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Pgm Market Report

February 2019

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Our figures for 2018 are preliminary estimates based on information available to the end of October 2018, with the exception of investment, which reflects full-year data. Final 2018 numbers will be published in our May 2019 report.

Platinum Summary

Supply and Demand in 2018

- Gross platinum demand declined in 2018, despite buoyant industrial purchasing.
- Chemical, glass and petroleum demand was unusually strong, reflecting Chinese capacity additions.
- However, consumption on European diesel cars contracted, and net investment was down sharply.
- Primary supplies were flat, but vehicle recycling continued to grow strongly, boosting secondary recoveries.
- The market moved further into surplus, and prices fell to below $800 at the year end.

Platinum Supply and Demand '000 oz			
Supply	**2016**	**2017**	**2018**
South Africa	4,392	4,449	4,471
Russia	717	703	657
Others	988	953	980
Total Supply	**6,097**	**6,105**	**6,108**
Gross Demand			
Autocatalyst	3,342	3,218	3,052
Jewellery	2,412	2,400	2,363
Industrial	1,806	2,022	2,321
Investment	620	361	89
Total Gross Demand	**8,180**	**8,001**	**7,825**
Recycling	-1,934	-2,072	-2,215
Total Net Demand	**6,246**	**5,929**	**5,610**
Movements in Stocks	-149	176	498

The platinum market moved further into surplus in 2018. Combined primary and secondary supplies rose by 1.8%, reflecting further growth in autocatalyst recycling, while demand fell by 2.2% on weaker investment purchasing and a decline in platinum use on European diesel cars. Jewellery demand was also lacklustre, but strong buying from the Chinese glass, chemicals and petroleum sectors helped lift consumption in industrial applications by nearly 15%.

World primary supplies of platinum were flat in 2018. In South Africa, the impact of shaft closures was outweighed by incremental gains at other operations and some pipeline inventory releases. However, there was a decline in shipments from Russia, due to a steep fall in alluvial platinum production.

The South African pgm mining industry began 2018 with unusually large inventories of semi-processed pgm. Northam Platinum built stocks of concentrate ahead of the commissioning of its new furnace in December 2017, while Impala Platinum accumulated pipeline inventory during planned and unplanned smelter outages in 2017 and early 2018. During the first half of last year, Anglo Platinum also saw a build-up of in-process stocks due to smelter maintenance. In our May 2018 report, we assumed that all excess pipeline stocks would be refined before the year end, but it now appears that treatment will extend into 2019. Nevertheless, we think it likely that the release of work-in-progress during the second half of 2018 added about 75,000–100,000 oz to platinum supplies. It should be noted that our estimates are based on published data for the nine months to September 2018 and will be updated once full-year figures become available.

Underlying mine output in 2018 was impacted by the closure of the Bokoni and Maseve mines in the second

half of 2017. However, this was offset by positive performances at Anglo American Platinum's flagship Mogalakwena and Amandelbult mines, and by the ramp-up of production from Royal Bafokeng Platinum's Styldrift project (pgm from which is refined and marketed by Anglo).

Mogalakwena had an exceptionally strong start to 2018, reflecting optimisation at the concentrator plant and the extraction of an area of higher-grade ore. Although mining moved into lower-grade areas during the second half, output was up 13% in the January to October period. At Amandelbult, improved efficiencies and better productivity lifted platinum production by 5% in the first nine months of 2018.

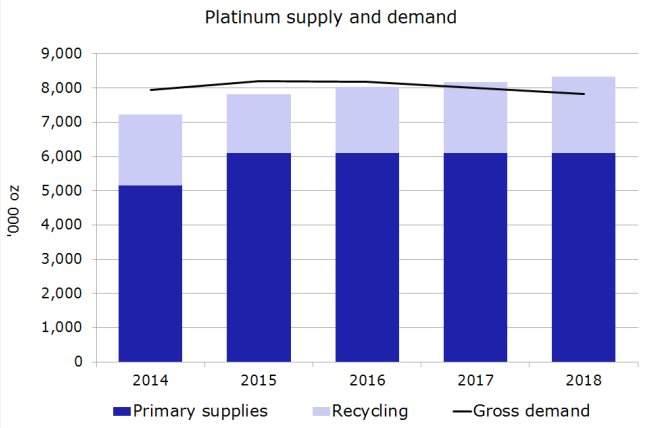
Royal Bafokeng Platinum has recommissioned the concentrator at the mothballed Maseve mine and is now using it to process ore from its own mining operations. Although output at the established BRPM operation declined, following the termination of UG2 mining at the South shaft, this was more than offset by the ramp-up of production from the new Styldrift mine.

Output of pgm at Norilsk Nickel was firm in 2018. Platinum production rose by 4% in the January to September period, and our estimate of full-year output is at the upper end of the company's forecast range (600,000–650,000 oz). Additional ounces were derived from the treatment of copper concentrate purchased from the state enterprise Rostec (see page 14). In addition, we believe that the company has been processing increased quantities of low grade surface materials such as tailings and smelter reverts. This has helped compensate for the depletion of stocks of old pyrrhotite concentrate, the refining of which has been augmenting pgm output at Norilsk for a number of years.

Alluvial platinum production in Russia dropped steeply in 2018, due to declining grades at placer operations in the far east of the country. These operations have in the past contributed as much as 150,000 oz of platinum annually but output is now under 20,000 oz a year. As a result, total Russian supplies declined 6.5% to 657,000 oz in 2018.

Sibanye-Stillwater's Blitz expansion project – part of the Stillwater mining complex – made its first meaningful contribution to production last year, lifting the company's US output. Sibanye-Stillwater's Montana mines are the only primary producers of platinum in the USA, although small amounts of by-product pgm are derived from base metals mining.

We estimate that platinum production from Canadian ores fell slightly in 2018, reflecting lower output of by-product pgm from the Sudbury nickel mines. At Vale, reported platinum production, including metal produced from purchased materials, fell by 5% in the first nine months of last year. This decline may be partly due to a steep drop in ore production from the company's Sudbury mines in



"With weaker demand in the automotive, jewellery and investment sectors, the platinum market moved to a surplus of around 500,000 ounces in 2018."

2017: mined tonnes fell by nearly 30% due to the closure of the Stobie mine and an interruption to mining at the Coleman operation (where pgm grades are thought to be unusually high). Because of the length of the processing pipeline, changes in mine output take several months to be fully reflected in refined pgm production.

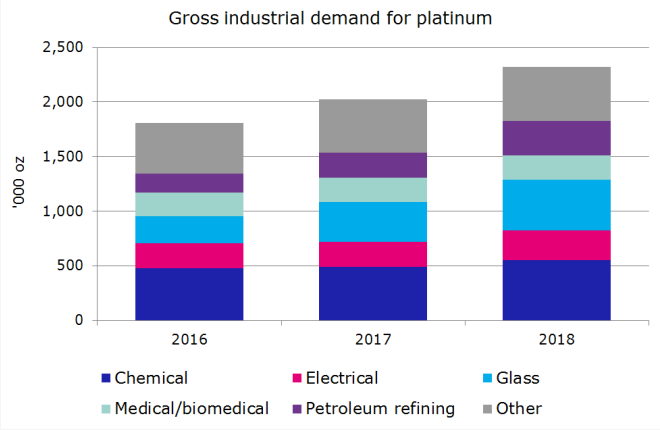
At Glencore's Integrated Nickel Operations, platinum output fell by more than 20% in the January to September period. This is consistent with declining grades at the company's Sudbury mines, as the pgm-rich Nickel Rim South operation approaches the end of its life. The company is investing in replacement capacity at its Onaping Depth project, due to enter production in around 2023.

While global primary output was not much changed, secondary supplies benefited from further growth in the volume of spent autocatalyst collected and processed. Activity in this sector was unusually muted during 2015 and 2016, especially in the large European and North American markets, due to low steel prices resulting in fewer end-of-life vehicles entering the scrap circuit. However, over the last two years, an improvement in scrap steel values has stimulated a strong recovery in the number of vehicles being dismantled. Growth in platinum recoveries has been somewhat lower than that of the other autocatalyst metals, reflecting the shift away from platinum in three-way catalysts on gasoline vehicles over the last twenty years.

Demand for platinum in the chemical industry has been at unusually high levels over the last five years, and posted further gains in 2018. Consumption is underpinned by the speciality silicones sector, the largest single chemical user of platinum, and by the nitric acid industry, both of which generate significant on-going demand that is proportional to production volumes. In contrast, purchasing of platinum for other chemical processes such as paraxylene and propylene dehydrogenation (PDH) occurs primarily at the time of plant construction; thereafter, only small amounts of metal are required to cover losses during plant operation and catalyst change-outs.

Worldwide, the use of platinum in speciality silicones is rising at 2–3% per annum, with much of this growth concentrated in China, reflecting underlying trends in end-use markets and government policies to reduce imports of chemical products. This process is unusual in that the platinum catalyst is consumed and no metal is recovered; platinum consumption is therefore directly linked to silicone production volumes.

The manufacture of nitric acid involves the use of a platinum catalyst gauze, from which metal is lost due to volatilisation over the course of a production campaign. Manufacturers often employ a palladium 'catchment' gauze to capture platinum lost from the catalyst, but as palladium prices have risen above those of platinum this is becoming less economic. With global nitric acid



"Demand for platinum posted further gains in the chemical industry in 2018, and was also exceptionally strong in the petroleum refining and glass fibre sectors."

Platinum Demand: Industrial '000 oz			
	2016	2017	2018
Chemical	476	490	550
Electrical	230	230	273
Glass	247	366	466
Medical & Biomedical	217	220	224
Petroleum	175	233	311
Other	461	483	497
Total	**1,806**	**2,022**	**2,321**

consumption rising at around 2% annually, platinum use in this application continues to increase gradually.

Demand for platinum catalysts in other chemical processes varies greatly from year to year, depending on new plant construction activity. While investment in PDH has now passed its peak, 2018 saw exceptionally large purchasing of platinum for new paraxylene units in China and the Rest of World region. In China, this represents a first wave of buying related to the construction of several very large integrated refining and petrochemical complexes, designed to improve the country's self-sufficiency across a range of bulk chemicals, and to improve fuel quality. The construction of these refinery complexes has also generated significant demand for platinum catalysts used in petroleum refining processes, with the result that platinum sales to the petroleum sector were also unusually strong last year.

Last year also saw exceptionally buoyant demand for platinum from the glass industry. Purchases by the glass fibre sector set a new all-time high: manufacturers, particularly in China, are investing heavily in new production capacity to meet anticipated growth in end uses such as construction, renewable energy (where glass fibre is used in the sails of wind turbines) and automotive (where fibre-reinforced plastics are employed in place of metal as a means of reducing vehicle weight). There was also an increase in platinum purchasing for new display glass facilities, as companies invested in equipment to produce larger next-generation LCD glass panels in China; however, demand in this segment remains well below the 2011 peak.

In the electrical sector, demand for platinum in hard disks proved resilient last year, despite a continuing decline in the number of hard disk drives (HDD) produced. HDDs continue to lose market share in consumer products, but enjoy strong demand from the near-line and enterprise sectors, which require larger drives with more disks per unit. While competition from solid state memory continues to intensify, it remains significantly more expensive than HDDs. Thus, hard disks remain the mainstay of near-line and enterprise applications that require data-storage media with very high capacities.

We include platinum usage in fuel cells in our electrical numbers. The fuel cell sector saw strong growth in 2018, especially in China, where the government's New Energy Vehicle (NEV) programme has stimulated the market for electric vehicles. NEV subsidies for battery electric and plug-in hybrid vehicles are being reduced, but incentives for fuel cell electric vehicles (FCEVs) have been maintained; this has encouraged investment in fuel cell stack production capacity, and in the development of new FCEV platforms, including passenger cars, buses, logistics trucks and trams. As a result, orders have been placed for significant numbers of fuel cell stacks to be delivered over the 2018–2021 period and this contributed to a doubling in demand for platinum in FCEVs in 2018. For further information, please refer to the special feature on fuel cells in our May 2018 report.

While industrial applications remained buoyant, consumption of platinum in autocatalysts fell by over 5% in 2018. World output of light duty diesel vehicles contracted by around 3%, due to a 9% drop in European production that was only partly offset by double-digit gains in the recovering, but much smaller, Indian market. In addition, there was a decline in average platinum loadings, primarily due to a reduction in the pgm content of European diesel aftertreatment systems.

This reduction in loadings reflects changes in catalyst fitment strategies adopted by European automakers to meet Euro 6d-TEMP regulations, which impose 'conformity factors' for both particulate number and NOx emissions under Real Driving Emissions (RDE) conditions (see page 40 for further details of European emissions legislation). The phase-in of Euro 6d-TEMP regulations began in September 2017, and has resulted in greater

Platinum Demand: Autocatalyst '000 oz									
	Gross			Recycling			Net		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
Europe	1,801	1,717	1,510	-501	-544	-603	1,300	1,173	907
Japan	359	350	344	-66	-73	-69	293	277	275
North America	344	322	325	-470	-535	-579	-126	-213	-254
China	151	157	153	-16	-20	-24	135	137	129
Rest of World	687	672	720	-111	-120	-128	576	552	592
Total	**3,342**	**3,218**	**3,052**	**-1,164**	**-1,292**	**-1,403**	**2,178**	**1,926**	**1,649**

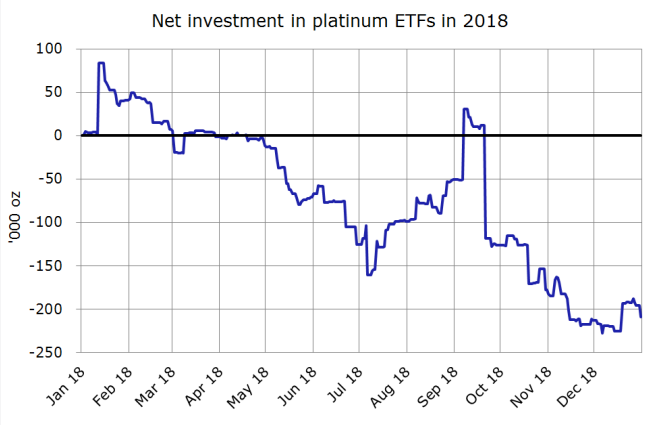
use of systems that rely on non-pgm selective catalytic reduction (SCR) and SCRF technology for NOx conversion. SCRFs displace pgm-containing filters (DPFs), and while NOx traps continue to be used in combination with SCR technology by some OEMs, the average platinum content of these bricks has fallen. Euro 6d-TEMP will apply fully to all passenger cars sold in Europe from September 2019 and to all light commercial vehicles a year later.

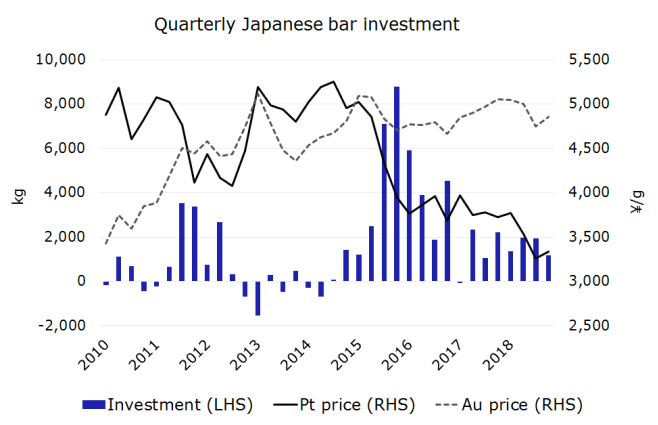
In total, we estimate that consumption of platinum on European diesel cars fell by over 10% in 2018. This was partly offset by a strong recovery in the Indian diesel market, but catalyst loadings on Indian vehicles remain much lower than in Europe (although they will increase in future, as Bharat 6 legislation is rolled out starting in April 2020).

Global demand for platinum in heavy duty vehicles rose by 4% in 2018, reflecting higher catalyst fitment rates in China and some Rest of World countries, including India. Worldwide, we estimate that over 60% of heavy duty diesel trucks were fitted with a pgm-containing catalyst system in 2018, and this percentage is expected to grow rapidly over the next three years as increasing numbers of trucks meet China VI and Bharat VI legislation.

Demand for platinum ETFs was negative in 2018, although changes in total holdings were moderate compared with the consistent heavy liquidation seen in palladium. Over the last three years, platinum ETF holdings have fluctuated in a relatively narrow range around 2.5 million oz, with the vast majority of holders locked into loss-making positions. Nevertheless, there was some selling last year, as the platinum price fell through $900 per ounce and then $800, prompting some investors to liquidate their positions. This selling was concentrated in Europe and South Africa; in contrast, there was some buying by US ETF investors during the second half of 2018.

In Japan, investment demand primarily occurs in the form of 'over-the-counter' sales of platinum bars, and has historically been associated with periods of weak price. As recently as 2015–2016, sharp downward movements in the yen platinum price coincided with





Platinum Demand: Jewellery '000 oz									
	Gross			Recycling			Net		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
Europe	177	176	184	-5	-5	-5	172	171	179
Japan	310	305	307	-241	-222	-204	69	83	103
North America	220	238	239	-3	0	0	217	238	239
China	1,510	1,470	1,400	-485	-515	-563	1,025	955	837
Rest of World	195	211	233	-4	-4	-4	191	207	229
Total	**2,412**	**2,400**	**2,363**	**-738**	**-746**	**-776**	**1,674**	**1,654**	**1,587**

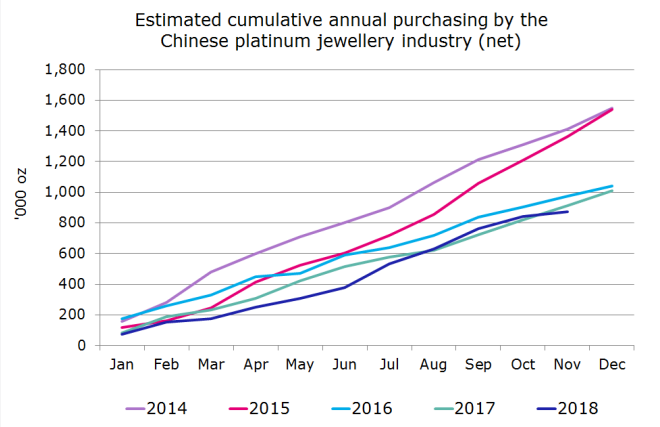
a move to a discount to gold, and generated massive demand for platinum bars totalling over half a million ounces in each of those years. However, in 2018, a fall in the yen platinum price to ten-year lows failed to stimulate investment to the same extent, perhaps because investors are now accustomed to platinum trading at a wide discount to gold. Nevertheless, net bar demand remained in positive territory, and slightly above the levels seen in 2017.

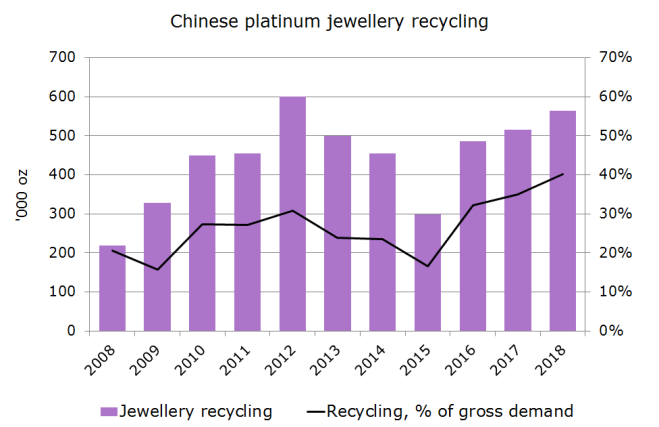
Net consumption of platinum by Chinese jewellers fell once again in 2018, as gross jewellery demand continued to decline and recycling to rise. Younger consumers, who are key fashion jewellery purchasers, no longer have a specific preference for platinum; purchasing decisions are more likely to be motivated by the availability of attractive designs or specific gemstones.

In response to these evolving consumer trends, manufacturers and retailers have expanded their ranges of karat gold jewellery, which is typically priced per piece rather than per gram, and which enables better margins to be earned. While this is primarily an industry-driven phenomenon, it does appear to be gaining some traction with consumers, who increasingly prefer to own several lighter, less expensive jewellery items which can be coordinated with different outfits, rather than one or two heavier, more valuable pieces.

The capital cost of switching from platinum to karat gold production is now relatively low, so there is less incentive for established platinum jewellery fabricators to defend platinum's share of the market. As a result, many manufacturers have swapped part of their production to karat gold. There have been some efforts to introduce per-piece pricing for platinum jewellery, but to date this does not appear to have been successful.

At the same time, there is evidence of increasing recycling outside the established closed-loop circuit, via which consumers have traditionally returned old jewellery items and exchanged them for new, heavier pieces. Independent recycling booths are now present in most major jewellery retailing areas, enabling



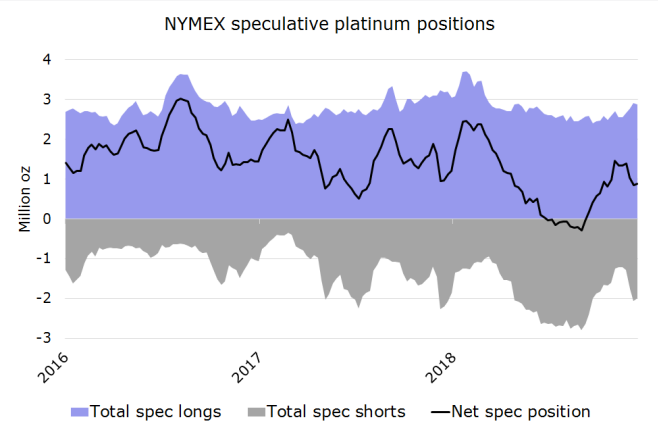


consumers to sell their old jewellery for cash. This metal is processed at local refineries and may subsequently be purchased by jewellery manufacturers, many of whom are sourcing an increasing percentage of their metal requirements from scrap.

Part of the decline in the Chinese jewellery market was offset by expanding demand in India, where consumption of platinum in jewellery is still growing at double-digit rates, albeit off a relatively small base. Overall, after accounting for recycling, net world platinum jewellery demand fell by 4.1%.

With weaker demand in the automotive, jewellery and investment sectors, the platinum market moved to a surplus of around 500,000 oz in 2018. This was reflected in consistent weakness in the dollar price, although it remains the case that platinum pricing is more influenced by short-term speculator sentiment and futures market activity than by its fundamentals.

The net long position on NYMEX declined by over 2.7 million ounces between February and September 2018, and during the third quarter, speculative positioning was consistently 'net short' for the first time since 2004. This was primarily due to a significant build-up in speculative short positions over this eight-month period (long positions remained broadly unchanged), reflecting increasingly negative investor sentiment. This drove the platinum price downwards, from the year's high of $1,020 per ounce in January to a low of $772 in September. Between mid-September and mid-November, speculators reduced their short positions, and the price recovered modestly to around $850. However, as the year ended, renewed shorting once again depressed the price below the $800 level.



"In 2018 net speculative positions turned 'short' for the first time since 2004, due primarily to a significant build-up in total speculative short positions."

Platinum Outlook

Supply and Demand in 2019

- The outlook for automotive platinum use is improving, due to stricter vehicle testing procedures and tighter heavy duty limits.
- Industrial consumption will be supported by further capacity expansions in China.
- However, jewellery demand will remain lacklustre, while investment demand could fall if prices improve and investors react as they have done in the palladium market.
- With primary supplies flat and some growth in recycling, the market will remain in surplus.

The platinum market is expected to remain in surplus this year, despite flat primary supplies and potential for some modest demand growth. Autocatalyst consumption will stabilise and then begin to rise in due course, as stricter heavy duty vehicle emissions legislation is enforced in China and then India. The outlook for industrial applications is also positive, with demand set to remain close to 2018 levels. However, the prospects for the jewellery sector are lacklustre, while investment demand could fall if prices improve and investors react as they have done in the palladium market.

Platinum supplies will probably not change a great deal in 2019. Although platinum price weakness has resulted in significant rationalisation of the South African pgm mining industry over recent years, to date this has had surprisingly little impact on platinum output. Shaft closures have been broadly offset by the ramp-up of some newer, more profitable operations, along with an increase in the amount of metal recovered from the retreatment of chrome and pgm tailings. With the exception of one strike-hit year (2014), underlying mine production in South Africa has been remarkably stable at around 4.3–4.4 million oz of platinum per annum since 2013, although this flat profile has been partly obscured by fluctuations in inventories.

We think that the industry can probably maintain a steady production profile for at least one more year, but there are increasing risks to output going forward, as strategic decisions motivated by several years of weak prices begin to take effect. For much of the 2014–2018 period, the rand-denominated value of a typical basket of South African pgm traded in a range between R12,000 and R14,000 per ounce, with movements in the dollar price muted by exchange rate fluctuations. At these prices, many platinum mines came under intense

financial pressure, leading producers to restrict capital investment and rationalise their operations.

Since September 2018, strong gains in palladium have lifted the rand basket price towards R16,000 per ounce, not far off the highs seen in 2008, but this has come too late to avoid another round of shaft closures. Output at Lonmin's Marikana mining complex is set to fall sharply in 2019 and 2020, due to the decommissioning of older shafts, while Impala Platinum announced a new strategic plan in August 2018 which will see production from its lease area fall to 520,000 oz of platinum per annum by 2021. Overall, we think that the industry should be able to compensate for shaft closures in 2019, but thereafter it will become more difficult to replace lost output. Much will depend on the speed at which new projects – such as Northam's Booysendal and Royal Bafokeng Platinum's Styldrift mines – can be ramped-up.

This year should once again see higher output from Styldrift, which continues to ramp-up towards steady-state production of 230,000 tonnes of ore per month. At Booysendal, development of a second UG2 portal is underway, and a small stockpile of ore has already been accumulated. Recommissioning of a second processing plant – which formerly served the now-mothballed Everest South mine – is due for completion in the first half of 2019. The company has begun to re-treat material from the tailings dam, which derives from previous mining activity at the site and contains significant quantities of chrome along with small amounts of pgm.

There is also potential for modest gains from some pgm and chrome tailings projects. Northam is recommissioning the concentrator at the Eland Platinum project, acquired from Glencore last year, and will re-treat tailings from previous UG2 mining to recover chrome and pgm. It has also signed an agreement with Jubilee Metals Group to treat pgm-bearing material from the latter's PlatCro chrome operation.

South African platinum supplies will also be supported by the refining of excess pipeline inventories. We estimate that in-process platinum stocks at Anglo American Platinum, Impala Platinum and Northam Platinum exceeded normal levels by as much as 400,000 oz at the end of September 2018; some of this metal was still in the refining pipeline at the year end, and will therefore contribute to supply totals in 2019.

Russian output is unlikely to rise in the short-term, although Norilsk Nickel is targeting medium-term increases in both base metal and pgm production. Over the past two years, output has been supported by the refining of metal recovered from defunct processing plant, and the treatment of pgm-rich surface materials including old pyrrhotite and copper concentrates (see page 2). Pyrrhotite stocks have been exhausted, but we expect the refining of copper concentrates to continue for another two years. Further ahead, Norilsk is evaluating a large open-cast expansion at its 'Southern Cluster' mining operations, but this is unlikely to contribute to production before around 2023.

Automotive consumption of platinum set a five-year low in 2018, but demand is forecast to stabilise or even rise modestly over the next few years, as heavy duty vehicle legislation tightens in the large Chinese and Indian markets, and as a result of more stringent light duty vehicle testing procedures in Europe.

The final phase of Euro 6d will begin to take effect in January 2020, further limiting permitted NOx emissions during RDE testing, with a reduction in the conformity factor from 2.1 at Euro 6d-TEMP to 1.43 at Euro 6d. Meeting these NOx limits over the wide range of conditions permissible in an RDE test is very challenging, both under cold-start conditions when the aftertreatment system is not fully warmed up, and under high load conditions, when the engine creates most NOx. This is stimulating an increase in platinum loadings on diesel oxidation catalysts used upstream of SCR bricks on light duty diesel vehicles. These gains will help to offset the negative impact of increasing adoption of SCRF technology, which combines the functions of SCR and a particulate filter on a single brick, thus removing the pgm-coated filter.

With platinum consumption in the Indian diesel car sector set to rise as Bharat VI legislation comes into

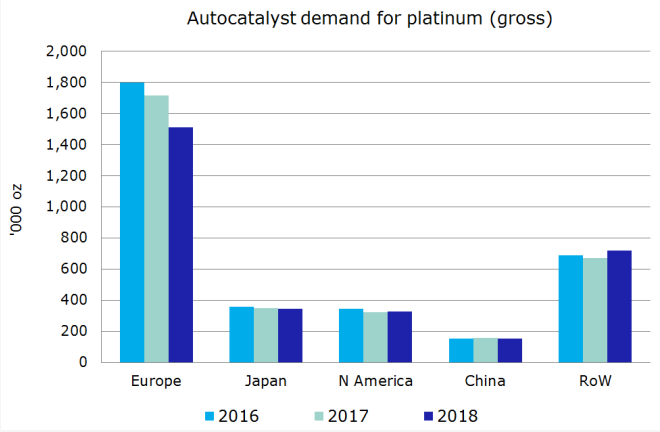
force in 2020, total platinum use in the light duty diesel market is expected to flatten out over the next two to three years. Heavy duty demand is forecast to rise sharply over the same period, as the implementation of China VI and Bharat VI regulations results in the addition of platinum-containing aftertreatment systems to all trucks sold in China and India, compared with fewer than half in 2018. The proportion of heavy vehicles equipped with a catalyst is expected to rise sharply this year, because a number of Chinese provinces and cities will adopt the new standards in advance of the national implementation of China VI legislation.

Consumption of platinum in light duty gasoline applications is now confined to some residual use of platinum-rhodium or tri-metal formulations mainly by Japanese OEMs, and totals less than 200,000 oz per annum. With palladium trading at parity with platinum since 2017, and at a widening premium during 2018, there has been some renewed research into the use of platinum in gasoline catalyst applications. However, despite some positive test results for platinum-rhodium catalyst bricks in specific applications, it appears that it will be difficult to match the performance of existing palladium-rhodium catalysts without improvements in technology. In particular, palladium has better thermal stability than platinum under typical gasoline exhaust temperatures, which means that catalyst activity remains more consistent over time.

Even if platinum catalysts can demonstrate equivalent performance, substitution is unlikely to occur rapidly. Automakers are already devoting enormous technical resources to meeting tightening legislation, while the introduction of RDE testing in major markets is inciting the adoption of more conservative emissions strategies that prioritise compliance over cost. Thus, even though it may be theoretically possible to reduce costs by replacing palladium with platinum, there is so far only limited evidence that automakers may be prepared to take the plunge, even in Japan where some automakers have recent experience of the use of platinum-containing catalyst formulations.

Nevertheless, with stabilising demand in light duty diesel applications, and the prospect of strong growth in the heavy duty sector, we now believe there is potential for gross automotive consumption of platinum to rise over the next few years, even without substitution in the gasoline sector.

At the same time, the recent upward trend in autocatalyst recycling is set to flatten off, in line with the move away from platinum in three-way catalysts since the early 1990s. While we still expect some growth in the recycling of platinum from diesel scrap, this will be partly offset by a fall in the platinum content of end-of-life gasoline cars, meaning that there is now only limited scope for overall growth in the recovery of platinum from end-of-life vehicles.



"Automotive platinum consumption set a five-year low in 2018, but should stabilise or even rise over the next few years."

The outlook for industrial demand is also positive, with consumption expected to remain close to or above the 2018 level over the next few years, although the exact trajectory of demand in any individual year will depend largely on the timing of purchases for capacity expansions.

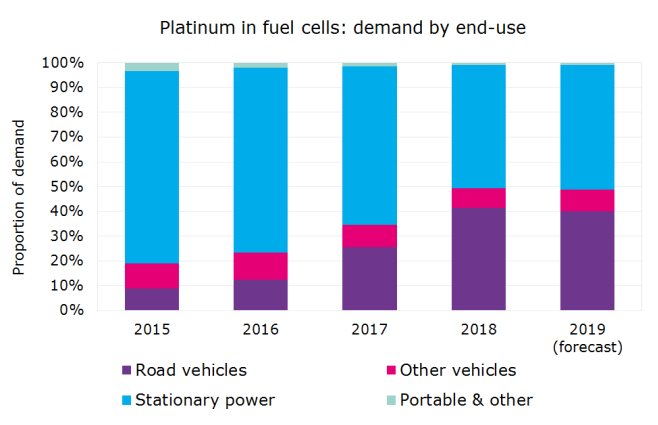
Chinese refinery expansions boosted purchasing of platinum for petroleum reforming catalyst in 2018, but we now expect the rate of capacity additions to slow and platinum demand could ease as a result. The pace of further additions will depend to a large extent on how the market for downstream petrochemicals evolves. There is also potential for some additional consumption in novel refinery applications, where the use of platinum catalysts in place of established processes can be justified by improved safety, superior product quality and a better environmental profile.

Purchasing of platinum catalysts by the chemicals industry is forecast to set new highs over the next two years, as the construction of several large integrated refinery complexes in China approaches completion and catalyst charges are installed. These complexes typically incorporate large paraxylene units which may require an initial charge of several tens of thousands of ounces of platinum.

The outlook for demand from the glass fibre industry also remains positive, although platinum purchasing in 2019 may fall below the exceptional levels seen last year. Not only is global glass fibre consumption set to expand substantially over the next several years, supporting further investment in new production capacity, but high rhodium prices are expected to stimulate an increase in the platinum content of platinum-rhodium alloys used in fibreglass bushings, at the expense of rhodium.

Rhodium is an essential component of many platinum alloys used in glass-making, because it increases melting point, and thereby improves strength and durability at the extremely high temperatures involved in the manufacturing process. At the low rhodium prices seen over the last few years, there was an incentive for glass makers to increase the proportion of rhodium in their alloys, to improve the stability and longevity of their equipment. Conversely, the rise in the rhodium price since late 2017 is expected to result in progressive thrifting of rhodium and its substitution with platinum. This process will be gradual: changes in alloy composition are typically implemented at the end of a production campaign, after which glass-making equipment is returned to suppliers for melting and refabrication.

Consumption of platinum in fuel cells is expected to see another year of double-digit gains in 2019. While last year's growth was primarily in the automotive market, this year the majority of the increase will come from phosphoric acid fuel cell (PAFC) units used in stationary power generation for baseload power. A new 50 megawatt PAFC plant is being constructed in Korea, with completion scheduled for 2020: once operational,



"While last year's growth in fuel cell platinum use was primarily in the automotive market, this year the majority of the increase will come from stationary power generation."

the plant will generate enough electricity to power an estimated 170,000 homes. It will also be the first plant of its type to be fuelled using by-product hydrogen, sourced from a nearby petrochemical complex, rather than natural gas. This means the electricity produced by the plant is effectively 'carbon free'.

While the outlook for industrial and automotive demand is largely positive, this is less true for jewellery and investment. The rate of decline in the Chinese platinum jewellery market appears to have moderated, but we are less optimistic than we were in our May 2018 report about the potential for this market to bottom-out in the short term. The results of Johnson Matthey's latest survey of Chinese manufacturers were mixed, but the overall picture was of a further modest contraction of platinum fabrication activity, combined with an increase in the proportion of metal being sourced from scrap.

There is growing evidence that the rise in karat gold fabrication is not only driven by margin considerations, but increasingly reflects a consumer pull, as younger jewellery buyers respond positively to the wide variety of designs offered at affordable prices. At the same time, the platinum jewellery sector is being hampered by a lack of attractive, modern designs, required to generate interest from a new generation of consumers that has no preference for a particular metal. We are aware of efforts being made to improve platinum casting technology in China, to make it easier to offer lighter and more appealing jewellery items, while per-piece pricing could ultimately make it more profitable to develop lightweight, intricate styles. However, it is not yet clear how successful these initiatives will be.

On a brighter note, there is still significant potential for growth in the Indian market, where platinum demand continues to expand at double-digit rates. To date, platinum jewellery sales have mainly been confined to southern cities such as Chennai and Bangalore, with marketing activities focusing on the self-purchase and bridal gift markets, targeting younger, wealthier consumers. Demographic trends suggest that there is potential for a significant expansion of Indian platinum jewellery sales in the coming years, but this market is nevertheless likely to remain small compared to China. In the Indian market, jewellery is priced on a per-piece basis, as it is in most developed markets.

The outlook for investment is mixed, but with the platinum price having fallen below $800 at the end of 2018, there appears to be limited scope for further price declines to stimulate new buying by Japanese investors. At the same time, any significant increase in price could give rise to ETF liquidation. Most platinum ETF investors are 'out of the money', and this has undoubtedly been a major factor in the relatively small changes in total holdings over the last four years (liquidation over this period has amounted to under 350,000 oz). In contrast, investors redeemed more than 2.2 million oz of palladium ETFs over the same period. This suggests that there is potential for price rallies to trigger significant 'pent-up' selling by platinum ETF investors, muting the impact of rising industrial and automotive demand.

Palladium Summary

Supply and Demand in 2018

- The palladium prices surged to $1,274 in December 2018 and lease rates peaked at over 30%.
- Producer stock sales, higher recycling and heavy ETF liquidation were not sufficient to support market liquidity.
- Autocatalyst demand hit record levels, as stricter vehicle testing procedures lifted loadings on European cars.
- Our figures suggest that the market moved closer to balance, but the underlying structural deficit continues to grow.

Palladium Supply and Demand '000 oz

Supply	2016	2017	2018
South Africa	2,570	2,550	2,590
Russia	2,773	2,406	2,840
Others	1,417	1,405	1,450
Total Supply	**6,760**	**6,361**	**6,880**
Gross Demand			
Autocatalyst	7,951	8,428	8,655
Jewellery	191	173	166
Industrial	1,875	1,832	1,855
Investment	-646	-386	-555
Total Gross Demand	**9,371**	**10,047**	**10,121**
Recycling	-2,491	-2,899	-3,212
Total Net demand	**6,880**	**7,148**	**6,909**
Movements in Stocks	-120	-787	-29

Last year saw the palladium market deficit narrow, as supplies were boosted by sales of producer stocks and an increase in recycling, while demand growth was moderated by further heavy liquidation of ETF holdings. However, there remains an underlying, long-term discrepancy between primary mine production and industrial consumption. This fundamental shortfall continued to grow in 2018, with autocatalyst demand at record levels and exceptionally strong activity in the chemicals industry.

The palladium market remained exceptionally tight throughout 2018, with lease rates consistently above 5% (versus an average of less than 1% for the 2012–2016 period). At the start of the year, a physical squeeze saw short-term lease rates rise briefly above 10% and the price surge from under $1,000 per ounce in December 2017 to over $1,120 in January 2018. Thereafter, liquidity in the market improved somewhat, and palladium gradually retreated to an annual low of under $850 in mid-August. Investor confidence was damaged by concerns that a US-China trade war could lead to lower global economic growth: this led investors to reduce their long futures positions, with the result that the net speculative long position on NYMEX fell from over 2.8 million oz in January to a low of just 20,000 oz in August.

At this point, renewed tightness in the physical market saw short-term lease rates spike above 15%, and the price began a steep recovery, climbing through $1,000 in September and $1,100 in November. As the year ended, short-term lease rates moved dramatically higher, peaking at over 30%, and the price surged to a new all-time record of $1,274 in late December.

These periods of extreme market tightness occurred despite substantial injections of liquidity in the form of producer selling and further ETF disinvestment. During the

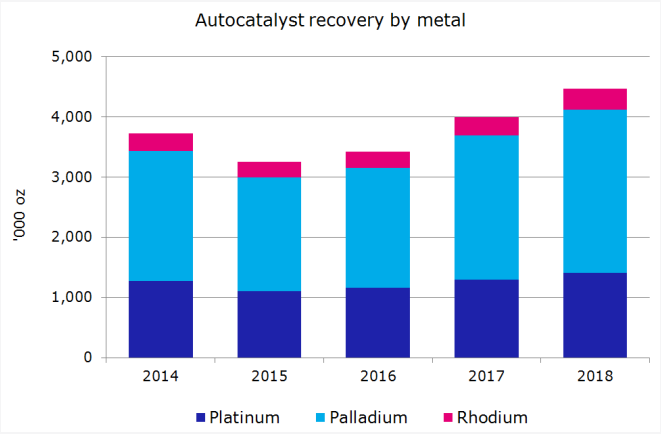
January to June period, Norilsk Nickel sold 1.53 million oz of palladium, of which around 160,000 oz were sourced from stocks of primary metal, produced but not sold in 2017, and held temporarily in the company's Global Palladium Fund. The purpose of this fund is to improve the security of supply for Norilsk's industrial customers; as well as primary metal, it also holds palladium acquired from pre-existing market stocks (the sale of which we do not count as fresh supply).

Sustained selling of investment holdings also helped support availability, returning over 550,000 oz of palladium to the market during the calendar year. High prices continued to stimulate profit-taking by ETF holders, particularly in South Africa, where gains in the dollar price have been intensified by exchange rate movements, lifting palladium to a series of record rand-denominated prices during the final quarter.

Including the producer stock sales referred to above, we estimate that Russian supplies rose by 18% to 2.84 million oz in 2018 (our figures are based on January to September data, and are subject to revision in our forthcoming May 2019 report). Underlying production at Norilsk Nickel remained relatively strong, although below the exceptional level seen in 2017, when refined output was boosted by releases of in-process stock following major changes to the process flowsheet. Palladium production from the company's mines continues to be supplemented by the processing of surface materials, in particular old copper concentrate, derived from mining activities in the Norilsk area during the Soviet era, and purchased from the state-controlled corporation Rostec in 2017.

Shipments of palladium from South Africa also rose slightly, boosted by an exceptionally strong performance from the Mogalakwena mine. In North America, output of by-product palladium from nickel smelters was subdued, but Stillwater's Blitz expansion project delivered significant quantities of metal for the first time, and North American Palladium lifted output from its Lac des Iles mine. Overall, we estimate that primary supplies rose by 8% to 6.88 million oz.

We estimate that secondary supplies grew by 10% to 3.2 million oz in 2018, as recoveries of palladium from automotive scrap again climbed at double-digit rates, in the wake of a 20% gain the previous year. The volume of spent catalyst collected was up strongly, as the market continued to recover from a period of weak vehicle recycling activity during 2015–2016 caused by low scrap steel prices. At the same time, the palladium content of spent catalysts continues to rise in line with historic trends in palladium loadings. This has been particularly true in the US market, which was the first to see widespread substitution of platinum with palladium in three-way gasoline catalysts starting in the 1990s. At this time, palladium catalyst technology was less advanced and fuels less clean, so substitution usually involved



"Recoveries of palladium from automotive scrap again climbed at double-digit rates in 2018, in the wake of a 20% gain the previous year."

Palladium Demand: Autocatalyst '000 oz									
	Gross			Recycling			Net		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
Europe	1,642	1,700	1,883	-424	-489	-549	1,218	1,211	1,334
Japan	785	835	859	-110	-127	-125	675	708	734
North America	1,950	2,053	2,041	-1,152	-1,422	-1,620	798	631	421
China	2,038	2,179	2,117	-75	-100	-130	1,963	2,079	1,987
Rest of World	1,536	1,661	1,755	-228	-261	-296	1,308	1,400	1,459
Total	**7,951**	**8,428**	**8,655**	**-1,989**	**-2,399**	**-2,720**	**5,962**	**6,029**	**5,935**

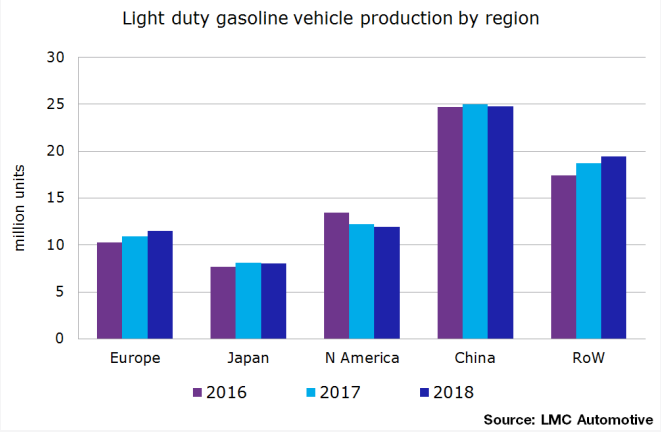
adding greater quantities of palladium than the amount of platinum removed, with the result that overall loadings on palladium-rich catalysts were often much higher than on platinum-rich equivalents.

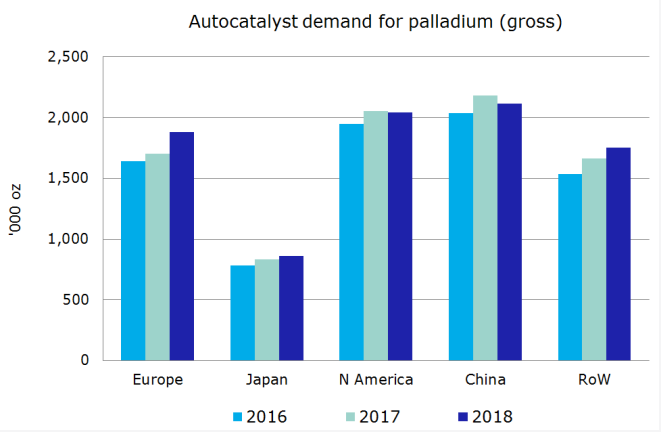
Gross demand for palladium rose by 1% to 10.12 million oz, as an increase in redemptions by ETF holders was outweighed by growth in the auto and chemicals sectors. Automotive demand recorded a new all-time high of 8.66 million oz, up 3%, with gains running ahead of trends in global gasoline vehicle output, due to significant growth in palladium loadings on European gasoline catalyst systems.

The progressive enforcement of Euro 6c and Euro 6d-TEMP legislation has been positive for palladium loadings on gasoline vehicles. Euro 6c imposes a mandatory particle number (PN) limit for gasoline direct injection (GDI) engines, while Euro 6d-TEMP extends emissions compliance for PN and NOx from the laboratory to the real world, via 'real driving emissions' (RDE) testing using portable emissions measurement equipment. The phase-in of Euro 6c and Euro 6d-TEMP began in September 2017, initially applying only to new passenger car models; the legislation will extend progressively to all new light vehicles by September 2020.

Because vehicles are now being tested under a wider range of conditions, emissions control has become significantly more challenging, and this is driving increases in both the complexity and the pgm content of aftertreatment systems. In particular, there has already been a significant rise in average loadings on three-way catalyst bricks, while GDI vehicles are also being fitted with a gasoline particulate filter (GPF) to meet the new standards.

In a GDI engine, the injection of a very fine mist of fuel encourages the formation of ultrafine soot particles which are harmful to human health and which are explicitly addressed by Euro 6c regulations. Previously, EU legislation imposed only a particulate mass (PM) standard, expressed in grams per kilometre, but did





Palladium Demand: Industrial '000 oz			
	2016	**2017**	**2018**
Chemical	418	462	493
Dental	430	392	380
Electrical	872	842	828
Other	155	136	154
Total	**1,875**	**1,832**	**1,855**

not place any restrictions on the number of particles emitted as long as their total mass fell below the legal threshold. In contrast, Euro 6c mandates an absolute particle number limit and this is driving the addition of GPFs to gasoline aftertreatment systems. The impact on overall pgm content is extremely variable: some filters do not have a pgm coating, others have relatively light pgm loadings, while some have a pgm content comparable to a three-way catalyst.

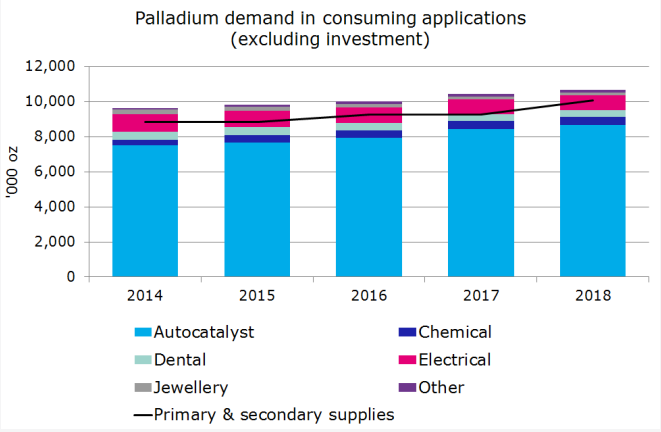
Because of the phase-in schedule, only a minority of vehicles met Euro 6c and Euro 6d-TEMP standards in 2018, but this was enough to lift loadings by around 10%, reversing the thrifting seen since 2014 and lifting average palladium loadings on European gasoline cars to their highest level since the early 2000s.

In contrast, demand in the two largest palladium autocatalyst markets fell slightly in 2018. Both North America and China saw modest declines in passenger car output, while loadings were little changed on the previous year. Going forward, both these markets are expected to see increases in palladium loadings as legislation tightens over the next few years; in China, these changes will be particularly significant. The impact of forthcoming China 6 emissions legislation is discussed on pages 18–19.

The use of palladium in industrial applications was flat in 2018. Purchasing by the chemicals sector remained at historically elevated levels, with strong investment in new capacity for purified terephthalic acid (PTA), a feedstock for the manufacture of polyesters used in packaging and textiles. However, dental and electronics applications continue to be impacted by thrifting and substitution.

With combined primary and secondary supplies up by 9%, and gross demand rising only marginally, the market moved close to balance in 2018. However, this has not been reflected in either price movements or in physical availability, both of which suggest a market in structural deficit.

Two factors which are not fully captured by our supply and demand measurements may be contributing to market tightness. Firstly, our estimates of secondary supplies are primarily made on the basis of underlying market trends such as vehicle scrappage figures and historical loading information, combined with data on refinery inputs. In a market where refiners are operating increasingly close to capacity limits, and where there is evidence that inventories of unprocessed pgm have risen, there is some uncertainty regarding the timing of



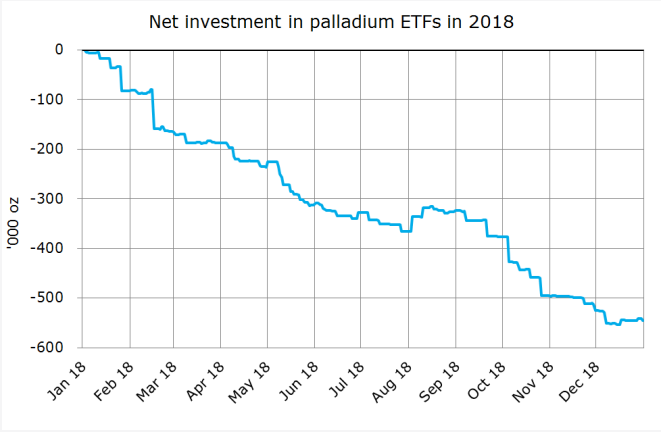
"The market moved close to balance in 2018. However, price movements and physical availability both suggest a market in structural deficit."

physical delivery of refined metal. It is possible that our recycling figures underestimate the impact of pipeline inventory fluctuations at secondary refiners.

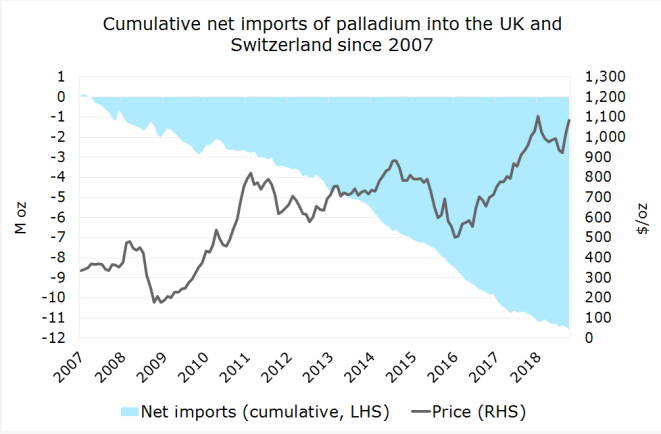
Secondly, our estimates of autocatalyst consumption reflect the timing and location of vehicle production. During periods of sharply rising loadings, there can be significant increases in work-in-progress stocks of pgm across the supply chain, which can increase tightness in the market, but which are not measured as demand in our figures.

While our headline figures suggest a market near to balance, removing temporary distortions such as producer stock movements and ETF disinvestment from our figures would put the market in a shortage of around 800,000 oz. It should be noted that neither of these sources can continue to supply additional metal for much longer: producer stocks are small, while ETFs held only around 730,000 oz of palladium at the end of 2018.

Analysis of trade data remains highly supportive of the view that the market overhang created by Russian government sales in the 1990s and early 2000s is being consumed rapidly: since 2007, we estimate that around 11.5 million oz of palladium has been withdrawn from inventories in the UK and Switzerland. While we believe that there are some residual stocks of metal, including unknown quantities of palladium produced during the Soviet years and which have ended up in the ownership of the Russian Central Bank, it is hard to predict when this inventory will be released to the market.



"Investors liquidated 546k oz in ETF positions in 2018, the fourth consecutive year of net redemptions. Remaining ETF holdings stood at around 730k oz by year end."



"Since 2007, we estimate that around 11.5 million oz of palladium has been withdrawn from inventories in the UK and Switzerland."

Palladium Outlook

Supply and Demand in 2019

- Strong growth in autocatalyst demand will drive the palladium market further into deficit in 2019.
- Recycling should rise again, but there is little prospect of growth in primary supplies.
- With ETF holdings now at 730,000 oz, disinvestment can no longer bridge the supply gap.
- In January 2019, the palladium price hit new all-time records and lease rates remained exceptionally high.

The deficit in the palladium market looks set to widen dramatically in 2019, with stricter emissions legislation forecast to stimulate double-digit rises in palladium demand from European and Chinese automakers. Although recoveries from autocatalyst scrap should rise again, the rate of growth in secondary supplies is likely to be lower than in 2018, while primary shipments are expected to be flat. With remaining ETF holdings having fallen to 730,000 oz at the end of last year, these funds no longer hold enough metal to bridge the gap between industrial demand and supplies.

At their height in 2014, ETFs held nearly 3 million oz of palladium. In the four years since then, the redemption of these holdings has added more than 2.2 million oz of liquidity, but this has not been sufficient to prevent a series of market deficits and a gradual tightening of physical availability. Short-term lease rates peaked at over 30% in 2018 and the price reached $1,280, a new record.

Assuming that the palladium price remains high, we expect some further ETF profit-taking to occur in 2019, but this is unlikely to be sufficient to prevent the deficit widening significantly. On the demand front, tightening emissions legislation and stricter vehicle testing regimes are now driving palladium autocatalyst loadings higher in most major vehicle markets. This year, the impact on demand will be especially significant in Europe and China.

According to the official nationwide timetable, China 6 emissions legislation is due to be enforced in two phases, with China 6a limits mandated from July 2020 and China 6b standards, including RDE testing, from July 2023. However, a number of provinces and cities will adopt the new standards in July 2019, under the 'Blue Sky Protection Plan'; by the second half of this year, we

estimate that around 30% of the Chinese car market will be covered by stricter legislation.

The transition to China 6 will result in a step-change in palladium and rhodium loadings compared to current China 5 systems; when RDE testing is rolled out, this is expected to result in further increases in the pgm content of catalyst systems. The exact requirements for RDE are not yet known, but it is likely to be extremely challenging to meet, as China 6b emissions limits are even tighter than Euro 6 standards.

The trajectory of palladium demand will also be influenced by trends in vehicle output. A slowdown in sales during the second half of 2018 left the Chinese car market with some excess inventory at the start of this year, which could result in cuts to short-term production forecasts. Nevertheless, we expect to see double-digit growth in palladium consumption over the 2019–2020 period.

In Europe, it is now clear that the implementation of the next stages of Euro 6 legislation will have a much larger impact on demand than we previously anticipated. The technical difficulty of meeting the new regulations, and the commercial risk of not doing so, mean that the average pgm content of European gasoline catalyst systems is rising quite significantly, although there is considerable variation in loadings strategies between companies. It is likely to be a number of years before European car companies are able to focus attention on thrifting again, because the EU is now implementing regulations which will increase the severity, frequency and duration of emissions testing.

The final phase of Euro 6d will be implemented starting in January 2020, further limiting permitted NOx emissions during RDE testing. In addition, new rules for in-service conformity (ISC) testing apply from the start of 2019. Previously, ISC tests were only carried out by automakers on their own vehicles but from now on they will also be performed by the type-approval authority, which will undertake RDE testing on vehicles with up to 100,000 km on the clock, and a laboratory test on vehicles up to 160,000 km. This means that vehicles will be required to meet type approval standards for almost their entire working life, increasing the emphasis on catalyst durability.

Separately, the EU's type-approval framework has been amended to give the EC the power to carry out its own checks on in-use vehicles and to issue fines for non-compliance, starting in September 2020. This amendment also introduces independent market surveillance of in-use vehicles by approved authorities, and the results of these controls may be used by EU member states to restrict or prohibit the sale of non-compliant vehicles.

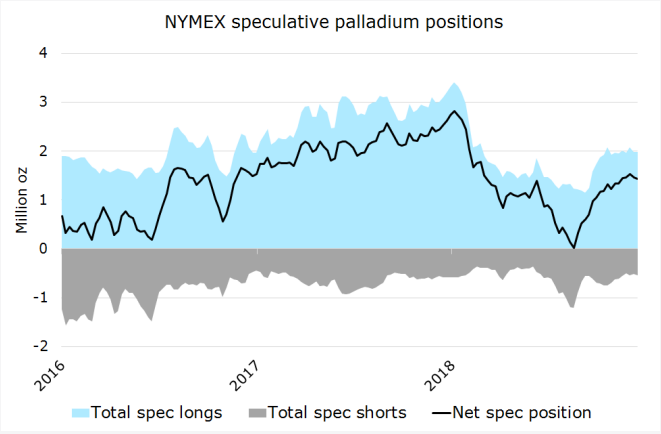
Automakers therefore face a potent mix of stricter emissions legislation, more rigorous testing, and more serious consequences for any failure to meet standards. This is encouraging a very cautious approach to emissions control, which will be positive for pgm loadings on gasoline vehicles.

There have also been some changes in testing procedures in other regions. The Worldwide Harmonised Light Vehicle Test Procedure (WLTP) type-approval protocol (used in Europe from September 2017) is being adopted in a number of other regions. In Japan, the JC08 test cycle was replaced by the WLTP testing regime in October 2018, while China will move to WLTP for China 6. Under the new procedures, vehicle homologation involves a cold start and a shorter warm-up period, meaning that catalysts are required to convert pollutants in a colder exhaust gas stream. Higher palladium loadings can accelerate catalyst 'light-off' in these conditions.

Industrial demand for palladium is forecast to be flat to slightly up in 2019, with continued firm demand from the chemicals sector offsetting a modest contraction in demand in the electronics and dental sectors. Palladium's use in multi-layer ceramic capacitors (MLCC) is now mainly confined to high-end products used in automotive, medical and military applications, and is not thought to be price sensitive. However, in plating applications it competes directly with gold, and at current prices some substitution may begin to occur.

Primary supplies of palladium are also expected to be flat, with modest releases of metal from pipeline inventories offsetting the impact of shaft closures in South Africa. In Russia, palladium shipments from Norilsk Nickel will continue to benefit from the processing of palladium-rich surface materials, while we expect some further sales of primary metal from the Global Palladium Fund. Secondary supplies are forecast to increase again, but it is likely that the rate of growth will moderate following two years of very rapid gains.

With automotive demand growing strongly, and combined primary and secondary supplies only increasing modestly, there is little doubt that the palladium market deficit will widen in 2019. The size of this deficit will depend once again on the extent to which remaining ETF holders choose to take profits. Excluding investment, the underlying 'structural' deficit in palladium is forecast to approach 1 million oz in 2019: even if all remaining ETF holdings were liquidated, this would not be sufficient to fill the shortfall.



"Investor confidence was hit by the potential impact of a US–China trade war, resulting in a sharp fall in net speculative long positions in 2018."

Rhodium Summary

Supply and Demand in 2018

- The rhodium price climbed to an eight-year high of $2,600 in December 2019.
- Automotive demand was buoyant, as European car companies raised loadings to comply with stricter testing procedures.
- Combined primary and secondary supplies grew, but fluctuations in refinery work-in-progress affected availability.
- Chinese imports of rhodium fell sharply, suggesting that locally-held stocks were used to meet consumer demand.

Combined primary and secondary shipments of rhodium rose by nearly 3% in 2018, on the back of robust growth in autocatalyst recycling and a seven-year high in South African shipments. In contrast, demand contracted by 4%, with gains in automotive consumption offset by a fall in purchasing by the glass and chemicals sectors, while a steep climb in the price stimulated further profit-taking by holders of rhodium ETFs. As a result, the market moved further into surplus.

This apparent surplus is at odds with price movements and market liquidity, suggesting that market participants and perhaps consumers are purchasing and holding rhodium that is not immediately required for industrial processes. In particular, we believe that there has been an increase in forward purchasing by some automotive and industrial companies this year, and that this has been accompanied by additional physical buying on the spot market to hedge these transactions. We do not count this as demand, because we measure consumption at the point when metal is used in a physical product or process (or when the consumer physically takes possession of pgm, if we can identify this). However, it is likely that this activity has removed some liquidity from the market.

While there is evidence that private investment in rhodium has taken place in China over the last few years, we do not believe that Chinese investors were net buyers in 2018. Indeed, there is some evidence that Chinese holders may have returned metal to the market last year: imports of rhodium into China were unusually low during 2018, and well below the level of identified consumption. In China, locally-sourced rhodium has been trading at an increased discount to world market prices, which may suggest that market tightness is partly a function of the physical location of metal stocks.

Rhodium Supply and Demand '000 oz

Supply	**2016**	**2017**	**2018**
South Africa	615	611	623
Russia	85	78	69
Others	73	70	67
Total Supply	**773**	**759**	**759**
Gross Demand			
Autocatalyst	809	842	862
Other	193	209	149
Total Gross Demand	**1,002**	**1,051**	**1,011**
Recycling	-271	-311	-344
Total Net demand	**731**	**740**	**667**
Movements in Stocks	42	19	92

Short-term fluctuations in inventories of semi-processed rhodium at pgm refineries may also have played a role in availability and hence price movements. Some major primary producers in South Africa ended 2017 with excess in-process stocks at their smelters and refineries, and there was a further pipeline build during the first nine months of 2018. Outside South Africa, there has been rationalisation in the pgm refining sector, at a time of strong growth in recycling, with the result that capacity utilisation is unusually high and stocks of work-in-progress are above normal levels. In addition, a fire at Umicore's Hoboken refinery in September appears to have had a short-term impact on rhodium market liquidity.

Because rhodium is a small, illiquid market, any short-term misalignment between supply and demand can have significant consequences for price and physical availability. Last year saw a steady climb in the rhodium price, from $1,690 per ounce in January 2018 to a peak of $2,600 in early December. However, in the second half of December, there were reports of increased selling from producers and investors, and the price retreated to $2,460 at the year end.

Underlying primary production of rhodium was flat in 2018, although we think that supplies from South African producers were augmented by some releases of metal from pipeline and refined stocks. In contrast, it was another year of strong growth in secondary production of rhodium: up 11% in 2018, following a 15% gain the previous year. However, the rate of increase in autocatalyst recoveries of rhodium continues to lag that of palladium, reflecting rhodium thrifting in North America and Europe which occurred in the mid-to-late 2000s following a period of extremely high prices; in many cases, thrifting was achieved at the expense of increased palladium loadings.

Thrifting of rhodium from gasoline autocatalysts has been a consistent feature of the auto market for the past decade: global average rhodium loadings on gasoline cars were about 40% lower in 2017 than in 2007. However, changes to emissions regulations and testing procedures have started to drive loadings higher again. This was particularly true in Europe in 2018, but we expect to see increases in the rhodium content of gasoline catalysts in most regions going forward. Last year, on a global basis, the average rhodium content of a gasoline aftertreatment system rose by around 3%, and this helped lift gross world demand for rhodium in autocatalysts by 20,000 oz.

Much of this gain occurred in Europe, where the rhodium content of gasoline vehicles rose sharply as more models were equipped with aftertreatment systems capable of meeting Euro 6d-TEMP standards. While aftertreatment of NOx is less technically difficult in gasoline engines than diesels, the implementation of RDE testing and stricter in-service conformity testing has considerably widened the range of conditions under which automakers must demonstrate that their vehicles can meet NOx (and other pollutant) emissions limits. This has been positive for pgm loadings on three-way catalysts generally and for rhodium in particular.

In contrast, the phase-in of Euro 6d-TEMP legislation has tended to reduce the use of rhodium in diesel vehicles, because it has encouraged wider adoption of non-pgm SCR technology to convert NOx, and less use of rhodium-containing lean NOx traps (although all European diesels continue to carry at least one pgm-containing catalyst brick). However, rhodium use on diesel vehicles has always been a relatively minor component of total autocatalyst demand.

Demand in the two largest rhodium-consuming auto markets, North America and China, was lacklustre in 2018. Both markets saw a modest decline in output of light duty gasoline vehicles, while average rhodium loadings were little changed. In the Rest of World region, higher rhodium usage reflected strong growth in Indian car production and a recovery in the Russian automotive sector.

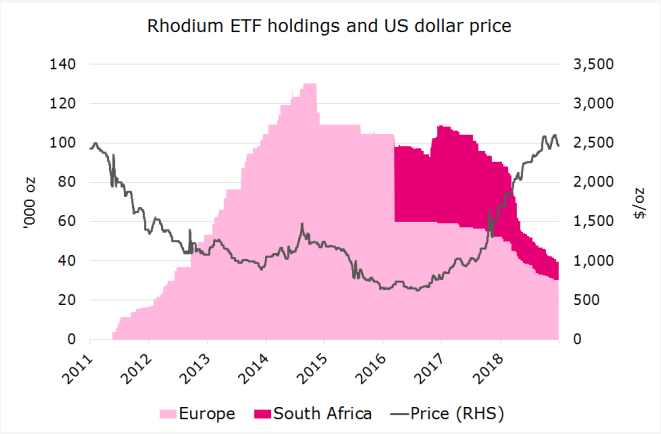
Growth in auto demand was offset by a fall in rhodium consumption in industrial applications last year, in the wake of unusually heavy buying by chemical and glass companies in 2017. This reduction was primarily related to the timing of rhodium purchases, and was not reflective of weaker underlying conditions in either

Rhodium Demand: Industrial '000 oz			
	2016	**2017**	**2018**
Chemical	64	71	63
Electrical	3	4	4
Glass	85	113	93
Other	41	21	-11
Total	**193**	**209**	**149**

industry, both of which continue to see significant investment in new production capacity.

In the glass sector, higher rhodium prices have also played a role: glass makers are among the few rhodium consumers who have some ability to make short-term adjustments to rhodium usage in response to price. Rhodium is an essential component of platinum alloys used in glass-making equipment such as fibreglass bushings, because it increases melting point and improves strength and durability. The rhodium content typically varies between 10% and 20%, depending partly on the relative prices of the two metals: when the rhodium price is significantly above that of platinum, it can make economic sense to thrift rhodium, even though doing so may reduce the working life of the apparatus, and despite differing metal densities which mean that each ounce of rhodium must be replaced by 1.7 oz of platinum (assuming that the dimensions of the fibreglass bushing are unchanged).

Rising prices also stimulated further profit-taking by ETF investors, with the result that our figure for 'other' applications (which includes investment) turned negative in 2018. In total, some 50,000 oz of rhodium ETFs were redeemed last year, up from around 20,000 oz in 2017; by the year end, total holdings were under 40,000 oz, down from nearly 130,000 oz at their peak in 2014. It should be noted that without this negative investment, overall rhodium demand would have risen, although the market would still have been in a modest surplus.



"Rising prices stimulated profit-taking by ETF investors. In total, some 50,000 oz of rhodium ETFs were redeemed last year, leaving total holdings under 40,000 oz by year end."

Rhodium Outlook

Supply and Demand in 2019

- Rhodium use in autocatalysts is set to grow strongly, as emissions limits and in-use testing become more stringent
- This should outweigh potential price-related thrifting in industrial applications
- Primary supplies will be flat, but further growth in recycling could again leave the market in fundamental surplus.

Consumption of rhodium in autocatalysts is forecast to see strong growth in 2019, as car companies increase pgm loadings in response to tighter emissions legislation and more stringent in-use testing. This should outweigh thrifting in the glass industry, leaving industrial demand up on last year and close to record levels. Primary supplies are expected to be flat, but there will be further growth in recycling, which could leave the market in surplus for another year.

Rhodium supplies from South Africa will start to contract in the near future, as shaft closures at Lonmin and Impala Platinum are implemented, and as some other UG2 operations are near the end of their lives. However, the release of more rhodium from the processing pipeline in 2019 could result in South African output remaining above 600,000 oz for another year. With further growth in autocatalyst recovery, we could see a modest increase in combined primary and secondary rhodium supplies in 2019. However, looking further ahead, growth in recycling will probably not be enough to offset declining mine production.

The UG2 reef is richer in rhodium than other pgm ores mined in South Africa, so the depletion and closure of UG2 operations will be particularly significant for supplies of this metal. Typically, rhodium accounts for about 9–11% of the pgm (4E) grade in UG2 ores, compared to 4–6% in Merensky Reef, and around 3% in Platreef. Elsewhere in the world, ores tend to have an even lower rhodium content: we estimate that rhodium accounts for only around 2% of pgm output at Norilsk Nickel's operations in Russia, and under 1% at Sibanye-Stillwater's US mines. With global pgm production forecast to decline moderately over the medium term, and lower-rhodium-content ores expected to account for a greater share of pgm production, the medium-term outlook for rhodium production is negative.

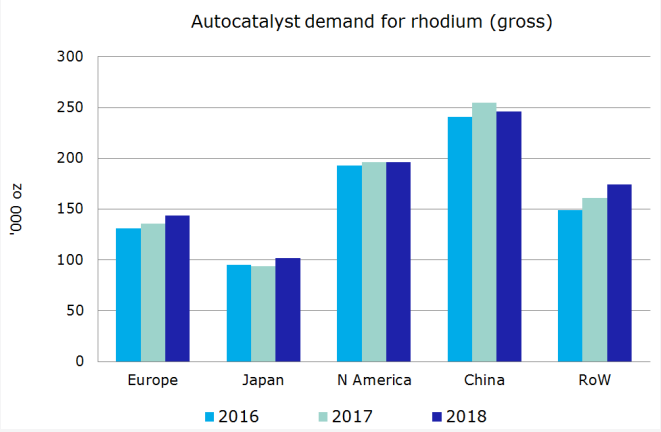
In contrast, the outlook for demand is increasingly positive. Emissions legislation is tightening in most major markets, contributing to an upward trend in global rhodium loadings. In 2019, the largest changes will be seen in Europe, as a result of more stringent testing of passenger vehicles, and in China, where a new phase of legislative tightening is about to get underway.

Over the next three years, the phasing-in of Euro 6d legislation will further restrict permitted NOx emissions during RDE testing. At the same time, automakers will also face new in-service conformity regulations, designed to ensure that catalyst systems meet type approval standards not just at the point that the vehicle is put into service, but during a significant portion of its lifetime. This is dramatically increasing the stakes for non-compliance and is driving an increasingly risk-averse approach to aftertreatment system design. For gasoline vehicles, the new testing regime is expected to result in a significant increase in loadings of palladium and, particularly, rhodium.

China is also entering a period of regulatory change. Some cities and provinces will start to implement China 6 legislation this year, ahead of its nationwide application which is scheduled to take place between 2020 (China 6a) and 2023 (China 6b, including RDE testing). Meeting China 6a and 6b limits will require higher palladium and rhodium loadings compared to current China 5 systems. When RDE testing is rolled out, currently slated for China 6b in July 2023, this is likely to drive further increases in pgm content.

While autocatalyst demand is set to rise strongly, consumption in other applications could weaken this year, primarily due to lower purchasing from the glass industry, where higher prices have begun to stimulate some thrifting of rhodium (see page 23). However, the timing of thrifting is still uncertain, while its impact will be limited by technical factors (the rhodium content of glass alloys cannot typically be reduced below 10%). Elsewhere, demand in the chemicals sector is forecast to remain firm, while 'other' demand (including investment) is almost certain to rise because there is now only limited potential for further ETF selling.

Our supply and demand forecasts suggest that the rhodium market could again be in a technical surplus in 2019, although much will depend on the exact trajectory of automotive demand in China, the speed of thrifting in the glass sector, and the ability of primary and secondary refineries to manage in-process inventories. As the year began, there was some evidence of increased physical availability: the price eased from a peak of $2,600 in December 2018 to stabilise at around $2,400 in early January 2019. However, we expect any improvements in availability to be temporary, with metal likely to be readily absorbed by rising automotive consumption and, potentially, strategic purchasing in anticipation of future demand growth.



"Emissions legislation is tightening in most major markets, contributing to an upward trend in global rhodium loadings."

Platinum Supply & Demand

Troy ounces

PLATINUM '000 oz - Supply and Demand							
							2018 numbers are a forecast
		2013	2014	2015	2016	2017	2018
Supply[1]	South Africa	4,208	3,546	4,572	4,392	4,449	4,471
	Russia[2]	736	700	670	717	703	657
	North America	318	339	314	337	328	335
	Zimbabwe[3]	410	401	400	489	466	480
	Others[3]	174	167	151	162	159	165
	Total Supply	**5,846**	**5,153**	**6,107**	**6,097**	**6,105**	**6,108**
Demand[4]	Autocatalyst[4]	2,937	3,064	3,244	3,342	3,218	3,052
	Chemical	522	576	502	476	490	550
	Electrical[4]	219	225	228	230	230	273
	Glass	102	143	227	247	366	466
	Investment	871	277	451	620	361	89
	Jewellery[4]	2,984	2,839	2,746	2,412	2,400	2,363
	Medical and Biomedical[5]	217	214	215	217	220	224
	Petroleum	146	172	140	175	233	311
	Other	419	434	443	461	483	497
	Total Gross Demand	**8,417**	**7,944**	**8,196**	**8,180**	**8,001**	**7,825**
Recycling[6]	Autocatalyst	-1,199	-1,272	-1,110	-1,164	-1,292	-1,403
	Electrical	-24	-27	-29	-32	-34	-36
	Jewellery	-790	-762	-574	-738	-746	-776
	Total Recycling	**-2,013**	**-2,061**	**-1,713**	**-1,934**	**-2,072**	**-2,215**
Total Net Demand[7]		**6,404**	**5,883**	**6,483**	**6,246**	**5,929**	**5,610**
Movement in Stocks[8]		**-558**	**-730**	**-376**	**-149**	**176**	**498**

Platinum Gross Demand by Region

Troy ounces

PLATINUM '000 oz - Gross Demand by Region

2018 numbers are a forecast

		2013	2014	2015	2016	2017	2018
Europe	Autocatalyst	1,280	1,475	1,655	1,801	1,717	1,510
	Chemical	98	111	120	122	119	123
	Electrical	15	12	13	13	11	13
	Glass	7	11	11	11	11	11
	Investment	-40	-73	-88	109	36	-102
	Jewellery	217	204	203	177	176	184
	Medical and Biomedical	74	72	71	71	71	71
	Petroleum	-12	22	-4	3	13	31
	Other	106	108	105	108	111	112
	Total	**1,745**	**1,942**	**2,086**	**2,415**	**2,265**	**1,953**
Japan	Autocatalyst	503	448	382	359	350	344
	Chemical	42	41	43	42	39	40
	Electrical	27	31	33	32	31	36
	Glass	-20	-96	4	2	25	7
	Investment	-40	19	700	543	171	220
	Jewellery	310	313	314	310	305	307
	Medical and Biomedical	19	16	16	15	15	16
	Petroleum	-1	3	3	3	2	2
	Other	70	71	79	75	76	76
	Total	**910**	**846**	**1,574**	**1,381**	**1,014**	**1,048**
N. America	Autocatalyst	339	356	368	344	322	325
	Chemical	102	113	114	103	112	116
	Electrical	19	18	22	26	32	37
	Glass	7	10	10	29	45	17
	Investment	57	7	-32	109	127	66
	Jewellery	213	218	227	220	238	239
	Medical and Biomedical	85	85	85	86	87	88
	Petroleum	23	21	40	36	18	17
	Other	122	125	117	122	123	122
	Total	**967**	**953**	**951**	**1,075**	**1,104**	**1,027**
China	Autocatalyst	130	130	136	151	157	153
	Chemical	133	155	131	121	110	136
	Electrical	36	39	38	39	40	51
	Glass	93	144	178	135	163	351
	Investment	0	0	0	0	0	0
	Jewellery	2,100	1,935	1,796	1,510	1,470	1,400
	Medical and Biomedical	17	18	19	19	20	21
	Petroleum	56	30	32	64	119	197
	Other	48	53	59	71	80	89
	Total	**2,613**	**2,504**	**2,389**	**2,110**	**2,159**	**2,398**
RoW	Autocatalyst	685	655	703	687	672	720
	Chemical	147	156	94	88	110	135
	Electrical	122	125	122	120	116	136
	Glass	15	74	24	70	122	80
	Investment	894	324	-129	-141	27	-95
	Jewellery	144	169	206	195	211	233
	Medical and Biomedical	22	23	24	26	27	28
	Petroleum	80	96	69	69	81	64
	Other	73	77	83	85	93	98
	Total	**2,182**	**1,699**	**1,196**	**1,199**	**1,459**	**1,399**
	Grand total	**8,417**	**7,944**	**8,196**	**8,180**	**8,001**	**7,825**

Platinum Supply & Demand

Tonnes

PLATINUM Tonnes - Supply and Demand							
							2018 numbers are a forecast
		2013	2014	2015	2016	2017	2018
Supply[1]	South Africa	130.9	110.3	142.2	136.6	138.4	139.1
	Russia[2]	22.9	21.8	20.8	22.3	21.9	20.5
	North America	9.9	10.5	9.8	10.5	10.2	10.4
	Zimbabwe[3]	12.7	12.5	12.4	15.2	14.5	14.9
	Others[3]	5.4	5.2	4.7	5.0	4.9	5.1
	Total Supply	**181.8**	**160.3**	**189.9**	**189.6**	**189.9**	**190.0**
Demand[4]	Autocatalyst[4]	91.2	95.3	101.0	104.0	100.1	95.0
	Chemical	16.3	18.0	15.5	14.8	15.2	17.0
	Electrical[4]	6.8	7.1	7.1	7.1	7.1	8.5
	Glass	3.2	4.4	6.9	7.7	11.4	14.4
	Investment	27.2	8.6	14.1	19.3	11.2	2.7
	Jewellery[4]	92.8	88.3	85.5	75.0	74.7	73.5
	Medical and Biomedical[5]	6.7	6.6	6.6	6.8	6.8	7.0
	Petroleum	4.5	5.4	4.4	5.4	7.3	9.7
	Other	13.1	13.5	13.8	14.3	15.1	15.5
	Total Gross Demand	**261.8**	**247.2**	**254.9**	**254.4**	**248.9**	**243.3**
Recycling[6]	Autocatalyst	-37.3	-39.6	-34.4	-36.3	-40.1	-43.6
	Electrical	-0.7	-0.8	-0.9	-1.0	-1.0	-1.2
	Jewellery	-24.6	-23.7	-17.9	-23.0	-23.2	-24.1
	Total Recycling	**-62.6**	**-64.1**	**-53.2**	**-60.3**	**-64.3**	**-68.9**
Total Net Demand[7]		**199.2**	**183.1**	**201.7**	**194.1**	**184.6**	**174.4**
Movement in Stocks[8]		**-17.4**	**-22.8**	**-11.8**	**-4.5**	**5.3**	**15.6**

Platinum Gross Demand by Region

Tonnes

PLATINUM Tonnes - Gross Demand by Region

2018 numbers are a forecast

		2013	2014	2015	2016	2017	2018
Europe	Autocatalyst	39.8	45.9	51.5	56.0	53.4	47.0
	Chemical	3.0	3.5	3.7	3.8	3.7	3.8
	Electrical	0.5	0.4	0.4	0.4	0.3	0.4
	Glass	0.2	0.3	0.3	0.3	0.3	0.3
	Investment	-1.2	-2.3	-2.7	3.4	1.1	-3.2
	Jewellery	6.8	6.3	6.3	5.5	5.5	5.7
	Medical and Biomedical	2.3	2.2	2.2	2.2	2.2	2.2
	Petroleum	-0.4	0.7	-0.1	0.1	0.4	1.0
	Other	3.3	3.4	3.3	3.4	3.5	3.5
	Total	**54.3**	**60.4**	**64.9**	**75.1**	**70.4**	**60.7**
Japan	Autocatalyst	15.6	13.9	11.9	11.2	10.9	10.7
	Chemical	1.3	1.3	1.3	1.3	1.2	1.2
	Electrical	0.8	1.0	1.0	1.0	1.0	1.1
	Glass	-0.6	-3.0	0.1	0.1	0.8	0.2
	Investment	-1.2	0.6	21.8	16.9	5.3	6.8
	Jewellery	9.6	9.7	9.8	9.6	9.5	9.6
	Medical and Biomedical	0.6	0.5	0.5	0.5	0.5	0.5
	Petroleum	0.0	0.1	0.1	0.1	0.1	0.1
	Other	2.2	2.2	2.5	2.3	2.4	2.4
	Total	**28.3**	**26.3**	**49.0**	**43.0**	**31.7**	**32.6**
N. America	Autocatalyst	10.5	11.1	11.5	10.7	10.0	10.1
	Chemical	3.2	3.5	3.5	3.2	3.5	3.6
	Electrical	0.6	0.6	0.7	0.8	1.0	1.2
	Glass	0.2	0.3	0.3	0.9	1.4	0.5
	Investment	1.8	0.2	-1.0	3.4	4.0	2.1
	Jewellery	6.6	6.8	7.1	6.8	7.4	7.4
	Medical and Biomedical	2.6	2.6	2.6	2.7	2.7	2.7
	Petroleum	0.7	0.7	1.2	1.1	0.6	0.5
	Other	3.8	3.9	3.6	3.8	3.8	3.8
	Total	**30.0**	**29.7**	**29.5**	**33.4**	**34.4**	**31.9**
China	Autocatalyst	4.0	4.0	4.2	4.7	4.9	4.8
	Chemical	4.2	4.8	4.1	3.8	3.4	4.2
	Electrical	1.1	1.2	1.2	1.2	1.2	1.6
	Glass	2.9	4.5	5.5	4.2	5.1	10.9
	Investment	0.0	0.0	0.0	0.0	0.0	0.0
	Jewellery	65.3	60.2	55.9	47.0	45.7	43.5
	Medical and Biomedical	0.5	0.6	0.6	0.6	0.6	0.7
	Petroleum	1.7	0.9	1.0	2.0	3.7	6.1
	Other	1.5	1.6	1.8	2.2	2.5	2.8
	Total	**81.2**	**77.8**	**74.3**	**65.7**	**67.1**	**74.6**
RoW	Autocatalyst	21.3	20.4	21.9	21.4	20.9	22.4
	Chemical	4.6	4.9	2.9	2.7	3.4	4.2
	Electrical	3.8	3.9	3.8	3.7	3.6	4.2
	Glass	0.5	2.3	0.7	2.2	3.8	2.5
	Investment	27.8	10.1	-4.0	-4.4	0.8	-3.0
	Jewellery	4.5	5.3	6.4	6.1	6.6	7.3
	Medical and Biomedical	0.7	0.7	0.7	0.8	0.8	0.9
	Petroleum	2.5	3.0	2.2	2.1	2.5	2.0
	Other	2.3	2.4	2.6	2.6	2.9	3.0
	Total	**68.0**	**53.0**	**37.2**	**37.2**	**45.3**	**43.5**
	Grand total	**261.8**	**247.2**	**254.9**	**254.4**	**248.9**	**243.3**

Palladium Supply & Demand

Troy ounces

PALLADIUM '000 oz - Supply and Demand							
							2018 numbers are a forecast
		2013	2014	2015	2016	2017	2018
Supply[1]	South Africa	2,464	2,126	2,683	2,570	2,550	2,590
	Russia[2]	2,628	2,589	2,434	2,773	2,406	2,840
	North America	831	912	874	892	886	939
	Zimbabwe[3]	322	327	320	396	386	378
	Others[3]	152	160	144	129	133	133
	Total Supply	**6,397**	**6,114**	**6,455**	**6,760**	**6,361**	**6,880**
Demand[4]	Autocatalyst[4]	7,069	7,517	7,649	7,951	8,428	8,655
	Chemical	378	315	452	418	462	493
	Dental	457	464	468	430	392	380
	Electrical[4]	1,017	970	903	872	842	828
	Investment	-8	943	-659	-646	-386	-555
	Jewellery[4]	354	272	222	191	173	166
	Other	109	111	134	155	136	154
	Total Gross Demand	**9,376**	**10,592**	**9,169**	**9,371**	**10,047**	**10,121**
Recycling[6]	Autocatalyst	-1,899	-2,159	-1,882	-1,989	-2,399	-2,720
	Electrical	-463	-474	-475	-481	-479	-478
	Jewellery	-157	-89	-46	-21	-21	-14
	Total Recycling	**-2,519**	**-2,722**	**-2,403**	**-2,491**	**-2,899**	**-3,212**
Total Net Demand[7]		**6,857**	**7,870**	**6,766**	**6,880**	**7,148**	**6,909**
Movement in Stocks[8]		**-460**	**-1,756**	**-311**	**-120**	**-787**	**-29**

Palladium Gross Demand by Region

Troy ounces

PALLADIUM '000 oz - Gross Demand by Region

2018 numbers are a forecast

		2013	2014	2015	2016	2017	2018
Europe	Autocatalyst	1,502	1,583	1,609	1,642	1,700	1,883
	Chemical	71	-23	77	79	80	79
	Dental	80	77	70	66	61	56
	Electrical	112	113	101	99	96	94
	Investment	-14	-74	-200	-269	-287	-141
	Jewellery	61	60	59	58	55	55
	Other	24	25	27	24	23	30
	Total	**1,836**	**1,761**	**1,743**	**1,699**	**1,728**	**2,056**
Japan	Autocatalyst	782	794	757	785	835	859
	Chemical	18	16	15	15	15	15
	Dental	184	205	227	200	174	171
	Electrical	220	214	231	227	220	214
	Investment	-4	-2	4	-3	-3	-1
	Jewellery	70	67	66	64	57	56
	Other	9	9	9	9	8	8
	Total	**1,279**	**1,303**	**1,309**	**1,297**	**1,306**	**1,322**
N. America	Autocatalyst	1,770	1,963	2,032	1,950	2,053	2,041
	Chemical	68	71	76	73	74	77
	Dental	168	156	145	138	131	126
	Electrical	159	140	131	128	124	120
	Investment	10	-205	-181	-71	-19	-86
	Jewellery	43	44	41	38	33	33
	Other	43	43	60	46	43	43
	Total	**2,261**	**2,212**	**2,304**	**2,302**	**2,439**	**2,354**
China	Autocatalyst	1,499	1,608	1,654	2,038	2,179	2,117
	Chemical	144	160	209	156	182	205
	Dental	8	8	8	7	7	7
	Electrical	168	169	158	156	155	155
	Investment	0	0	0	0	0	0
	Jewellery	155	78	34	10	9	3
	Other	15	16	17	43	46	55
	Total	**1,989**	**2,039**	**2,080**	**2,410**	**2,578**	**2,542**
RoW	Autocatalyst	1,516	1,569	1,597	1,536	1,661	1,755
	Chemical	77	91	75	95	111	117
	Dental	17	18	18	19	19	20
	Electrical	358	334	282	262	247	245
	Investment	0	1,224	-282	-303	-77	-327
	Jewellery	25	23	22	21	19	19
	Other	18	18	21	33	16	18
	Total	**2,011**	**3,277**	**1,733**	**1,663**	**1,996**	**1,847**
	Grand total	**9,376**	**10,592**	**9,169**	**9,371**	**10,047**	**10,121**

Palladium Supply & Demand

Tonnes

PALLADIUM Tonnes - Supply and Demand							
							2018 numbers are a forecast
		2013	2014	2015	2016	2017	2018
Supply[1]	South Africa	76.6	66.1	83.4	79.9	79.3	80.6
	Russia[2]	81.7	80.5	75.7	86.3	74.8	88.3
	North America	25.9	28.4	27.2	27.7	27.6	29.2
	Zimbabwe[3]	10.0	10.2	10.0	12.3	12.0	11.8
	Others[3]	4.7	5.0	4.5	4.0	4.1	4.1
	Total Supply	**198.9**	**190.2**	**200.8**	**210.2**	**197.8**	**214.0**
Demand[4]	Autocatalyst[4]	219.9	233.8	237.8	247.4	262.3	269.2
	Chemical	11.8	9.8	14.1	13.0	14.5	15.4
	Dental	14.1	14.4	14.6	13.4	12.2	11.7
	Electrical[4]	31.5	30.2	28.1	27.1	26.0	25.8
	Investment	-0.2	29.3	-20.5	-20.1	-12.0	-17.3
	Jewellery[4]	11.0	8.5	6.9	6.0	5.4	5.2
	Other	3.4	3.5	4.2	4.7	4.1	4.7
	Total Gross Demand	**291.5**	**329.5**	**285.2**	**291.5**	**312.5**	**314.7**
Recycling[6]	Autocatalyst	-59.1	-67.2	-58.5	-61.8	-74.6	-84.6
	Electrical	-14.4	-14.8	-14.8	-15.0	-15.0	-14.9
	Jewellery	-4.9	-2.7	-1.4	-0.7	-0.6	-0.4
	Total Recycling	**-78.4**	**-84.7**	**-74.7**	**-77.5**	**-90.2**	**-99.9**
Total Net Demand[7]		**213.1**	**244.8**	**210.5**	**214.0**	**222.3**	**214.8**
Movement in Stocks[8]		**-14.2**	**-54.6**	**-9.7**	**-3.8**	**-24.5**	**-0.8**

Palladium Gross Demand by Region

Tonnes

PALLADIUM Tonnes - Gross Demand by Region

2018 numbers are a forecast

		2013	2014	2015	2016	2017	2018
Europe	Autocatalyst	46.7	49.2	50.0	51.1	52.9	58.6
	Chemical	2.2	-0.7	2.4	2.5	2.5	2.5
	Dental	2.5	2.4	2.2	2.1	1.9	1.7
	Electrical	3.5	3.5	3.1	3.0	2.9	2.9
	Investment	-0.4	-2.3	-6.2	-8.4	-8.9	-4.4
	Jewellery	1.9	1.9	1.8	1.8	1.7	1.7
	Other	0.7	0.8	0.8	0.7	0.7	0.9
	Total	**57.1**	**54.8**	**54.1**	**52.8**	**53.7**	**63.9**
Japan	Autocatalyst	24.3	24.7	23.5	24.4	26.0	26.7
	Chemical	0.6	0.5	0.5	0.5	0.5	0.5
	Dental	5.7	6.4	7.1	6.2	5.4	5.3
	Electrical	6.8	6.7	7.2	7.1	6.8	6.7
	Investment	-0.1	-0.1	0.1	-0.1	-0.1	0.0
	Jewellery	2.2	2.1	2.0	2.0	1.8	1.8
	Other	0.3	0.3	0.3	0.3	0.2	0.2
	Total	**39.8**	**40.6**	**40.7**	**40.4**	**40.6**	**41.2**
N. America	Autocatalyst	55.1	61.1	63.2	60.7	63.9	63.5
	Chemical	2.1	2.2	2.4	2.3	2.3	2.4
	Dental	5.2	4.8	4.5	4.3	4.1	3.9
	Electrical	4.9	4.3	4.1	4.0	3.8	3.8
	Investment	0.3	-6.4	-5.6	-2.2	-0.6	-2.7
	Jewellery	1.3	1.4	1.3	1.2	1.0	1.0
	Other	1.3	1.3	1.9	1.4	1.3	1.3
	Total	**70.2**	**68.7**	**71.8**	**71.7**	**75.8**	**73.2**
China	Autocatalyst	46.6	50.0	51.4	63.4	67.8	65.8
	Chemical	4.5	5.0	6.5	4.8	5.7	6.4
	Dental	0.2	0.2	0.2	0.2	0.2	0.2
	Electrical	5.2	5.3	4.9	4.9	4.8	4.8
	Investment	0.0	0.0	0.0	0.0	0.0	0.0
	Jewellery	4.8	2.4	1.1	0.3	0.3	0.1
	Other	0.5	0.5	0.5	1.3	1.4	1.7
	Total	**61.8**	**63.4**	**64.6**	**74.9**	**80.2**	**79.0**
RoW	Autocatalyst	47.2	48.8	49.7	47.8	51.7	54.6
	Chemical	2.4	2.8	2.3	2.9	3.5	3.6
	Dental	0.5	0.6	0.6	0.6	0.6	0.6
	Electrical	11.1	10.4	8.8	8.1	7.7	7.6
	Investment	0.0	38.1	-8.8	-9.4	-2.4	-10.2
	Jewellery	0.8	0.7	0.7	0.7	0.6	0.6
	Other	0.6	0.6	0.7	1.0	0.5	0.6
	Total	**62.6**	**102.0**	**54.0**	**51.7**	**62.2**	**57.4**
	Grand total	**291.5**	**329.5**	**285.2**	**291.5**	**312.5**	**314.7**

Rhodium Supply & Demand

Troy ounces

RHODIUM '000 oz - Supply and Demand							
							2018 numbers are a forecast
		2013	2014	2015	2016	2017	2018
Supply[1]	South Africa	554	470	611	615	611	623
	Russia[2]	80	80	80	85	78	69
	North America	23	24	22	24	23	23
	Zimbabwe[3]	36	36	36	44	42	39
	Others[3]	8	7	5	5	5	5
	Total Supply	**701**	**617**	**754**	**773**	**759**	**759**
Demand[4]	Autocatalyst[4]	753	770	757	809	842	862
	Chemical	79	90	73	64	71	63
	Electrical	5	3	3	3	4	4
	Glass	47	49	52	85	113	93
	Other	87	38	30	41	21	-11
	Total Gross Demand	**971**	**950**	**915**	**1,002**	**1,051**	**1,011**
Recycling[6]	Autocatalyst	-281	-301	-260	-271	-311	-344
	Total Recycling	**-281**	**-301**	**-260**	**-271**	**-311**	**-344**
Total Net Demand[7]		**690**	**649**	**655**	**731**	**740**	**667**
Movement in Stocks[8]		**11**	**-32**	**99**	**42**	**19**	**92**

Rhodium Supply & Demand

Tonnes

RHODIUM Tonnes - Supply and Demand							
							2018 numbers are a forecast
		2013	2014	2015	2016	2017	2018
Supply[1]	South Africa	17.2	14.6	19.0	19.1	19.0	19.4
	Russia[2]	2.5	2.5	2.5	2.6	2.4	2.1
	North America	0.7	0.7	0.7	0.7	0.7	0.7
	Zimbabwe[3]	1.1	1.1	1.1	1.4	1.3	1.2
	Others[3]	0.2	0.2	0.2	0.2	0.2	0.2
	Total Supply	**21.7**	**19.1**	**23.5**	**24.0**	**23.6**	**23.6**
Demand[4]	Autocatalyst[4]	23.4	23.9	23.5	25.2	26.1	26.9
	Chemical	2.5	2.9	2.3	1.9	2.2	2.0
	Electrical	0.0	0.1	0.1	0.1	0.1	0.1
	Glass	1.4	1.5	1.7	2.6	3.4	2.8
	Other	2.8	1.2	1.0	1.3	0.8	-0.3
	Total Gross Demand	**30.1**	**29.6**	**28.6**	**31.1**	**32.6**	**31.5**
Recycling[6]	Autocatalyst	-8.7	-9.4	-8.1	-8.4	-9.7	-10.7
	Total Recycling	**-8.7**	**-9.4**	**-8.1**	**-8.4**	**-9.7**	**-10.7**
Total Net Demand[7]		**21.4**	**20.2**	**20.5**	**22.7**	**22.9**	**20.8**
Movement in Stocks[8]		**0.3**	**-1.1**	**3.0**	**1.3**	**0.7**	**2.8**

Ruthenium Demand

Troy ounces and tonnes

RUTHENIUM '000 oz - Demand							
							2018 numbers are a forecast
		2013	2014	2015	2016	2017	2018
Demand	Chemical	321	332	444	365	428	267
	Electrical	336	360	457	447	427	458
	Electrochemical	145	136	151	188	205	200
	Other	105	108	149	155	173	192
	Total Demand	**907**	**936**	**1,201**	**1,155**	**1,233**	**1,117**

RUTHENIUM Tonnes - Demand							
							2018 numbers are a forecast
		2013	2014	2015	2016	2017	2018
Demand	Chemical	10.0	10.3	13.8	11.4	13.3	8.3
	Electrical	10.5	11.2	14.2	13.9	13.3	14.2
	Electrochemical	4.5	4.2	4.7	5.8	6.4	6.2
	Other	3.3	3.4	4.6	4.8	5.4	6.0
	Total Demand	**28.3**	**29.1**	**37.3**	**35.9**	**38.4**	**34.7**

Iridium Demand

Troy ounces and tonnes

IRIDIUM '000 oz - Demand							
							2018 numbers are a forecast
		2013	2014	2015	2016	2017	2018
Demand	Chemical	21	22	22	23	17	19
	Electrical	35	49	89	100	73	53
	Electrochemical	41	39	41	59	84	61
	Other	68	71	76	81	84	91
	Total Demand	**165**	**181**	**228**	**263**	**258**	**224**

IRIDIUM Tonnes - Demand							
							2018 numbers are a forecast
		2013	2014	2015	2016	2017	2018
Demand	Chemical	0.7	0.7	0.7	0.7	0.5	0.6
	Electrical	1.1	1.5	2.8	3.1	2.3	1.6
	Electrochemical	1.3	1.2	1.3	1.8	2.6	1.9
	Other	2.1	2.2	2.4	2.5	2.6	2.8
	Total Demand	**5.2**	**5.6**	**7.2**	**8.1**	**8.0**	**6.9**

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 sold in all regions, including Russia and the CIS. Demand in Russia and the CIS 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.

[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, allocated to where the car was first registered, rather than where the metal is finally recovered. 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

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 will apply 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 has 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 will be 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 apply 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 will be reduced to 1.43, applying to new type approvals for passenger cars from January 2020, and to all vehicles from January 2022.

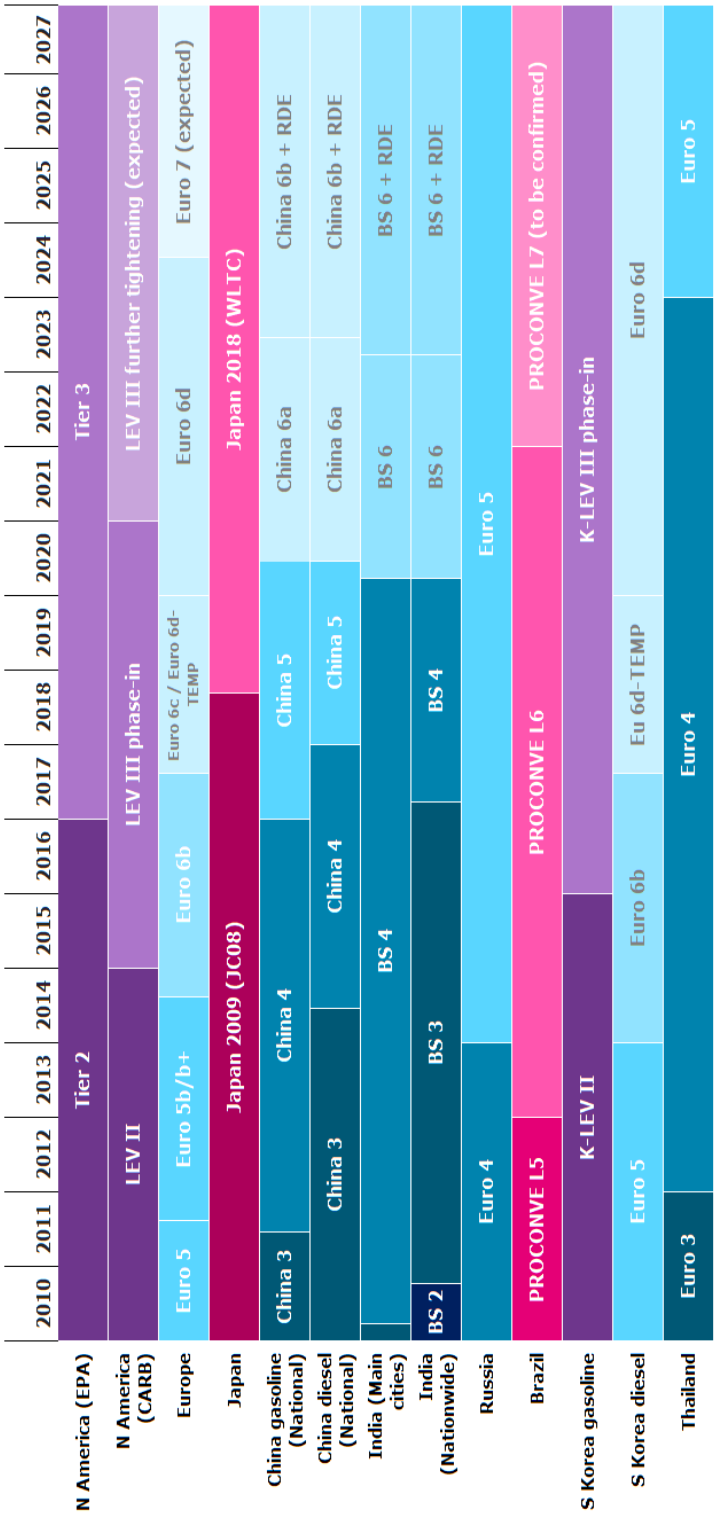
The European Commission (EC) intends to review the CFs over time as the measurement accuracy of PEMS equipment improves, with the intention of lowering them to 1.0 by 2023, allowing for no measurement error in the tests[1].

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

[1]A recent decision by the Court of Justice of the European Union would bring the NOx CF of 1.0 forward to 2020, but at the time of writing this decision is subject to appeal by the EC.

Emissions Legislation

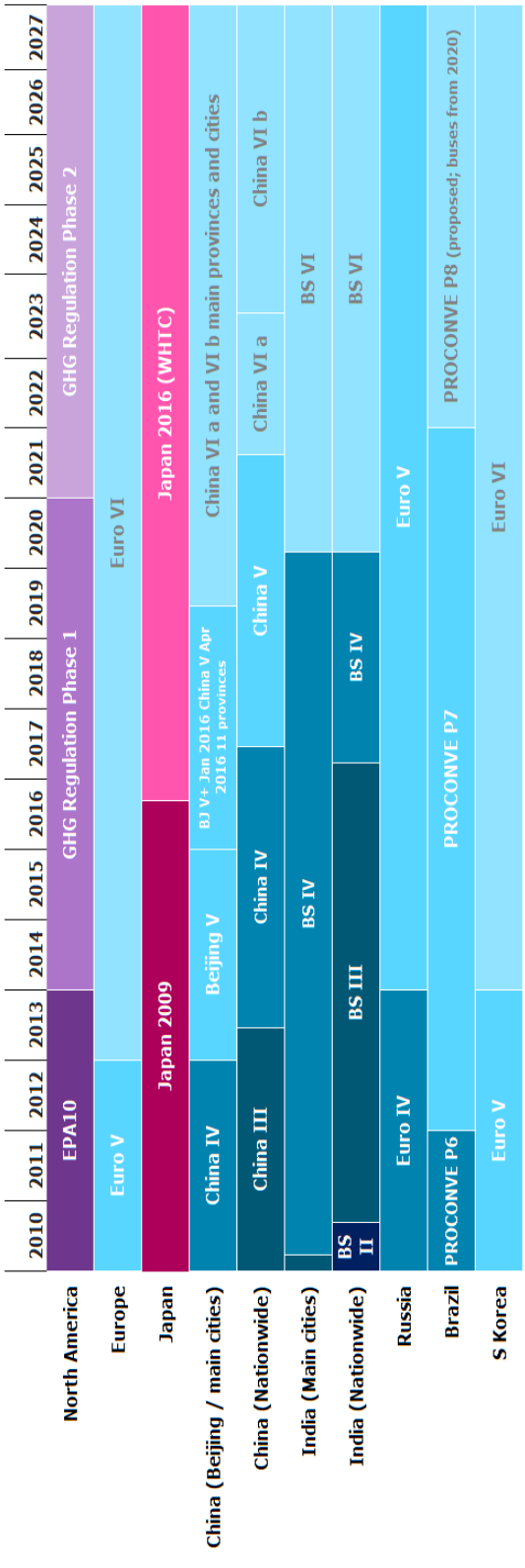
Light Duty



Dates shown are for New Vehicle Type Approvals for passenger cars

Emissions Legislation

Heavy Duty Diesel



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