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Pgm Market Report

February 2020

Johnson Matthey
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Definitions

Europe	EU+ (includes Turkey but excludes Russia)
Japan	Japan only
North America	USA and Canada (excludes Mexico)
China	China only
RoW	Rest of World: all countries not captured in the above

Supply

Supply figures represent sales of **primary pgm** by producers and are allocated to the region where mining took place, rather than the region of subsequent processing.

Recycling

Recycling figures represent **secondary pgm supplies** and are the quantity of metal recovered from **open-loop recycling** (i.e. where the original purchaser does not retain control of the pgm throughout). Outside the autocatalyst, jewellery and electronics markets, open-loop recycling is negligible.

Autocatalyst recycling represents the weight of metal recovered from end-of-life vehicles and aftermarket scrap. It does not include warranty or production scrap. It is allocated to the region where the vehicle was originally sold (but not necessarily scrapped).

Gross demand

Gross demand figures for any given application represent the sum of industry demand for new metal in that application; that is it is net of any **closed-loop recycling** (i.e. where industry participants retain ownership of the metal: an example would be recycling of spent chemical catalysts where the metal is retained to be used on fresh catalyst that replaces the spent charge).

Gross demand also includes any changes in unrefined metal stocks in the sector. Increases in unrefined stocks lead to additional demand, while reductions in stocks (including any metal released from industry, e.g. in the case of chemical plant closures) lead to lower demand.

Autocatalyst demand is allocated to the region where the vehicle is manufactured and is accounted for at the time of vehicle production. It includes emissions catalysts on vehicles, motorcycles and three-wheelers, and non-road mobile machinery. (Fuel cell vehicles are counted under industrial demand.)

Jewellery demand is allocated to the region where the finished jewellery is manufactured, not sold.

Net demand is gross demand less open-loop recycling.

Movements in stocks

This figure gives the overall market balance in any one year and reflects the extent of stocks that must be mobilised to balance the market in that year. It is thus a proxy for changes in stocks held by fabricators, dealers, banks and depositories, but excludes stocks held by primary and secondary refiners and final consumers. A positive figure (market surplus) thus reflects an increase in global market stocks. A negative value (market deficit) indicates a decrease in global market stocks.

Platinum Summary

Supply and Demand in 2019

- Resurgent investment demand, with over a million ounces added to ETF holdings, pushed the platinum market into deficit in 2019.
- Platinum use in autocatalysts dropped 2% on lower diesel car output and a delay in stricter heavy vehicle emissions limits in China.
- Chinese jewellery sector weakness intensified as fabricators increasingly switched to gold.
- Industrial demand remained elevated by Chinese capacity expansions, but retreated somewhat from 2018's record level.
- Auto recycling rose, but was affected by rising industry lead times.
- Primary supplies fell slightly as disruptions to mine output offset the release of pipeline stocks.

The platinum market swung into deficit in 2019, as a resurgence in ETF buying lifted physical investment demand to a record 1.13 million ounces. This outweighed a modest contraction in global industrial and automotive demand and a double-digit drop in the Chinese platinum jewellery market. Combined primary and secondary supplies rose marginally, as growth in autocatalyst scrap volumes was partly offset by a slight decline in supply from South Africa and Russia. In South Africa, underlying mine output fell by about 3% as high-cost shafts continued to close, but our supply estimates allow for the shipment of some metal released from inventories.

During the first ten months of 2019, investors added over one million ounces of platinum to their ETF holdings, taking the total volume of platinum under investment to a record 3.4 million ounces. Unlike past periods of rapid growth in platinum ETFs, this activity was not associated with the launch of new ETF products, nor was it driven by a sustained price rally. Instead, it appears to have been triggered by an abrupt shift in sentiment towards platinum, particularly among European and South African investors.

Although palladium has seen dramatic gains over the past three years, the platinum price has remained subdued and range-bound. This has led some investors to conclude that platinum is under-priced, especially in view of its future potential to substitute for palladium in some autocatalyst applications.

At the same time, the perceived downside risk to South African supplies has risen: further shaft closures occurred in 2019 (and more are planned), periodic electricity shortages have caused some disruption to processing activities, and there were concerns that the 2019 wage negotiation round might culminate in strike action,

Platinum Supply and Demand '000 oz

Supply	**2017**	**2018**	**2019**
South Africa	4,450	4,467	4,411
Russia	720	687	667
Others	969	956	942
Total Supply	**6,139**	**6,110**	**6,020**
Gross Demand			
Autocatalyst	3,208	2,967	2,913
Jewellery	2,387	2,261	2,082
Industrial	2,038	2,493	2,358
Investment	361	67	1,131
Total Gross Demand	**7,994**	**7,788**	**8,484**
Recycling	-2,049	-2,098	-2,261
Total Net Demand	**5,945**	**5,690**	**6,223**
Movements in Stocks	194	420	-203

as occurred in 2014. (However, by year-end, all major producers had reached new three-year wage agreements).

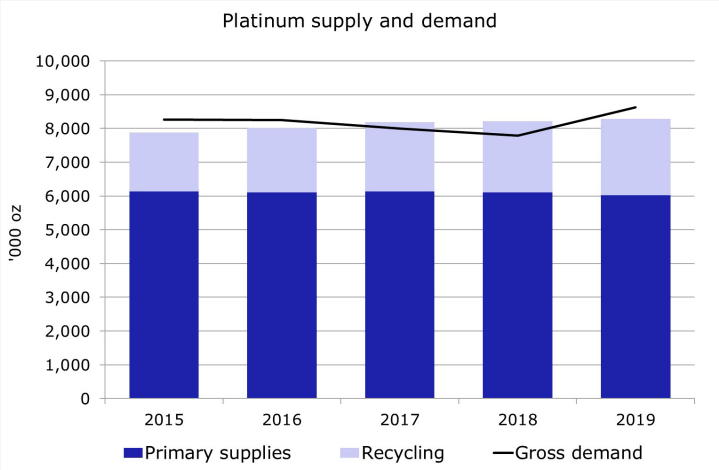
Most of the ETF buying which took place in 2019 was net new investment in pgm, rather than investors switching out of palladium (holdings of which fell only modestly over the same period). In addition to the industry-specific factors discussed above, it is likely that platinum benefited from a generally positive environment for 'safe-haven' investments such as precious metals. The trade dispute between the USA and China has exacerbated a slowdown in world economic growth and has enhanced the attractiveness of gold. With platinum trading at a record discount to gold, it has drawn renewed interest from precious metal investors.

In contrast, sales of physical platinum products to Japanese investors were lacklustre in 2019. Japanese investment demand typically runs counter to trends elsewhere in the world, because domestic investors have historically taken advantage of periods of falling prices to add to their platinum holdings. Between 2015 and 2018, as the retail platinum price moved down through ¥4,000 and then ¥3,500 per gram, and to a historically wide discount to gold, Japanese investors acquired over 1.5 million ounces of platinum in the form of bars purchased over the counter from bullion houses. However, by the time the price hit a nine-year low of ¥3,040 in August 2018, it appeared that investors' appetite for platinum had largely been sated, with weak prices in the second half of that year stimulating only modest amounts of buying.

During 2019, price movements were less conducive to Japanese investment. Retail platinum prices trended generally upwards, from around ¥3,100 in early January to over ¥3,700 at the year end. There was some moderate purchasing during a sharp mid-year correction, as platinum lost 14% of its yen value during May, but investor activity was otherwise subdued for most of the year. However, perhaps surprisingly after four years of significant purchasing into a falling market, there was only limited evidence of profit-taking as prices climbed. Overall, we estimate that Japanese investors acquired around 50,000 oz of platinum bars last year.

With total investment exceeding 1.1 million ounces, the platinum market moved into deficit last year despite falling consumption in all other major demand sectors. Autocatalyst demand was hit by declining diesel car sales which outweighed a slight increase in average catalyst loadings, while industrial demand retreated slightly from an all-time high the previous year, and weakness in the Chinese jewellery sector intensified. Overall, total non-investment demand fell by around 5%.

In our May 2019 report, we predicted that autocatalyst demand would recover modestly from a five-year low in 2018. However, global heavy and light duty production volumes fell in 2019, while plans for the



"Platinum swung into deficit in 2019, as physical investment surged to a record 1.13 million ounces."

Platinum Demand: Autocatalyst '000 oz (Gross)			
	2017	**2018**	**2019**
Europe	1,691	1,440	1,365
Japan	358	337	337
North America	325	325	317
China	157	143	147
Rest of World	677	722	747
Total	**3,208**	**2,967**	**2,913**

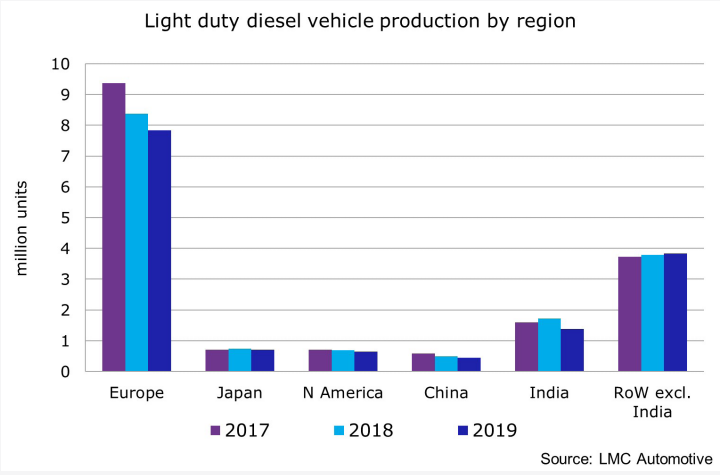
early implementation of China VI legislation on heavy duty trucks have been pushed back. As a result, we now believe that platinum consumption in autocatalysts fell by 2% to 2.91 million ounces last year.

Demand for platinum in light duty diesel applications fell by 4%, primarily due to declining production of diesel passenger cars in the two largest markets, Europe and India. Preliminary estimates suggest that European diesel car output contracted by 6% last year, reflecting an overall decline in light duty production combined with market share losses to both gasoline and battery electric vehicles. In India, the car market was dented by a government clampdown on unofficial lending, but the diesel segment was especially hard-hit: output tumbled by an estimated 20%, as domestic automakers began to withdraw diesel models ahead of the implementation of stricter emissions legislation.

Diesel cars have been popular in India in recent years, primarily because of a significant price differential between gasoline and diesel fuel, and Indian car companies have offered a wide range of diesel models at attractive price points. However, rising diesel fuel prices have already begun to dampen consumer demand in this segment, while the implementation of Bharat VI (BSVI) legislation in April 2020 is set to make diesel uncompetitive in smaller vehicle segments.

Pre-2020, Indian emissions standards (Bharat IV) could be met with a diesel oxidation catalyst, an old and relatively low-cost technology. The new BSVI standards will require vehicles to be fitted with advanced emissions control systems incorporating particulate filters and NOx abatement technology, the cost of which is prohibitive for entry-level vehicles in the Indian market. While stricter emissions limits also have implications for gasoline vehicle pricing, the additional cost of equipping a gasoline car to BSVI standards is estimated to be less than half that for a diesel vehicle. As a result, it is likely to be difficult to sell entry-level diesel cars in India in future. One Indian automaker has already announced that it intends to exit the diesel segment ahead of BSVI, while others plan to cease production of smaller diesel engines.

European diesel car production is also in retreat. Output dropped by 6% in 2019, to a ten-year low of 7.8 million units, representing a 40% share of European light duty vehicle production, down from a peak of over 50% in 2011. Following the 'dieselgate' crisis in 2015, production volumes in Europe were initially rather slow to react, but a combination of changing public attitudes and the



"European diesel car output contracted by 6% last year, while output in India tumbled by around 20%."

increasing cost of diesel aftertreatment systems is now beginning to have a more significant impact. Diesel car output is becoming more focused on larger and more expensive vehicles, where the CO_2 benefits are greatest and where it is easiest to recoup the high cost of emissions control systems.

European automotive platinum demand fell in 2019, reflecting trends in vehicle production. Although more vehicles were equipped to Euro 6d-TEMP standards, this had only a modest impact on average platinum loadings.

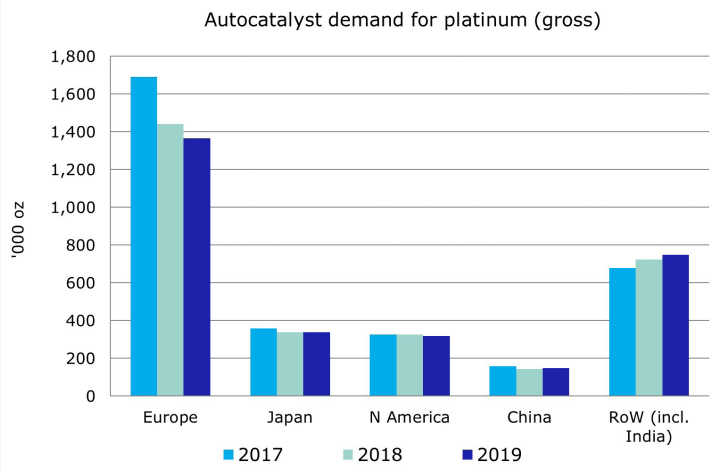
The implementation of Euro 6d-TEMP began in September 2017 and since then has been progressively applied to a greater percentage of new passenger cars and light commercial vehicles, requiring these vehicles to comply with emissions limits under 'real driving emissions' (RDE) conditions as well as in the laboratory (see page 40 for further details of the phases of Euro 6 legislation). RDE legislation specifically targets NOx and particulate emissions and sets 'conformity factors' for these pollutants, which adjust the nominal emissions limits to allow for measurement error in road testing. These factors will tighten during future phases of regulation.

The rollout of Euro 6d-TEMP has resulted in fundamental changes in European diesel aftertreatment technology. In particular, it has stimulated near-universal use of selective catalytic reduction (SCR), a non-pgm technology, for diesel NOx control. As recently as 2017, only about half of European diesel cars used SCR – these were usually larger vehicles, because of the dimensions of SCR systems and the additional complexity and cost involved. In contrast, smaller vehicles tended to be equipped with platinum-rich NOx storage catalysts (NSCs). However, by 2019 and following the implementation of RDE testing, we estimate that almost all new European diesel cars used SCR as their primary NOx-abatement technology.

Increasingly, European cars are using SCR bricks that also function as a particulate filter ('SCRF'), eliminating the need for a separate pgm-containing diesel particulate filter (DPF). These SCRF and SCR bricks are used in series with one or more platinum-rich catalysts, usually a diesel oxidation catalyst (DOC), although a wide variety of catalyst combinations and configurations exists.

Although the phase-in of RDE testing has resulted in SCR becoming the primary NOx control technology on Euro 6d diesel cars, it has also stimulated some additional use of pgm-containing NSCs in combination with SCR technology. These NSCs may be used in place of oxidation catalysts, performing classic diesel catalyst functions (CO and HC oxidation) as well as providing some additional capacity for NOx treatment when required, for example during cold starts.

RDE standards are technically challenging to meet, and the legal and commercial risks of non-compliance are high. Automakers are therefore adopting risk-averse



"Auto platinum demand fell by only 2% in 2019, despite significant headwinds from falling vehicle production and diesel share."

Platinum Demand: Jewellery '000 oz									
	Gross			Recycling			Net		
	2017	2018	2019	2017	2018	2019	2017	2018	2019
Europe	176	191	190	-5	-5	-5	171	186	185
Japan	305	296	297	-222	-185	-208	83	111	89
North America	225	224	224	0	0	0	225	224	224
China	1,470	1,316	1,119	-515	-526	-490	955	790	629
Rest of World	211	234	252	-4	-4	-5	207	230	247
Total	**2,387**	**2,261**	**2,082**	**-746**	**-720**	**-708**	**1,641**	**1,541**	**1,374**

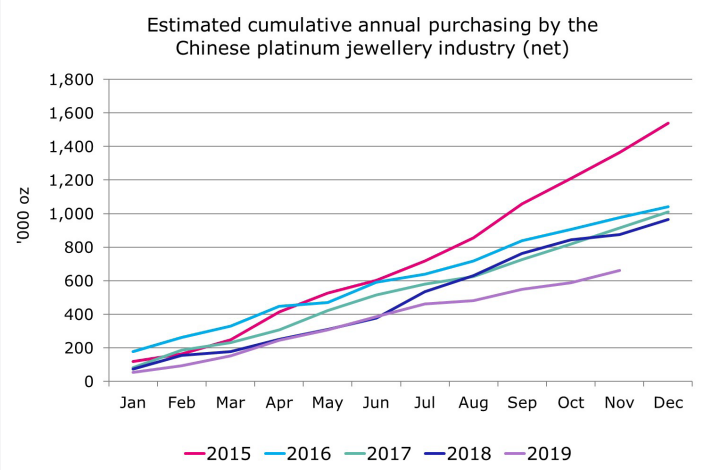
aftertreatment strategies that prioritise compliance over cost, and this has been positive for average platinum loadings on both DOCs and NOx storage catalysts. This has helped to compensate for negative impacts due to other changes in aftertreatment design, in particular the loss of the DPF brick from many systems.

In the heavy duty sector, we had expected to see a sharp increase in platinum demand in 2019, due to the early implementation of China VI emissions legislation in some cities and provinces under the Blue Sky Protection Plan. However, we now believe that the first introduction of the new standards will be delayed to 2020 to give truck manufacturers additional time to implement changes to their supply chains. The move from China V to China VI standards will in many cases require significant improvements in engine technology, in addition to a wholesale redesign of emissions control systems.

Overall, platinum demand in autocatalyst fell by only 2% despite significant headwinds from falling world vehicle production and diesel share. However, demand for platinum in its other major market, jewellery, appears to be facing much more serious challenges.

Johnson Matthey's biannual survey of Chinese jewellery factories suggests that there was further erosion of platinum's share of the Chinese jewellery market during the first half of 2019, and that the pace of decline may have increased compared to 2017–2018. Over the past five years, there has been a trend away from platinum towards gold in the fashion jewellery sector, with manufacturers initially developing and promoting 18 and 22 karat gold designs, and more recently expanding their fashion jewellery ranges with pieces made from pure gold, known as '5G'.

This 5G jewellery is offered in modern, lightweight styles and, like karat gold, is priced on a per-piece basis. (It is distinct from traditional Chinese 24 karat gold jewellery, which is primarily purchased as a store of value, in heavier and less sophisticated designs.)



"In 2019, new metal demand from the Chinese jewellery industry declined on 2018, reflecting further erosion in platinum's market share."

Platinum Demand: Industrial '000 oz			
	2017	**2018**	**2019**
Chemical	462	565	613
Electrical	233	240	224
Glass	314	488	439
Medical & Biomedical	220	222	229
Petroleum	234	377	253
Other	575	601	600
Total	**2,038**	**2,493**	**2,358**

Because the technical and financial barriers to switching between metals are relatively low, there is little incentive for established platinum jewellery makers to defend platinum's share of the fashion jewellery market. During the past five years, manufacturers have increasingly converted part of their production capacity to karat gold and more recently to '5G' gold fabrication. This switching process appears to have accelerated during 2019.

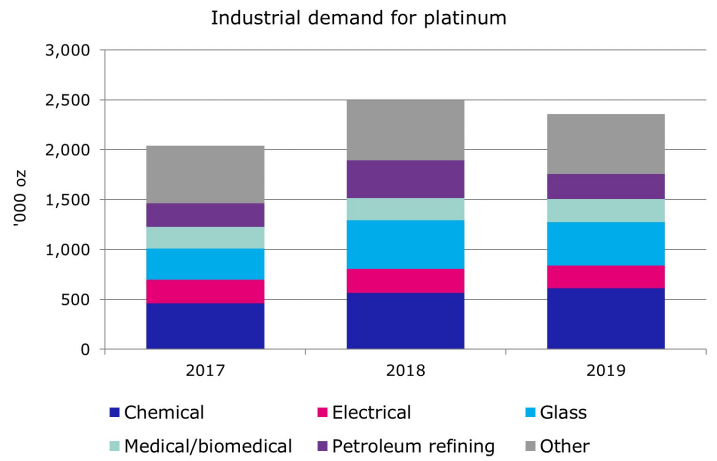
These trends have been driven primarily by margin considerations, with manufacturers and retailers seeking to maximise their profitability during a lacklustre period for the jewellery industry. In a stagnant overall market, growth in one type of product has generally been at the expense of another, with karat gold jewellery initially taking market share from platinum, and 5G gold now taking market share from both platinum and karat gold.

Jewellery recycling remained at elevated levels in 2019, with Chinese platinum jewellery manufacturers continuing to source a significant percentage of their metal needs from scrap. Recent years have seen growth in the number of independent scrap collectors who buy jewellery scrap for cash, and some jewellery retailers have also begun to offer this service.

Industrial demand for platinum remained at historically high levels in most applications, even though total industrial demand fell slightly compared to 2018's record level. The largest year-on-year change occurred in the petroleum refining sector, where demand fell by a quarter to 253,000 oz; this was nevertheless the second-highest annual total that we have recorded in our data series since 1975.

In the past two years, Chinese purchasing of petroleum refining catalyst has been at exceptionally high levels, due to the development of several very large integrated oil refining and petrochemicals complexes, and the simultaneous liberalisation of petroleum trade, which has enabled independent companies to import crude for the first time. Thus, although investment in new capacity at Chinese oil refineries was down in 2019 versus the previous year, it remained well above long-term trends.

Sales of platinum to chemicals producers in China hit a new peak in 2019. The integrated petrochemicals complexes referred to above typically incorporate large paraxylene units, requiring an initial catalyst charge that can involve tens of thousands of ounces of platinum.



"Industrial platinum demand fell slightly compared to 2018's record level, but remained at historically high levels."

Demand for platinum in the glass sector remained strong last year, although it retreated slightly from the 2018 peak. Purchasing was once again heavily concentrated in China, where fibreglass manufacturers have been investing heavily in new production capacity to meet anticipated growth in the electronics, construction, renewable energy and automotive sectors. There was also an increase in purchases of platinum for new display glass facilities in China, as manufacturers acquired the equipment needed to produce next-generation LCD glass panels for large-screen televisions measuring over 60 inches.

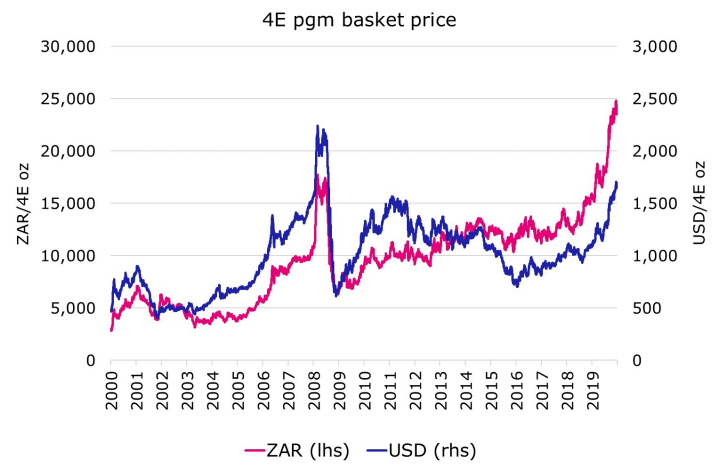
On the supply side, global supplies fell by 1%, with modest declines in shipments from Russia and South Africa. The South African platinum industry began last year with excess in-process inventories, which were partly drawn down during the year, despite periodic disruption to processing activities caused by electricity outages, stocktakes and smelter maintenance. This release of pipeline stock helped compensate for an estimated 3% decline in underlying mine production due to a combination of shaft closures, geotechnical issues and plant outages.

Rationalisation and restructuring of the South African platinum industry continued in 2019, with several older, high-cost shafts slated for closure, and the completion of Sibanye-Stillwater's acquisition of Lonmin's mining assets, which include the large Marikana mining complex. The Marikana mine is among those most affected by rationalisation: several of its first-generation shafts have been mothballed in the past three years, with further closures planned. Refined platinum output at Marikana is thought to have fallen from 650,000 oz in 2018 to around 550,000 oz last year.

Impala Platinum's Rustenburg lease area is also undergoing rationalisation following a strategic review in 2018. However, production of platinum in concentrate was broadly stable in 2019, despite the mothballing of 4 shaft and the scaling-down of production at 1 shaft ahead of its eventual closure.

Declining output at deep western limb mines was largely offset by improved performance elsewhere. Anglo American Platinum's large Mogalakwena mine continued to set new production records, with platinum output estimated at around half a million ounces last year. Royal Bafokeng Platinum's Styldrift mine continued its ramp-up, while Northam Platinum recommissioned a mothballed concentrator at its Booysendal project, to treat ore from a new UG2 shaft. Northam also reactivated a second plant, at the Eland Platinum project, where it has begun processing tailings.

During 2019, several major producers entered negotiations over a new three-year wage deal. While these discussions were often protracted, in some cases involving referral to the Commission for Conciliation,



"The rand price of a typical South African pgm basket surged higher during 2019 to a new all-time high."

Mediation and Arbitration, the mines were ultimately able to reach a settlement with labour unions without any impact on production from industrial action.

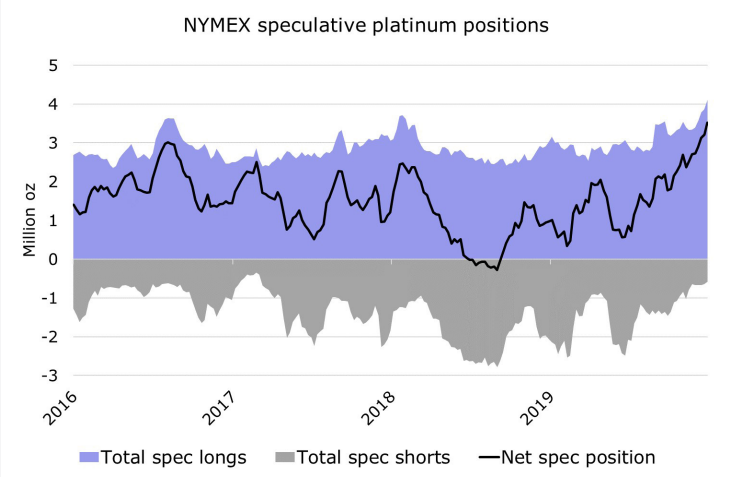
Higher pgm basket prices have probably facilitated a settlement, giving producers some flexibility to agree above-inflation wage increases. The rand price of a typical pgm basket (containing platinum, palladium, rhodium and gold in a split that reflects average South African mine production) was below R15,000 per ounce as recently as September 2018. During 2019, it surged higher, climbing past the 2008 peak to set a new all-time high of over R24,000 in December. Although a minority of operations have continued to struggle even at higher prices, most shafts are now cash-positive and producers' margins are at their highest levels for many years.

In contrast, the exceptional rise in pgm prices in 2019 has created some short-term problems for the secondary supplies sector, and in particular for recyclers of spent autocatalyst. Because most automotive scrap is purchased for cash, rising pgm prices have increased the funding requirements of scrap collectors. This has made it difficult for collectors to expand their businesses in tandem with growth in the availability of automotive scrap and may have contributed to a general increase in lead-times across the industry.

Other factors have also contributed to rising lead-times, specifically the closure of two major pgm refineries in Europe, and technical difficulties with processing some diesel particulate filter scrap. We allow for this increase in lead-times in our estimates of autocatalyst recycling volumes.

The platinum market moved into a technical deficit last year, but availability remains good and lease rates low. Although Swiss and UK platinum inventories have fallen sharply in recent years (see graph on page 12), this probably reflects the relocation of metal out of Europe and into Asia and has not been associated with any shortages of liquidity. In 2019, combined Swiss and UK stocks recovered somewhat, probably as a result of heavy ETF buying: these products are physically-backed and metal is stored in vaults in Europe.

Increased ETF buying has been associated with a general improvement in market sentiment over the past year. This has also been reflected in the futures markets, with a dramatic decline in the speculative short position on NYMEX during 2019, and a more modest increase in the speculative long position. Although the impact of this investor and speculative activity on price has been rather muted, it has helped to support platinum above $900 per ounce, up from $800 at the start of last year.



"A general improvement in platinum market sentiment over the past year has been reflected in the futures markets."

Platinum Outlook

Supply and Demand in 2020

- Unless investor appetites are sustained into 2020, the platinum market could move back into surplus.
- Rising autocatalyst recycling will at best offset a fall in primary supplies, but demand excluding investment is more likely to fall than to rise.
- Increased use of platinum on Indian and Chinese trucks will provide some support to auto demand.
- Interest among automakers is rising, but 2020 is still too early to see significant substitution of platinum into gasoline emissions catalysts.
- Chinese jewellery demand will remain depressed and could contract further this year.
- A wave of purchasing for new fibreglass capacity will end, causing industrial demand to dip.

Demand for platinum will be supported this year by rising pgm loadings on heavy duty trucks in China and India, where stricter emissions legislation is due to be implemented in 2020. However, we expect this to be offset by further erosion of platinum jewellery demand, and a drop in purchasing in the glass sector. With weaker primary supplies balanced by further growth in autocatalyst recycling, investment will again be the primary factor which determines the direction of market balance. Significant purchasing by investors will be required to prevent the market moving back into surplus.

Platinum supplies in 2020 could fall below 6 million ounces for the first time in six years. This reflects the impact of ongoing rationalisation programmes in South Africa, a lower contribution from the release of excess pipeline stocks, and the depletion of pgm-rich surface materials that have supported pgm output at Norilsk Nickel in recent years.

South African supplies are forecast to fall slightly, mainly because we anticipate that there will be less potential for producers to supplement output by processing excess pipeline stock. Electricity shortages remain a downside risk, especially for processing operations, but the risk of industrial action related to wage negotiations appears to have receded.

Underlying South African mine production is not expected to change very much in 2020, as ongoing rationalisation should be at least partly offset by the ramp-up of some newer mines. There are still some shaft closures to come at the Impala Rustenburg lease area and at Sibanye-Stillwater's Marikana operation, but the full impact of rationalisation is likely to be delayed beyond this year.

We expect current rand prices to incentivise tactical decisions to maintain or maximise short-term production where possible, for example by contracting-out the operation of end-of-life shafts to extract remaining ore as Impala Platinum intends to do at its 1 shaft. However, it is not yet clear to what extent a high rand pgm basket price will influence longer-term strategic decisions on replacement and expansion capex. While the price for their main product, platinum, continues to be relatively lacklustre, South African producers are likely to remain cautious.

Russian platinum supplies are expected to decline in 2020. The treatment of old pyrrhotite and copper concentrates at Norilsk Nickel is now largely complete, and there is probably lower potential for the company to supplement its output from surface materials in future. There are longer-term plans to raise pgm output by increasing ore volumes from the underground Talnakh mines and developing a new open pit at the 'South Cluster' operation. However, the impact of these expansions will mainly be felt after 2023, when a large concentrator upgrade is due to be commissioned.

While autocatalyst recycling is expected to rise again in 2020, this will at best offset the decline in primary supplies. Recent growth in platinum recoveries reflects the dramatic expansion in platinum use on diesel catalysts that occurred between 2000 and 2007. Platinum consumption on light duty vehicles peaked at around 3.5 million ounces in 2006–2007, but fell steeply during the global financial crisis; thereafter demand was also affected by falling diesel vehicle registrations and increased use of palladium in diesel catalyst systems. This means that platinum recycling volumes are expected to reach a plateau in the next few years.

Combined platinum demand in the autocatalyst, industrial and jewellery sectors is not expected to change much in 2020. On balance we think combined demand in these 'consuming' applications (i.e. excluding investment) is more likely to fall than to rise, but this will depend on factors such as vehicle production volumes and the timing of industrial platinum purchases for new chemical, glass and petroleum refining plants.

There may be some modest upside potential for automotive demand this year, as Chinese and Indian manufacturers introduce truck models meeting China VI and Bharat VI (BSVI) legislation. Prior to this year, a majority of trucks sold in China and India were fitted with aftertreatment systems that either had a low pgm content or contained no pgm at all. Once the new regulations are fully enforced, all trucks sold in China and India will be equipped with advanced platinum-containing aftertreatment systems, typically incorporating an oxidation catalyst and diesel particulate filter, with SCR used for NOx control.

We believe that most Indian truck manufacturers had ceased producing trucks homologated to earlier standards by the end of 2019, because of the risk of being left with stocks of unsaleable vehicles when BSVI legislation comes into force in April 2020. We therefore assume that the vast majority of heavy duty vehicles produced in India this year will be fitted with advanced pgm-containing emissions control equipment. As a result, we expect average heavy duty diesel loadings to at least triple versus previous low levels, and platinum demand to rise proportionately.

China VI emission legislation is currently expected to be adopted in some major cities and provinces under the Blue Sky Protection plan during 2020, ahead of its official nationwide implementation in July 2021. Our current assumption is that about a quarter of trucks produced this year will meet China VI standards, although this estimate may prove conservative based on experience last year in the light duty gasoline vehicle sector. Thus, we expect heavy duty platinum demand in China to at least double in 2020 compared with 2019.

In the light duty diesel market, production volumes will be the principal factor determining the direction of platinum demand. European diesel car output is expected to shrink only marginally in 2020; although the overall production trend is down, the 2020/21 CO_2 emission standards for light vehicles are providing some short- and medium-term support for production volumes, especially in larger vehicle segments. New post-2020 CO_2 standards

for Europe were announced in 2019: versus 2021, they require OEMs to achieve a 15% reduction in CO_2 by 2025 and a 37.5% reduction by 2030. In the longer term, this is likely to drive deeper electrification of the European fleet, but it may encourage automakers to continue offering diesel engine variants, especially in larger and premium vehicle segments.

In contrast, Indian diesel car volumes are predicted to tumble by 40–50% in 2020 as some domestic automakers cease offering entry-level diesel cars ahead of the introduction of BSVI legislation in April. As a result, platinum consumption in this segment will be flat to slightly down, despite a significant increase in average platinum loadings.

High palladium prices have, to date, had almost no impact on platinum consumption in the automotive sector, but there may be some near-term potential for platinum to substitute some of the palladium used in diesel catalysts. This is especially true in North America, where light duty diesel emissions systems typically have a much higher palladium content than in other regions. However, in view of the subdued outlook for light duty diesel vehicles, we think the impact of platinum substitution in this segment is likely to be small.

Interest among automakers in the use of platinum in three-way catalysts is gaining momentum, but there are still technical hurdles to overcome and we do not expect to see a significant substitution effect in the gasoline sector in 2020.

Platinum's lower thermal durability is currently a major obstacle to its widespread adoption in three-way catalysts. This is especially true in regions that have implemented RDE testing, because this involves harsher test cycles with faster driving speeds and higher engine temperatures. Compared to palladium-rhodium formulations, the effectiveness of platinum-containing catalysts tends to deteriorate more rapidly as they age. At the high operating temperatures experienced in a typical gasoline car, platinum particles may sinter (agglomerate), resulting in a loss of surface area and hence of catalytic activity.

This is particularly problematic for 'close-coupled' catalysts, which are fitted close to the engine and exposed to the highest temperatures. These bricks have relatively high loadings, to boost catalytic activity during 'cold starts' before the engine has reached its normal operating temperature. They therefore represent the largest potential to generate future demand for platinum, but also the greatest technical challenge. If platinum is going to make significant inroads into this segment, this is more likely to occur within a two- to three-year timeframe.

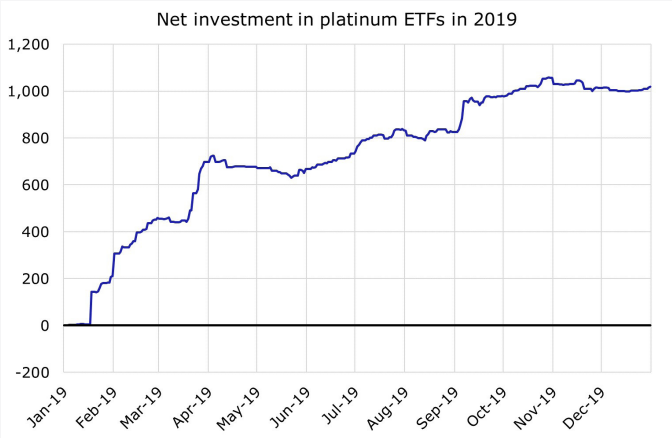
Substitution is somewhat easier in 'underfloor' bricks, which are fitted in a cooler location further from the engine and are designed to mop up any pollutants that are not converted by the close-coupled brick. Underfloor catalysts tend to have lower pgm loadings, so the potential impact of substitution is much smaller, but there could be some very modest additional demand in this application within the next year.

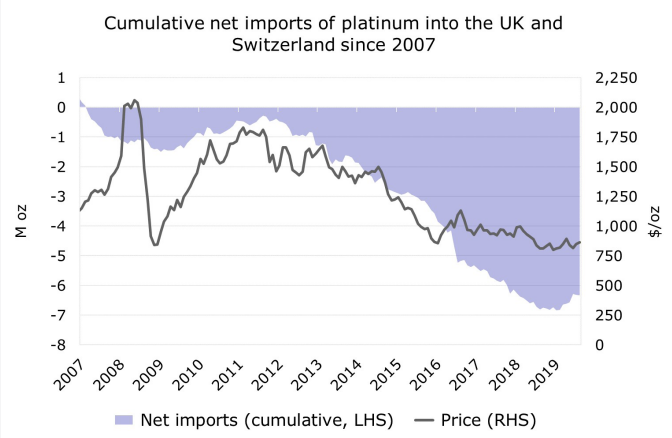
In contrast, we expect consumption of platinum jewellery to remain depressed and there is potential for demand to contract further. While the Chinese jewellery market remains subdued, jewellery fabricators will continue to reallocate their resources in order to maximise their margins. Although there have been some initiatives aimed at improving the margins earned on platinum jewellery – in particular, efforts to introduce per-piece pricing – to date this has not had any significant impact.

Industrial consumption of platinum has been at historically high levels in the past two years, but could dip temporarily in 2020 as a wave of investment in new fibreglass capacity comes to an end. The pace of capacity additions in the Chinese petroleum refining sector is also slowing, but we expect another year of buoyant demand for platinum process catalysts from new chemical plants in China.

With a muted outlook for supplies and potential upside in autocatalyst demand, platinum could see further interest from investors in 2020, especially if economic uncertainty continues to support the gold price, and platinum's discount to gold remains at record levels.

However, ETF holdings began 2020 at a record 3.4 million ounces, and clearly the risk of redemptions has risen. There may also be potential for disinvestment in the physical bar market in Japan, especially if the retail platinum price moves above ¥4,000 per gram. To balance the market in 2020, investment demand will need to be close to 1 million ounces: this means that there is a significant risk that the market will move back into surplus. This ready availability of platinum is likely to be a factor in future decisions regarding autocatalyst substitution, which may be driven as much by concerns about market liquidity as by price.





Palladium Summary

Supply and Demand in 2019

- All-time highs were seen in the palladium price as the market moved over a million ounces into deficit in 2019.
- Intensifying use of palladium on gasoline cars in Europe and China pushed auto demand to a record level, despite falls in vehicle output.
- Industrial demand fell, although mainly for reasons unrelated to price.
- ETF disinvestment moderated last year, with the final quarter seeing some return to buying.
- Primary supplies declined in 2019, on lower Russian shipments, but this was offset by increased recoveries from autocatalyst scrap.

The palladium market deficit widened to over 1 million ounces in 2019, as combined primary and secondary supplies grew only modestly, while autocatalyst demand surged higher on the back of new legislation in China and more stringent testing regimes in Europe. Industrial demand fell slightly, mainly due to slowing world economic growth; even though the palladium price set a series of all-time highs, there were only modest increases in thrifting and substitution, mainly in the dental industry. Meanwhile, the rate of ETF redemptions fell sharply despite the rise in price, and during the second half of 2019 there were signs of a return to positive investment buying.

Tightening emissions legislation and stricter vehicle testing regimes are driving up the pgm content of three-way catalysts in most major vehicle markets. Last year saw a 14% rise in global average palladium loadings on gasoline cars, with double-digit growth in both Europe and China. This propelled automotive demand for palladium to a new all-time high of 9.7 million ounces, a 10% gain versus 2018 despite falls in gasoline vehicle production in most regional car markets.

The Chinese market was particularly hard-hit by falling production: light duty vehicle output slumped by an estimated 7%, while gasoline cars also lost market share to battery electric vehicles (production of which grew by over one-third to exceed 1 million units for the first time. Light vehicle volumes were hit by slowing economic growth, with consumers becoming more cautious about purchasing big-ticket items.

In addition, the termination of government incentive schemes continued to affect the market, particularly in some lower-tier cities where sales had been inflated by vehicle tax reductions during the 2016–2017 period.

Palladium Supply and Demand '000 oz

Supply	**2017**	**2018**	**2019**
South Africa	2,547	2,543	2,648
Russia	2,452	2,976	2,802
Others	1,452	1,487	1,444
Total Supply	**6,451**	**7,006**	**6,894**
Gross Demand			
Autocatalyst	8,462	8,782	9,677
Jewellery	167	148	140
Industrial	1,820	1,848	1,742
Investment	-386	-574	-57
Total Gross Demand	**10,063**	**10,204**	**11,502**
Recycling	-2,861	-3,121	-3,416
Total Net demand	**7,202**	**7,083**	**8,086**
Movements in Stocks	-751	-77	-1,192

Palladium Demand: Autocatalyst '000 oz (Gross)			
	2017	**2018**	**2019**
Europe	1,701	1,899	2,075
Japan	829	851	923
North America	2,028	2,114	2,150
China	2,179	2,080	2,658
Rest of World	1,725	1,838	1,871
Total	**8,462**	**8,782**	**9,677**

Car production and sales were also temporarily impacted by the mid-year introduction of China 6 emissions legislation in some provinces and cities (the legislation will be formally enforced countrywide in July 2020). Consumer demand for China 6 models was higher than expected, and some automakers were left with excess inventory of China 5 vehicles and a shortage of China 6 variants. By the final quarter of 2019, inventories of older vehicles had been drawn down, and most production lines had been switched to China 6 models.

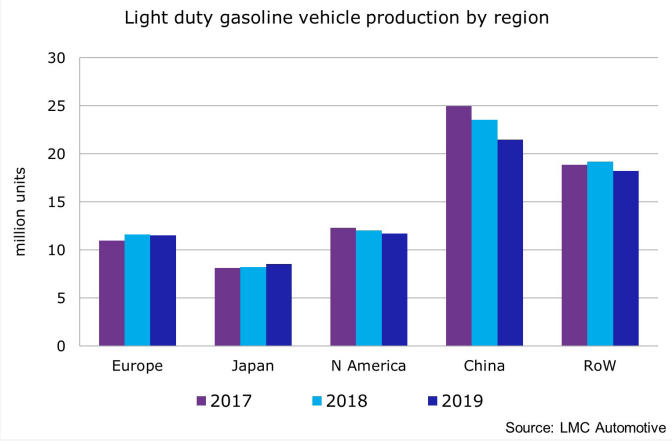
The cities and provinces affected by the early implementation of China 6 standards account for around 60% of annual Chinese car sales. On this basis, we forecast in our May 2019 report that around one-third of new cars produced in China last year would be China 6 models. This was a significant underestimate, with China 6 vehicles ultimately accounting for about 70% of new gasoline vehicles produced in 2019. As a result, and despite the fall in car production volumes, total palladium consumption on Chinese cars leapt by around 20%.

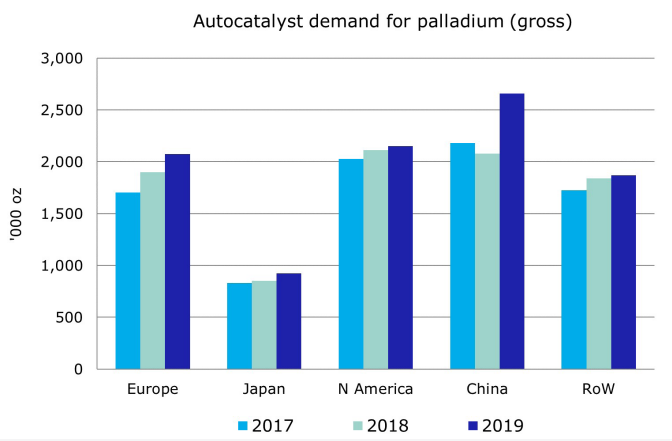
There was also an increase in the use of palladium in heavy duty vehicles in China in 2019. There is a small market in China for trucks powered by compressed natural gas (CNG), some of which were equipped with China VI catalyst systems last year. These vehicles use three-way catalyst technology but typically require heavier palladium loadings compared to gasoline vehicles.

The European market also saw further strong growth in the palladium content of gasoline aftertreatment systems, reflecting the implementation of new phases of Euro 6 emissions legislation.

Euro 6c legislation has been enforced on all new passenger cars sold in Europe since September 2018. This imposes a particle number (PN) limit on gasoline vehicles (in line with the existing limit on diesels) and is intended to reduce emissions of the smallest soot particles, which pose serious risks for human health. The rollout of Euro 6d-TEMP legislation began in September 2017 and was extended to all new cars in September 2019, requiring vehicles to demonstrate NOx and particle number emissions compliance in real driving emissions (RDE) testing as well as in laboratory tests. (Further information on Euro 6c and 6d legislation can be found in the special feature on page 14 of our May 2019 report.)

With the introduction of a particle number limit, many gasoline direct injection (GDI) models are now being





Palladium Demand: Industrial '000 oz			
	2017	2018	2019
Chemical	442	545	511
Dental	391	358	323
Electrical	843	768	728
Other	144	177	180
Total	**1,820**	**1,848**	**1,742**

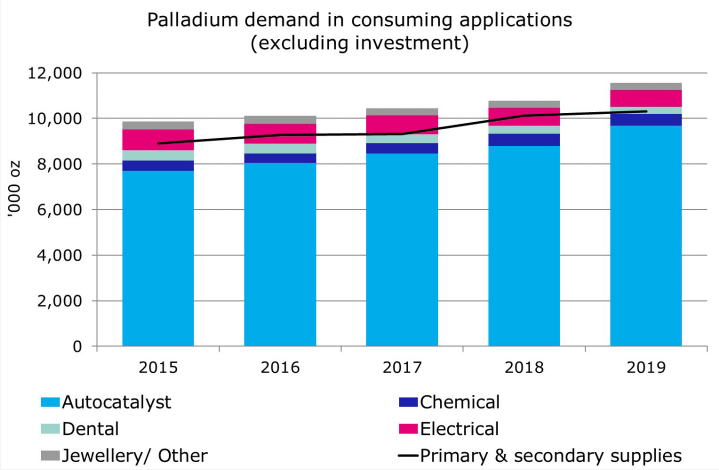
fitted with gasoline particulate filters (GPF) in addition to three-way catalysts. The pgm content of GPFs varies widely, depending on engine characteristics and the filter's precise function in the aftertreatment system. Some filters do not contain any pgm, while others have a relatively low pgm content to help with the 'regeneration' process, during which captured soot particles are periodically burnt off. However, some GPF bricks are designed both to act as a soot filter and to provide conversion capacity for other pollutants. These GPFs may have loadings similar to those on a three-way catalyst. Overall, Euro 6c has greatly increased the complexity of aftertreatment systems fitted to gasoline direct injection cars, but has probably had only a minor impact on total pgm loadings.

The impact of Euro 6d-TEMP has been much more significant. During RDE testing, vehicles are driven according to random acceleration and deceleration patterns, which are intended to replicate the wide range of operating conditions that cars might experience during a lifetime on the road. At the same time, European legislation has drastically reduced car manufacturers' scope to calibrate their emissions control systems to protect the catalyst or the engine under extreme operating conditions. This means that automakers now need to ensure that emissions control equipment will be effective under almost all conceivable operating conditions and for almost the entire operating life of the vehicle.

The technical difficulty of achieving this, and the commercial risk of not doing so, have had a very significant impact on average pgm loadings on three-way catalysts: between 2017 and 2019, the average pgm content of a European gasoline car rose by over a quarter. As a result, despite lacklustre conditions in the European automotive industry, we estimate that palladium demand in this region reached a record 2.08 million ounces.

Demand in industrial applications fell last year. Most of palladium's industrial applications are relatively insensitive to price, but consumption in the dental industry has been affected by high prices, which make palladium dental alloys less competitive compared with alternative materials such as resins and ceramics, and even platinum-containing gold alloys.

Palladium use in electronics also fell last year, but this was primarily for reasons unrelated to price. Plating applications are palladium's largest demand segment in the electronics industry. Palladium plating salts are typically used to apply a thin palladium layer, usually as part of a 'sandwich' between layers of nickel and gold, on



"Auto palladium demand reached a new all-time high of 9.7 million ounces, but demand in industrial applications fell last year."

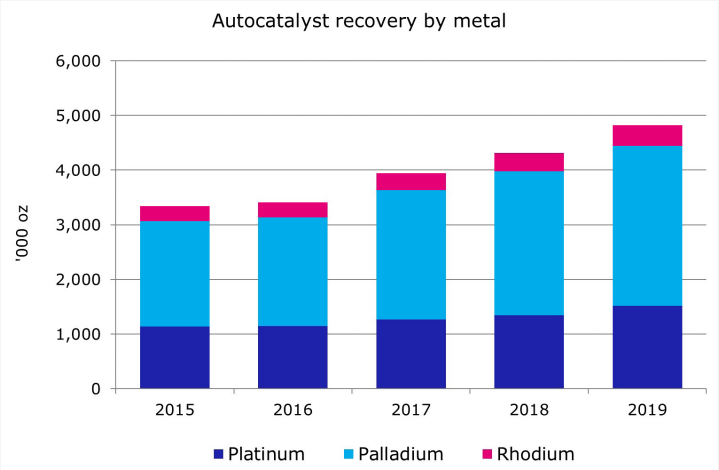
electronic components such as connectors, lead-frames and printed circuit boards (PCBs). In 2019, world demand for these components dropped steeply, hit by the impact of trade disputes and tariff increases on economic activity, especially in China. This downturn is expected to be short-lived, with the introduction of 5G technology over the next two years likely to be positive for the market for electronic components.

Consumption of palladium in the chemicals industry remained at unusually high levels in 2019. Purchasing of palladium process catalyst by Chinese chemicals companies was exceptionally strong, stimulated by capacity additions for purified terephthalic acid (PTA), a feedstock in the manufacture of polyethylene terephthalate (PET) which is widely used in the packaging and textiles industries. With more than eight million tonnes of PET capacity due to come onstream during 2019–2020, this has stimulated capacity additions for PTA. There has also been further investment in new monoethylene glycol (MEG) plants, which in China typically use coal as a feedstock and involve a palladium catalyst.

Investment demand remained negative, but the rate of liquidation fell sharply compared to the 2015–2018 period, during which over 2.2 million ounces of palladium ETFs were redeemed. At the start of 2019, only just over 700,000 oz of palladium remained in ETF vaults (down from a peak of nearly 3 million ounces in 2015); by August, this had fallen to a low of 590,000 oz. However, during the final quarter, there was some moderate ETF buying even as the price advanced to a series of all-time highs.

We estimate that primary palladium supplies declined by around 2% in 2019, mainly due to lower shipments from Russia. Over the past three years, palladium output at Norilsk has been boosted by the processing of old copper concentrate derived from historic mining activities and purchased from the state-owned company Rostec. At the same time, quarterly production volumes have been highly volatile, due to changes in the company's process flowsheet that have contributed to significant variations in work-in-progress inventories. Output of pgm was unusually strong during the first six months of 2019, but is thought to have declined sharply in the second half. While there was some release of palladium from in-process stocks in South Africa, this was not enough to offset lower Russian supplies.

Inventory fluctuations also played a role in the secondary sector, where the industry is facing capacity constraints following the closure of two European refineries at a time of rising autocatalyst recycling volumes. This has resulted in rising lead-times across the sector; we allow for this in our estimate of recycling volumes. Nevertheless, total palladium recoveries rose by 9% last year, offsetting the fall in shipments of primary metal, and leaving combined primary and secondary supplies up 2%.



"Despite refinery capacity constraints, total palladium recoveries rose by 9% last year, offsetting a fall in primary shipments."

Palladium Outlook

Supply and Demand in 2020

- A further rise in automotive demand is expected to push the palladium market deeper into deficit this year.
- Stricter emissions legislation in China and Europe will drive up vehicle palladium loadings.
- Efforts to reduce palladium consumption in the automotive industry are unlikely to prevent demand rising in 2020.
- Remaining ETF holdings of palladium are not enough to offset the shortfall in supply.
- The response of supplies to price is constrained by capacity and other factors.

The palladium deficit is likely to deepen in 2020, as an increasing number of Chinese and European vehicles meet China 6 and Euro 6d legislation, respectively. This is expected to drive up global average loadings on gasoline catalysts and could lift world automotive demand above 10 million ounces. Although secondary recoveries from spent catalytic converters will continue to rise, primary supplies may fall slightly, reflecting rationalisation at South African mines and the depletion of palladium-rich surface materials at Norilsk Nickel. While the market remains in significant deficit, prices are likely to remain strong, stimulating efforts to thrift and substitute palladium where possible, and incentivising the mobilisation of market stocks.

These stocks include metal held in ETFs, which at the end of 2019 amounted to some 660,000 oz of palladium. However, it is impossible to predict when or indeed whether this metal will be made available to the market, even if prices continue to climb. Indeed, during the final quarter of last year, there was some modest net buying of palladium ETFs in most regions, even as the price set a series of all-time records.

Other stocks potentially available to the market include some historic Norilsk Nickel production acquired many years ago by the Central Bank of Russia. In recent years, some of this Central Bank metal has been purchased by Norilsk's Global Palladium Fund and used to support market liquidity (we treat this as a relocation of market stocks rather than as fresh supply). We estimate that up to one million ounces of Central Bank metal may still be available.

It may also be possible to mobilise metal held in the form of work-in-progress stocks at refineries and fabricators, if higher prices motivate companies to

reduce inventories. Finally, banks, other financial market participants, and even private individuals hold physical palladium in forms that we do not count as 'investment demand' (because it is not 'allocated' metal or because volumes are impossible to estimate). For example, in China, individuals associated with industrial interests have a history of purchasing significant quantities of pgm for speculative purposes, with the intention of selling it on to fabricators at a profit. Some metal held by banks, hedge funds and other speculators may be released to the market as prices rise.

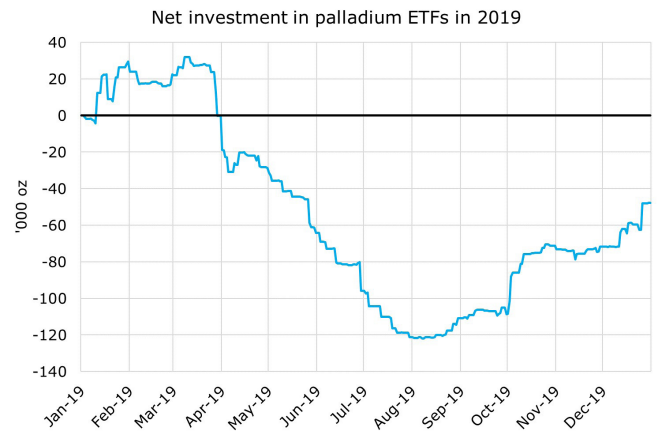
Higher prices are also likely to incentivise efforts to thrift or substitute palladium. In the short term, we think that the North American and European dental markets are the sectors most likely to display significant price-elasticity, because alternative products are readily available and the cost of switching is low. However, the large Japanese dental alloy market is protected to some degree by state health insurance, which covers the palladium-containing Kinpala alloy, making it cheaper for patients than alternatives such as ceramics and resins.

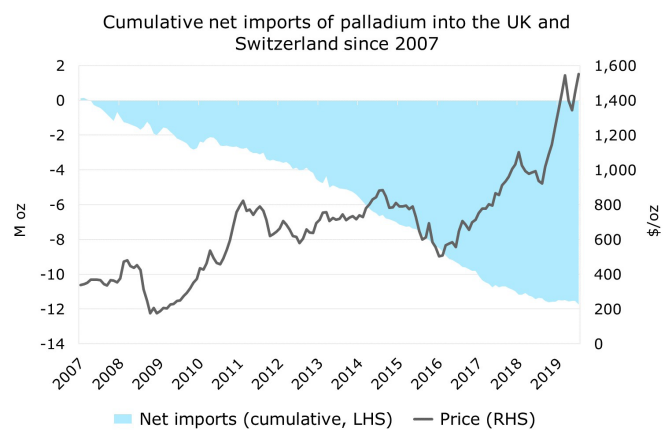
There is also some potential to reduce palladium usage in the electronics industry, although over a somewhat longer timescale: alternatives to palladium (such as gold and nickel) are available, but there are some technical and capital hurdles to overcome. On the other hand, most demand from the chemical industry is relatively price-inelastic because, even where substitute catalysts exist, their adoption would require changes to process flowsheets, potentially requiring significant capital investment.

There may now be some short-term potential for thrifting and substitution in the automotive industry (see below), but this is unlikely to be enough to prevent demand from rising again in 2020, with both Europe and China expected to see further increases in average palladium loadings on gasoline cars this year.

Almost all gasoline cars manufactured in China in 2020 will meet China 6 standards (versus around two-thirds in 2019), even though the legislation will not be enforced nationwide until mid-year. As a result, the average palladium content per vehicle will rise again, albeit at a lower rate than last year. Automakers are already beginning to optimise their engines and catalyst systems as they acquire more experience of meeting the new legislation and in some cases this is facilitating thrifting of pgm.

Due to the compressed phase-in schedule for China 6, the automotive industry had only limited time for technical development ahead of the implementation of the new standards. As a result, car companies' main priority last year was to obtain approval for China 6 models and to bring them to market. While the joint-venture automakers were able to draw on their experience of meeting European legislation, some domestic companies had a much higher technical hurdle to overcome, often





with less advanced engine platforms. This led to very high initial pgm loadings on some China 6 vehicles.

Work to cut the pgm content of these catalysts is already underway, incentivised by high pgm prices, weak vehicle sales and falling profitability in the Chinese auto industry. In particular, some domestic carmakers are achieving significant reductions in loadings via the introduction of new engine platforms that have been optimised to reduce engine-out emissions. We expect this thrifting process to intensify during 2020, limiting but not reversing overall increases in demand.

In Europe, palladium loadings on gasoline catalysts are expected to see another double-digit increase, with limited short-term potential for thrifting due to the technical challenge of meeting RDE standards. The final stage of Euro 6d will be phased in starting in January 2020, further reducing permitted NOx emissions during RDE testing as the 'conformity factor' tightens from 2.1 to 1.43.

Conformity factors are intended to reflect measurement error from the use of portable emissions measurement systems (PEMS), providing automakers with a small margin above the official laboratory test limits. However, companies are increasingly wary of the potential reputational damage that could result from any apparent breach of the limits, and in some cases they are already designing catalyst systems to meet a conformity factor of 1.

We do not currently expect any significant substitution of palladium in gasoline autocatalysts in 2020, although (as we noted on page 11) we believe that some additional use of platinum in underfloor catalysts on gasoline vehicles is achievable within the next year to eighteen months. This will depend largely upon whether automakers are willing and able to commit the technical resources necessary to qualify new catalysts and to introduce them into their vehicle programmes, in what is a relatively short timeframe for this industry. There may also be some regional variations; in particular, we believe that the Chinese auto industry may be more responsive to price and have greater flexibility to implement new catalyst programmes.

However, given current trends in loadings, it would require quite significant uptake of platinum-rich gasoline catalysts to halt the rise in global palladium demand, let alone begin to reverse it. In the diesel sector, there may be some short-term scope to reduce the palladium content of catalyst systems, particularly in North America, but the impact is unlikely to be greater than a few thousand ounces this year.

Short-term primary and secondary supplies of palladium are constrained by mining and refining capacity as well as by the availability of secondary materials for recycling. Rationalisation programmes in South Africa are expected to cut mine output of all the pgm this year, although a high pgm basket price could result in the final closure of some shafts being postponed. In Russia, significant quantities of metal have been recovered in recent years from old concentrates from historic mining activities. Processing of these materials is now complete, although output in 2020 should be supported by the release of the last of the recovered metal from the processing pipeline. Norilsk Nickel plans to raise pgm output at both its Talnakh and South Cluster mining operations, but processing capacity will be a limiting factor until a planned concentrator expansion is commissioned in 2023.

Growth in secondary supplies may slow somewhat in 2020, although high pgm prices will continue to incentivise catalyst collection. Based on historical vehicle sales and catalyst pgm content, we think that autocatalyst recycling volumes in Europe and North America are likely to peak in the near future, and we could even see a medium-term decline in palladium recoveries in these markets. While there is significant potential for higher recycling in China and some Rest of World countries, the autocatalyst recovery industry here is still relatively underdeveloped, and the precise trajectory of future growth is still uncertain.

Rhodium

Summary of 2019 & Outlook for 2020

- Rhodium moved into a modest deficit in 2019, as a small rise in combined supplies was not enough to meet a 10% increase in total demand.
- Additional factors have acted to compound the tightening of liquidity.
- Amid this unusual market tightness, strong purchasing by the auto industry helped to propel the rhodium price higher last year.
- We expect a deeper deficit in 2020, as automotive demand is likely to post further gains despite any price-driven thrifting.
- With limited capacity for underlying supplies to respond, the extent of in-process stocks will be key to market liquidity this year.

Global consumption of rhodium on autocatalysts leapt by nearly 15% in 2019, following a step-change in loadings on Chinese vehicles as the phase-in of China 6 legislation got underway. Car companies in other regions also used more rhodium, in response to tighter emissions standards and more stringent testing. These gains offset a sharp fall in rhodium use in the glass industry, as capacity expansion slowed after two years of exceptionally strong activity. Although combined primary and secondary supplies rose by 2%, this was not enough to prevent the market moving into deficit.

The rhodium price moved sharply higher last year, reflecting strong demand, limited market liquidity and fluctuations in primary supply. During the first quarter, as Chinese auto companies acquired metal ahead of the rollout of China 6 models, and with electricity shortages in South Africa causing some disruption at pgm refineries, rhodium climbed from under $2,500 per ounce in early January to over $3,300 in March. The price retreated below $3,000 during April, stabilising at this level for much of the second quarter. However, from mid-June, it began another steep ascent, climbing through $4,000 in August and $5,000 in September to reach $6,000 in December.

While the primary driver for these price gains was a surge in buying by car companies, supply factors also played a role. Rhodium supplies from South Africa have been relatively stable over the last four years, with shaft closures broadly offset by the ramp-up of production at other mines, and by an increase in the processing of pgm and chrome tailings. Our 2019 estimate shows rhodium shipments up slightly, but there were some fluctuations during the year as a combination of 'load-shedding' (rolling cuts in electricity supply), stock-takes and routine or emergency plant maintenance periodically affected refinery operations. In a very small

Rhodium Supply and Demand '000 oz

Supply	**2017**	**2018**	**2019**
South Africa	611	618	621
Russia	78	69	59
Others	70	70	66
Total Supply	**759**	**757**	**746**
Gross Demand			
Autocatalyst	834	877	1,003
Other	207	165	141
Total Gross Demand	**1,041**	**1,042**	**1,144**
Recycling	-310	-335	-372
Total Net demand	**731**	**707**	**772**
Movements in Stocks	28	50	-26

and illiquid market, small variations in supply may have a noticeable impact on price.

Secondary supplies grew by an estimated 11%, as greater volumes of scrapped autocatalyst entered the recycling network. However, the secondary refining sector has been affected by unusually high work-in-progress inventories and rising lead-times, with the industry facing some capacity constraints following the closure of two European refineries.

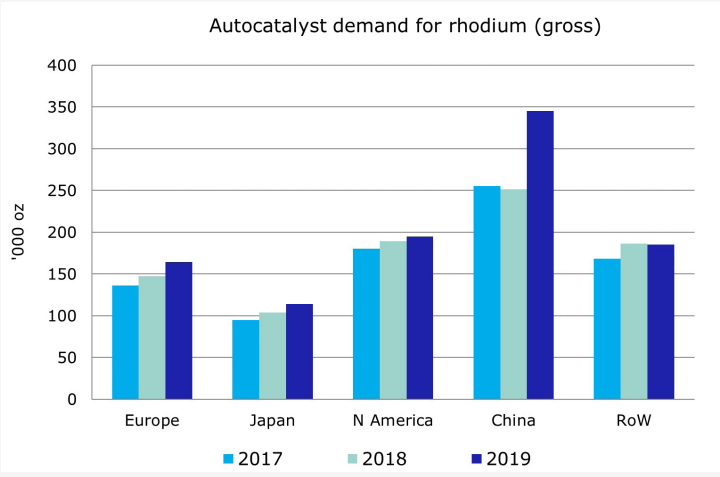
Total rhodium demand rose by 10%, as lower demand from glassmakers was offset by surging demand from the automotive sector. With emissions legislation tightening in most major markets, the average rhodium content of a gasoline car rose by around 20%, greatly outweighing a 4% fall in light duty gasoline vehicle production. The largest changes were seen in Europe, as a result of more stringent testing of passenger vehicles, and in China, where a new phase of legislative tightening got underway.

From September 2019, all new passenger cars sold in Europe were required to meet Euro 6d-TEMP standards, which require vehicles to demonstrate NOx and particle number (PN) emissions compliance in real driving emissions (RDE) on-road testing, as well as in the laboratory. The final phase of Euro 6d will be implemented starting in January 2020, further limiting permitted NOx emissions. At the same time, automakers have also been facing new in-service conformity regulations, which were introduced in January 2019 and are intended to ensure that catalyst systems meet RDE standards not just at the point that the vehicle is put into service, but for most of its lifetime.

Because rhodium is a particularly effective catalyst for NOx reduction, the impact of Euro 6d legislation on rhodium demand has been especially significant. Rhodium's history of price spikes has in the past encouraged aggressive thrifting of this metal, but the introduction of RDE testing has created new technical challenges, especially with regard to NOx control, and this is driving rhodium loadings higher.

In China, some cities and provinces began to implement China 6 legislation in July 2019, ahead of its nationwide application, which is officially scheduled to take place between July 2020 (China 6a) and July 2023 (China 6b, including RDE testing). We estimate that over two-thirds of gasoline cars sold in 2019 were China 6 vehicles and that the majority of these met China 6b standards (although without the RDE component). Meeting these standards involves significantly higher loadings for palladium and, particularly, rhodium when compared to previous China 5 systems.

Because of the relatively short time available for automakers to prepare for the new legislation, there has been limited opportunity to optimise engines



"The average rhodium content of a gasoline car rose by around 20% last year, outweighing a 4% fall in light duty gasoline vehicle production."

Rhodium Demand: Industrial '000 oz			
	2017	2018	2019
Chemical	72	63	62
Electrical	5	5	5
Glass	110	110	53
Other	20	-13	21
Total	**207**	**165**	**141**

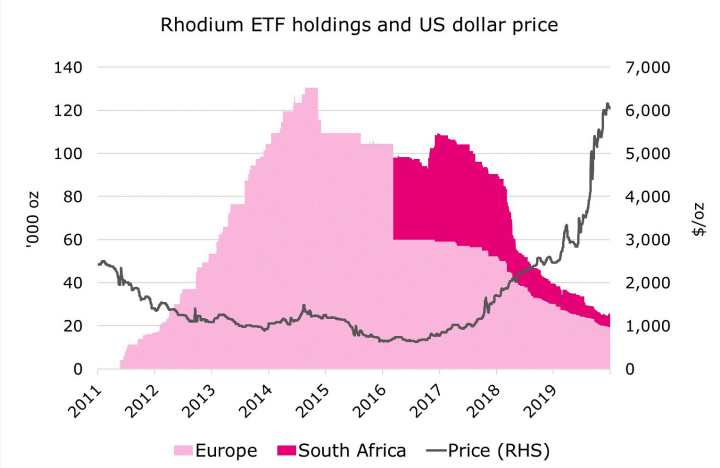
and catalyst systems. In addition, consumer demand for China 6 vehicles (as opposed to their China 5 predecessors) was higher than anticipated, and some car companies have had to rush out systems meeting the new standards. With automakers under pressure to obtain approval for China 6 models, the pgm content of catalysts became a secondary consideration, leading to some very large initial increases in loadings. There is already evidence that thrifting has begun, although to date it has primarily affected palladium.

Consumption of rhodium in industrial applications weakened in 2019, primarily due to lower purchasing from the Chinese glass industry, where increased economic uncertainty and overcapacity in the domestic market has resulted in some fibreglass expansions being deferred. In addition, high rhodium prices have begun to stimulate some substitution. Glassmakers are among the few consumers that can make short-term adjustments to their rhodium usage in response to price. The rhodium content of platinum alloys used in glassmaking equipment typically varies between 10% and 20%: alloys that contain less rhodium may be cheaper, but they are also less durable. As rhodium's premium over platinum rises, it can make economic sense to thrift rhodium even if this reduces the working life of the apparatus.

Elsewhere, demand in the chemicals sector remained firm in 2019, reflecting ongoing capacity additions in China. 'Other' demand (including investment) returned to positive territory. ETF redemptions fell sharply compared with 2018, although there was an increase in sales back to the market of small rhodium bars held by private investors.

Our supply and demand forecasts show the rhodium market in moderate deficit in 2019. Based on our estimates of market balance over the past five years, market stocks would appear to be sufficient to meet consumer demand. However, price movements and market liquidity over the past year suggest that market participants and perhaps consumers have purchased and held rhodium that was not immediately required for industrial processes.

Three factors which are not fully captured by our supply and demand measurements may have contributed to unusual market tightness. Firstly, we consider autocatalyst demand to occur at the time of vehicle production, because the precise timing of physical metal acquisition is not easy to determine. During periods of sharply rising loadings – as is the case in Europe and China at present – manufacturers may see significant increases in their work-in-progress inventories of pgm ahead of vehicle



"Much lower ETF redemptions compared with 2018 returned 'other' rhodium demand to positive territory."

production. As a result, when step-changes in legislation occur, our figures may underestimate physical demand in any single annual period.

In China, this issue has been compounded by the exceptionally rapid rate at which the auto industry moved from China 5 to China 6 legislation. This resulted in surplus inventories of China 5 catalysts, which have been scrapped. We do not treat this production scrap as demand (since it is recovered and reused). However, it does have some impact on physical liquidity, because metal on scrapped catalysts or in refinery pipelines is not available for consumers to purchase.

Secondly, we think that refinery capacity constraints in some regions are tending to increase recycling lead-times. Almost all of rhodium's industrial applications involve a constant 'closed-loop' cycle in which rhodium-bearing materials such as chemical process catalysts are regularly removed, recycled and replaced. The contained metal is not returned to the market, but remains in the ownership of the industrial user, and is generally reused in the same application. We therefore measure only the 'top-up' demand that occurs due to losses in the industrial process itself and during subsequent recycling. If there are delays in recovering metal due to refinery bottlenecks, this may have a physical impact on the market that is not fully captured in our demand estimates.

Finally, our figures do not capture investment activity that occurs outside 'retail' rhodium investment products such as rhodium coins and rhodium ETFs. Rhodium appears to have seen some speculative and strategic buying in recent years, particularly in China, but the extent of this is impossible to quantify.

The overall impact has been a general tightening of rhodium availability, pushing prices to levels not seen since 2008. Rhodium ended 2019 at around $6,000 per ounce, as further electricity shortages caused disruption to South African mining and processing operations during December. In early January 2020, the price moved abruptly above $8,000 on reports of producer purchasing.

The outlook for 2020 is for a deepening market deficit, with further strong gains expected in autocatalyst demand, albeit at a slower rate than last year.

In China, almost all vehicles sold in 2020 will meet China 6 emissions limits, while European automakers are ramping up production of Euro 6d vehicles. We predict that this will raise the global average rhodium loading on a gasoline car by around 8% (versus a 20% rise in 2019). It may be that there is some scope for higher prices to drive thrifting, especially in China, where automakers have already begun to optimise their engines and catalyst systems to limit palladium consumption. However, this is unlikely to be enough to halt the rise in overall rhodium demand.

On the supply side, South African producers will once again start the year with excess in-process stocks, the refining of which should help maintain rhodium shipments at around 2019 levels despite further shaft closures. We also anticipate some further gains in recycling volumes, although secondary refining capacity is likely to be a constraint, and lead-times and refinery pipelines are expected to remain higher than normal. Thus, the stability of processing operations (especially in the context of South African electricity supply shortages) and the ability of refiners to minimise in-process stocks will remain a key factor in determining market liquidity. However, even without disruptions to refinery operations, it seems likely that the market stocks of rhodium will need to be drawn down again in order to meet consumer demand.

Platinum Supply & Demand

Troy ounces

PLATINUM '000 oz - Supply and Demand							
							2019 numbers are preliminary
		2014	2015	2016	2017	2018	2019
Supply[1]	South Africa	3,546	4,572	4,392	4,450	4,467	4,411
	Russia[2]	700	670	714	720	687	667
	North America	340	339	353	346	330	323
	Zimbabwe[3]	401	400	489	466	474	480
	Others[3]	167	158	162	157	152	139
	Total Supply	**5,154**	**6,139**	**6,110**	**6,139**	**6,110**	**6,020**
Demand[4]	Autocatalyst[4]	3,062	3,263	3,326	3,208	2,967	2,913
	Chemical	576	502	476	462	565	613
	Electrical[4]	225	228	232	233	240	224
	Glass	143	227	247	314	488	439
	Investment	277	451	620	361	67	1,131
	Jewellery[4]	2,839	2,746	2,413	2,387	2,261	2,082
	Medical and Biomedical[5]	214	215	218	220	222	229
	Petroleum	172	140	187	234	377	253
	Other	468	494	535	575	601	600
	Total Gross Demand	**7,976**	**8,266**	**8,254**	**7,994**	**7,788**	**8,484**
Recycling[6]	Autocatalyst	-1,255	-1,135	-1,146	-1,268	-1,340	-1,513
	Electrical	-28	-30	-32	-35	-38	-40
	Jewellery	-762	-574	-738	-746	-720	-708
	Total Recycling	**-2,045**	**-1,739**	**-1,916**	**-2,049**	**-2,098**	**-2,261**
Total Net Demand[7]		**5,931**	**6,527**	**6,338**	**5,945**	**5,690**	**6,223**
Movement in Stocks[8]		**-777**	**-388**	**-228**	**194**	**420**	**-203**

Platinum Gross Demand by Region

Troy ounces

PLATINUM '000 oz - Gross Demand by Region

2019 numbers are preliminary

		2014	2015	2016	2017	2018	2019
Europe	Autocatalyst	1,476	1,662	1,773	1,691	1,440	1,365
	Chemical	111	120	122	118	122	124
	Electrical	12	13	13	10	11	12
	Glass	11	11	11	11	11	13
	Investment	-73	-88	109	36	-102	566
	Jewellery	204	203	177	176	191	190
	Medical and Biomedical	72	71	71	70	68	69
	Petroleum	22	-4	3	13	31	12
	Other	127	136	154	172	183	185
	Total	**1,962**	**2,124**	**2,433**	**2,297**	**1,955**	**2,536**
Japan	Autocatalyst	448	384	360	358	337	337
	Chemical	41	43	42	37	40	42
	Electrical	31	33	32	31	31	29
	Glass	-96	4	2	25	7	9
	Investment	19	700	543	171	220	32
	Jewellery	313	314	310	305	296	297
	Medical and Biomedical	16	16	15	15	16	16
	Petroleum	3	3	3	2	2	2
	Other	71	80	77	79	79	80
	Total	**846**	**1,577**	**1,384**	**1,023**	**1,028**	**844**
N. America	Autocatalyst	356	379	360	325	325	317
	Chemical	113	114	103	112	116	118
	Electrical	18	22	26	33	37	30
	Glass	10	10	29	45	18	18
	Investment	7	-32	109	127	66	156
	Jewellery	218	227	221	225	224	224
	Medical and Biomedical	85	85	87	88	89	93
	Petroleum	21	40	36	18	17	17
	Other	141	138	146	147	156	156
	Total	**969**	**983**	**1,117**	**1,120**	**1,048**	**1,129**
China	Autocatalyst	130	136	151	157	143	147
	Chemical	155	131	121	83	152	246
	Electrical	39	38	42	44	51	47
	Glass	144	178	135	111	375	313
	Investment	0	0	0	0	0	0
	Jewellery	1,935	1,796	1,510	1,470	1,316	1,119
	Medical and Biomedical	18	19	19	20	21	22
	Petroleum	30	32	76	120	263	175
	Other	53	59	72	83	88	84
	Total	**2,504**	**2,389**	**2,126**	**2,088**	**2,409**	**2,153**
RoW	Autocatalyst	652	702	682	677	722	747
	Chemical	156	94	88	112	135	83
	Electrical	125	122	119	115	110	106
	Glass	74	24	70	122	77	86
	Investment	324	-129	-141	27	-117	377
	Jewellery	169	206	195	211	234	252
	Medical and Biomedical	23	24	26	27	28	29
	Petroleum	96	69	69	81	64	47
	Other	76	81	86	94	95	95
	Total	**1,695**	**1,193**	**1,194**	**1,466**	**1,348**	**1,822**
	Grand total	**7,976**	**8,266**	**8,254**	**7,994**	**7,788**	**8,484**

Platinum Supply & Demand

Tonnes

PLATINUM Tonnes - Supply and Demand							
							2019 numbers are preliminary
		2014	2015	2016	2017	2018	2019
Supply[1]	South Africa	110.3	142.2	136.6	138.4	138.9	137.2
	Russia[2]	21.8	20.8	22.2	22.4	21.4	20.8
	North America	10.6	10.6	11.0	10.8	10.3	10.0
	Zimbabwe[3]	12.5	12.4	15.2	14.5	14.7	14.9
	Others[3]	5.2	4.9	5.0	4.9	4.7	4.3
	Total Supply	**160.4**	**190.9**	**190.0**	**191.0**	**190.0**	**187.2**
Demand[4]	Autocatalyst[4]	95.2	101.4	103.4	99.8	92.3	90.6
	Chemical	18.0	15.6	14.8	14.4	17.5	19.0
	Electrical[4]	7.1	7.1	7.2	7.3	7.5	7.0
	Glass	4.4	7.0	7.7	9.8	15.2	13.7
	Investment	8.6	14.1	19.3	11.2	2.1	35.2
	Jewellery[4]	88.3	85.5	75.1	74.2	70.3	64.7
	Medical and Biomedical[5]	6.6	6.7	6.8	6.8	6.9	7.1
	Petroleum	5.3	4.3	5.8	7.3	11.7	7.9
	Other	14.6	15.4	16.6	17.9	18.7	18.7
	Total Gross Demand	**248.1**	**257.1**	**256.7**	**248.7**	**242.2**	**263.9**
Recycling[6]	Autocatalyst	-38.9	-35.3	-35.6	-39.4	-41.6	-47.1
	Electrical	-0.9	-0.9	-1.0	-1.1	-1.2	-1.2
	Jewellery	-23.7	-17.9	-23.0	-23.2	-22.4	-22.0
	Total Recycling	**-63.5**	**-54.1**	**-59.6**	**-63.7**	**-65.2**	**-70.3**
Total Net Demand[7]		**184.6**	**203.0**	**197.1**	**185.0**	**177.0**	**193.6**
Movement in Stocks[8]		**-24.2**	**-12.1**	**-7.1**	**6.0**	**13.0**	**-6.4**

Platinum Gross Demand by Region

Tonnes

PLATINUM Tonnes - Gross Demand by Region

2019 numbers are preliminary

		2014	2015	2016	2017	2018	2019
Europe	Autocatalyst	45.9	51.7	55.1	52.6	44.8	42.4
	Chemical	3.5	3.7	3.8	3.6	3.8	3.8
	Electrical	0.4	0.4	0.4	0.3	0.3	0.4
	Glass	0.3	0.3	0.3	0.3	0.3	0.4
	Investment	-2.3	-2.7	3.4	1.1	-3.2	17.6
	Jewellery	6.3	6.3	5.5	5.5	5.9	5.9
	Medical and Biomedical	2.2	2.2	2.2	2.2	2.1	2.1
	Petroleum	0.7	-0.1	0.1	0.4	1.0	0.4
	Other	4.0	4.2	4.8	5.3	5.7	5.7
	Total	**61.0**	**66.0**	**75.6**	**71.3**	**60.7**	**78.7**
Japan	Autocatalyst	13.9	11.9	11.2	11.1	10.5	10.5
	Chemical	1.3	1.3	1.3	1.2	1.2	1.3
	Electrical	1.0	1.0	1.0	1.0	1.0	0.9
	Glass	-3.0	0.1	0.1	0.8	0.2	0.3
	Investment	0.6	21.8	16.9	5.3	6.8	1.0
	Jewellery	9.7	9.8	9.6	9.5	9.2	9.2
	Medical and Biomedical	0.5	0.5	0.5	0.5	0.5	0.5
	Petroleum	0.1	0.1	0.1	0.1	0.1	0.1
	Other	2.2	2.5	2.4	2.5	2.5	2.5
	Total	**26.3**	**49.0**	**43.1**	**32.0**	**32.0**	**26.3**
N. America	Autocatalyst	11.1	11.8	11.2	10.1	10.1	9.9
	Chemical	3.5	3.6	3.2	3.5	3.6	3.7
	Electrical	0.6	0.7	0.8	1.0	1.2	0.9
	Glass	0.3	0.3	0.9	1.4	0.6	0.6
	Investment	0.2	-1.0	3.4	4.0	2.1	4.9
	Jewellery	6.8	7.1	6.9	7.0	7.0	7.0
	Medical and Biomedical	2.6	2.6	2.7	2.7	2.8	2.9
	Petroleum	0.6	1.2	1.1	0.6	0.5	0.5
	Other	4.4	4.3	4.5	4.6	4.8	4.9
	Total	**30.1**	**30.6**	**34.7**	**34.9**	**32.7**	**35.3**
China	Autocatalyst	4.0	4.2	4.7	4.9	4.4	4.6
	Chemical	4.8	4.1	3.8	2.6	4.7	7.6
	Electrical	1.2	1.2	1.3	1.4	1.6	1.5
	Glass	4.5	5.6	4.2	3.5	11.7	9.7
	Investment	0.0	0.0	0.0	0.0	0.0	0.0
	Jewellery	60.2	55.9	47.0	45.7	40.9	34.8
	Medical and Biomedical	0.6	0.6	0.6	0.6	0.6	0.7
	Petroleum	0.9	1.0	2.4	3.7	8.1	5.4
	Other	1.6	1.9	2.2	2.6	2.7	2.6
	Total	**77.8**	**74.5**	**66.2**	**65.0**	**74.7**	**66.9**
RoW	Autocatalyst	20.3	21.8	21.2	21.1	22.5	23.2
	Chemical	4.9	2.9	2.7	3.5	4.2	2.6
	Electrical	3.9	3.8	3.7	3.6	3.4	3.3
	Glass	2.3	0.7	2.2	3.8	2.4	2.7
	Investment	10.1	-4.0	-4.4	0.8	-3.6	11.7
	Jewellery	5.3	6.4	6.1	6.5	7.3	7.8
	Medical and Biomedical	0.7	0.8	0.8	0.8	0.9	0.9
	Petroleum	3.0	2.1	2.1	2.5	2.0	1.5
	Other	2.4	2.5	2.7	2.9	3.0	3.0
	Total	**52.9**	**37.0**	**37.1**	**45.5**	**42.1**	**56.7**
	Grand total	**248.1**	**257.1**	**256.7**	**248.7**	**242.2**	**263.9**

Palladium Supply & Demand

Troy ounces

PALLADIUM '000 oz - Supply and Demand							
							2019 numbers are preliminary
		2014	2015	2016	2017	2018	2019
Supply[1]	South Africa	2,126	2,683	2,570	2,547	2,543	2,648
	Russia[2]	2,589	2,434	2,781	2,452	2,976	2,802
	North America	893	872	911	935	959	943
	Zimbabwe[3]	327	320	396	386	393	378
	Others[3]	160	144	129	131	135	123
	Total Supply	**6,095**	**6,453**	**6,787**	**6,451**	**7,006**	**6,894**
Demand[4]	Autocatalyst[4]	7,518	7,693	8,041	8,462	8,782	9,677
	Chemical	313	449	413	442	545	511
	Dental	464	468	429	391	358	323
	Electrical[4]	970	903	872	843	768	728
	Investment	943	-659	-646	-386	-574	-57
	Jewellery[4]	272	220	189	167	148	140
	Other	111	134	157	144	177	180
	Total Gross Demand	**10,591**	**9,208**	**9,455**	**10,063**	**10,204**	**11,502**
Recycling[6]	Autocatalyst	-2,117	-1,930	-1,986	-2,361	-2,634	-2,932
	Electrical	-474	-475	-481	-479	-475	-471
	Jewellery	-89	-46	-21	-21	-12	-13
	Total Recycling	**-2,680**	**-2,451**	**-2,488**	**-2,861**	**-3,121**	**-3,416**
Total Net Demand[7]		**7,911**	**6,757**	**6,967**	**7,202**	**7,083**	**8,086**
Movement in Stocks[8]		**-1,816**	**-304**	**-180**	**-751**	**-77**	**-1,192**

Palladium Gross Demand by Region

Troy ounces

PALLADIUM '000 oz - Gross Demand by Region

2019 numbers are preliminary

		2014	2015	2016	2017	2018	2019
Europe	Autocatalyst	1,583	1,624	1,635	1,701	1,899	2,075
	Chemical	-25	74	74	75	72	72
	Dental	77	70	65	60	51	42
	Electrical	113	101	99	96	91	88
	Investment	-74	-200	-269	-287	-141	-41
	Jewellery	60	59	58	53	49	43
	Other	25	27	24	23	30	26
	Total	**1,759**	**1,755**	**1,686**	**1,721**	**2,051**	**2,305**
Japan	Autocatalyst	794	759	787	829	851	923
	Chemical	16	15	15	17	17	17
	Dental	205	227	200	174	156	149
	Electrical	214	231	227	221	199	188
	Investment	-2	4	-3	-3	-1	1
	Jewellery	67	66	64	57	52	50
	Other	9	9	9	9	9	9
	Total	**1,303**	**1,311**	**1,299**	**1,304**	**1,283**	**1,337**
N. America	Autocatalyst	1,963	2,039	1,992	2,028	2,114	2,150
	Chemical	71	76	73	75	76	73
	Dental	156	145	138	131	125	107
	Electrical	140	131	128	124	112	105
	Investment	-205	-181	-71	-19	-87	10
	Jewellery	44	39	36	29	27	27
	Other	43	60	46	44	43	47
	Total	**2,212**	**2,309**	**2,342**	**2,412**	**2,410**	**2,519**
China	Autocatalyst	1,608	1,654	2,038	2,179	2,080	2,658
	Chemical	160	209	156	181	192	237
	Dental	8	8	7	7	7	6
	Electrical	169	158	156	155	141	133
	Investment	0	0	0	0	0	0
	Jewellery	78	34	10	9	2	1
	Other	16	17	45	51	75	74
	Total	**2,039**	**2,080**	**2,412**	**2,582**	**2,497**	**3,109**
RoW	Autocatalyst	1,570	1,617	1,589	1,725	1,838	1,871
	Chemical	91	75	95	94	188	112
	Dental	18	18	19	19	19	19
	Electrical	334	282	262	247	225	214
	Investment	1,224	-282	-303	-77	-345	-27
	Jewellery	23	22	21	19	18	19
	Other	18	21	33	17	20	24
	Total	**3,278**	**1,753**	**1,716**	**2,044**	**1,963**	**2,232**
	Grand total	**10,591**	**9,208**	**9,455**	**10,063**	**10,204**	**11,502**

Palladium Supply & Demand

Tonnes

PALLADIUM Tonnes - Supply and Demand							
							2019 numbers are preliminary
		2014	2015	2016	2017	2018	2019
Supply[1]	South Africa	66.1	83.5	79.9	79.2	79.1	82.4
	Russia[2]	80.5	75.7	86.5	76.3	92.6	87.1
	North America	27.8	27.1	28.3	29.1	29.8	29.3
	Zimbabwe[3]	10.2	10.0	12.3	12.0	12.2	11.8
	Others[3]	5.0	4.5	4.0	4.1	4.2	3.8
	Total Supply	**189.6**	**200.8**	**211.0**	**200.7**	**217.9**	**214.4**
Demand[4]	Autocatalyst[4]	233.8	239.2	250.2	263.3	273.2	301.0
	Chemical	9.7	14.0	12.9	13.6	16.9	15.9
	Dental	14.4	14.6	13.3	12.2	11.2	10.0
	Electrical[4]	30.3	28.1	27.1	26.3	23.9	22.6
	Investment	29.3	-20.5	-20.1	-12.0	-17.8	-1.8
	Jewellery[4]	8.5	6.9	5.9	5.2	4.6	4.3
	Other	3.5	4.2	4.8	4.5	5.4	5.6
	Total Gross Demand	**329.5**	**286.5**	**294.1**	**313.1**	**317.4**	**357.6**
Recycling[6]	Autocatalyst	-65.9	-60.0	-61.7	-73.4	-81.9	-91.1
	Electrical	-14.8	-14.8	-15.0	-15.0	-14.8	-14.7
	Jewellery	-2.7	-1.4	-0.7	-0.6	-0.3	-0.4
	Total Recycling	**-83.4**	**-76.2**	**-77.4**	**-89.0**	**-97.0**	**-106.2**
Total Net Demand[7]		**246.1**	**210.3**	**216.7**	**224.1**	**220.4**	**251.4**
Movement in Stocks[8]		**-56.5**	**-9.5**	**-5.7**	**-23.4**	**-2.5**	**-37.0**

Palladium Gross Demand by Region

Tonnes

PALLADIUM Tonnes - Gross Demand by Region

2019 numbers are preliminary

		2014	2015	2016	2017	2018	2019
Europe	Autocatalyst	49.2	50.5	50.9	52.9	59.1	64.5
	Chemical	-0.8	2.3	2.3	2.3	2.2	2.2
	Dental	2.4	2.2	2.0	1.9	1.6	1.3
	Electrical	3.5	3.1	3.1	3.0	2.8	2.7
	Investment	-2.3	-6.2	-8.4	-8.9	-4.4	-1.3
	Jewellery	1.9	1.8	1.8	1.6	1.5	1.3
	Other	0.8	0.8	0.7	0.7	0.9	0.8
	Total	**54.7**	**54.5**	**52.4**	**53.5**	**63.7**	**71.5**
Japan	Autocatalyst	24.7	23.6	24.5	25.8	26.5	28.7
	Chemical	0.5	0.5	0.5	0.5	0.5	0.5
	Dental	6.4	7.1	6.2	5.4	4.9	4.6
	Electrical	6.7	7.2	7.0	6.9	6.2	5.8
	Investment	-0.1	0.1	-0.1	-0.1	0.0	0.0
	Jewellery	2.1	2.1	2.0	1.8	1.6	1.6
	Other	0.3	0.3	0.3	0.3	0.3	0.3
	Total	**40.6**	**40.9**	**40.4**	**40.6**	**40.0**	**41.5**
N. America	Autocatalyst	61.1	63.4	62.0	63.1	65.7	66.9
	Chemical	2.2	2.4	2.3	2.3	2.4	2.3
	Dental	4.8	4.5	4.3	4.1	3.9	3.3
	Electrical	4.4	4.1	4.0	3.9	3.5	3.3
	Investment	-6.4	-5.6	-2.2	-0.6	-2.7	0.3
	Jewellery	1.4	1.2	1.1	0.9	0.8	0.8
	Other	1.3	1.9	1.4	1.4	1.3	1.5
	Total	**68.8**	**71.9**	**72.9**	**75.1**	**74.9**	**78.4**
China	Autocatalyst	50.0	51.4	63.4	67.8	64.7	82.7
	Chemical	5.0	6.5	4.8	5.6	6.0	7.4
	Dental	0.2	0.2	0.2	0.2	0.2	0.2
	Electrical	5.3	4.9	4.9	4.8	4.4	4.1
	Investment	0.0	0.0	0.0	0.0	0.0	0.0
	Jewellery	2.4	1.1	0.3	0.3	0.1	0.0
	Other	0.5	0.5	1.4	1.6	2.3	2.3
	Total	**63.4**	**64.6**	**75.0**	**80.3**	**77.7**	**96.7**
RoW	Autocatalyst	48.8	50.3	49.4	53.7	57.2	58.2
	Chemical	2.8	2.3	3.0	2.9	5.8	3.5
	Dental	0.6	0.6	0.6	0.6	0.6	0.6
	Electrical	10.4	8.8	8.1	7.7	7.0	6.7
	Investment	38.1	-8.8	-9.4	-2.4	-10.7	-0.8
	Jewellery	0.7	0.7	0.7	0.6	0.6	0.6
	Other	0.6	0.7	1.0	0.5	0.6	0.7
	Total	**102.0**	**54.6**	**53.4**	**63.6**	**61.1**	**69.5**
	Grand total	**329.5**	**286.5**	**294.1**	**313.1**	**317.4**	**357.6**

Rhodium Supply & Demand

Troy ounces

RHODIUM '000 oz - Supply and Demand							
							2019 numbers are preliminary
		2014	2015	2016	2017	2018	2019
Supply[1]	South Africa	470	611	615	611	618	621
	Russia[2]	80	80	85	78	69	59
	North America	24	22	24	23	22	22
	Zimbabwe[3]	36	36	44	42	43	39
	Others[3]	7	5	5	5	5	5
	Total Supply	**617**	**754**	**773**	**759**	**757**	**746**
Demand[4]	Autocatalyst[4]	771	760	806	834	877	1,003
	Chemical	90	73	64	72	63	62
	Electrical	3	3	4	5	5	5
	Glass	49	52	85	110	110	53
	Other	38	30	41	20	-13	21
	Total Gross Demand	**951**	**918**	**1,000**	**1,041**	**1,042**	**1,144**
Recycling[6]	Autocatalyst	-297	-277	-275	-310	-335	-372
	Total Recycling	**-297**	**-277**	**-275**	**-310**	**-335**	**-372**
Total Net Demand[7]		**654**	**641**	**725**	**731**	**707**	**772**
Movement in Stocks[8]		**-37**	**113**	**48**	**28**	**50**	**-26**

Rhodium Supply & Demand

Tonnes

RHODIUM Tonnes - Supply and Demand							
							2019 numbers are preliminary
		2014	2015	2016	2017	2018	2019
Supply[1]	South Africa	14.6	19.0	19.1	19.0	19.2	19.3
	Russia[2]	2.5	2.5	2.6	2.4	2.2	1.8
	North America	0.8	0.7	0.7	0.7	0.7	0.7
	Zimbabwe[3]	1.1	1.1	1.4	1.3	1.3	1.2
	Others[3]	0.2	0.2	0.2	0.2	0.2	0.2
	Total Supply	**19.2**	**23.5**	**24.0**	**23.6**	**23.6**	**23.2**
Demand[4]	Autocatalyst[4]	24.0	23.6	25.1	25.9	27.3	31.1
	Chemical	2.8	2.3	1.9	2.3	2.0	2.0
	Electrical	0.1	0.1	0.1	0.2	0.2	0.2
	Glass	1.5	1.7	2.6	3.3	3.3	1.7
	Other	1.2	0.9	1.3	0.6	-0.4	0.6
	Total Gross Demand	**29.6**	**28.6**	**31.0**	**32.3**	**32.4**	**35.6**
Recycling[6]	Autocatalyst	-9.2	-8.6	-8.5	-9.6	-10.4	-11.6
	Total Recycling	**-9.2**	**-8.6**	**-8.5**	**-9.6**	**-10.4**	**-11.6**
Total Net Demand[7]		**20.4**	**20.0**	**22.5**	**22.7**	**22.0**	**24.0**
Movement in Stocks[8]		**-1.2**	**3.5**	**1.5**	**0.9**	**1.6**	**-0.8**

Ruthenium Demand

Troy ounces and tonnes

RUTHENIUM '000 oz - Demand							
							2019 numbers are preliminary
		2014	2015	2016	2017	2018	2019
Demand	Chemical	357	470	365	397	257	334
	Electrical	351	454	436	437	417	399
	Electrochemical	145	149	176	169	198	249
	Other	108	150	155	173	187	192
	Total Demand	**961**	**1,223**	**1,132**	**1,176**	**1,059**	**1,174**

RUTHENIUM Tonnes - Demand							
							2019 numbers are preliminary
		2014	2015	2016	2017	2018	2019
Demand	Chemical	11.1	14.6	11.4	12.3	8.0	10.4
	Electrical	10.9	14.1	13.6	13.6	13.0	12.4
	Electrochemical	4.5	4.6	5.5	5.2	6.2	7.7
	Other	3.4	4.7	4.8	5.4	5.8	6.0
	Total Demand	**29.9**	**38.0**	**35.3**	**36.5**	**33.0**	**36.5**

Iridium Demand

Troy ounces and tonnes

IRIDIUM '000 oz - Demand							
							2019 numbers are preliminary
		2014	2015	2016	2017	2018	2019
Demand	Chemical	22	22	23	17	19	20
	Electrical	40	78	100	73	52	58
	Electrochemical	57	44	45	49	59	94
	Other	72	77	83	86	90	93
	Total Demand	**191**	**221**	**251**	**225**	**220**	**265**

IRIDIUM Tonnes - Demand							
							2019 numbers are preliminary
		2014	2015	2016	2017	2018	2019
Demand	Chemical	0.7	0.7	0.7	0.5	0.6	0.6
	Electrical	1.2	2.4	3.1	2.3	1.6	1.8
	Electrochemical	1.8	1.4	1.4	1.5	1.8	2.9
	Other	2.2	2.4	2.6	2.7	2.8	2.9
	Total Demand	**5.9**	**6.9**	**7.8**	**7.0**	**6.8**	**8.2**

Notes to Tables

[1]Supply figures represent estimates of sales by the mines of primary pgm and are allocated to where the initial mining took place rather than the location of refining.

[2]Our Russian supply figures represent the total pgm mined in Russia and the CIS. Demand in Russia is included in the Rest of the World region.

[3]Supplies from Zimbabwe have been split from Others' supplies. Platinum group metals mined in Zimbabwe are currently refined in South Africa, and our supply figures represent shipments of pgm in concentrate or matte, adjusted for typical refining recoveries.

[4]Gross demand figures for any given application represent the sum of manufacturer demand for new metal in that application and any changes in unrefined metal stocks in that sector. Increases in unrefined stocks lead to additional demand, reductions in stock lead to a lower demand figure.

[5]Our Medical and Biomedical category represents combined metal demand in the medical, biomedical and dental sectors; however, pharmaceutical metal use is included under Chemical demand.

[6]Recycling figures represent estimates of the quantity of metal recovered from open-loop recycling (i.e. where the original purchaser does not retain control of the metal throughout). For instance, autocatalyst recycling represents the weight of metal recovered from end-of-life vehicles and aftermarket scrap in an individual region. These figures do not include warranty or production scrap. Where no recycling figures are given, open-loop recycling is negligible.

[7]Net demand figures are equivalent to the sum of gross demand in an application less any metal recovery from open-loop scrap in that application, whether the recycled metal is reused in that industry or sold into another application. Where no recycling figure is given for an application, gross and net demand are identical.

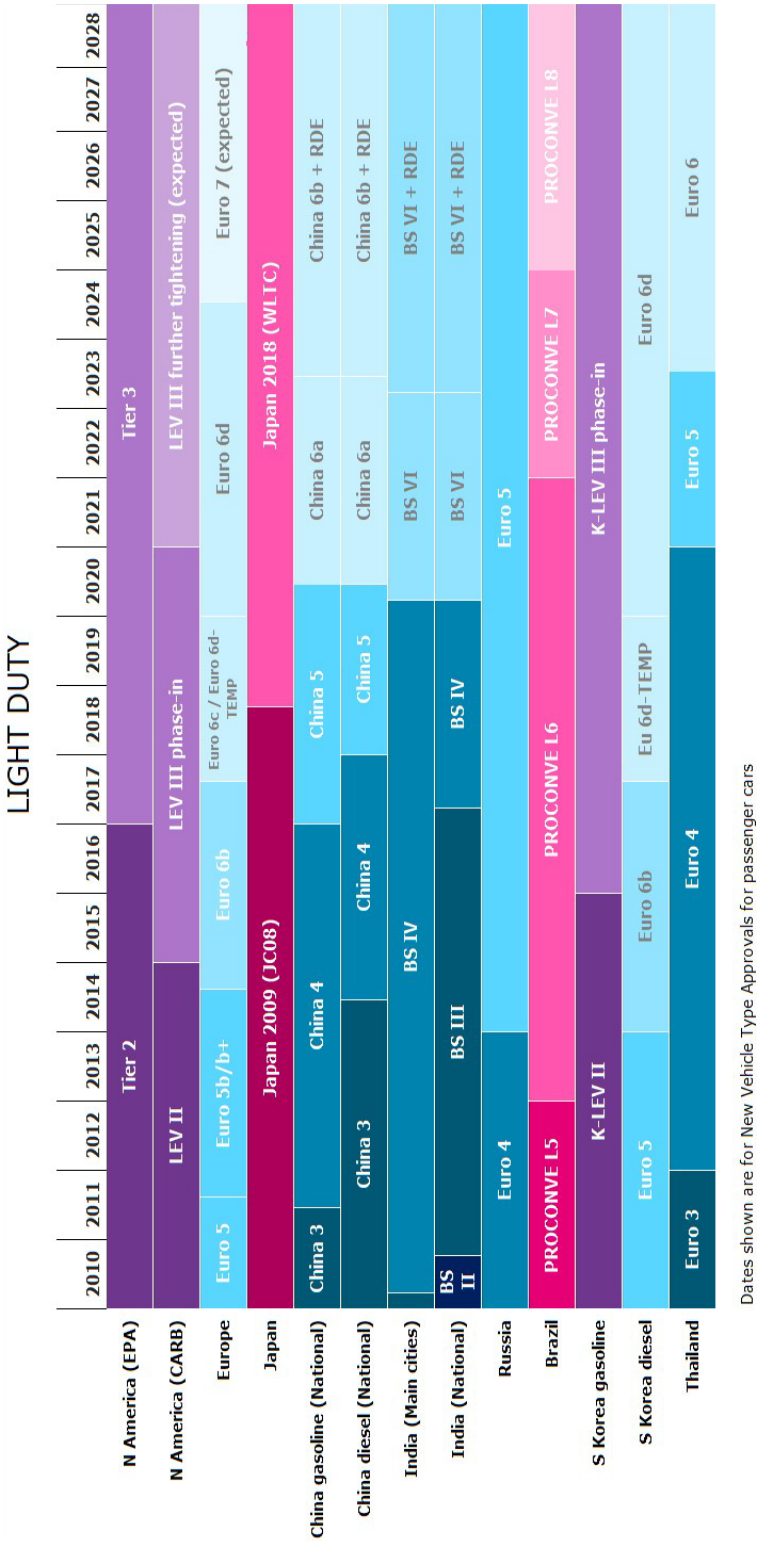
[8]Movements in stocks in any given year reflect changes in stocks held by fabricators, dealers, banks and depositories but excluding stocks held by primary refiners and final consumers. A positive figure (sometimes referred to as a 'surplus') reflects an increase in market stocks. A negative value (or 'deficit') indicates a decrease in market stocks.

Glossary

ASC	Ammonia slip catalyst
BEV	Battery electric vehicle
CF	Conformity factor
CO	Carbon monoxide
CO_2	Carbon dioxide
DOC	Diesel oxidation catalyst
DPF	Diesel particulate filter
EC	European Commission
ELV	End-of-life vehicle
ETF	Exchange traded fund
FCEV	Fuel cell electric vehicle
GDI	Gasoline direct injection
GPF	Gasoline particulate filter
HC	Hydrocarbon
HDD	Heavy duty diesel
ISC	In-service conformity
LAB	Linear alkyl benzene
LDG	Light duty gasoline
LDD	Light duty diesel
LEV	Low emission vehicle
MLCC	Multi-layer ceramic capacitor
NEDC	New European Driving Cycle
NEV	New energy vehicle (BEV, PHEV or FCEV)
NOx	Oxides of nitrogen
NRMM	Non-road mobile machinery
NYMEX	New York Mercantile Exchange
PDH	Propane dehydrogenation
PHEV	Plug-in hybrid vehicle
PM	Particulate matter or soot
PN	Particle number
PNA	Passive NOx adsorber
PTA	Purified terephthalic acid
PX	Paraxylene
RDE	Real driving emissions
RoW	Rest of world region
SCR	Selective catalytic reduction
SCRF®	SCR integrated with a soot filter
SGE	Shanghai Gold Exchange
SUV	Sports utility vehicle
WLTP	Worldwide Harmonised Light Vehicle Test Procedure
4E grade	Combined content of four elements: platinum, palladium, rhodium and gold

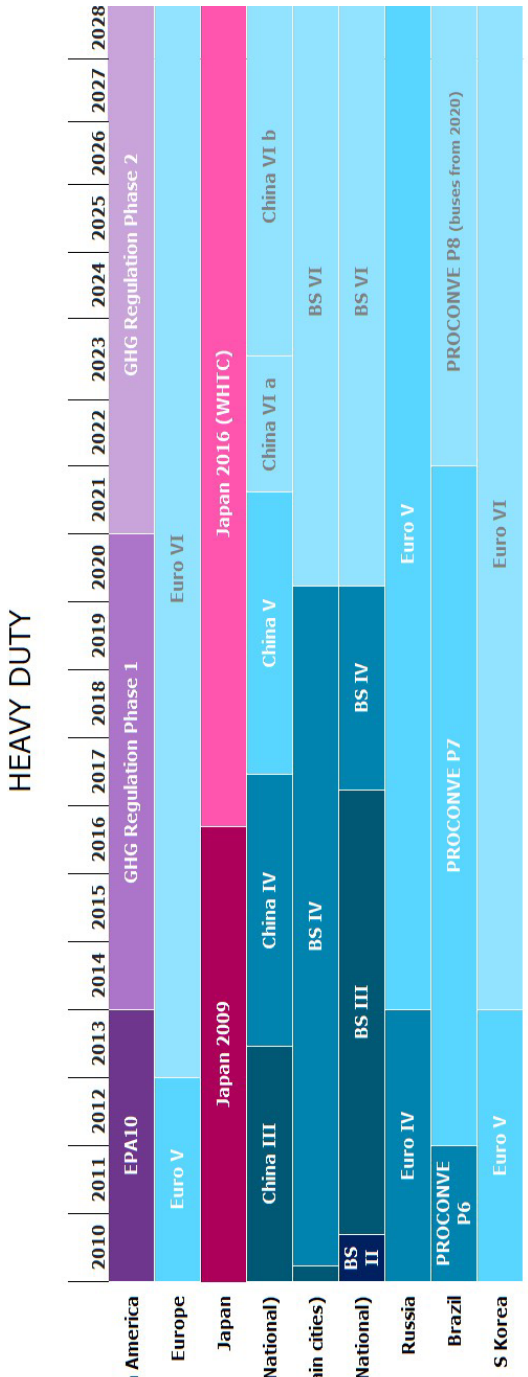
Emissions Legislation

Light Duty



Emissions Legislation

Heavy Duty Diesel



Euro 6 Emissions Legislation

Euro 6 is a generic standard that defines emissions limits for light vehicles to be phased in on various dates and according to various tests and procedures.

Euro 6a was a voluntary stage which allowed vehicles to be introduced with Euro 6 type approval earlier than required. It had minimal impact on pgm demand.

Euro 6b applied to new type approvals for passenger cars from September 2014, and to all vehicles sold in the European market from September 2016. From this point vehicles had to meet Euro 6 emissions limits when tested over the New European Driving Cycle (NEDC). At Euro 6b there was no change to the emissions limits for gasoline vehicles from Euro 5 limits, other than the introduction of a particle number limit on these engines (although manufacturers could apply for a three-year exemption to meet a slightly higher limit). For diesel vehicles, allowable NOx emissions over the test cycle were reduced by 56% relative to Euro 5 legislation. This had significant implications for pgm loadings on diesel vehicles.

Euro 6c began to be phased in from September 2017 and applied to all vehicles from September 2019. In terms of emissions limits, there are no differences between 6b and 6c for diesel engines and the only difference for gasoline engines is that 6c brings particle number emissions down for all vehicles, fully in line with those from diesel vehicles. This has implications for gasoline particulate filter (GPF) fitment.

In parallel, a new laboratory test replaced the NEDC. The Worldwide Harmonised Light Vehicle Test Procedure (WLTP) applied to new type approvals from September 2017 and to all vehicles from September 2018.

Euro 6d is being phased in over several years, starting in September 2017. Euro 6d differs from 6b/6c in that it changes the way in which NOx emissions and particle number (PN) emissions are tested and measured, with the introduction of Real Driving Emissions (RDE) testing, alongside laboratory testing. During RDE testing, vehicles are driven on the road according to random acceleration and deceleration patterns, with emissions measured using on-board portable emissions monitoring systems (PEMS).

Conformity Factors (CFs) have been introduced, which govern the multiple by which the vehicles' NOx and PN emissions can exceed the emissions limits during RDE testing. The exceedance is intended to allow a margin for measurement error using PEMS. The phase-in of CFs takes place in two stages:

In the first stage (Euro 6d-TEMP), a NOx CF of 2.1 and a PN CF of 1.5 were introduced for new type approvals of passenger cars from September 2017, and for new type approvals of light commercial vehicles (LCVs) from September 2018. The CFs applied to all new passenger vehicles from September 2018 for PN and September 2019 for NOx, and a year later to all new LCVs.

In the second stage (Euro 6d), the NOx CF is being reduced to 1.43, applying to new type approvals for passenger cars from January 2020, and to all vehicles from January 2022.

The European Commission (EC) intends to review the CFs over time as the measurement accuracy of PEMS equipment improves, with the intention of lowering them to 1.0 by 2023, allowing for no measurement error in the tests.

These transitions are inevitably leading to changes in catalyst system designs and loadings.

JM

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