. In total, the planned expansions will facilitate a 22% increase in Group smelting capacity and a >80% and >90% increase in nickel and copper refining capacity, respectively.

Planned increases in base metal refining capacity will restore flexibility and efficiency despite expected production growth

Accelerating investment in Zimplats

Implats' planned capital programme marks a step-change in the pace and scope of capital investment in Zimplats, with projects covering mining, beneficiation and renewable energy supply. This is the third material phase of investment in Zimplats and will unlock the next phase of growth from this remarkable asset.

Implats' five-year capital programme



Source: Impala Platinum

A renewed commitment to meaningful investment by Implats in Zimplats

A brief history of Zimplats

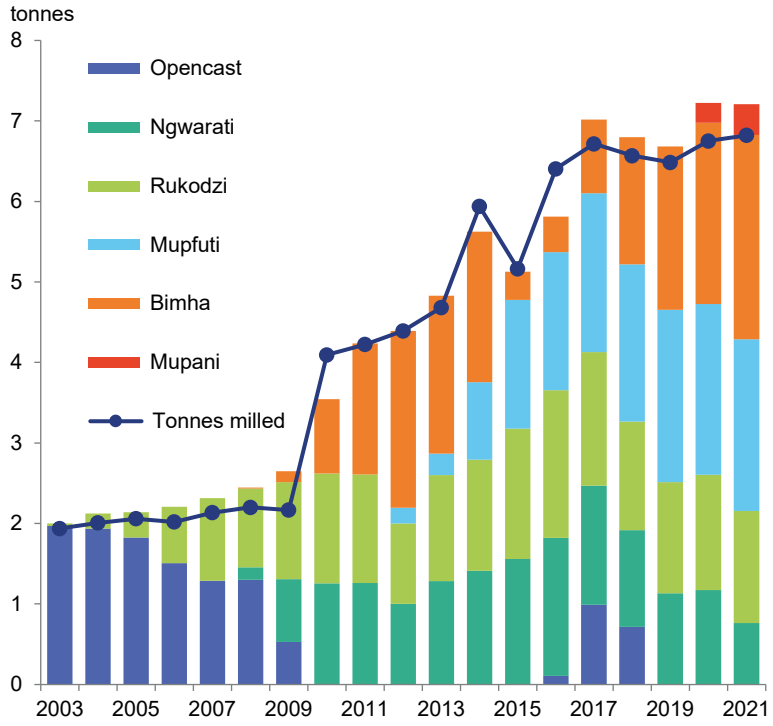
In 1986, Delta Gold Limited (Delta) acquired rights to its first platinum resources on the Great Dyke in Zimbabwe. By 1998, it had extended its cover to include interests in all the platinum resources of the Hartley Complex. Delta brought BHP into a joint venture (66% BHP and 33% Delta) to develop Hartley Platinum Mine and development started in 1994. In 1998, Delta demerged its platinum interests into a special purpose vehicle: Zimplats. By 1999 Hartley had failed to meet its development targets and was put on care and maintenance by BHP. Zimplats subsequently took over BHP's share of Hartley and in 2001 it initiated the Ngezi/SMC project with the assistance of an Implats and ABSA investment.

After a somewhat patchy start...

A 2.2 million tonne per year open pit mine was established at Ngezi and ore was trucked to Selous where it was processed in the Hartley Mine concentrator and smelting facilities. The first converter matte was exported to IRS in South Africa in April 2002. Implats progressively increased its shareholding in Zimplats until 2003, when it made an unconditional cash offer to minority shareholders. Implats currently holds 87% of Zimplats. Zimplats started to develop underground operations at Ngezi in 2003. These replaced the open pit production in 2008 and expanded to the current 6.8 million tonne per year operation with ore sourced from five underground mining complexes.

...Zimplats has gone from strength to strength over the past two decades

Zimplats tonnes mined vs. tonnes milled



Source: Impala Platinum

Mining and beneficiation expansions approved and underway

Project development at Zimplats is focused on harnessing the inherent mining flexibility and optionality offered by the asset by optimising processing capacity and infrastructure, while simultaneously delivering a step-change in the mine's carbon footprint and environmental performance. This will position Zimplats as a large, low-carbon producer of PGMs and base metals, entrenching its position as a premier, low-cost, and capital-efficient asset.

Investment in mining, milling, smelting and emissions control planned at Zimplats

During 2022, processing capacity will be expanded through the construction of a third concentrator plant at Ngezi at a cost of US$94 million. The initial module of increased milling capacity will be commissioned in mid-2022 and will add circa 80,000 ounces 6E to the operation's annual production capacity of circa 580,000 ounces 6E. Further potential upgrades to the new plant could provide a further 100,000 ounces 6E of milling capacity.

Initial concentrator capacity of 80,000 6E oz can be scaled to 180,000 6E oz once mining feeds are decided

The concentrator will be commissioned with a combination of ore stockpile and run-of-mine feed from existing portals, including Mupani. Over a seven-year period, the existing portals at Mupani and Bimha will be expanded to provide feed to the installed processing capacity once Ngwarati, Rukodzi and Mupfuti come to an end of their production lives.

The mining capex associated with this expansion is estimated at US$204 million and will be spent between 2022 and 2028. Concentrates in excess of smelting capacity will be exported for processing at IRS, until the new smelter is commissioned.

Excess concentrates will be exported to IRS ahead of commissioning of increased smelting capacity

Investing to deliver an industry-leading environmental performance

Both South Africa and Zimbabwe face a renewed electricity security crisis. Eskom continues to battle with the unreliability of its ageing fleet, delays in commissioning new coal power plants, and challenges with new plants achieving design capacity. In Zimbabwe, the country's prolonged droughts are affecting water security and hydro-power schemes supplying electricity.

Power security is a key challenge to Southern African PGM production

At Zimplats, 50% of the electricity consumed is currently generated from hydro-power schemes (electricity is approximately 69% of total energy consumed at the operation). The remainder is derived from thermal coal, generated in-country, or imported from Eskom.

Zimplats has finalised a feasibility study to construct a large-scale solar photovoltaic (PV) plant and in January 2022 was granted a generation licence by the authorities in this regard. The 185 MW project will reduce demand on the national power grid, reduce national supply constraints during daytime and has the potential to channel excess power generated to surrounding communities. Board approval has been secured for Phase 1A of the project, with installed capacity of 35 MW, and will enable a 6% reduction in Scope 2 emissions at Zimplats. On completion, the full project scope will reduce 33% of Zimplats' Scope 2 emissions.

Zimplats will invest in solar power to complement its current access to hydropower

Air quality and air emissions are integral to our environmental management activities and permitting processes. At Implats, we strive to minimise the negative impact of our operations on air quality and to keep our atmospheric emissions within legal limits. PGM industry lobbying for more comprehensive air emissions legislation in Zimbabwe continues, but while current air quality regulations prescribe stringent limits for point-source emissions, they do not include ambient air or ground level concentration limits.

Zimplats strives to perform in line with the more comprehensive and progressive South African standards, and to this end, the planned smelter expansion includes the construction of an SO_2 abatement plant to mitigate air quality impacts. Access to hydro-power, supplemented by electricity provided by the phased PV project, will result in an industry-leading environmental footprint for the enlarged Zimbabwean smelting facilities.

Zimplats will achieve industry-leading environmental performance

Promoting sustained, inclusive and sustainable economic growth for Zimbabwe

Implats' commitment to delivering superior value to all stakeholders is premised on ensuring full compliance with the legislative and policy environments in which the Group operates. While the socio-political context in both South Africa and Zimbabwe remains dynamic, in some respects the mining regulatory and policy environments have become more predictable in recent years. In Zimbabwe, we maintain open and constructive engagement with our stakeholders to advance positive and mutually beneficial relationships.

In July 2018, mining lease area and mining tenure issues were resolved, paving the way for open, constructive, and collaborative engagements with the Zimbabwean Government. In February 2021, a joint press statement issued by the Minister of Finance and Economic Development and Minister of Mines and Mining Development, clarified the amendment to the Indigenisation and Empowerment Act and confirmed the removal of the required 51% ownership by an appropriate designated entity. The Government has expressed its intention to focus on empowerment in alignment with its drive to open Zimbabwe for business, and enactment of empowerment related legislation is pending.

Mature, open and constructive engagement with the host Government has enabled increased levels of investment in advancing the PGM industry in Zimbabwe

Our commitment to increased levels of investment and advancement was provided after a period characterised by robust engagement with the Government, which culminated in the signing of a Memorandum of Understanding (MOU) for the duration of the implementation of the Zimplats Expansion Programme, inclusive of mining and beneficiation between 2021 and 2030. This provides for assurances on the ability to manage the substantial foreign exchange considerations associated with our investment commitment, while deferring the implementation of the previously mooted levy on semi-processed PGMs in recognition the Group's plans to advance in-country beneficiation.

ROADBLOCKS FOR A ZERO-EMISSION LIGHT-VEHICLE FLEET

Roadblocks for a zero-emission light-vehicle fleet

As critical EV battery materials and global energy prices hit record highs, is the roadmap to a zero-emission light-vehicle fleet at risk?

Al Bedwell, Director Global Powertrain, LMC Automotive

High battery material and energy prices come at a time when global light-vehicle (LV) electrification demand is growing at an unprecedented rate. By the end of 2022, car buyers around the world will be able to choose from more than 350 battery electric vehicle (BEV) models as original equipment manufacturers (OEMs) increase the pace of transition from combustion to battery.

Disruptions to electrification of the global fleet are worsening...

While the uptake of BEVs varies hugely by market, there are a growing number of countries in which the move from early adopter to early mass-market has already been achieved and at least one where non-BEV buyers could be described as laggards (Norway).

...but popularity of BEVs is still on the rise

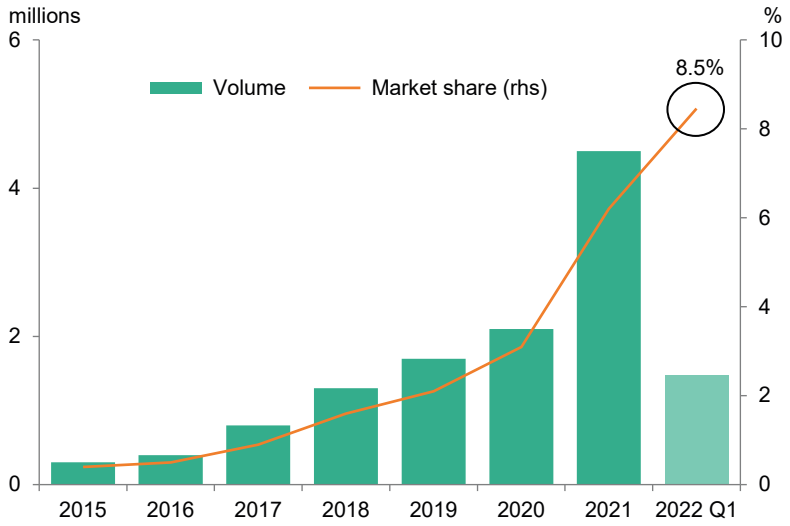
Ultimately, BEV demand is driven by net-zero carbon emission targets to which 130 countries have signed up. Most of those are 2050 commitments which implies the elimination of gasoline and diesel LV sales sometime between 2035 and 2040 in order that all vehicles in use are zero emission by the required date. Some countries, such as China (2060) and India (2070), have longer to stop selling combustion cars but may wish to move faster in any case.

The race towards net zero is on as nations jostle for the closest date

By means of more vehicle choice, BEV incentives, fuel efficiency/ CO_2 targets, and mandated BEV share of sales or production, the shift to electrification is well underway, as the charts below clearly show. From the consumer side, BEV acceptance is correlated to affordability, infrastructure, model choice and, to some degree, environmental awareness.

World electrified private vehicle market

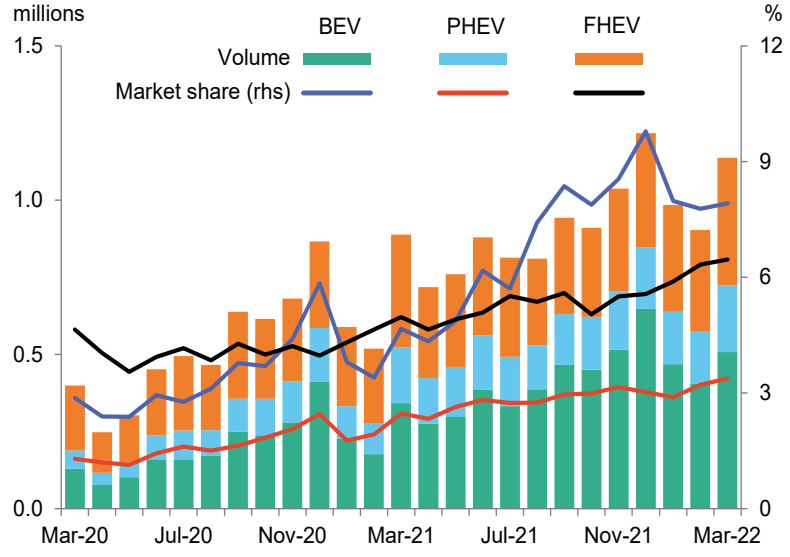
BEV annual view



Source: LMC Automotive Global Hybrid & EV Bulletin

Year-on-year, world passenger vehicle sales were down 5% in Q1, while BEV sales grew 101%*

BEV, PHEV & FHEV markets



Source: LMC Automotive Global Hybrid & EV Bulletin

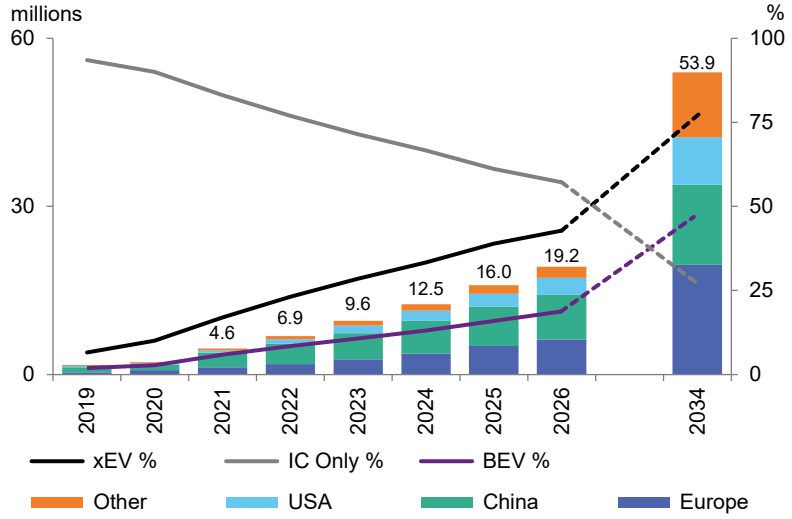
** Including US light trucks.*

LMC's base case forecast indicates that 10% of global passenger cars and US light truck sales this year will be BEVs and that by 2025 this figure will be approaching 20%.

20% of global passenger cars and US light truck sales will be fully battery powered by 2025

Looking further ahead, many mature vehicle markets are successfully putting the building blocks in place to keep the current BEV momentum going and to achieve interim milestones on the route to all-ZEV sales. Uncertainties remain in some of those markets – until early last year US environmental policy didn't offer much support to vehicle de-carbonisation while Japan's dominant OEMs preferred a more gradual shift to ZEVs, favouring hybrids over BEVs. Of the non-mature markets, China is bucking the trend dramatically and, in fact, is leading the global move to BEVs from a volume standpoint.

World LV BEV sales vs. powertrain market share



Source: LMC Automotive. Note: xEV includes BEV.

With this in mind, and seemingly non-negotiable vehicle CO_2 reduction targets in place, our base case BEV forecasts are, for the most part, aligned with country or regional policies. In some cases, markets are moving faster than required by policy and growth has outstripped our expectations. The robust performance and technical lead of Tesla is often instrumental in those cases.

Where BEV sales are outperforming forecasts, Tesla is usually the catalyst

By 2034, our forecast is for around half of global LV sales to be pure electric, with some markets and regions at much higher levels. Adding hybrids to the mix raises the share to around 75%. Europe leads the way with a BEV share in excess of 90% by that time, in advance of the expected EU mandate for 100% ZEV for new LV sales by 2035.

Forecasts are suggesting that decarbonisation and electrification targets will be met

So, with varying speeds but one direction of travel, all *appears* set for the world's LV market to comply with its decarbonisation targets and fully play its part in reducing greenhouse gas emissions.

But there are many risks that could derail the path to a comprehensive battery electric LV fleet. Early in the pure electric journey, it was thought that range anxiety would be a major barrier to adoption. There is less discussion of that topic these days. Compared with the first generation of electric cars, typical electric range has more than doubled and a public fast charger network is being deployed, quite quickly in some areas. It remains far from complete in most countries but for an increasing number of users the viability of a BEV for everyday use has now been proved beyond doubt.

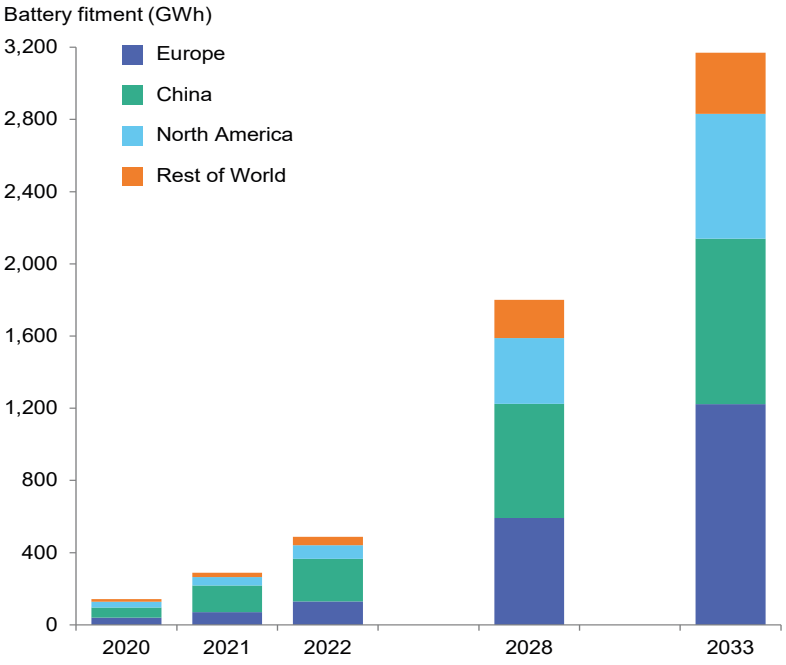
Cost compared to ICE alternatives is one of the most important factors driving EV growth. By 2025, in many markets BEVs should have price parity

Future battery demand will strain raw material supply chain

The other significant barrier to the mass adoption of BEVs is cost versus alternatives – diesel, gasoline, and hybrid cars. The accepted wisdom is that although typically more expensive to acquire (than ICE cars) at the moment, BEV costs would fall over time as production volume increased. In addition, the reduced complexity of BEVs versus ICE cars would result in cost savings, not only in terms of parts but also in assembly times. All this would lead to a point around the middle of this decade when mass-market BEV cost of ownership in many markets around the world would be lower than ICE. All other things being equal, the decision for car buyers to switch to BEVs would then become an easy one to make. At the same time, policy (fiscal and regulatory) would be working away in the background to steer people towards the new technology by making life easier (and cheaper) for those choosing BEVs.

Auto manufacturers' targets have largely been set with little regard for global metal supply

xEV LV battery demand in major markets



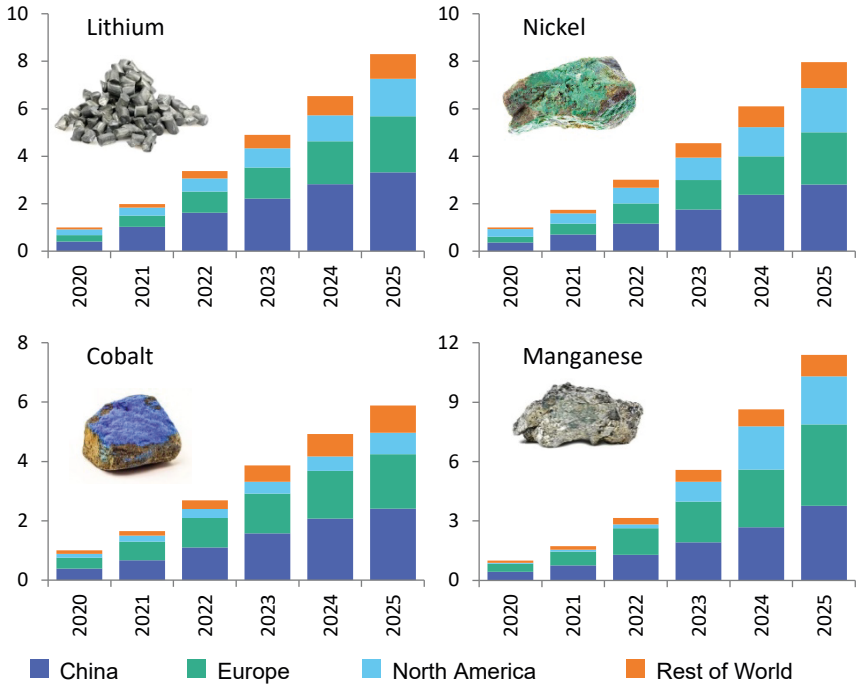
Source: LMC Automotive

But what if that BEV cost reduction curve does not go according to plan? Even before recent events in Ukraine, analysts familiar with the BEV battery materials supply chain were raising concerns that the huge increase in demand for cathode metals implied by the transition to an electric LV fleet would be more than some of the relevant industries could deliver. At the same time OEMs were trying to outdo each other (and calm their investors) by setting increasingly ambitious targets for shifting to 100% ZEV sales as they nervously watched Tesla's sales dominance, technical lead, and market capitalisation increase. In addition, regulation of LV CO_2 emissions and average fuel efficiency (aside from a blip under US President Trump) has moved in one direction only – that of tougher targets.

LMC's base case LV electrification forecast implies that global LV battery energy demand will rise from 290 GWh in 2021 to circa 3,200 GWh by 2033. Some other electrification forecasts, including those of many leading OEMs, are more aggressive than this, implying an even higher battery requirement. Whatever the eventual outcome, the transition of a market that could approach 100 million vehicles in normal times to a completely different technology requires the supply of certain raw and processed materials at a scale never before seen. Lithium is the most obvious example of this. The supply infrastructure of other key battery metals is more mature, but they too will see increases in demand that will put them under strain and result in relentless price pressure.

The charts below give an illustration of how demand for key battery metals for global LV BEV build could evolve out to the middle of this decade, compared with 2020.

Demand growth index for key battery metals (2020 = 1)



Demand for manganese will grow faster than demand for other battery metals

Source: LMC Automotive Global Light Powertrain Forecast

Concerns over adequate supplies of some of these materials have heightened as a result of the conflict in Ukraine. Around 20% of class 1 nickel (required for BEV batteries) comes from Russia and although there are currently no sanctions or export bans preventing its availability, the conflict has resulted in volatile pricing, shunning by some Western buyers and redirection to China. While neither Russia nor Ukraine are major lithium suppliers at the moment, Ukraine is known to have large lithium reserves with both Australian and Chinese lithium firms hoping to exploit these and become large exporters of Ukrainian lithium. Those plans are now on hold for obvious reasons.

The war in Ukraine saw price volatility spike across metals that are key to the automotive industry

Cobalt has historically been the most contentious of the battery materials, not necessarily because of scarcity but because of ethically dubious sourcing. As a result, OEMs and battery cell makers have been steadily moving to thrift or eliminate cobalt from battery chemistries and considerable progress has been made in that pursuit. In the first quarter of 2022, almost half of the cars that Tesla produced were fitted with cobalt-free lithium iron phosphate (LFP) batteries.

OEMs are transitioning away from batteries containing cobalt as consumers become more ESG-aware

Manganese is typically used in low quantities in battery cathodes, as a stabilising element rather than a key cathode metal due to it not being able to compete with nickel in terms of battery energy storage. However, its use could become more widespread with requisite battery energy storage being obtained by making batteries physically bigger. This sounds counter-intuitive as bigger and heavier batteries equate to lower vehicle performance and range, but in the case of manganese it may be a price worth paying for some vehicle categories for the simple reason that manganese is abundant and hasn't seen the price volatility that is a feature of the lithium and nickel markets.

But there is no getting away from the fact that not only have the prices of nickel and lithium reached record levels in recent times but also, especially in the case of lithium, it is almost certain that supply will not be sufficient to meet demand as the shift to BEVs gathers pace during the remainder of this decade. Aside from using more (nickel-free) LFP chemistry or increasing the use of manganese, there may be other ways to mitigate some of the price intensity of nickel for BEV battery cells (for example, by redirecting class 1 nickel from stainless steel use to more lucrative battery use). But the dynamic surrounding lithium is different. It is an essential ingredient of all mainstream BEV battery chemistries and while LFP batteries will help with the cobalt and nickel problems, they typically need more lithium per kWh than nickel manganese cobalt (NMC) chemistries.

No-cobalt batteries are great for green-washing but require even more lithium than the NMC alternative

Estimates of the likely lithium shortfall vary. Anticipated future outputs of both current and planned lithium production projects are open to significant uncertainty, as reported by SFA and others. However, analysis and forecasts typically reveal one message: *everything* has to go right for there to be enough of the right grade of lithium to fulfil the creation of sufficient battery cells to power the transition to an electrified LV fleet. And that's despite the price of lithium carbonate being way above the ~US$10k/tonne threshold that is seen as the point of project viability. Although money talks and lithium carbonate at US$70k/tonne has a very loud voice, we can say with some certainty that not everything will go right for all the lithium projects in the pipeline. A clear example of this is the freezing of the Jadar project in Serbia primarily due to ESG concerns. And the problem is most intense for Western OEMs since China dominates the lithium supply and processing industry globally.

Current lithium prices can 'green light' almost any lithium project, but everything must fall into place to provide the raw materials for an electrified fleet

The cost of fleet electrification

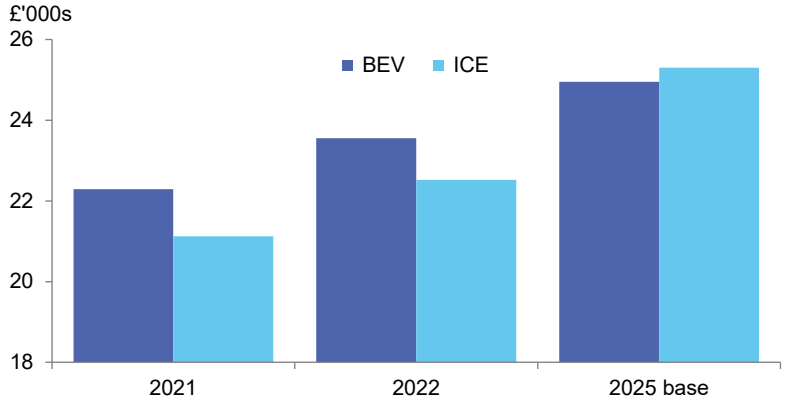
So, what might this mean for the light-vehicle ZEV roadmap? LMC uses total cost of ownership (TCO) as an input to forecast modelling. Aside from early adopters, and all other things (such as vehicle choice, utility and regulation) being equal, buyers are motivated to move to new technologies when they perceive that they can save money over their ownership or lease period for the car. We saw this vividly when diesel cars were on the ascendency in Europe. There was a clear correlation between TCO (diesel versus gasoline) and diesel penetration within a particular market. Although there isn't a level playing field yet between BEVs and ICE cars as regards model availability and refuelling (charging) infrastructure, we assume that those things will fall into place over time, at which point buying decisions will be increasingly dominated by acquisition and operating costs. At present, BEVs typically lose out to ICE on acquisition costs while winning on refuelling costs, particularly if charging is carried out at home on a favourable tariff.

Lower total cost of ownership encouraged uptake of diesel over gasoline

Electric vehicles are currently losing out to ICE vehicles in terms of acquisition cost…

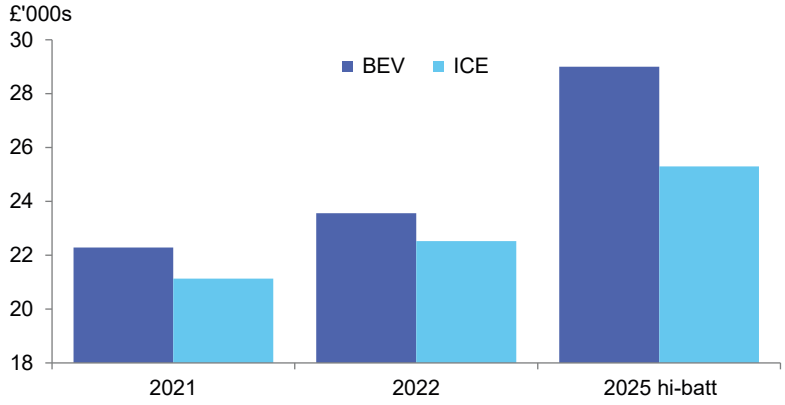
…but drastically lower fuelling costs and government incentives are beginning to shift the balance

New BEV vs. ICE three-year TCO UK – base scenario



Source: LMC Automotive

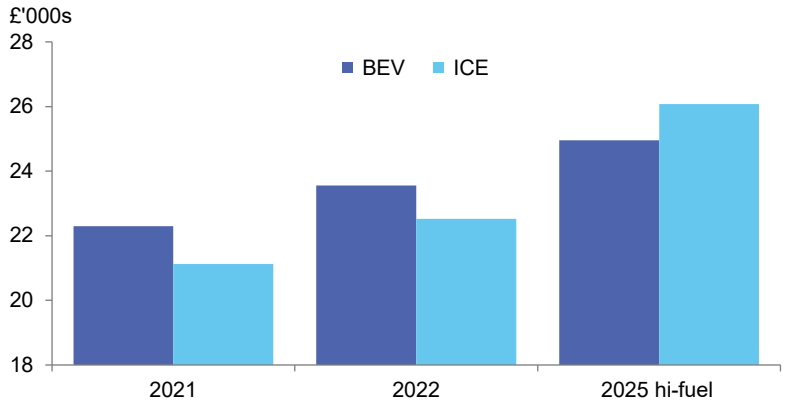
New BEV vs. ICE three-year TCO UK – hi-battery scenario



Source: LMC Automotive

Total cost of ownership for BEVs could remain above that of ICE if battery price reduction is thrown off course by a shortfall in lithium availability

New BEV vs. ICE three-year TCO UK – hi-fuel scenario



Source: LMC Automotive

Our base case three-year BEV-ICE TCO modelling, which includes depreciation, fuel costs, maintenance, circulation taxes and BEV incentives as key inputs, points to BEV TCO falling below ICE around 2025. The example overleaf is for the UK; other markets would yield different results but for the sake of seeing how disruptive battery or fuel cost changes would impact the model, we'll stick with the UK example here. The figures are for a basket of new mass-market, upper mid-size SUV/crossover-style vehicles for which current BEV prices are circa £45k. That part of the market is close to BEV-ICE parity at the moment, with ICE being around £1,000 more affordable over the three-year period. It is the higher acquisition cost of BEVs that causes them to lose out on this comparison and were one able to negotiate a good discount on a new BEV, one may already benefit from a lower TCO (than ICE). By 2025, three-year TCO for this category of new BEV in the UK, all other things being equal, is predicted to fall below that of ICE.

Base case model sees TCO for BEVs fall below ICE by 2025...

While vehicle-makers have supply contracts in place with battery cell makers and may also use hedging to guard against market volatility, a lithium market in severe deficit would result in sustained high prices – higher than those required to keep a battery pack price decline, and hence BEV price falls, on track. Our base case assumes that BEV prices fall modestly in real terms by 2025 while ICE prices grow. But what if a severe lithium shortage meant that 2025 BEV prices were 25% higher than today? Then we would see the situation in the second chart where BEV prices climb relative to ICE rather than fall, with a severe risk to the base BEV demand forecast.

...but sensitivity to lithium prices could extend ICE's price attractiveness

Conversely, what if BEV prices followed the assumed trend in the base case, but road fuel prices not only remained high, but also increased by a further 25% compared to today's price. As many sectors compete for a flow of oil that may exclude Russian input for an extended period, this is not an outlandish suggestion. In this case, as expected, ICE TCO rises above BEV, but the relative shift is less dramatic than that resulting from the high battery cost scenario – TCO in this (admittedly limited) analysis is more sensitive to acquisition price than to fuel price. We have made no adjustment to BEV 'fuel' prices under a high oil-price scenario. In fact, electricity prices would go up alongside ICE fuel (as they already have for some home charging cases).

Less lithium equals fewer BEVs on the road. To keep to targets for BEV market share, a smaller global fleet could be required

We consider the 'high-battery' scenario to be a significant risk to our current BEV forecast. Quantifying the risk is a work in progress as we try to narrow the range of lithium deficit outcomes. But what might this mean? Insufficient lithium leads to fewer, higher-priced BEVs and hence a threat to LV fleet de-carbonisation targets. Preserving the required ZEV (BEV) ratio to meet targets would imply a smaller LV market than currently forecast. *We see this as a distinct possibility.* Alternatively, LV carbon reduction targets could be made more flexible or delayed, but this seems unimaginable given what is at stake. Or there could be a pivot from BEV to fuel cell (FCEV) to meet ZEV targets. But 'green' or 'blue' hydrogen for fuel cells is in short supply and there is intense competition from other sectors for it. In addition, most LV OEMs have abandoned FCEV development and have thrown everything at BEV.

One avenue that may well be accelerated is BEV battery 'rightsizing' in order to enable lithium thrifting. Drivers rarely need the range that they think they do. Batteries could be smaller without seriously hurting the BEV experience. Unfortunately, in the world of BEV marketing, high range is at the top of the desirable features list so this will be a tough sell with only a few Japanese brands going down that route so far. Another way to thrift lithium in the medium term (before 100% ZEV mandates apply) is to rely more heavily on strong hybrids – either plug-in hybrids or range extenders. The latter are in a growth phase in China (though not in Europe or the USA) for this very reason. And a lack of battery materials at the right price may extend the life of the ICE hybrid, perhaps running on carbon-neutral fuels and achieving ZEV status.

Reducing battery size could boost lithium thrifting and help BEV growth, but range anxiety could prove a tough nut to crack

ICE hybrids running on CO_2-neutral fuels could be a compromise for net-zero if BEV's adoption stalls

Maybe the lithium industry will prevail and will produce sufficient material, but this is not the view of the experts in the field that we speak to. For the moment, we are highlighting the risk and will be releasing more analysis over time. Some OEMs are currently releasing statements to the effect that they have appropriate lithium supply deals in place for their requirements, but this cannot be true for all OEMs. We feel that there will be winners, losers, more consolidation, smaller markets, and upward price pressure on LVs generally as the shift to ZEVs exposes weaknesses among both legacy and start-up carmakers and in the supply chain.

PGM AUTOCATALYST RECYCLING AND GLOBAL VEHICLE PROJECTIONS REPORT

SFA (Oxford) has unrivalled business intelligence and market analysis of the spent autocatalyst recycling market. We have fully evaluated the recycling of autocatalysts from scrapyards, collectors, decanners, smelters and refiners, new technology developments and business economics. For more than a decade, we have tracked the development of PGM usage and subsequent PGM scrap generation in the autocatalyst (as well as the jewellery, electrical and electronic) sector, enabling us to provide a comprehensive independent review.

Our understanding of the regional and global recycling infrastructure, the main players in the value chain, new vehicle production rates, scrapping and collection rates, and current and future emissions legislation enables us to effectively model the secondary PGM supply from autocatalysts. This allows us to contextualise both the risks and opportunities for the PGM recycling sector.

SFA's analysis of autocatalysts and the assumptions are underpinned by data on vehicle production, sales, trade, age distribution, collector locations and vehicle parc, as well as an understanding of historical, regional catalyst introduction and associated changes in loadings. The analysis has enabled us to model and define, by region, the existing and potential future volumes of PGMs and associated substrate components available for recovery and recycling out to 2040. The report takes a closer look at China where recycling could increase significantly over the next decade.

Our new report "PGM autocatalyst recycling and global vehicle projections" is available now.

Available now

The Iridium & Ruthenium Markets

Quarterly Core Analysis Package Q2'22

44 **Ru** Ruthenium 101.07

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Stay up-to-date with short-term supply and demand developments of the iridium and ruthenium markets and our latest five-year outlook

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

The Iridium Ruthenium 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 iridium and ruthenium 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, and the emerging hydrogen economy.

It offers **commercial insights into primary metal supply** and the link to the rest of the PGM basket, plus insights into end-uses, their price elasticity and the risks of substitution.

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 2026
- Demand trends
- The only S-D market balance available
- Trade flow analysis
- Supply challenges and mine economics

THE PGM MARKETS IN 2021/22

The PGM markets in 2021/22

Dr. Ralph Grimble, SFA (Oxford) Ltd

The platinum market

Last year was a year of recovery from the dramatic falls in supply and demand seen in 2020 as a result of Covid lockdowns. Rebounding supply from South Africa was boosted by stockpiled material being processed and this overwhelmed a small loss of Russian production from the temporary closure of two mines that suffered from a flooding incident. Recovering demand from the automotive, jewellery and industrial sectors paled in comparison to the supply increase and the platinum market is estimated to have had a 1.6 moz surplus (ex. investment).

This year, the market surplus is predicted to narrow to 1.2 moz as supply does not receive the same boost from the processing of stockpiled material and automotive and industrial demand both expand further. Russia has once again proved to be the source of a shock to the market when it invaded Ukraine. Western countries have imposed various sanctions on Russia, but have not targeted PGMs or PGM miners, and so platinum from Russia is still likely to reach the market. Vehicle production in Russia has essentially ceased and this, along with disruption to Western European automakers' supply chains, has resulted in a downgrade of the light-vehicle production forecast. This has a limited impact on platinum automotive demand which is expanding with the wider use of gasoline autocatalysts with higher platinum loadings, particularly in the US and China, and the still significant increase in light-vehicle production as the availability of semiconductor chips is expected to improve as the year progresses.

Platinum is exposed to weak fundamentals as investors have lost interest

Investment demand is no longer soaking up the surplus metal. In 2021, investment demand was limited as a good level of coin purchases was offset by a decline in ETF holdings and net sales of physical platinum bars in Japan. So far in 2022, that trend has continued.

Mine supply

Primary platinum production increased by 30% last year to 6,425 koz as Covid impacts and processing problems were overcome. Refined production in South Africa jumped by 48% to 4,815 koz owing to a combination of a recovery in mine production after Covid stoppages in 2020 and the processing of material stockpiled in 2020 due to converter plant maintenance.

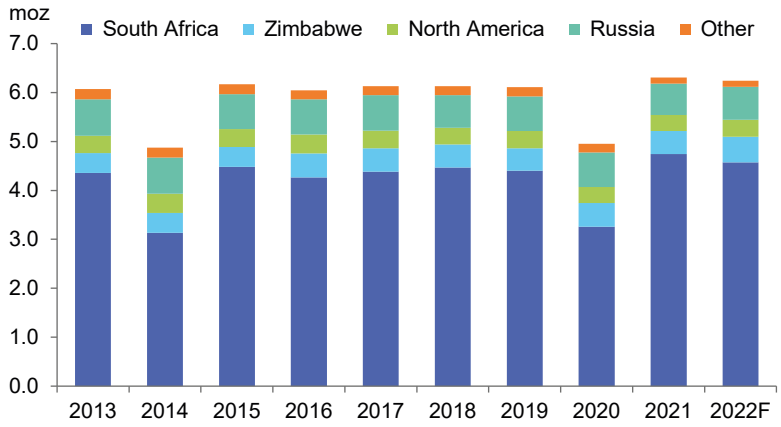
In 2021, platinum supply rebounded by 30%

Russian output was cut by 9% to 645 koz by a mine flooding incident and concentrator collapse. In Zimbabwe, production increased during 2020 and dipped slightly to 470 koz in 2021. North American supply was up 15 koz but 'Other' regions saw a loss of 25 koz.

In 2022, global platinum production is predicted to fall by 1% to 6,280 koz. Output is once again boosted by stockpiled material being processed, but significantly more stock was processed in 2021, leading to the overall year-on-year decline. South African platinum supply is estimated to be down by 4% to 4,570 koz, owing to the smaller amount of stock remaining to be processed this year. Platinum supply from Russia is expected to rebound by 4% to 670 koz, as the mines that suffered flooding in 2021 were back to full operating capacity by the end of the year. Production in Zimbabwe is set to grow by 55 koz following debottlenecking at Unki and from the continued ramp-up of Bimha and Mupani mines at Zimplats. North American output improves by 25 koz following safety stoppages and the ongoing impact of Covid in 2021.

Platinum supply falls by 1% in 2022

Primary platinum supply



Source: SFA (Oxford)

Recycling

Secondary platinum supply grew by 5% to 1,830 koz last year as gains in autocatalyst and industrial recycling offset a small decline in jewellery recycling. This year, platinum recycling is predicted to be up just 10 koz owing to a modest increase in jewellery recycling more than offsetting slight declines in autocatalyst and industrial recycling.

Recycling changes very little at 1.8 moz in 2022

Demand

Global platinum demand (ex. investment) rebounded by 14% to 6,635 koz last year owing to less impact from Covid and lockdowns. Jewellery demand recovered from the pandemic lows with fewer restrictions on shops or consumers. Automotive demand also improved, despite the chip shortage limiting growth in light-vehicle production, owing to the initial rollout of gasoline autocatalysts in which some palladium had been substituted by some platinum. The introduction of China VI emissions legislation, which increased platinum autocatalyst loadings on heavy-duty vehicles (HDVs) in China, also helped to lift demand. Industrial demand also had a strong recovery from the pandemic low.

In 2022, platinum consumption is predicted to increase by 5% to 6,995 koz as solid gains for automotive and industrial usage outweigh the small decline expected for jewellery demand.

Platinum demand recovers to 7 moz this year

Automotive demand

Platinum automotive demand is forecast to rise by 12% to 2,975 koz in 2022. Although the chip shortage continues to hamper light-vehicle production, the availability of chips is expected to improve in the second half of the year, enabling an increase in production of almost 8 million units. This is somewhat lower than expected at the start of the year owing to the cessation of production in Russia and the negative impact on Western European manufacturers' supply chains following the Russian invasion of Ukraine.

Automotive demand continues to gain from substitution of some platinum into gasoline autocatalysts which are being more widely used, particularly in China and North America and to a lesser extent in Western Europe. Diesel cars' market share is still declining in Western Europe and could drop below 20%, but, even so, with the market recovering from the chip shortage, the total number of diesel cars produced this year is expected to rise modestly, lifting platinum requirements. Global HDV demand is estimated to be slightly higher this year, but it is held back by lower HDV production in China.

Platinum automotive demand gains from greater light-vehicle production and substitution into gasoline autocatalysts in 2022

Jewellery demand

In 2021, platinum jewellery demand climbed by 14% to 1,780 koz owing to fewer Covid restrictions and improved consumer spending. Jewellery demand in the US, in particular, had a robust recovery.

This year, jewellery consumption is predicted to fall by 3% to 1,735 koz, owing to lower demand in China and the US. In the US, sales are expected to return to a more typical level after a very strong 2021. China remains the largest jewellery market by far, but it is facing headwinds. The zero-tolerance Covid policy has led to lockdowns in Shenzhen and Shanghai, as well as other regions. This has depressed consumer spending in those regions and the wider economic impact could result in more cautious consumers. Platinum jewellery demand in India is expected to continue to recover having been hampered by significant Covid restrictions for the last two years.

Jewellery demand slips by 3% this year

Industrial demand

Industrial platinum requirements rose by 11% to 2,145 koz in 2021, mainly owing to robust rebounds in the petroleum, chemical and glass sectors. Net petroleum catalyst demand was boosted by greater oil-refining capacity expansions. Requirements for chemical catalysis increased, particularly in China and the RoW. Platinum use in the glass sector was lifted by capacity expansions, especially for photovoltaic glass in China following a change in government policy.

Industrial demand exceeds 2.2 moz in 2022

In 2022, industrial demand is predicted to increase by 3% to 2,215 koz, largely owing to further growth in glass, chemical and other industrial applications. The wave of new glass capacity in China is set to keep new metal demand at historically high levels, aided by new plants and expansions in the RoW. Chemical catalyst requirements are expected to expand in line with economic growth, while improving light-vehicle production should lift demand for other automotive components (sensors and plugs).

Investment and movement of above-ground stocks

Investment demand had a disappointing year in 2021. Coin purchases remained robust but physical bar purchases were negligible and ETF holdings fell by 264 koz. Japanese investors are typically price-sensitive and the rising platinum price in the first part of the year took it above the psychological ¥4,000/g level, resulting in some profit-taking and net sales of physical bars in the first quarter. Although net purchases resumed in the second quarter, as the price fell back, for the year as a whole Japanese investors were net sellers of platinum bars. Investors in ETFs began the year in bullish mood and by July ETF holdings had reached a record 3,987 koz, up 131 koz from the start of the year. However, with the price declining in the second half of the year investors sold some of their holdings, reducing the total to 3,593 koz.

Platinum ETF holdings are declining...

Investment demand has continued to be lacklustre so far this year. ETF holdings are down 171 koz in the first four months of the year. In addition, with the yen weakening dramatically in 2022, the platinum price in Japan once again rose above ¥4,000/g so some additional disinvestment is likely to have occurred.

...and a platinum price above ¥4,000/g in Japan has led to disinvestment

The palladium market

The palladium market suffered two dramatic and opposing events in 2021. First came news in February that the Oktyabrsky and Taimyrsky mines in Russia had been flooded, cutting palladium production. With the loss of a portion of Russian supply, the market looked likely to have a significant deficit. Then the semiconductor chip shortage that had, at first, appeared to be contained, turned into a much more serious problem in the second half of the year, resulting in just 1.6 million more light vehicles being produced than in 2020. This much lower than expected automotive palladium demand left the market with a 480 koz surplus at the end of the year.

Recovery in South African supply outweighed lost output from Russia last year...

...and constrained automotive production resulted in a surplus market

This year, the palladium market was initially expected to be close to balance but light-vehicle production forecasts have been downgraded owing to the Russian invasion of Ukraine reducing automotive demand, while palladium production in Russia has recovered from last year's incidents and is expected to continue to reach the market as Western countries' sanctions have not targeted PGMs or PGM miners. The market is forecast to have a surplus of 130 koz this year, but with China continuing to pursue a zero-Covid policy and locking down major cities and regions, automotive demand could be lower than currently predicted and the surplus larger.

Palladium market remains in surplus in 2022

Last year, primary palladium production increased by 10% to 7,050 koz, as a strong rebound in South African output more than offset the partial curtailment of production in Russia. South African mine production surged by 52% to 2,805 koz owing to a combination of a much-reduced impact from anti-Covid measures and the processing of stockpiled material. In Russia, output fell by 8% to 2,585 koz, although the shortfall was not as large as initially feared as the flooded mines were rehabilitated and brought back into full production by the end of the year. Palladium supply from Zimbabwe and North America declined modestly.

Palladium supply expands by 1% this year

This year, global palladium supply is predicted to be up by 1% to 7,150 koz. With the incidents that hampered production in 2021 overcome by the end of the year, Russian output is forecast to grow by 5% to 2,710 koz. South African output is estimated to drop by 7% to 2,620 koz, as refined production gains a much smaller boost from the processing of stockpiled material than in 2021. Zimbabwean palladium supply is forecast to rise by 50 koz, while North American output is projected to increase by 105 koz.

Secondary supply on an upward trajectory

Secondary supply of palladium is predicted to grow by 7% to 2,980 koz in 2022. The number of scrapped vehicles is expected to rise, along with the loadings on the spent catalysts, but there is a constraint on the growth. The chip shortage, which has held back new light-vehicle production, has had the knock-on effect of making second-hand vehicles more sought after, thus keeping them on the road for longer. This is particularly the case in Western Europe and North America. Price volatility has also led to some uneven flows of material as collectors have waited for prices to rebound following dips before releasing spent autocatalysts.

Palladium demand hits 10 moz in 2022

Global palladium demand is forecast to rise by 7% to 10,000 koz in 2022. Automotive demand is projected to climb by 10% to 8,240 koz, but this is still below 2019 levels. Although the chip shortage is expected to be less of a problem this year, it continues to restrain light-vehicle production and the recovery in palladium demand. The demand forecast has also been downgraded owing to the Russian invasion of Ukraine which has resulted in the closure of most vehicle plants in Russia. In addition, Ukrainian automotive parts suppliers have been forced to reduce or stop production which has negatively impacted light-vehicle output in Western Europe.

Industrial demand is predicted to drop by 6% to 1,530 koz this year as chemical consumption eases after a strong rebound in 2021 and electrical and dental usage continues to edge lower owing to the high price.

The rhodium market

Disruption to light-vehicle production keeps the rhodium market in surplus this year

The rhodium market is expected to have a small surplus of 25 koz this year as automotive demand recovers from a weak 2021 and supply slips back owing to less stockpiled material being processed in 2022 than in 2021.

Last year, primary rhodium supply increased by 32% to 825 koz as the recovery in South African production from Covid impacts was boosted by the processing of some stockpiled material, more than making up for a small decline in Russian output owing to the mine flooding incident early in the year. Including stock processing, South African output jumped by 42% to 675 koz. Zimbabwean and Russian production both fell by 5 koz while North American output was unchanged.

Rhodium supply falls 6% in 2022 as less stockpiled material is processed

Rhodium supply is predicted to contract by 6% to 780 koz in 2022. South African output has much less of a boost from processing stockpiled material, dropping 8% to 630 koz. Zimbabwean and Russian production both edge up this year while other regions' output remains stable.

Rhodium demand is estimated to increase by 10% to 1,130 koz in 2022. Demand is largely dictated by automotive requirements which are forecast to exceed 1 moz for the first time this year, rising by 12% to 1,010 koz. The chip shortage is expected to be mostly overcome later in the year, leading to greater light-vehicle production than in 2021. However, the effects of the Russia-Ukraine conflict have already resulted in a downward revision to light-vehicle production and the risk is that China's zero-Covid policy and lockdowns cause a reduction in light-vehicle manufacture, reducing rhodium demand further. Industrial demand is forecast to rise by 2% to 120 koz owing to a rebound in chemical usage.

The price outlook for the next six months

Platinum $950/oz

The platinum market is improving in 2022, with demand growing faster than supply. There is increasing demand from the automotive industry as vehicle production rises and more heavily platinum-loaded gasoline autocatalysts are rolled out. Industrial demand is also recovering, although jewellery demand has taken a knock from Covid lockdowns in China. However, the starting point was a significantly oversupplied market and that remains the case this year. A surplus of more than 1 moz is anticipated once again. ETF holdings are down 171 koz this year despite the potential for real assets to benefit in a high inflation environment. That leaves the platinum price exposed to weak fundamentals and with little investment support, so the price is predicted to average $950/oz.

Platinum has weak fundamental support

Palladium $2,000/oz

Concerns around supply from Russia saw the palladium price hit record highs earlier this year. However, the invasion of Ukraine has negatively impacted the automotive industry, with reduced vehicle production in Russia and supply chain disruption for European manufacturers from parts suppliers in Ukraine. This has resulted in a downgrade to the already modest forecast for light-vehicle production this year. Now, with the lockdowns in China and growing economic headwinds, further reductions in vehicle production are likely easing demand lower. This should put downward pressure on the palladium price.

Automotive production downgrades hold back post-Covid recovery

The market has a modest surplus and the palladium price is expected to trend lower and average $2,000/oz. However, a supply disruption from either Russia or South Africa could result in a sharp rally.

Rhodium $15,000/oz

Downward revisions to light-vehicle production forecasts could keep automotive rhodium demand from reaching a record 1 moz this year. However, tighter emissions standards mean that demand is robust even with constrained light-vehicle production. Supply edges lower this year with less stockpiled material being processed but the revisions to automotive demand mean the market is now expected to have a small surplus this year.

Tighter emissions standards help maintain demand

Wage negotiations in South Africa could prove problematic as the mining unions see record profits, while the mining companies face rampant cost inflation. With rhodium highly exposed to South Africa (80% of mine supply) any disruption could result in a sharp price rally. That eventuality aside, the price is predicted to average $15,000/oz over the next six months.

2050 PGM: Joining the Dots to 'Net Zero'

Implications for platinum, palladium and rhodium

As politicians target environmental ambitions for the rest of this century, SFA (Oxford)'s clients are requesting ever longer-term outlooks for PGMs. This has encouraged SFA to look beyond its established and definitive 10-year market outlook of PGM demand/supply modelling and forecasting – into less definitive uncharted waters and far distant horizons where big trends dominate small cycles.

This unique 2050 report starts from 'home port' – SFA's 10-year view. It is anchored in our tried and tested PGM demand/supply modelling which then extrapolates a framework of macroeconomic, environmental regulatory and technological scenarios.

Given that there are no exact compass bearings to take us 'from here to there', our projections beyond 2030 to 2050 identify a selection of high-level, well-reasoned potential pathways. These include a combination of global trends in demand (vehicle powertrains, emissions legislation) and supply - likely primary and secondary production.

The report also investigates today's PGM uses that may endure longer than many expect and the potential for new end-uses, e.g. in the hydrogen economy.

SFA's broad-brush approach beyond 2030 reflects that the very long-term and broad horizons in this report prohibit accurate forecasting. That said, our report's extrapolations to 2050 provide an indicative view from SFA on the bandwidth of market balances and prices, highlighting content for PGM sector conceptual thinking including:

- The rise of BEVs and their influence on PGM automotive demand.
- The impact of demographics on platinum demand.
- PGM use in the hydrogen economy.
- Changes to industrial demand as end-uses evolve.
- Primary mine supply projections and incentive pricing for new projects. Can mine supply meet the potential demand from the hydrogen economy?
- How secondary supply evolves as BEVs displace ICE production.

Available now

The PGM Radar

Market Outlook Report Q2'22

78 **Pt** Platinum 195.084

45 **Rh** Rhodium 102.9055

Pd Palladium 106.42

Stay up-to-date with short-term developments in the PGM markets and our latest three-year outlook

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.

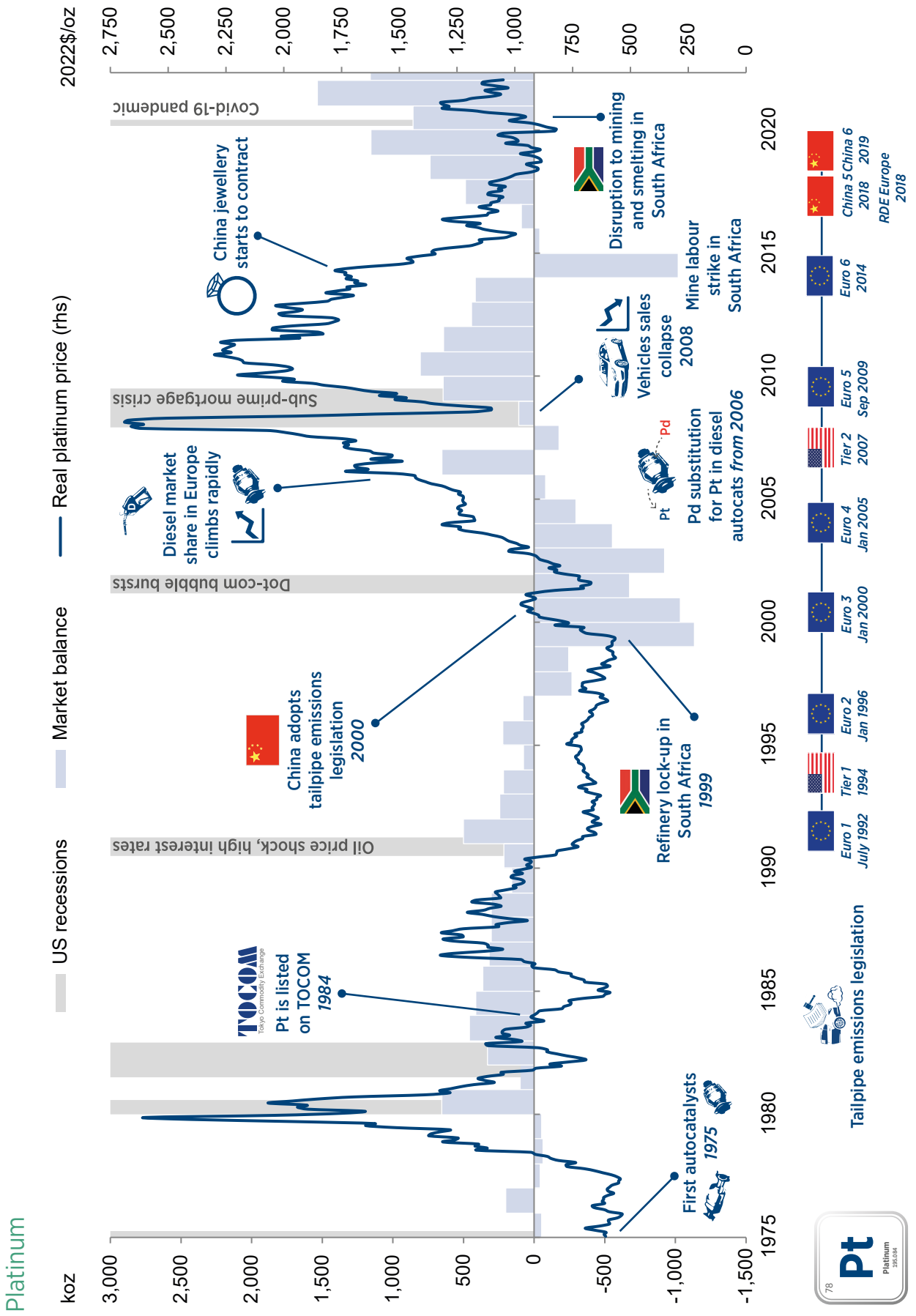
Our unique quarterly PGM Market Outlook report will provide you with SFA's hands-on, forward-looking commentary and analysis on the events and trends currently impacting **PGM supply, demand and pricing, and their market implications.**

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.

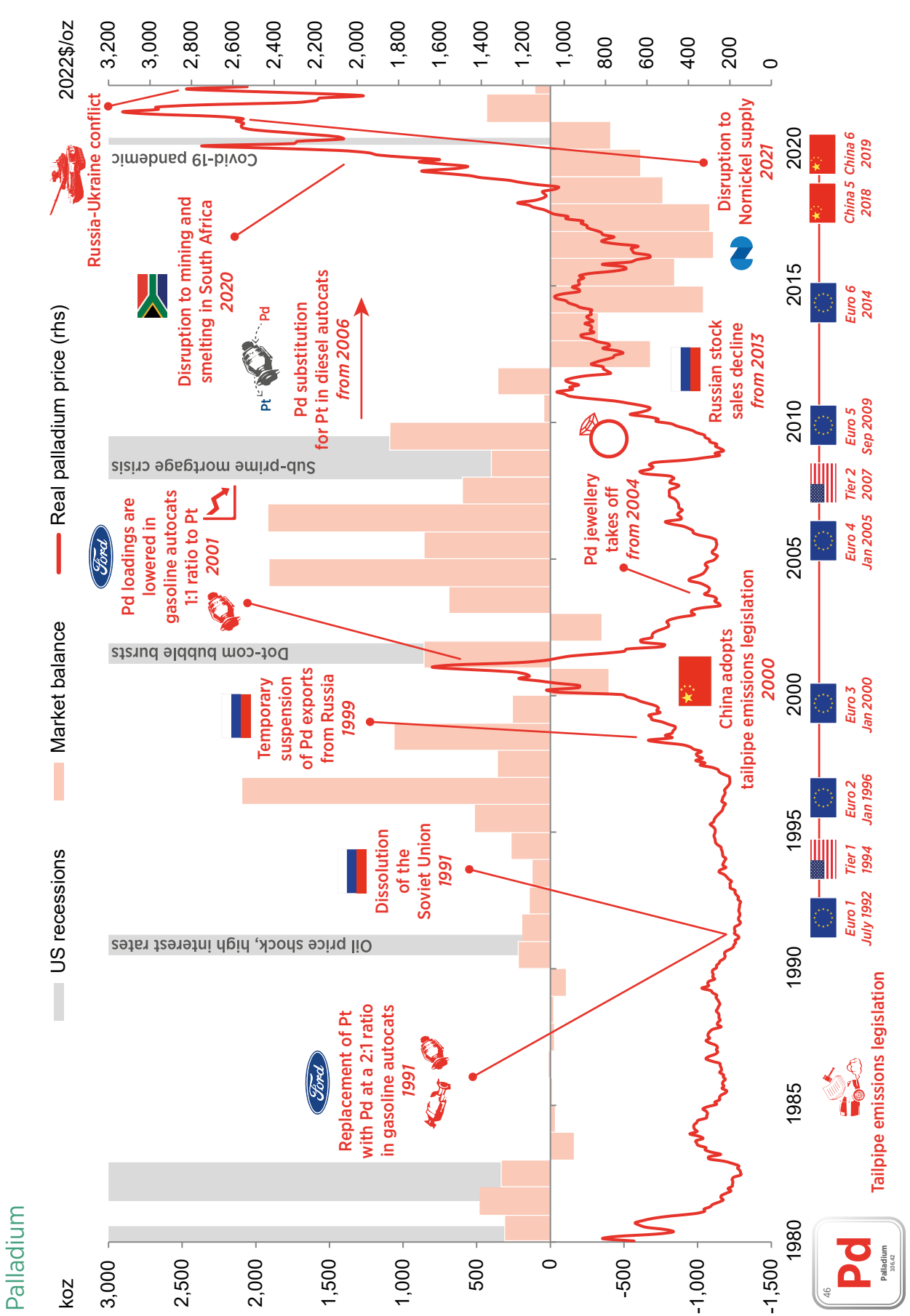
Key report features:

- **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.**

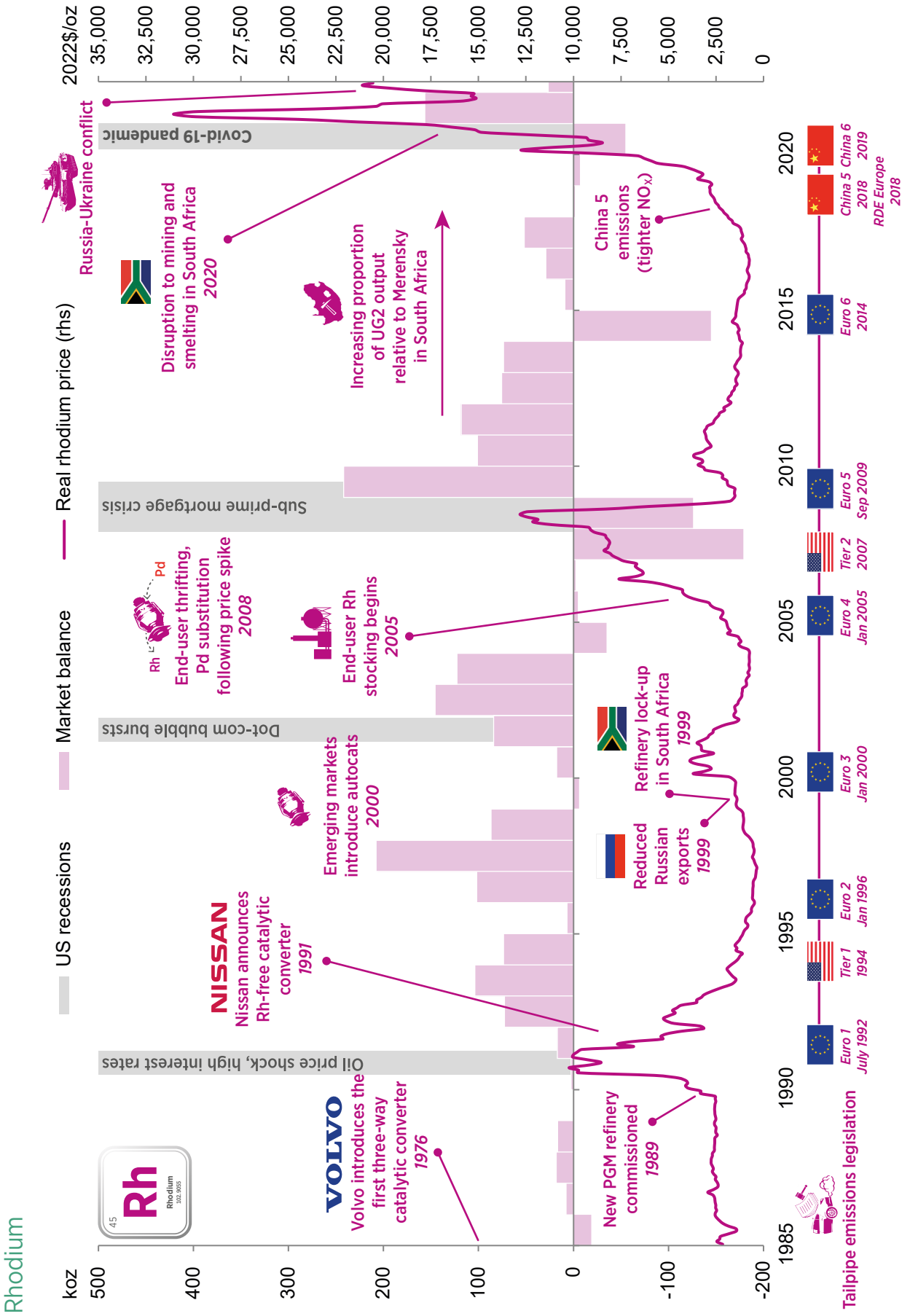
PGM PRICE HISTORY



Source: SFA (Oxford), Bloomberg

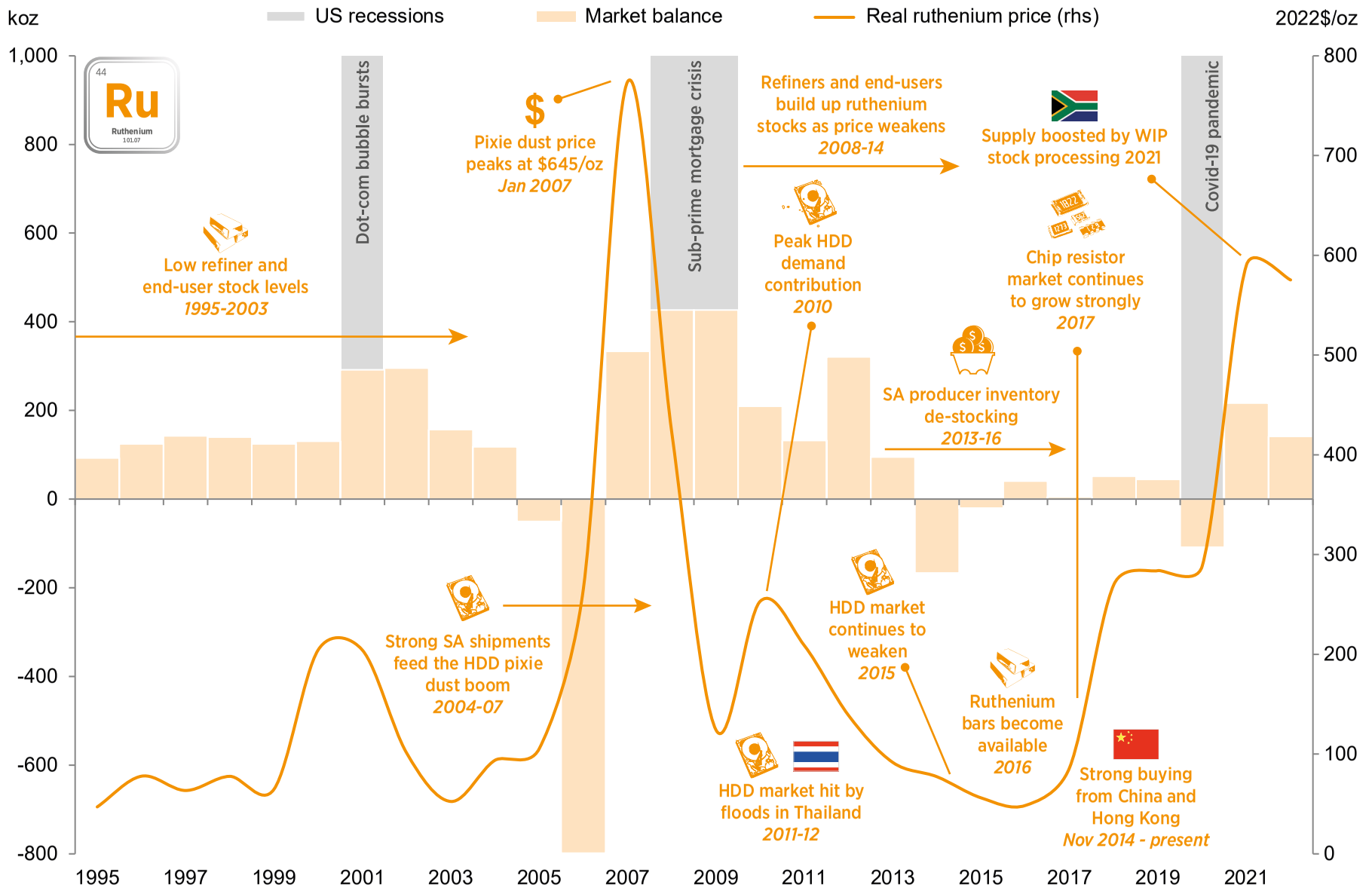


Source: SFA (Oxford), Bloomberg



Source: SFA (Oxford), Bloomberg

Ruthenium



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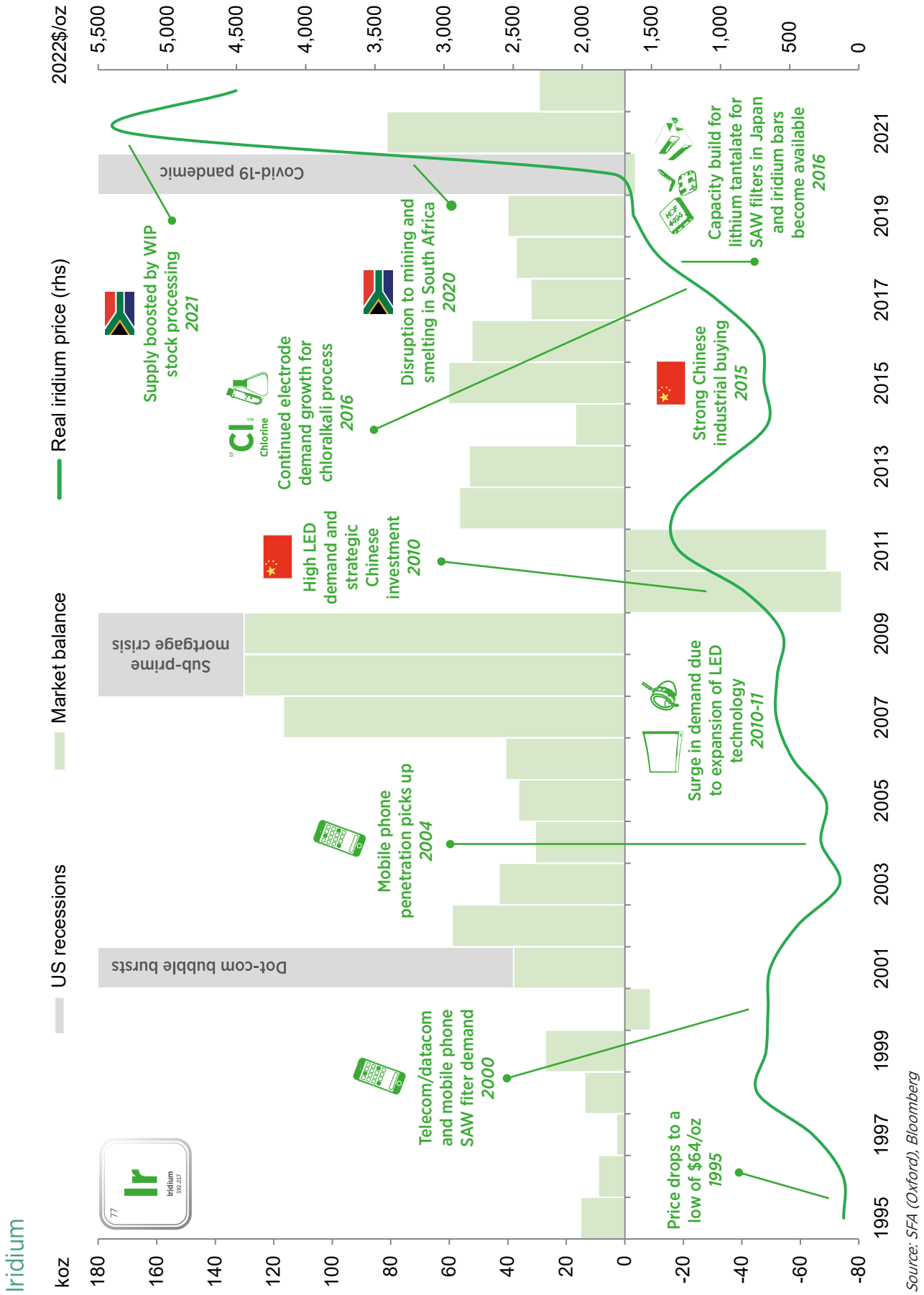

Source: SFA (Oxford), Bloomberg

APPENDIX

Platinum supply-demand balance

koz	2014	2015	2016	2017	2018	2019	2020	2021	2022f
Primary supply									
Regional									
South Africa	3,135	4,480	4,265	4,385	4,470	4,405	3,255	4,490	4,570
Russia	740	710	715	720	665	710	705	580	670
Zimbabwe	405	405	490	480	465	460	480	490	525
North America	395	365	390	360	345	350	330	375	350
Other	200	200	185	185	180	185	175	160	155
Total	**4,870**	**6,165**	**6,045**	**6,125**	**6,130**	**6,105**	**4,950**	**6,100**	**6,270**
Demand & recycling									
Autocatalyst									
Gross demand	3,240	3,245	3,350	3,290	3,090	2,815	2,315	2,665	2,975
Recycling	1,255	1,185	1,210	1,325	1,420	1,495	1,300	1,385	1,380
Net demand	1,985	2,065	2,140	1,965	1,670	1,320	1,015	1,280	1,595
Jewellery									
Gross demand	3,000	2,835	2,510	2,450	2,245	2,090	1,560	1,780	1,685
Recycling	775	515	625	560	505	500	410	400	420
Net demand	2,225	2,325	1,885	1,890	1,740	1,595	1,150	1,380	1,265
Industrial demand	**1,675**	**1,815**	**1,910**	**1,770**	**1,940**	**2,025**	**1,925**	**2,140**	**2,215**
Hydrogen	**25**	**25**	**45**	**50**	**70**	**45**	**45**	**50**	**70**
Other recycling	**25**	**25**	**25**	**30**	**30**	**30**	**30**	**45**	**40**
Gross demand	**7,940**	**7,920**	**7,820**	**7,560**	**7,345**	**6,975**	**5,840**	**6,635**	**6,945**
Recycling	**2,055**	**1,720**	**1,860**	**1,915**	**1,955**	**2,020**	**1,745**	**1,830**	**1,840**
Net demand	**5,890**	**6,200**	**5,955**	**5,645**	**5,395**	**4,995**	**4,095**	**4,805**	**5,105**
Market balance									
Balance (before ETFs)	-1,015	-35	85	485	735	1,150	855	1,530	1,160
ETFs (stock allocation)	210	-240	-10	100	-240	995	505	-265	
Balance after ETFs	**-1,225**	**205**	**95**	**385**	**980**	**155**	**355**	**1,795**	

Source: SFA (Oxford)

Platinum demand and recycling summary

koz	2014	2015	2016	2017	2018	2019	2020	2021	2022f
Gross demand									
Autocatalyst									
North America	465	480	410	390	390	380	285	370	470
Western Europe	1,395	1,450	1,630	1,545	1,325	1,135	790	750	785
Japan	585	510	450	435	425	395	305	270	290
China	125	145	195	230	220	245	425	680	775
India	170	180	170	175	195	155	110	165	180
RoW	500	485	495	515	535	510	395	425	475
Total	**3,240**	**3,245**	**3,350**	**3,290**	**3,090**	**2,815**	**2,315**	**2,665**	**2,975**

Source: SFA (Oxford)

Platinum demand and recycling summary (continued)

koz	2014	2015	2016	2017	2018	2019	2020	2021	2022f
Gross demand									
Jewellery									
North America	230	250	265	280	280	275	210	255	210
Western Europe	220	235	240	250	255	260	175	190	180
Japan	335	340	335	340	345	330	245	260	270
China	1,975	1,765	1,450	1,340	1,095	945	755	875	820
India	175	180	145	175	195	210	120	135	160
RoW	65	70	70	75	75	75	55	60	50
Total	**3,000**	**2,835**	**2,510**	**2,450**	**2,245**	**2,090**	**1,560**	**1,780**	**1,685**
Industrial									
North America	330	265	400	350	350	300	245	300	340
Western Europe	250	310	285	280	315	300	280	265	305
Japan	35	95	85	40	100	105	85	80	85
China	500	585	650	590	510	620	735	850	865
RoW	560	560	490	505	665	700	580	640	620
Total	**1,675**	**1,815**	**1,910**	**1,770**	**1,940**	**2,025**	**1,925**	**2,140**	**2,215**
Hydrogen	**5**	**25**	**25**	**45**	**50**	**75**	**50**	**60**	**85**
North America	10	5	10	10	15	10	10	10	10
Western Europe	0	0	5	0	0	0	0	0	10
Japan	5	15	25	30	35	15	20	25	30
China	0	0	0	0	0	0	0	0	10
RoW	10	5	5	5	20	15	10	10	10
Total	**25**	**25**	**45**	**50**	**70**	**45**	**45**	**50**	**70**
Total gross demand									
North America	1,035	995	1,090	1,030	1,035	965	750	935	1,030
Western Europe	1,865	1,995	2,165	2,075	1,900	1,695	1,245	1,210	1,280
Japan	960	955	890	845	900	845	660	640	675
China	2,605	2,500	2,300	2,160	1,830	1,810	1,915	2,405	2,470
RoW	1,475	1,475	1,375	1,450	1,680	1,665	1,270	1,440	1,495
Total	**7,940**	**7,920**	**7,820**	**7,560**	**7,345**	**6,975**	**5,840**	**6,635**	**6,945**
Recycling									
Autocatalyst									
North America	560	505	535	585	640	645	575	565	525
Western Europe	465	370	400	440	465	505	425	490	500
Japan	105	95	95	100	110	110	100	115	125
China	30	55	40	40	35	40	30	35	40
RoW	90	155	150	160	170	190	170	185	190
Total	**1,255**	**1,185**	**1,210**	**1,325**	**1,420**	**1,495**	**1,300**	**1,385**	**1,380**
Jewellery									
North America	0	5	5	5	5	5	5	5	5
Western Europe	5	5	5	5	5	5	5	5	5
Japan	235	160	150	160	145	140	110	115	130
China	530	335	460	385	340	340	285	265	270
RoW	5	5	5	5	5	10	10	10	10
Total	**775**	**515**	**625**	**560**	**505**	**500**	**410**	**400**	**420**
WEEE	**25**	**25**	**25**	**30**	**30**	**30**	**30**	**45**	**40**

Source: SFA (Oxford)

Platinum demand and recycling summary (continued)

koz	2014	2015	2016	2017	2018	2019	2020	2021	2022f
Recycling									
Total recycling									
North America	560	565	515	535	590	645	650	580	570
Western Europe	365	475	375	405	445	470	515	430	525
Japan	345	340	255	245	265	255	255	210	230
China	625	560	395	500	425	380	380	320	340
RoW	90	95	165	160	170	180	200	180	200
Total	**1,985**	**2,035**	**1,705**	**1,845**	**1,895**	**1,930**	**2,000**	**1,720**	**1,865**

Source: SFA (Oxford)

Palladium supply-demand balance

koz	2014	2015	2016	2017	2018	2019	2020	2021	2022f
Primary supply									
Regional									
South Africa	1,870	2,560	2,375	2,530	2,500	2,555	1,845	2,770	2,630
Russia	2,690	2,605	2,555	2,740	2,670	2,870	2,810	2,585	2,710
Zimbabwe	330	325	395	395	380	385	405	395	445
North America	1,055	995	1,065	985	1,035	975	950	925	1,010
Other	460	455	420	415	395	395	385	325	330
Total	**6,405**	**6,940**	**6,810**	**7,065**	**6,975**	**7,180**	**6,395**	**7,000**	**7,120**
Demand & recycling									
Autocatalyst									
Gross demand	7,480	7,590	7,935	8,140	8,300	8,445	7,405	7,500	8,240
Recycling	1,720	1,605	1,710	1,920	2,035	2,175	2,010	2,300	2,550
Net demand	5,760	5,985	6,220	6,220	6,265	6,270	5,395	5,200	5,690
Jewellery									
Gross demand	290	245	240	215	215	215	200	215	225
Recycling	120	80	80	60	60	60	55	60	65
Net demand	170	165	165	155	155	155	145	155	160
Industrial demand	**1,935**	**1,950**	**1,910**	**1,855**	**1,845**	**1,730**	**1,620**	**1,630**	**1,530**
Other recycling	**430**	**430**	**380**	**375**	**370**	**365**	**330**	**415**	**365**
Gross demand	**9,705**	**9,780**	**10,085**	**10,215**	**10,360**	**10,390**	**9,225**	**9,345**	**10,000**
Recycling	**2,265**	**2,115**	**2,170**	**2,355**	**2,465**	**2,595**	**2,395**	**2,775**	**2,980**
Net demand	**7,440**	**7,670**	**7,915**	**7,860**	**7,895**	**7,790**	**6,835**	**6,575**	**7,020**
Market balance									
Balance (before ETFs)	-1,035	-730	-1,105	-795	-920	-615	-440	430	100
ETFs (stock allocation)	930	-665	-640	-375	-560	-90	-115	50	
Balance after ETFs	**-1,965**	**-65**	**-465**	**-420**	**-360**	**-525**	**-325**	**380**	

Source: SFA (Oxford)

Palladium demand and recycling summary

koz	2014	2015	2016	2017	2018	2019	2020	2021	2022f
Gross demand									
Autocatalyst									
North America	1,930	1,855	1,935	1,850	1,860	1,815	1,460	1,470	1,710
Western Europe	1,665	1,790	1,685	1,700	1,715	1,670	1,250	1,195	1,290
Japan	740	745	775	800	840	870	760	700	745
China	1,705	1,725	1,985	2,055	2,035	2,255	2,420	2,515	2,725
India	170	185	225	245	265	240	205	280	315
RoW	1,270	1,295	1,325	1,490	1,585	1,595	1,310	1,345	1,455
Total	**7,480**	**7,590**	**7,935**	**8,140**	**8,300**	**8,445**	**7,405**	**7,500**	**8,240**
Jewellery									
North America	35	35	35	35	35	35	35	35	40
Western Europe	60	55	55	55	55	55	50	50	55
Japan	55	50	50	50	50	50	45	45	50
China	120	75	75	50	50	50	50	55	60
RoW	25	25	25	25	25	25	25	25	25
Total	**290**	**245**	**240**	**215**	**215**	**215**	**200**	**215**	**225**
Industrial									
North America	385	380	370	340	300	295	240	235	230
Western Europe	290	315	325	310	290	285	255	260	265
Japan	425	420	395	360	335	300	250	235	225
China	395	395	385	440	500	435	515	535	455
RoW	440	435	430	410	420	415	360	365	360
Total	**1,935**	**1,950**	**1,910**	**1,855**	**1,845**	**1,730**	**1,620**	**1,630**	**1,530**
Total gross demand									
North America	2,350	2,275	2,345	2,225	2,200	2,145	1,735	1,745	1,975
Western Europe	2,010	2,160	2,065	2,065	2,060	2,010	1,555	1,505	1,605
Japan	1,220	1,215	1,225	1,210	1,220	1,220	1,060	980	1,020
China	2,215	2,190	2,445	2,540	2,585	2,740	2,980	3,105	3,240
RoW	1,905	1,935	2,005	2,170	2,290	2,275	1,900	2,010	2,155
Total	**9,705**	**9,780**	**10,085**	**10,215**	**10,360**	**10,390**	**9,225**	**9,345**	**10,000**
Recycling									
Autocatalyst									
North America	975	895	960	1,060	1,135	1,190	1,130	1,245	1,330
Western Europe	365	270	260	305	330	335	300	360	415
Japan	135	125	125	145	180	200	185	200	205
China	60	115	160	165	155	165	150	180	245
RoW	185	205	205	245	240	290	240	315	350
Total	**1,720**	**1,605**	**1,710**	**1,920**	**2,035**	**2,175**	**2,010**	**2,300**	**2,550**
Jewellery									
Japan	20	20	20	20	20	20	15	15	20
China	100	60	60	40	40	40	40	45	45
Total	**120**	**80**	**80**	**60**	**60**	**60**	**55**	**60**	**65**
WEEE									
North America	75	85	75	70	70	65	60	65	60
Western Europe	95	80	75	80	75	75	65	75	65
Japan	150	170	135	130	125	120	105	120	110
China	30	25	35	40	40	45	45	60	60
RoW	75	65	60	60	60	60	55	90	70
Total	**430**	**430**	**380**	**375**	**370**	**365**	**330**	**415**	**365**
Total recycling									
North America	1,050	980	1,040	1,130	1,200	1,255	1,190	1,310	1,390
Western Europe	460	350	335	385	405	410	370	435	485
Japan	305	315	280	295	320	335	310	335	330
China	190	195	255	240	235	250	235	285	350
RoW	260	270	260	305	295	345	295	405	425
Total	**2,265**	**2,115**	**2,170**	**2,355**	**2,465**	**2,595**	**2,395**	**2,775**	**2,980**

Source: SFA (Oxford)

Rhodium supply-demand balance

koz	2014	2015	2016	2017	2018	2019	2020	2021	2022f
Primary supply									
Regional									
South Africa	425	620	615	620	625	640	475	675	630
Russia	75	70	70	75	75	80	80	75	75
Zimbabwe	35	35	45	45	40	40	45	40	45
North America	30	30	25	25	20	20	20	20	20
Other	10	10	10	10	10	10	10	10	10
Total	**580**	**765**	**765**	**775**	**770**	**790**	**630**	**820**	**785**
Demand & recycling									
Autocatalyst									
Gross demand	840	865	835	870	900	985	880	905	1,010
Recycling	280	260	280	305	335	355	330	360	370
Net demand	565	605	555	565	565	630	550	550	640
Industrial demand	**160**	**155**	**180**	**160**	**210**	**170**	**135**	**120**	**120**
Other recycling	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**3**
Gross demand	**1,005**	**1,020**	**1,015**	**1,030**	**1,110**	**1,155**	**1,015**	**1,025**	**1,130**
Recycling	**280**	**265**	**280**	**305**	**340**	**355**	**335**	**360**	**370**
Net demand	**725**	**755**	**735**	**725**	**775**	**800**	**685**	**665**	**760**
Market balance									
Balance (before ETFs)	-145	10	30	50	0	-5	-55	155	25
ETFs (stock allocation)	5	-5	5	-20	-50	-15	-10	-5	
Balance after ETFs	**-150**	**15**	**25**	**70**	**50**	**5**	**-45**	**160**	

Source: SFA (Oxford)

Rhodium demand and recycling summary

koz	2014	2015	2016	2017	2018	2019	2020	2021	2022f
Gross demand									
Autocatalyst									
North America	240	240	235	230	225	220	175	170	200
Western Europe	225	250	210	215	225	290	225	215	240
Japan	140	125	125	125	130	130	110	100	105
China	110	110	130	150	155	180	235	280	305
India	15	15	20	20	20	20	15	20	25
RoW	115	120	115	130	145	150	125	125	135
Total	**840**	**865**	**835**	**870**	**900**	**985**	**880**	**905**	**1,010**
Industrial									
North America	20	15	20	20	20	20	15	15	15
Western Europe	15	10	15	15	25	15	10	5	10
Japan	5	10	10	10	10	10	10	10	10
China	75	70	85	70	80	70	65	60	60
RoW	50	45	50	50	75	50	30	25	25
Total	**160**	**155**	**180**	**160**	**210**	**170**	**135**	**120**	**120**
Total gross demand									
North America	260	255	260	245	245	235	190	185	215
Western Europe	240	265	225	225	250	305	235	220	250
Japan	145	135	135	135	140	140	120	110	115
China	180	185	215	220	235	255	295	340	365
RoW	180	180	185	200	240	220	170	170	185
Total	**1,005**	**1,020**	**1,015**	**1,030**	**1,110**	**1,155**	**1,015**	**1,025**	**1,130**
Recycling									
Autocatalyst									
North America	160	150	160	165	180	190	180	195	195
Western Europe	60	45	50	55	60	65	60	65	70
Japan	30	30	35	35	45	45	40	45	45
China	5	10	5	5	5	5	5	10	15
RoW	20	25	30	35	45	50	45	45	45
Total	280	260	280	305	335	355	330	360	370

Source: SFA (Oxford)

GLOSSARY OF TERMS

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

Beneficiation
The process in which ore material is reduced in size and waste minerals separated from ore.

BEV
Battery electric vehicle.

CAGR
Compound annual growth rate.

CAPEX
Capital expenditure.

China VI
China's current heavy-duty diesel vehicle emissions standard.

Circular economy
Model of production and consumption that extends the life-cycle of products as long as possible.

ESG
Environmental, social and governance.

Eskom
South Africa's public energy producer and supplier.

ETF
Exchange-traded fund.

FCEV
Fuel cell electric vehicle.

GDP
Gross domestic product.

Gross demand
A measure of intensity of use.

GWh
Gigawatt hour.

ICE
Internal combustion engine.

koz
A thousand troy ounces.

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.

MW
Megawatt.

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.

OEM
Original equipment manufacturer.

oz
Troy ounce.

PGM
Platinum-group metals.

Primary supply
Mine production.

Pyrometallurgy
Thermal treatment of ores to enable recovery of metals.

Secondary supply
Recycling output.

Thrifting
Using less metal in order to reduce costs.

TOCOM
Tokyo Commodity Exchange.

UG2 Reef
A PGM-bearing horizon within the Bushveld Igneous Complex, located stratigraphically below the Merensky Reef. One of the main chromite-bearing reefs of the Bushveld Igneous Complex. Typically comprises lower base metals contents than the Merensky Reef.

US light trucks
Pickups, SUVs and minivans up to 8,500 lbs.

ZEV
Zero-emission vehicle.

3E
Platinum, palladium and rhodium.

4E
Platinum, palladium, rhodium and gold.

Currency symbols:

ZAR	South African rand.
£	British pound sterling.
$	US dollar.

METHODOLOGY

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

Gross demand is a measure of intensity of use.

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

Automotive demand is based on vehicle production data not sales.

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Please note: Some tabulated data may not add up owing to rounding of individual numbers. © Published in May 2022 by SFA (Oxford) Ltd.

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