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Pgm market report

May 2020

Johnson Matthey
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Definitions

Europe	EU+ (includes Turkey but excludes Russia)
Japan	Japan only
North America	USA and Canada (excludes Mexico)
China	China only
RoW	Rest of World: all countries not captured in the above
Supply	Supply figures represent sales of **primary pgm** by producers and are allocated to the region where mining took place, rather than the region of subsequent processing.
Recycling	Recycling figures represent **secondary pgm supplies** and are the quantity of metal recovered from open-loop recycling (i.e. where the original purchaser does not retain control of the pgm throughout). Outside the autocatalyst, jewellery and electronics markets, **open-loop recycling** is negligible. **Autocatalyst recycling** represents the weight of metal recovered from end-of-life vehicles and aftermarket scrap. It does not include warranty or production scrap. It is allocated to the region where the vehicle was originally sold (but not necessarily scrapped).
Gross demand	Gross demand figures for any given application represent the sum of industry demand for new metal in that application; that is it is net of any **closed-loop recycling** (i.e. where industry participants retain ownership of the metal: an example would be recycling of spent chemical catalysts where the metal is retained to be used on fresh catalyst that replaces the spent charge). Gross demand also includes any changes in unrefined metal stocks in the sector. Increases in unrefined stocks lead to additional demand, while reductions in stocks (including any metal released from industry, e.g. in the case of chemical plant closures) lead to lower demand. **Autocatalyst demand** is allocated to the region where the vehicle is manufactured and is accounted for at the time of vehicle production. It includes emissions catalysts on vehicles, motorcycles and three-wheelers, and non-road mobile machinery. (Fuel cell vehicles are counted under industrial demand.) **Jewellery demand** is allocated to the region where the finished jewellery is manufactured, not sold.
Net demand	Gross demand less open-loop recycling.
Movements in stocks	This figure gives the overall market balance in any one year and reflects the extent of stocks that must be mobilised to balance the market in that year. It is thus a proxy for changes in stocks held by fabricators, dealers, banks and depositories, but excludes stocks held by primary and secondary refiners and final consumers. A positive figure (market surplus) thus reflects an increase in global market stocks. A negative value (market deficit) indicates a decrease in global market stocks.

Pgm outlook

Supply and demand in 2020

Pgm supply and demand will both be severely impacted by the COVID-19 pandemic.

South African pgm supplies are forecast to fall by at least 20%, while the collection of secondary materials will also be severely disrupted.

Autocatalyst demand will contract sharply on temporary plant closures, weak consumer demand and increased thrifting.

Industrial consumption will fall overall, but with significant variation between applications and regions.

Platinum lease rates rose sharply in March due to heavy buying by Chinese industrial consumers and Japanese investors.

Chinese jewellery distributors also bought into low prices, but full-year jewellery demand will drop sharply.

"The COVID-19 pandemic will inflict significant damage on pgm supply and demand in 2020. Both primary and secondary supplies will contract, due to temporary shutdowns at many mining operations, and disruption to the collection and refining of pgm-containing scrap"

The COVID-19 pandemic will inflict significant damage on pgm supply and demand in 2020. Both primary and secondary supplies will contract, due to temporary shutdowns at many mining operations, and disruption to the collection and refining of pgm-containing scrap. Autocatalyst pgm demand will fall steeply, reflecting short-term closures at most major automotive plants and a sharp contraction in consumer demand for new vehicles. The jewellery market is also expected to be badly hit, although weak platinum prices in March stimulated inventory building by the Chinese distribution chain. Some industrial applications for pgm may see only a limited impact in the short term but, going forward, there is a risk that a severe and prolonged recession could cause the installed base to contract. In the investment sector, demand for platinum bars soared in March, as a fall in yen-denominated prices to seventeen-year lows unleashed a wave of buying by Japanese investors.

At the time of writing, it was not possible to quantify these changes to supply and demand and we have elected not to publish forecasts for 2020. Our autocatalyst pgm demand models incorporate external industry estimates of vehicle production; at the time of preparing our report, these industry forecasts for 2020 were undergoing regular downgrades as the pandemic progressed across Asia and then to Europe and North America. It is also unclear to what extent primary and secondary supplies will be disrupted. Given these extreme levels of uncertainty, we do not believe that it is possible to make a meaningful prediction of market balance this year.

Moreover, it may be that conventional supply and demand estimates are not a good indicator of market liquidity during the crisis. By late March, it was clear that variations in the severity and timing of regional and national impacts were creating some distortions in the physical market for pgm. In particular, demand from Asia began to return, at a time when primary miners, secondary refiners and inventory holders located in South Africa, Europe and North America were reducing activity levels and encountering logistical difficulties in making shipments.

Not only have mining and refining activities been severely affected by measures taken to halt the spread of COVID-19, but transport of refined pgm has also been heavily impacted. During March and April 2020, an abrupt decline in the number of flights available, and hence in air freight capacity, caused serious disruption to metal shipments, both from South Africa to customers in the northern hemisphere, and also from trading hubs such as London and Zurich into Asia.

During March and early April 2020, this severe disruption to international pgm trade resulted in a mismatch between the

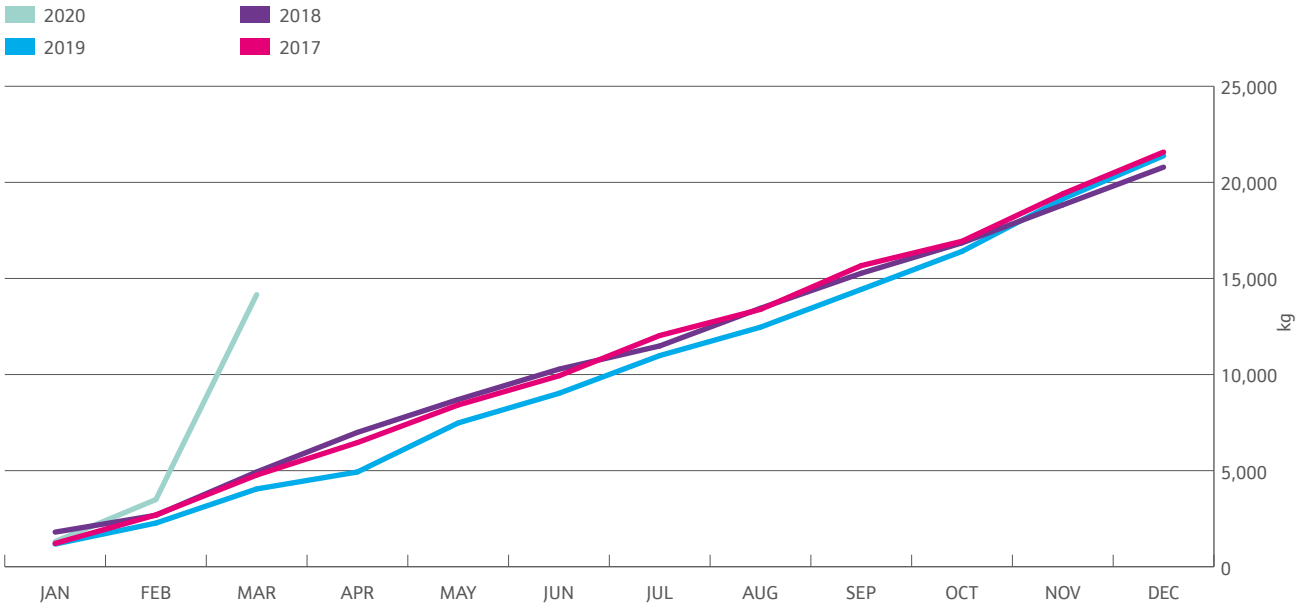


Figure 1 Cumulative SGE platinum sales

location of demand, primarily from Asian economies recovering from COVID-19 disruption, and of refined pgm production and stocks, mainly in South Africa, North America and Europe. This has probably helped support prices for palladium and rhodium, despite a steep fall in pgm demand in Western economies.

For platinum in particular, there was also evidence of a discrepancy between the form of metal available and the form required by consumers, with ample sponge on offer but limited availability of ingot. During March, there was exceptionally strong demand for platinum ingot in China and Japan, with investors, industrial consumers and jewellery distributors taking advantage of weak prices. This created shortages of ingot stocks in the traditional trading hubs in Europe, leading to a steep rise in platinum lease rates to highs of over 10% during late March and into April (see Figure 10).

Demand for physical investment bars in Japan set an all-time record in March 2020, with private investors estimated to have bought around 200,000 oz of platinum in a single month. This activity was consistent with past investor behaviour in the Japanese market: steep declines in price tend to stimulate buying, especially when important psychological price levels are breached (see Figure 2). The retail platinum price touched two-year highs of nearly ¥4,000 per gram in February, before plunging through the key ¥3,000 level in mid-March, briefly touching a seventeen-year low of just over ¥2,500 per gram. (It should be noted that these retail price figures allow for sales tax in force at the time; the current rate is 10%.)

In total, and after allowing for disinvestment in January 2020 due to relatively strong prices, the first quarter saw net Japanese investment of about 220,000 oz. This included

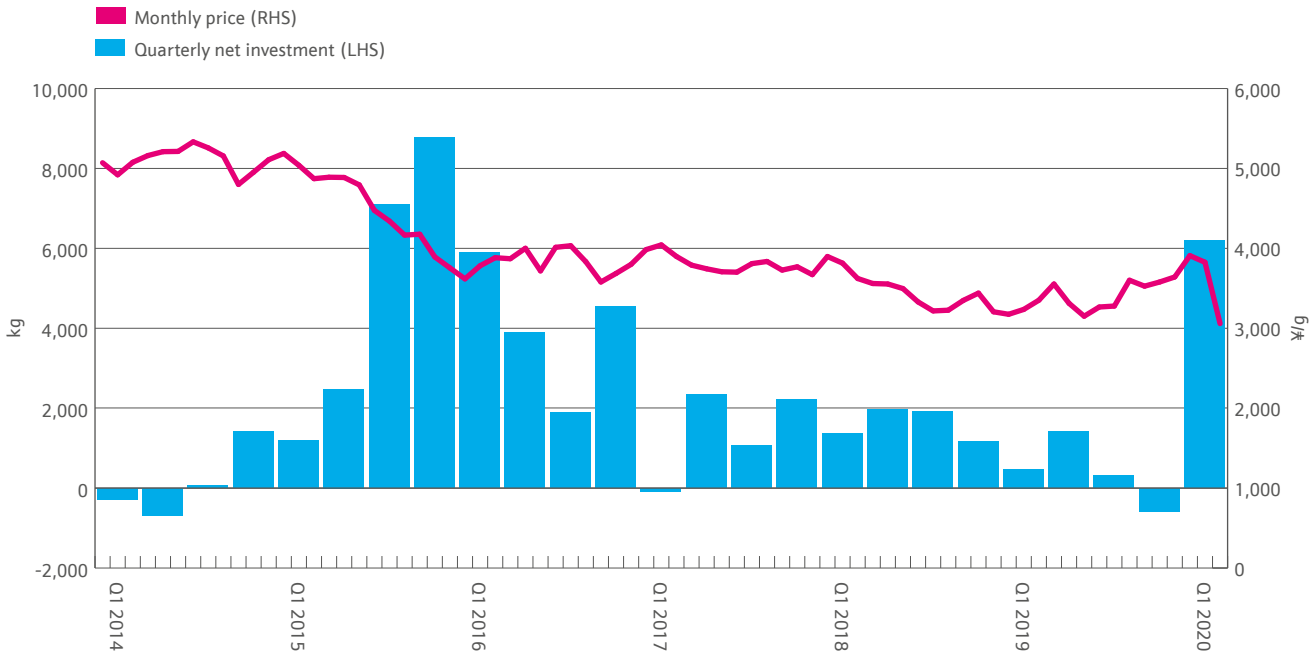


Figure 2 Japanese bar investment

around 23,000 oz of ETF buying as well as over-the-counter bar sales. However, second-quarter demand is likely to be weaker. Not only has the platinum price recovered to trade just below ¥3,000 for much of April, but the declaration of a state of emergency by the Japanese government has resulted in the temporary closure of retail counters at trading houses (although online trading remains possible).

Elsewhere, pgm investment was weak during the first four months of the year. Platinum, palladium and rhodium all saw falls in total ETF holdings, with some modest redemptions of palladium ETFs by investors in Europe and North America (who at current palladium prices are still largely 'in the money'), and heavier liquidation of both platinum and palladium in South Africa (see Figure 8 and 9). Total palladium ETF holdings fell below 500,000 oz in March 2020, but platinum holdings remained above 3 million oz, with the vast majority of investors in Europe and North America still 'out of the money'.

The fall in platinum prices during March 2020 also triggered heavy demand for platinum ingot in China. With other supply routes temporarily disrupted, sales of platinum ingot on the Shanghai Gold Exchange (SGE) set an all-time monthly high: in total, over 10.6 tonnes (340,000 oz) of platinum ingot was purchased by jewellery and industrial buyers, more than twice the previous monthly record (see Figure 1).

Much of this metal was destined for industrial applications, with petrochemical and glass companies taking the opportunity to buy metal at lower prices ahead of expansions planned for the 2021–2022 period. However, there was also an increase in sales to the jewellery sector. We believe that this phenomenon was largely the result of Chinese jewellery retailers and wholesalers taking advantage of lower prices to add to their stocks of finished jewellery. In the past, Chinese jewellery manufacturers often responded to weaker prices by accumulating inventories of unfabricated metal, but this does not appear to have happened in the first quarter of 2020.

"The fall in platinum prices during March 2020 triggered record monthly sales on the SGE"

Notwithstanding this distribution chain activity, consumer demand for platinum jewellery in China was exceptionally weak during the first four months of 2020, due to extended retail closures, low footfall following the reopening of stores during February and March, and reluctance to spend on luxury goods. We therefore anticipate that purchasing by the jewellery industry will weaken significantly going forward, as slow demand-pull from consumers limits the need for further restocking of the distribution pipeline.

In addition, it is likely that lower economic growth and weak jewellery demand will result in the permanent closure of

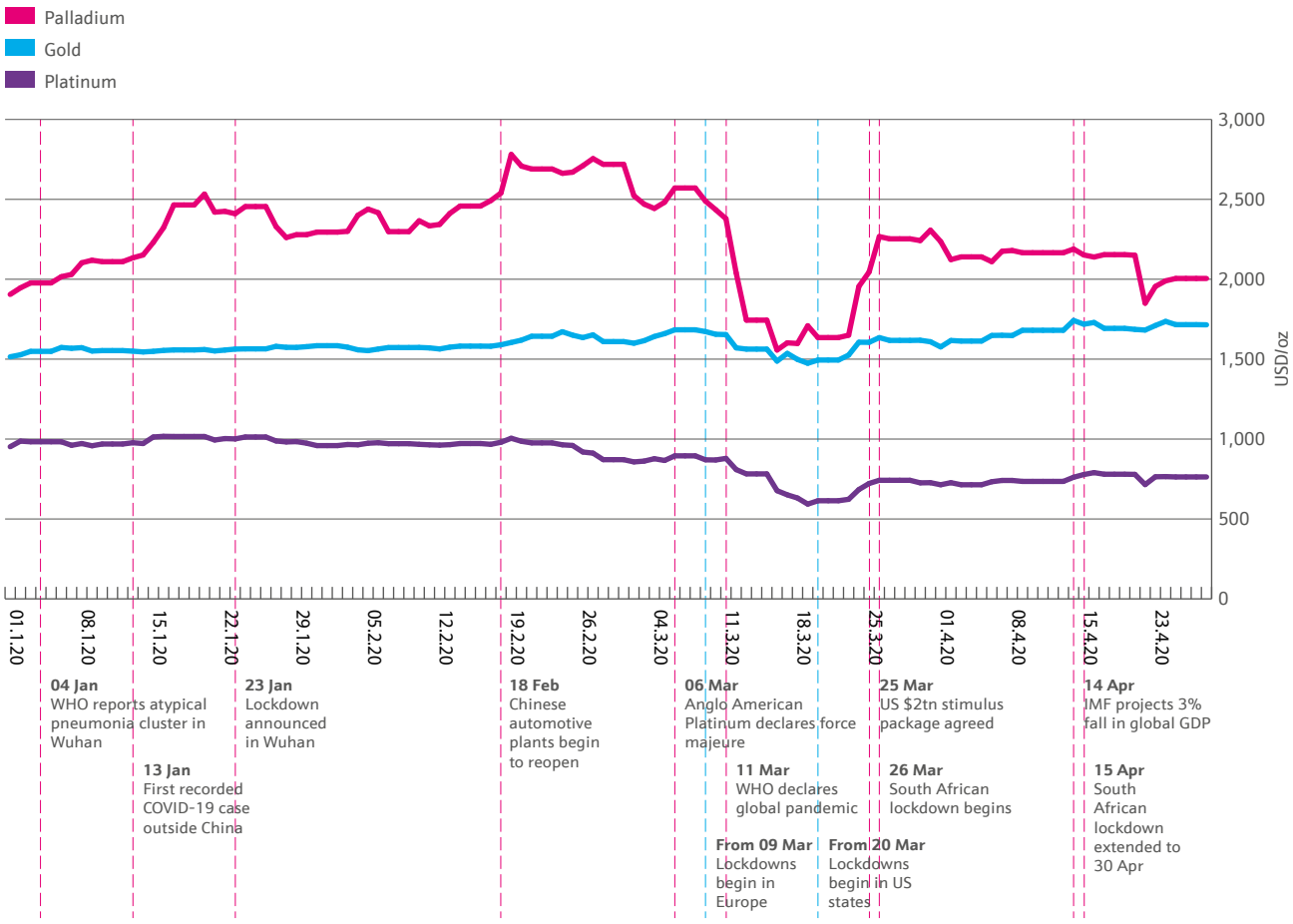


Figure 3 Platinum, palladium and gold prices and significant global events

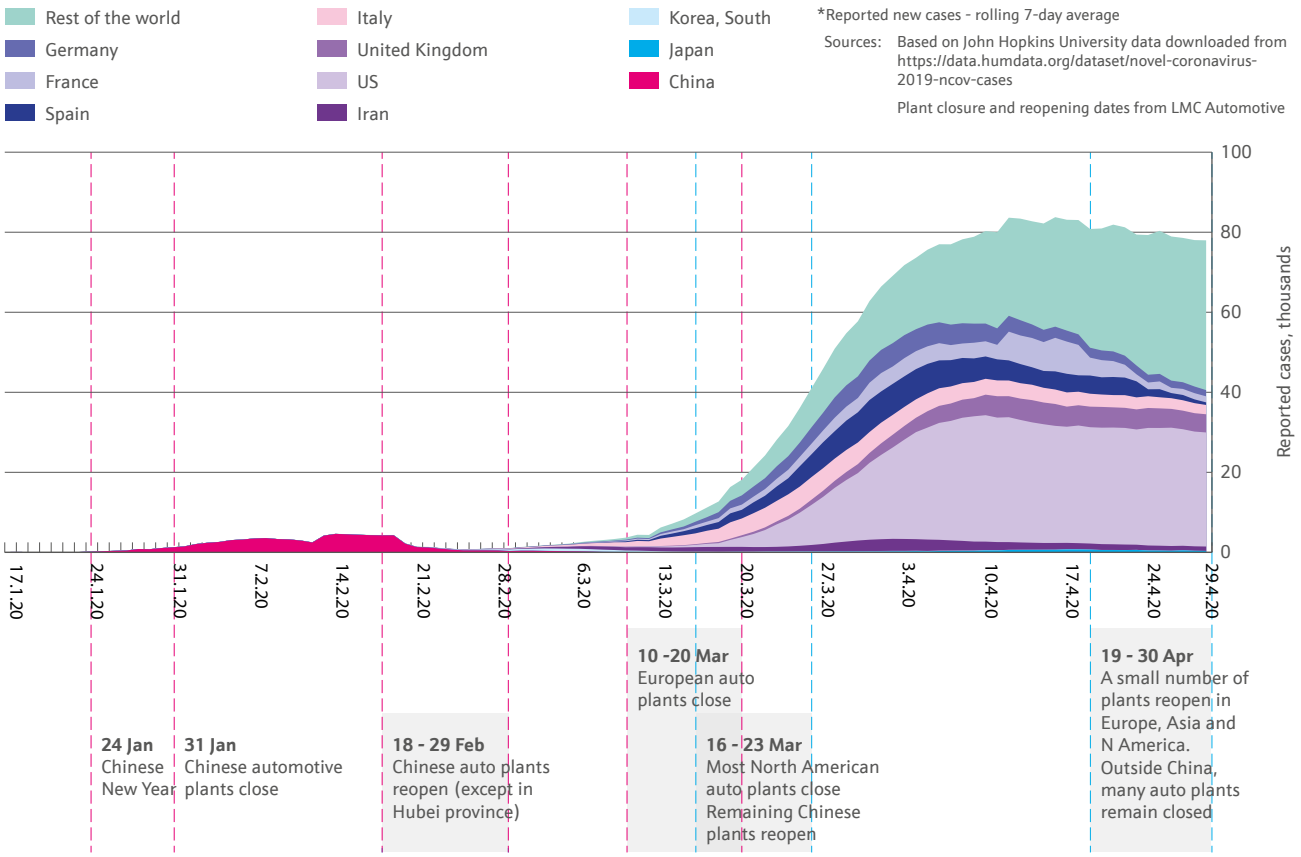


Figure 4 Automotive industry response to the COVID-19 epidemic*

some retail outlets, which would reduce overall inventory requirements at the industry level. Stock from closed stores may be distributed to other outlets in the same group, or returned to manufacturers and the metal used for future fabrication needs, reducing the need to purchase new metal.

Demand for pgm from major automotive and industrial consumers is also expected to see steep falls this year. Automotive consumption will be especially badly hit, with temporary plant closures hitting production during the first half of the year, and consumers' appetite for big-ticket purchases likely to remain depressed for the remainder of the year. Industrial demand may be less severely affected, at least in the short term, although we expect different sectors and regions to show large variation in the extent and the timing of the impact.

In the first quarter of 2020, world light duty vehicle production and sales are estimated to have fallen by around 25% and 20%, respectively, compared to the same period of 2019 (see Figures 5 and 6). Most of this decline was a direct result of the COVID-19 crisis, with Chinese car sales and production contracting by more than 80% in February following extended New Year shutdowns at all major automakers and the closure of dealerships due to COVID-19 lockdowns. Although some Chinese car plants reopened in mid-February, others remained closed into March, with some operations idled for up to eight weeks. In addition, the production ramp-up was hampered by labour and component shortages, and by early April 2020 Chinese light vehicle production had recovered to only around 75% of normal daily rates.

Other Asian markets also saw coronavirus-related impacts in early 2020, with some plants closed during February due to component shortages, although Western vehicle markets did not experience significant disruption until late in the quarter (see Figure 4). Some country-specific issues also played a role in vehicle production trends. For example, North America saw increases in vehicle sales and production during January and February, as the market recovered from last year's seven-week strike at General Motors (these gains were quickly reversed in March).

"In the first quarter of 2020, world light duty vehicle production and sales are estimated to have fallen by around 25% and 20%"

In Europe, light vehicle sales were already contracting in January and February, well before most countries in this region experienced any direct coronavirus-related impacts. This was mainly due to market distortion caused by the implementation of new EU targets for vehicle CO_2 emissions; sales figures for December 2019 were inflated by the pre-registration of a number of less fuel-efficient vehicles, as automakers sought to reduce their fleet-average CO_2 emissions in 2020 to comply with the new regulations. Indian car sales and production also saw significant falls in the first two months of the year, following a government clampdown on 'non-banking financial corporations' which have in the past been an important source of financing for big-ticket purchases.

The global collapse in vehicle sales and production intensified in April in all major markets except China. Starting in the second week of March, European car plants began to shut due to regional COVID-19 lockdowns, and most remained closed well into April. Major US automakers began to shutter their facilities from mid-March, while towards the month-end some Japanese factories also ceased production. Even in regions less affected by the pandemic, car production was hit by severe supply chain disruption.

At the time of writing, auto industry forecasts allowed for a contraction of around 20% in annual light vehicle production this year, with output of diesel vehicles in Europe particularly badly hit, and production of gasoline vehicles in some Asian countries less severely affected. Based on our current estimates of regional average pgm loadings, this would imply a decrease of 21% in autocatalyst platinum demand compared to 2019, with palladium and rhodium seeing a somewhat smaller drop of around 15%. However, it is important to emphasise that these numbers are based on vehicle production forecasts made in early April 2020; it is possible that these do not yet capture the full impact on the automotive industry, particularly in some Rest of World countries.

The above estimates do not allow for any potential short-term impact on pgm loadings resulting from government initiatives, such as delays to emissions legislation, or from changes in the vehicle mix or catalyst fitment strategies at individual companies. It is likely that financial stress due to the COVID-19 crisis will motivate car companies to take a fresh look at opportunities to reduce the cost of their exhaust aftertreatment systems, especially in China.

Domestic Chinese automakers were already under financial pressure, even before COVID-19 shutdowns, due to weak vehicle sales over the past year and the cost of meeting China 6 legislation. (The latter was implemented in July 2019, ahead of the national schedule, in sixteen provinces and cities, which together accounted for around 70% of China light duty vehicle sales in 2019.) In response to financial constraints, we expect to see an intensification of efforts to reduce the cost of exhaust emissions control systems; in some cases, this could involve a reduction in pgm loadings or a change to the pgm mix.

These efforts have been facilitated by government initiatives, including a temporary relaxation of the enforcement of stricter emissions limits in provinces that have not already implemented China 6 standards. In these regions, which typically account for about 30% of new Chinese light vehicle registrations, automakers will now be permitted to sell China 5 vehicles that were produced or imported before July 2020 until 1st January 2021 (six months later than the previous official deadline for nationwide China 6a implementation). This will give automakers additional time to sell remaining inventories of China 5 vehicles, which we estimate totalled around 1 million units at the end of March 2020.

In March 2020, a new simplified vehicle conformity certification process was introduced by the Chinese Ministry of Industry and Information Technology, allowing car companies to self-certify vehicles as compliant with type-approval criteria such as emissions limits. Previously, this certification was performed by external organisations in a procedure that took several months. The new process - which is intended to be temporary, but which does not at present have a fixed expiry date - will enable companies to make changes to catalysts more quickly than would normally be the case.

As we have previously reported, during the transition to China 6 legislation, Chinese automakers almost universally chose to equip their vehicles with catalysts capable of meeting China 6b emissions limits (which are already mandated across Guangdong province and in three major cities, but which are not scheduled to be enforced nationally until July 2023). However, in response to high pgm prices and the financial stress caused by falling car sales, some domestic Chinese car companies now intend to fit China 6a catalysts to vehicles sold in areas that have not yet enforced China 6b standards. The new self-certification procedure could facilitate such changes in catalyst fitment, but we do not yet know to what extent automakers will adopt this strategy, nor the number of vehicles potentially concerned. China 6a emission limits are significantly less stringent than China 6b, so this could have a material impact on average pgm loadings.

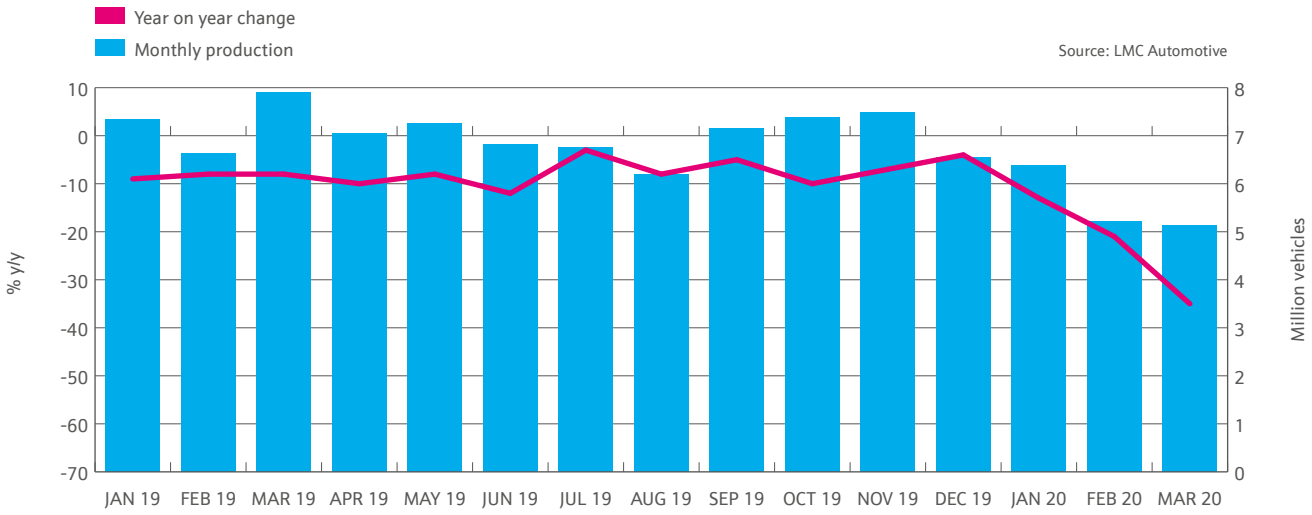


Figure 5 Monthly light vehicle production - Global

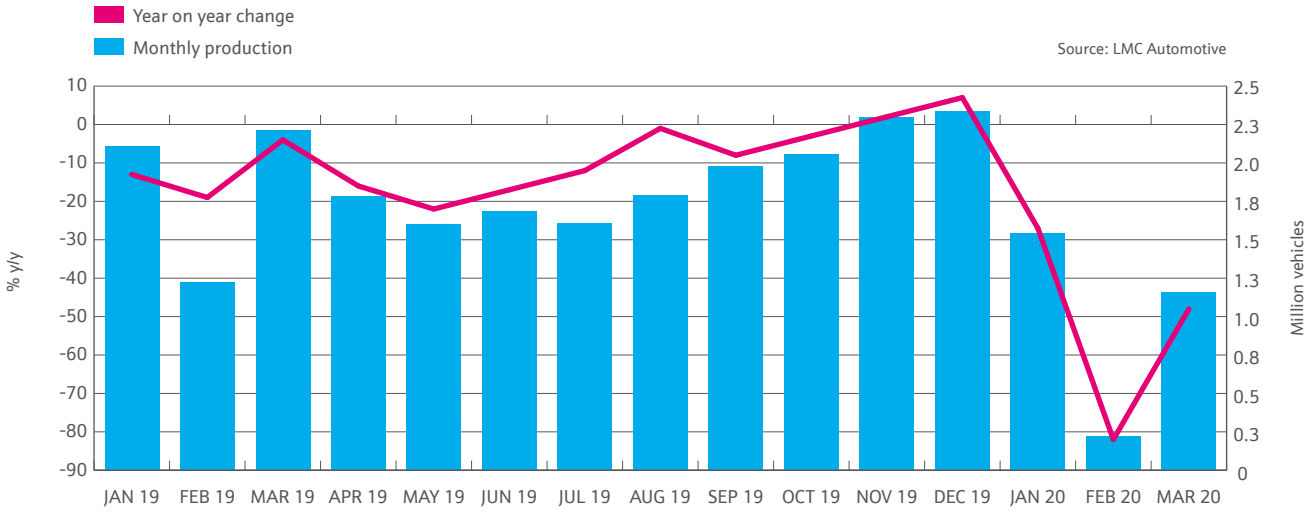


Figure 6 Monthly light vehicle production - China

Other measures taken by Chinese national and regional governments are expected to include incentives intended to boost car sales. For example, Beijing has already announced a new vehicle replacement subsidy scheme, to stimulate consumers to scrap older and more polluting China 3 vehicles and to replace them with China 6b models. Several other cities have introduced measures such as scrappage incentives and the relaxation of licence plate quotas.

It is likely that some of these replacement vehicles will be electric, although battery electric vehicle (BEV) sales have been falling since subsidies were cut in 2019. The Chinese government had planned to phase out subsidies for BEVs completely by the end of 2020, but the scheme has now been extended for two years. This should provide some support for BEV sales and should also stimulate demand for fuel cell vehicles (FCEVs), which are also covered by the subsidy extension. Early indications are that OEM plans to ramp up FCEV production in China are proceeding.

Some other regions could also see increased pgm thrifting, as cost-cutting is prioritised due to the collapse in car sales at a time when palladium and rhodium prices remain high. In Europe, the last two years have seen automakers' technical capacity absorbed by the need to comply with Euro 6d legislation, while many also initiated work on the design of catalyst systems for expected Euro 7 standards. During this period, minimising the pgm content of catalysts has generally been a secondary consideration. However, there is now more focus on cost, and companies are therefore expected to look closely at potential opportunities to reduce the pgm content of their systems, or to substitute some palladium with platinum, if they can do so without compromising their ability to meet current or future emissions limits.

The COVID-19 crisis is not expected to result in any change to European legislation for toxic exhaust emissions, and we expect Euro 6d standards to be phased in according to the current schedule, which requires all new cars to comply with the standards by July 2021. However, there may be some practical challenges with regard to the enforcement of stricter fleet-average CO_2 emissions in 2020. The precipitous fall in demand for new vehicles is likely to result in some regional and sectoral variations that may cause significant distortion to the composition of vehicle sales – and hence to fleet-average CO_2 emissions – compared with a more normal year. We think it possible that the EU will offer concessions to automakers, rather than enforcing penalties at a time when most car companies are already under severe financial pressure.

Not all regions will be equally well-placed to exploit opportunities to reduce loadings. India implemented Bharat VI legislation (BSVI, equivalent to Euro 6) starting in April 2020, and it may take some time before automakers are able to focus on reducing the cost of their catalyst systems. To date, the Indian government has not indicated any intention to roll back the new standards, but it has allowed automakers to sell some of their inventory of Bharat IV vehicles for a short period following the nationwide lockdown, which at the time of writing was scheduled to end on 3rd May.

Consumption of pgm in industrial processes in the chemical, glass and petroleum refining industries may be less severely affected than autocatalyst demand, at least in the short term. However, it is likely that some expansions will be cancelled or delayed, and ultimately – depending on the depth of the recession triggered by the pandemic – we could see the closure of some older and less efficient plants, followed by the return of their pgm inventory to the market.

It may take several years before the full impact of the COVID-19 crisis becomes clear: for example, a wave of petroleum refinery closures occurred around three years after the 2008 global financial crisis, as low-margin operations finally succumbed to the recovery in crude oil prices and increased competition from newer and more efficient facilities in Asia and the Middle East. This resulted in negative platinum demand in the petroleum refining industry in some regions in the 2011–2013 period.

It is clear that the impact on industrial demand for pgm will not be evenly spread across sectors or regions. In China, 2020 is the final year of the current five-year plan, a key pillar of which is to increase self-sufficiency in the petroleum refining and chemicals industries, and to promote feedstock production routes involving coal. Over the past three to four years, this has been highly supportive of pgm catalyst demand in processes such as catalytic

reforming, propane dehydrogenation and coal-to-monoethylene glycol (see Figure 7). We expect most planned expansions in the petrochemical sector to proceed this year, regardless of economic conditions, in response to government incentives and to accomplish the objectives set out in the five-year plan. In addition, low prices have stimulated some pre-buying of pgm for expansions that are due to come onstream in 2021–2022.

While some chemical market sectors have been severely affected by the COVID-19 crisis, with textiles feedstocks especially hard-hit, others have experienced relatively buoyant conditions. For example, propylene and polypropylene prices in China rose significantly during April, due to a surge in demand for polypropylene in the manufacture of personal protective equipment (PPE) and disposable medical products.

Exceptionally heavy purchasing of PPE is also helping to buoy up demand for platinum catalysts used in the manufacture of medical-grade silicones, although other silicone end-user markets such as automotive production are weak. In the pharmaceutical sector, a shortfall in supplies of active pharmaceutical ingredients (APIs) from producers affected by lockdowns in India and Western Europe is encouraging Chinese producers to raise their output. Pgm catalysts are used in the production of many APIs, including some antibiotics used in COVID-19 treatment.

While near-term pgm demand from the Chinese petrochemicals industry may therefore be relatively secure, the outlook for the chemicals and refining sector in Europe and North America is much more uncertain. Government financial support packages should help avoid plant closures, at least in the short term, but a reduction in capacity utilisation is likely to result in longer catalyst lifetimes and hence a decline in 'top-up' demand (metal purchases to cover losses, both in-process and during the refining of spent catalyst), which in these regions account for a large proportion of total pgm demand. Once lockdowns end, we expect governments to push for greater self-sufficiency in the production of some critical products, including PPE. This could provide some limited support for local production of some petrochemical feedstocks, but overall we think that pgm demand from the European and North American petrochemicals sector will be badly hit.

Globally, one major uncertainty affecting pgm demand in the petroleum sector is the impact of lower demand for gasoline and jet fuel on refinery operations. Some modern, integrated petrochemical complexes should be able to adjust their product mix, to increase output of petrochemical feedstocks required for downstream chemical processes while reducing fuel production volumes. However, older petroleum refineries may have limited flexibility to achieve this. If the COVID-19 crisis results in a lasting reduction in transport fuel requirements, we could ultimately see some older refineries close and their pgm inventory released back to the market.

In the glass sector, we anticipate steep near-term falls in demand for fibreglass from end-user industries such as automotive and construction, but this should be partly offset by rising consumption of glass-fibre-reinforced materials in telecommunications (for 5G infrastructure) and wind power. Overall, we expect plant utilisation rates to fall, and this will ultimately result in weaker investment in new capacity and perhaps some plant closures. However, we still expect some planned capacity expansions in China to proceed, as these are intended primarily to augment production for the domestic market. This will be supportive of pgm demand in the short term; as noted above, we believe that some pre-buying of platinum has already taken place this year.

At current price levels, we would expect to see further thrifting of rhodium by the fibreglass industry. However, lower plant utilisation rates may extend the life of the glass-making equipment currently installed in fibreglass plants, providing fewer natural opportunities to adjust the composition of platinum-rhodium alloys.

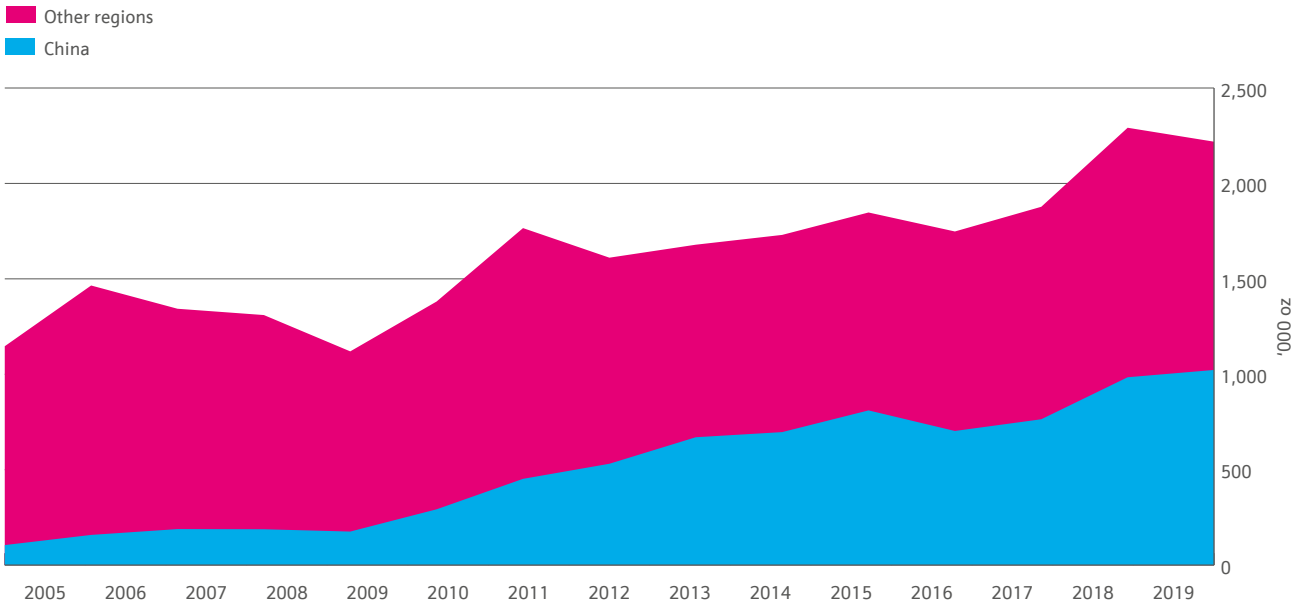


Figure 7 Chinese share of total pgm demand in chemical and petroleum applications, 2005-2019

The immediate risk to pgm demand is perhaps higher in the liquid crystal display (LCD) glass sector. One major LCD panel producer has recently announced plans to exit production of basic LCD products, and another is to close its LCD television factories in Korea. This is expected to result in the closure of some LCD glass capacity in the Rest of World region, and potentially the return of some platinum to the market.

In the electronics industry, national lockdowns have caused severe short-term disruption to the production and shipment of both components and finished devices, as well as to retail activity. This has contributed to very steep falls in shipments of devices such as smartphones during the first quarter, partly due to weak consumer demand but primarily due to severe supply chain issues, which slowed down the ramp-up of activity in China and caused delays in getting finished devices to customers. However, industry forecasts suggest that output of smartphones should bounce back as component availability improves, and the decline in production for the full year could be in the 8–10% range.

While the electronics sector will of course be significantly impacted by the COVID-19 crisis, there are reasons to believe that it could prove somewhat more resilient than other industries. Producers and distributors began 2020 with relatively lean inventories, following trade tensions between China and the USA last year, so once lockdowns are eased and consumer demand picks up, activity should bounce back to a certain degree (assuming supply chain issues can be overcome). In addition, there has been unusually strong consumer demand in some areas: for example, US sales of laptops rose by 10% in March, boosted by a dramatic increase in home working, while a growing need for 'cloud' storage is supporting sales of hard disk drives to server farms. These factors should provide some support for pgm consumption, although we still expect demand to fall sharply this year.

Among other pgm applications, the short-term impact on demand will be most significant in sectors closely linked to transport. For example, we expect the use of platinum to plate aero engine turbine blades to decline by at least a third this year, following reductions in aircraft production at Airbus and Boeing, and due to lower fleet utilisation rates that will result in a significant fall in refurbishment activity. Use of pgm in spark plugs and automotive sensors will also drop sharply, broadly following trends in vehicle production.

Even medical and biomedical demand will be affected, albeit to a lesser extent than some other applications, as non-urgent procedures are deferred, and as production and supply chains are disrupted. Consumption of pgm in the dental sector will be particularly hard-hit. Dental procedures are particularly dangerous for the practitioner, because they can cause transmission of virus via both droplets and aerosols. At the time of writing, dentists in Japan, the major market for palladium dental alloys, were providing only emergency treatment.

"While it is difficult to make a precise assessment of production losses at this stage, we expect mine pgm output in South Africa to fall by at least 20% in 2020"

Primary pgm supplies are expected to fall steeply in 2020, following a national lockdown in South Africa that began on 26th March and at the time of writing was expected to last until the end of April. This resulted in almost all South African platinum mining operations being placed on temporary care and maintenance, and the idling of most smelting and refining facilities, although we believe that some pgm refining activities continued during the lockdown.

From early April, Anglo American Platinum's open-cast Mogalakwena mine was permitted to resume limited mining operations, and on 16th April, the mining sector received general government dispensation to reopen mines at 50%

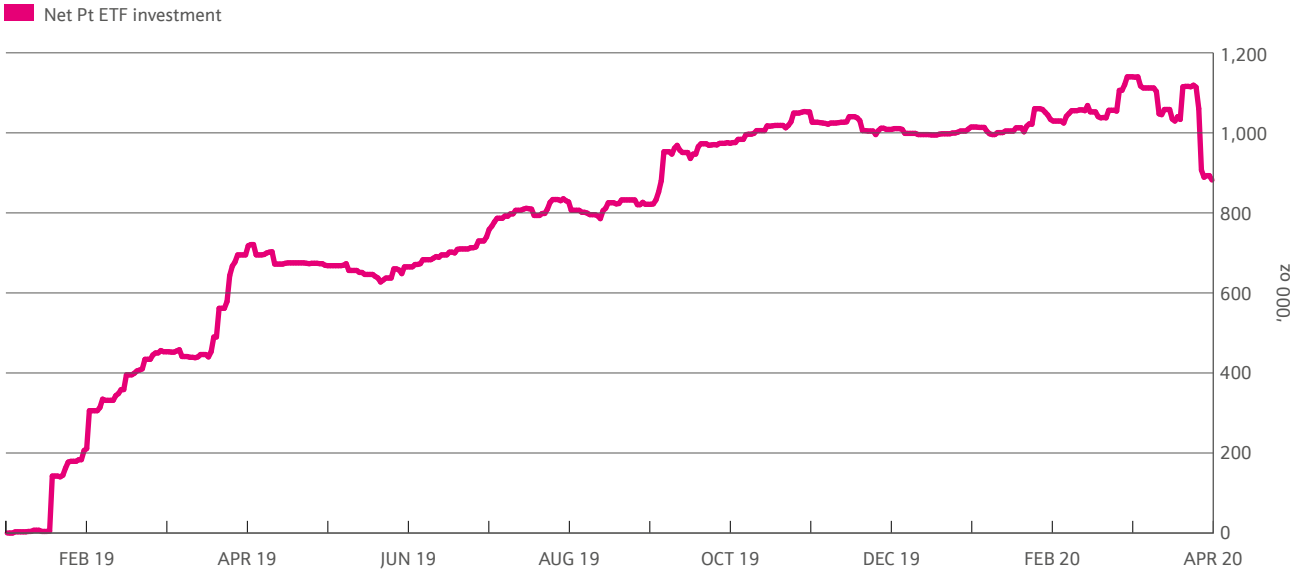


Figure 8 Net investment in platinum ETFs in 2019 & 2020

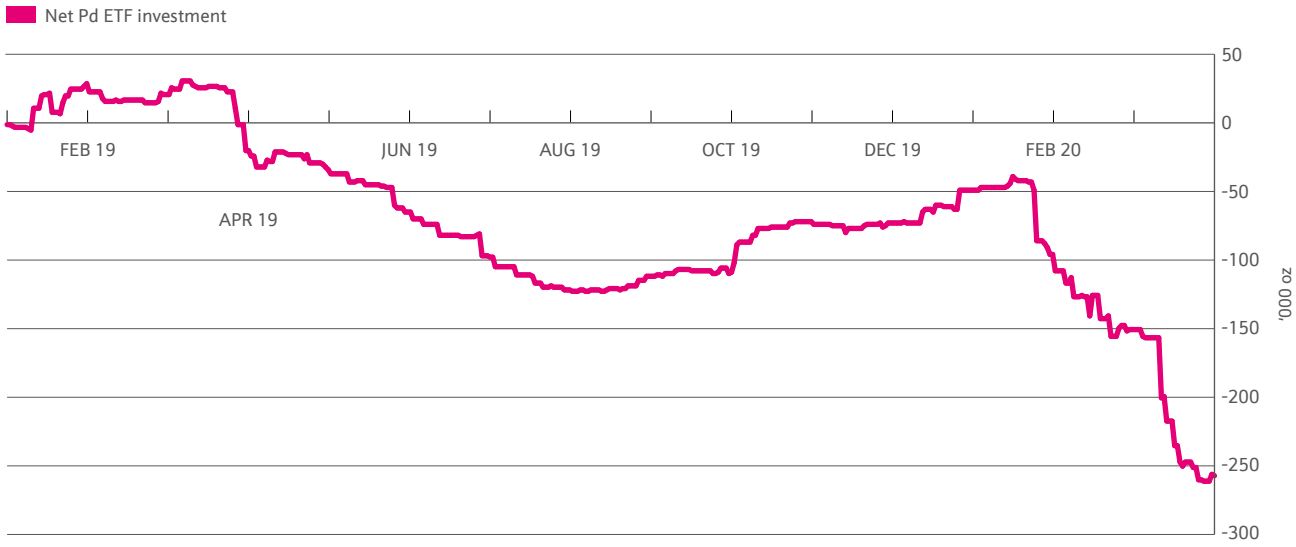


Figure 9 Net investment in palladium ETFs in 2019 & 2020

of normal production levels (conditional upon strict safety procedures including screening and testing workers). However, we expect output to remain extremely constrained, especially at underground operations, and a return to normal production volumes may be many weeks away. Physical distancing measures are likely to prove particularly challenging to implement at deeper shafts where the platinum reefs are extracted using conventional labour-intensive mining methods.

The impact of lost production is likely to be greatest for platinum and rhodium, with palladium being somewhat less affected. We expect to see some temporary distortion of the pgm split in South African production, with a greater percentage of total output deriving from Anglo Platinum's large open-cast Mogalakwena mine, which has been able to operate during much of the lockdown period. The Platreef ore extracted there is rich in palladium but has a low rhodium content. Conversely, a smaller than usual proportion of pgm production this year will be sourced from the large western limb operations, which mainly extract the rhodium-rich UG2 reef.

South African supplies will also be affected this year by a prolonged outage at Anglo American Platinum's converter plant (ACP). The company declared force majeure to customers and suppliers on 6th March 2020, following an explosion at its Phase A converter plant in February, and technical problems during the ramp-up of the standby Phase B unit. This second unit also had to be shut down, with repairs expected to take around 80 days. Government permission was granted for repair work on the converter plant to continue during the national COVID-19 related lockdown, and at the time of writing recommissioning was scheduled to take place in mid-May.

Converting is a critical step in the processing of pgm. Ore from the mines is milled then processed through the flotation plant, producing a concentrate which is sent for smelting. The pgm-containing matte from the smelter is fed to the converters, where it is upgraded through the removal of iron and sulphur to form converter matte. This product then undergoes final refining at base metal and precious metal refineries.

The shutdown of the ACP therefore resulted in an interruption of converter matte deliveries to Anglo's refineries, and the temporary suspension of refined pgm production (once the refining of metal already in the pgm refinery had been completed). Following the declaration of force majeure, Anglo ceased accepting deliveries from third-party mines with which it has purchase-of-concentrate or toll-refining agreements. Subsequently, agreement was reached with Sibanye-Stillwater to process some pgm from Rustenburg, Kroondal and Platinum Mile at its Marikana smelting and refining facilities during the force majeure period.

The ACP shutdown caused an increase in inventories of semi-processed pgm, both at Anglo's own operations, and at the third-party mines that were no longer able to deliver concentrate. The resulting backlog was initially expected to take up to two years to clear, but COVID-19 related mine closures have limited the build-up of work-in-progress ahead of the ACP, and Anglo now expects to be able to process any backlogs during the second half of this year.

While it is difficult to make a precise assessment of production losses at this stage, we expect mine pgm output in South Africa to fall by at least 20% in 2020; the rate of decline in palladium output will be slightly lower than for platinum, while rhodium will be the most affected of the three autocatalyst pgm. Even once mines are permitted to operate at normal levels, the ramp-up will take some time and – particularly in labour-intensive settings – volumes will be constrained by safety measures implemented to reduce the risk of virus transmission between workers. This is likely to have a significant impact on margins, due to the large fixed cost base, and could ultimately result in further rationalisation and/or downgrades to expansion plans, especially if pgm prices weaken further. However, during March and April, rand weakness helped support the basket price received by South African miners at historically high levels (see Figure 11).

Pgm production from Zimbabwe's three platinum mines will also be affected by COVID-19 lockdowns and to a lesser extent by the ACP incident (concentrate from Unki is treated at Anglo's South

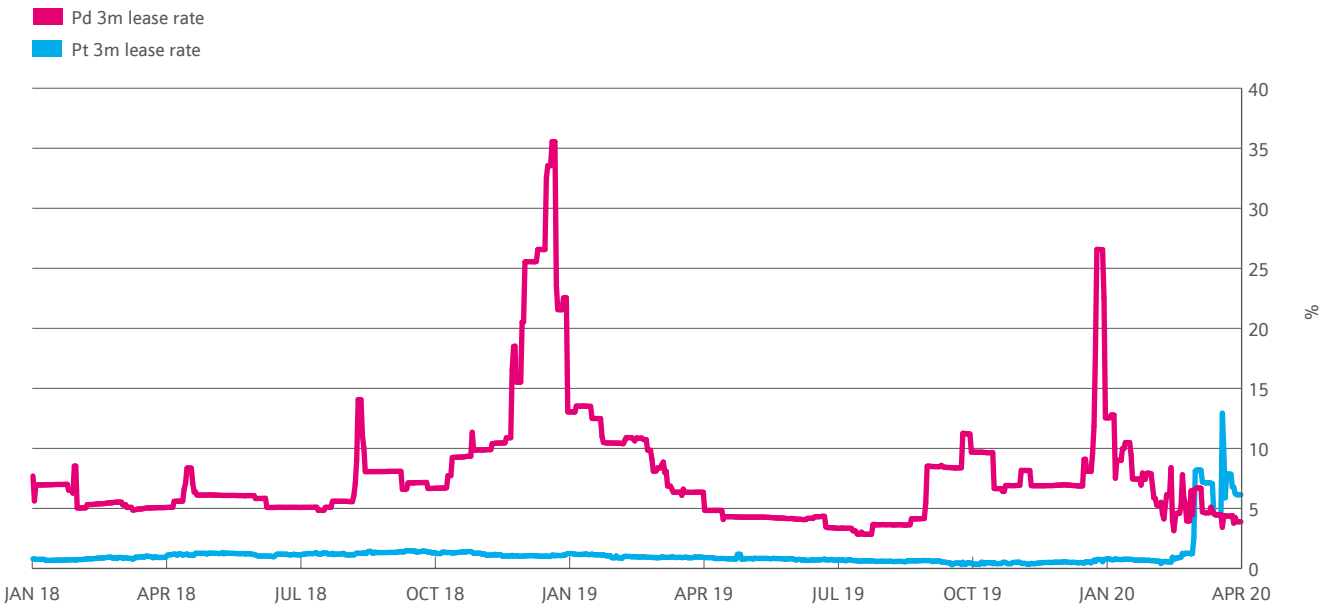


Figure 10 Platinum and palladium lease rates (3 month)

African smelting and refining facilities). However, the impact is likely to be much smaller than in South Africa. All Zimbabwe's platinum mines are mechanised and received government dispensation to operate during the country's lockdown period. However, disruption to the transport of concentrate and smelter matte may result in the accumulation of inventories of semi-processed pgm, which could take some time to clear.

Elsewhere, disruption to mine production due to COVID-19 appears to have been more limited than in South Africa. Norilsk Nickel has to date reported no interruptions at its mining operations and no changes to its production plans for this year. Palladium output is expected to fall in 2020, to 2.65–2.78 million oz, compared to 2.92 million oz in 2019, reflecting the depletion of palladium-rich surface materials that have contributed materially to pgm output during recent years.

With mining designated as an essential business by the Canadian government, both Vale and Glencore continued to operate their Sudbury nickel mines, which produce pgm as by-products. However, the latter shut its remote Raglan nickel mine, located in northern Quebec, for several weeks, while Impala Canada temporarily suspended operations at its Lac des Iles mine on 13th April. Sibanye-Stillwater's Montana, USA, mines continued to produce, although work on expansion projects was halted.

We also expect COVID-19 related disruption to have some impact on the processing of North American pgm. Concentrates and matte from these operations are often transported long distances for refining, either at in-house refineries that may be located at a significant distance from mining operations (for example, Glencore's refinery in Norway), or at third-party smelters and refiners. The pandemic has severely disrupted road, ship and air freight, and this is expected to result in extended lead-times for the shipment and processing of pgm-containing materials.

Secondary supplies will also be heavily impacted by a combination of supply chain and transport issues, and a fall in underlying volumes of autocatalyst scrap being collected. At the time of writing, global car sales are expected to fall by at least 20% in 2020, and this means that many fewer vehicles will be scrapped this year compared to last. While China is already implementing some vehicle replacement incentives, the Chinese market is a relatively minor component of the global autocatalyst recycling total, and the current incentives target a comparatively small number of vehicles. Other markets may also launch incentive schemes once their economies begin to recover from the immediate crisis, but the impact of such initiatives on pgm recoveries this year is likely to be minimal, due to the long delay between a vehicle reaching a scrap yard and the pgm from its catalytic converter being refined. We believe that it typically takes as long as five to six months for the pgm on a scrapped vehicle to return to the market, although this period varies considerably depending on the metal (rhodium takes longer to refine than platinum and palladium) and the type of catalyst. In particular, the pgm from scrapped diesel particulate filters and from contaminated or low-grade scrap may take longer to recover.

In addition to falling volumes of scrapped vehicles, we also expect significant disruption to the collection of autocatalyst scrap. Spent catalytic converters are removed from the vehicle at the scrap yard, then this material is purchased and partially processed by collectors, who in turn sell the upgraded catalyst scrap to refiners. During COVID-19-related lockdowns, some businesses in the recycling network have been closed, while those that are still operating have experienced difficulties with transporting scrap material, particularly where this involves international freight (catalyst scrap is often shipped to refineries in different countries or even continents).

While most secondary pgm refineries are operated by large multinational businesses, many market participants lower down the value chain are private businesses with limited cash resources. Some of these will be forced to reduce their activities due to inability to fund the purchase of scrap materials, and some may cease to operate temporarily or permanently. In the short term, we expect some continued flows of catalyst scrap as participants in the recycling market seek to reduce

"Overall, the economic incentive to recover pgm should remain strong, but at the same time, high pgm prices could impair the ability of scrap dealers and collectors to fund their purchases of scrap materials"

inventories of work-in-progress, but when the market begins to return to normal, companies may face financial constraints which prevent them ramping-up their activities rapidly.

We therefore expect even a relatively short period of disruption to have a lasting impact on the recycling sector. In the wake of the global financial crisis in 2008, there was a steep fall in the amount of pgm recovered from scrapped vehicles, largely because a fall in new car sales meant fewer vehicles were replaced. However, it is likely that depressed pgm recoveries during this period also reflected temporary capacity and funding constraints in the recycling network, leading to some catalyst scrap taking longer than usual to recover, and some of it being permanently lost.

While comparisons with 2008–2009 are useful, the crisis in 2020 is rather different from a recycling market perspective. Following the global financial crisis, pgm prices collapsed to multi-year lows, while scrap steel prices also fell, reducing the incentive to scrap and recycle vehicles. In contrast, in 2020, palladium and rhodium prices have remained at elevated levels (although steel prices have already weakened and this could impact vehicle scrappage rates). Overall, the economic incentive to recover pgm should remain strong, but at the same time, high pgm prices could impair the ability of scrap dealers and collectors to fund their purchases of scrap materials. This is expected to contribute to delays in rebuilding the 'pipeline' of work-in-progress inventory throughout the recycling network, leading to weak pgm recoveries for the remainder of 2020 and probably into 2021.

At the top end of the recycling value chain, refineries have also experienced some disruption to their operations. Most Western pgm refineries continued to operate during March and April 2020, but we expect a combination of transport constraints, increased safety measures, staff shortages and financial uncertainty to result in the refining sector limiting fresh intakes of scrap materials while COVID-19 lockdowns remain in force. This is likely to give refineries an opportunity to reduce backlogs caused by exceptionally high secondary flows during 2019, supporting pgm production in the short term. However, by mid-year, once refinery pipelines have been drawn down but have not yet been refilled by new scrap intakes, we could see a steep fall in the amount of pgm available from secondary sources.

Bottlenecks in secondary refining could temporarily affect not only those materials that we include in our estimates of 'open-loop' secondary supplies (primarily autocatalyst and electronic scrap, the pgm from which is recovered and then returned to the market), but also 'closed-loop' industrial recycling of products such as spent chemical and petroleum catalysts, which are periodically replaced on a like-for-like basis. This catalyst replacement activity is netted off our demand estimates, and does not usually result in significant new metal requirements. However, any extension of shipping or refinery lead-times could also create backlogs in the processing of spent industrial catalysts and similar materials. While it might not lead to additional demand according to our definitions, it could have an impact on physical availability and potentially on prices and lease rates.

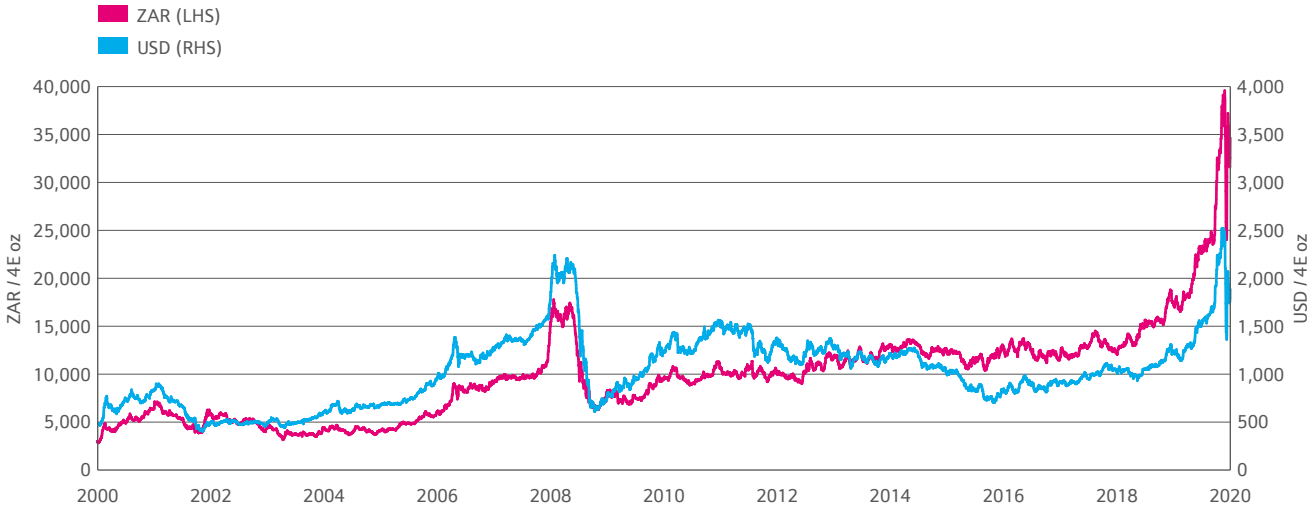


Figure 11 4E pgm basket price

Supply and demand in 2019

Platinum summary

Supply and demand in 2019

The platinum market moved into deficit in 2019, with resurgent investment demand adding over one million ounces to ETF holdings.

Platinum use in autocatalysts declined 5%, as higher average loadings partly offset an 11% fall in world diesel car output.

Weakness in the Chinese jewellery sector intensified, due to further market share losses to gold.

Industrial demand fell below 2018's record level but was supported by large capacity expansions in China.

Auto scrap volumes rose strongly, but pgm recoveries were affected by longer processing lead-times.

Primary supplies fell slightly, with more shaft closures in South Africa and some disruption due to electricity shortages.

Supply '000 oz	2017	2018	2019
South Africa	4,450	4,467	4,398
Russia	720	687	721
Others	969	956	914
Total primary supply	**6,139**	**6,110**	**6,033**

Gross demand '000 oz	2017	2018	2019
Autocatalyst	3,224	3,033	2,876
Jewellery	2,385	2,258	2,052
Industrial	2,031	2,611	2,400
Investment	361	67	1,131
Total gross demand	**8,001**	**7,969**	**8,459**
Recycling	-2,049	-2,084	-2,161
Total net demand	**5,952**	**5,885**	**6,298**
Movements in stocks	187	225	-265

Table 1 Platinum supply and demand

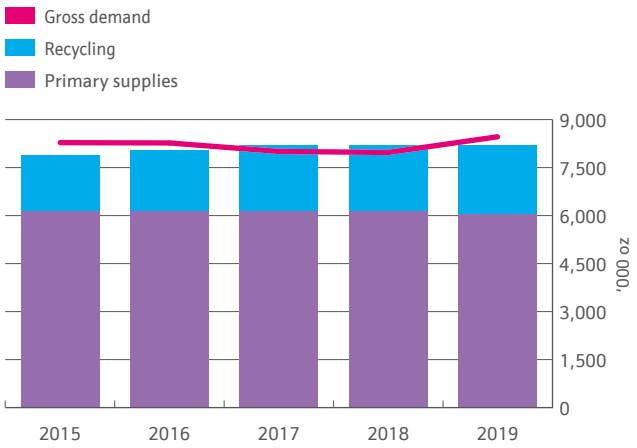


Figure 12 Platinum supply and demand

The platinum market swung into deficit in 2019, as a resurgence in ETF buying lifted physical investment demand to a record 1.13 million ounces. This outweighed a modest contraction in global industrial and automotive demand and a double-digit drop in the Chinese platinum jewellery market. Combined primary and secondary supplies rose marginally, as growth in autocatalyst scrap volumes was partly offset by a slight decline in primary supply. In South Africa, underlying mine output fell marginally, but shipments were supported by the release of some metal from inventories.

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

While the palladium price has seen significant gains over the last three years, the platinum price has remained subdued and range-bound. During 2019, investors began to view platinum as under-priced, especially in view of its future potential to substitute for palladium in some autocatalyst applications. At the same time, there was an increase in the perceived downside risk to South African supplies, in view of shaft closures, periodic electricity shortages, and the risk of industrial action.

Most of the ETF buying which took place in 2019 was net new investment in pgm, rather than investors switching out of palladium (holdings of which fell only modestly over the same period). In addition to the industry-specific

factors discussed above, it is likely that platinum benefited from a generally positive environment for 'safe-haven' investments such as precious metals, due to slower economic growth and a trade dispute between the USA and China. With platinum trading at a record discount to gold, it drew renewed interest from precious metal investors.

Gross demand '000 oz	2017	2018	2019
Europe	1,707	1,455	1,314
Japan	358	364	359
North America	325	337	344
China	157	143	152
Rest of World	677	734	707
Total	**3,224**	**3,033**	**2,876**

Table 2 Platinum demand: Autocatalyst

In contrast, sales of platinum bars in Japan were lacklustre, with price movements in 2019 less favourable for purchasing by Japanese retail investors, who typically buy into dips in the platinum price. Retail platinum prices trended generally upwards, from around ¥3,100 per gram in early January to over ¥3,700 at the year end. There was some moderate purchasing during a sharp mid-year correction, as platinum lost 14% of its yen value during May, but investor activity was otherwise subdued. However, perhaps surprisingly – after four years of significant purchasing into a falling market – there was only limited evidence of profit-taking as prices climbed. Overall, we estimate that Japanese investors acquired a net total of around 50,000 oz of platinum bars last year.

With total investment exceeding 1.1 million ounces, the platinum market moved into deficit in 2019 despite falling consumption in all other major demand sectors. Autocatalyst demand was hit by declining diesel car production, which outweighed a marginal increase in average catalyst loadings, while industrial demand retreated from an all-time high the previous year, and weakness in the Chinese jewellery sector intensified. Overall, total non-investment demand fell by 7%.

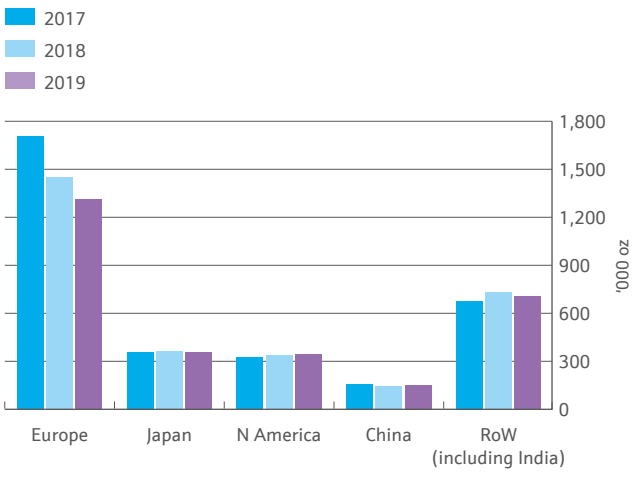


Figure 13 Autocatalyst demand for platinum (gross)

Autocatalyst demand declined by 5% to 2.88 million oz. Production of light duty diesel passenger cars contracted sharply in the two largest markets, Europe and India, but the impact on platinum consumption was moderated by rising loadings in some markets, especially in North America, where diesel is increasingly concentrated in the largest vehicle segments.

European diesel car output shrank by around 11% last year, reflecting general weakness in regional vehicle markets, and market share losses to both gasoline and battery electric vehicles. In India, the passenger car market was dented by a government clampdown on unofficial lending, but the diesel segment was especially hard-hit: output tumbled by a third, as domestic automakers began to withdraw diesel models ahead of the implementation of stricter emissions legislation.

Diesel cars have been popular in India in recent years, primarily because of a significant price differential between gasoline and diesel fuel, and until recently Indian car companies offered a wide range of diesel models at attractive price points. However, since the diesel market was deregulated in 2014, the fuel price gap has narrowed, dampening consumer demand for diesel cars. From 2020, stricter emissions standards will make diesel uncompetitive in smaller vehicle segments.

Previous Indian emissions standards (Bharat IV) could be met with a diesel oxidation catalyst, an old and relatively low-cost technology. The implementation of Bharat VI (BSVI) standards in April 2020 means that all diesel vehicles must be fitted with advanced emissions control systems incorporating particulate filters and NOx abatement technology. The cost of these systems is prohibitive for entry-level vehicles in the Indian market and Indian automakers therefore began to reduce their diesel car output during 2019: some plan to exit this segment completely, while others will cease production of smaller diesel engines. As a result, light duty diesel production fell by over a third in 2019, although platinum consumption fell by only 20% due to changes in the vehicle mix and the start of some BSVI car production.

European diesel car output dropped by 11% in 2019, to a ten-year low of 7.44 million units. This represented a 38% share of European light duty vehicle production, down from a peak of over 50% in 2011. Diesel car output in Europe has become increasingly focused on larger and more expensive vehicles, where the CO_2 benefits are greatest and where it is easiest to recoup the high cost of emissions control systems.

The average platinum content of a European diesel car was stable last year, despite the continued implementation of Euro 6d-TEMP emissions legislation, which requires vehicles to comply with emissions limits under 'real driving emissions' (RDE) conditions as well as in the laboratory (see page 43 for further details of the phases of Euro 6 legislation). RDE legislation specifically targets NOx and particulate emissions and sets 'conformity factors' for these pollutants, which adjust the nominal emissions limits to allow for measurement error in road testing. These factors will tighten during future phases of regulation.

The phase-in of RDE testing has had complex impacts on the design of diesel exhaust gas aftertreatment systems, both

positive and negative for platinum. RDE standards are technically challenging to meet, and the legal and commercial risks of non-compliance are high. Automakers have therefore adopted risk-averse aftertreatment strategies that prioritise compliance over cost, and this has been positive for average platinum loadings on the pgm-coated bricks that are used in diesel catalyst systems – typically, diesel oxidation catalysts (DOCs) and NOx storage catalysts (NSCs). This has helped to compensate for negative impacts due to other changes in aftertreatment design, in particular a move to SCR bricks that also function as a particulate filter (SCRF), entailing the loss of the platinum-coated diesel particulate filter (DPF) brick from many European diesel systems.

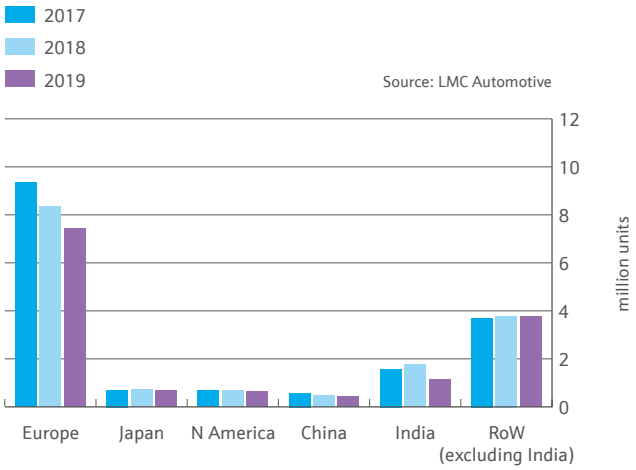


Figure 14 Light duty diesel vehicle production by region

Platinum also faced serious challenges in its other major market, jewellery. Johnson Matthey's biannual survey of Chinese jewellery factories suggests that there was further erosion of platinum's share of the Chinese jewellery market during 2019, and that the pace of decline has increased compared to 2017–2018. Over the past five years, there has been a trend away from platinum towards gold in the fashion jewellery sector, with manufacturers initially developing and promoting 18 and 22 karat gold designs, and more recently expanding their fashion jewellery ranges with pieces made from pure gold, known as '5G'. This 5G jewellery is offered in modern, lightweight styles and is distinct from traditional Chinese 24 karat gold jewellery, which is primarily purchased as a store of value, in heavier and less sophisticated designs.

For jewellery makers, the technical and financial barriers to switching between metals are relatively low, and during the past five years, manufacturers have increasingly converted part of their production capacity to karat gold and more recently to '5G' gold fabrication. This switching process appears to have accelerated during 2019. These trends have been driven primarily by margin considerations, with manufacturers and retailers seeking to maximise their profitability during a lacklustre period for the jewellery industry.

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

Industrial demand for platinum fell by 8%, but remained strong by historical standards. The largest year-on-year change occurred in the petroleum refining sector, where demand fell by nearly one third, to 250,000 oz; this was nevertheless the second-highest annual total that we have recorded in our data series since 1975.

Between 2017 and 2019, Chinese purchases of petroleum refining catalyst were exceptionally high, due to the development of several very large integrated oil refining and petrochemicals complexes, and the simultaneous liberalisation of petroleum trade, which has enabled independent companies to import crude for the first time. Thus, although investment in new capacity at Chinese oil refineries was down in 2019 versus the previous year, it remained well above long-term trends.

Sales of platinum to chemicals producers in China hit a new peak in 2019. The integrated petrochemicals complexes referred to above typically incorporate large paraxylene units, requiring an initial catalyst charge that can involve tens of thousands of ounces of platinum. There was also some further expansion of propylene capacity using the propane dehydrogenation process, which involves a platinum catalyst.

Demand for platinum in the glass sector remained strong last year, although it was down compared to 2018's exceptional total. Purchasing was once again heavily concentrated in China, where fibreglass manufacturers have been investing heavily in new production capacity to meet anticipated

	Gross			Recycling			Net		
Demand '000 oz	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**
Europe	176	191	190	-5	-5	-5	171	186	185
Japan	303	293	290	-222	-185	-175	81	108	115
North America	225	224	201	0	0	0	225	224	201
China	1,470	1,316	1,119	-515	-505	-465	955	811	654
Rest of World	211	234	252	-4	-4	-5	207	230	247
Total	**2,385**	**2,258**	**2,052**	**-746**	**-699**	**-650**	**1,639**	**1,559**	**1,402**

Table 3 Platinum demand: Jewellery

growth in the electronics, construction, renewable energy and automotive sectors. There was also an increase in purchases of platinum for 'next-generation' LCD glass production (for large-screen televisions measuring over 60 inches).

On the supply side, global primary shipments fell by 1%, with modest declines in sales by producers in South Africa, Zimbabwe and North America.

Demand '000 oz	2017	2018	2019
Chemical	462	677	700
Electrical	233	240	224
Glass	314	501	409
Medical & biomedical	220	222	229
Petroleum	227	372	250
Other	575	599	588
Total	**2,031**	**2,611**	**2,400**

Table 4 Platinum demand: Industrial

Rationalisation and restructuring of the South African platinum industry continued in 2019, with some older, high-cost shafts reaching the end of their lives, and the completion of Sibanye-Stillwater's acquisition of Lonmin's mining assets, which include the large Marikana mining complex. The Marikana mine is among those most affected by rationalisation: a number of its first-generation shafts were mothballed between 2017 and 2019. Refined platinum output from mining at Marikana is thought to have fallen from just over 600,000 oz in 2018 to below 550,000 oz last year.

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

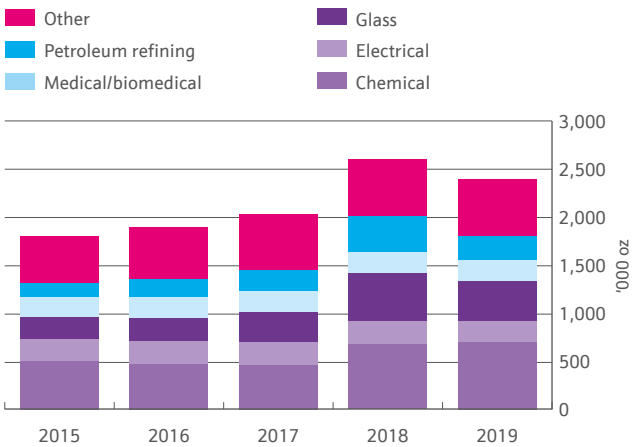


Figure 15 Industrial demand for platinum

During 2019, several major producers entered negotiations with labour unions over a new three-year wage deal. While these discussions were often protracted, in some cases involving referral to the Commission for Conciliation, Mediation and Arbitration, the mines were ultimately able to reach a settlement without any impact on production from industrial action.

Higher pgm basket prices probably facilitated a settlement, giving producers some flexibility to agree above-inflation wage increases. The rand price of a typical pgm basket (containing one combined ounce of platinum, palladium, rhodium and gold in a split reflecting average South African mine production) was below R15,000 as recently as September 2018. During 2019, it surged higher, climbing past the 2008 peak to set a new all-time high of over R24,000 per ounce in December.

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

Other factors have also contributed to rising lead-times, specifically the closure of two major pgm refineries in Europe, and technical difficulties with processing some diesel particulate filter scrap. We allow for this increase in lead-times in our estimates of secondary supplies, which show an 8% increase in the volume of platinum refined from spent catalytic converters during 2019.

The platinum market moved into a technical deficit last year, but availability remained good and lease rates low. Although Swiss and UK platinum inventories fell steadily between 2011 and 2018, this primarily reflected a relocation of metal out of Europe and into Asia rather than a consistent drawdown of market stocks. In 2019, combined Swiss and UK stocks recovered somewhat, probably as a result of heavy ETF buying: these products are physically-backed and metal is stored in vaults in Europe.

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

Palladium summary

Supply and demand in 2019

The palladium price set a series of all-time highs in 2019, as the deficit widened to nearly one million ounces.

Auto demand set a new record, despite lower vehicle output, as global average loadings rose by 14%.

Industrial demand fell, with the electronics sector hit by weaker economic growth, and some thrifting in dental alloys.

ETF redemptions slowed, and the final quarter of 2019 saw a modest return to positive investment.

Primary supplies were broadly flat, but secondary recoveries rose 10% despite capacity constraints and rising lead-times.

The palladium market deficit widened to 950,000 oz in 2019, with only limited growth in combined primary and secondary supplies, and a surge in autocatalyst demand on the back of new legislation in China and more stringent testing regimes in Europe. Industrial demand fell slightly, mainly due to slowing world economic growth; even though the palladium price set a series of all-time highs, there were only modest increases in thrifting and substitution, mainly in the dental sector. Meanwhile, the rate of ETF redemptions fell sharply despite the rise in price, and during the second half of 2019 there were signs of a return to positive investment buying.

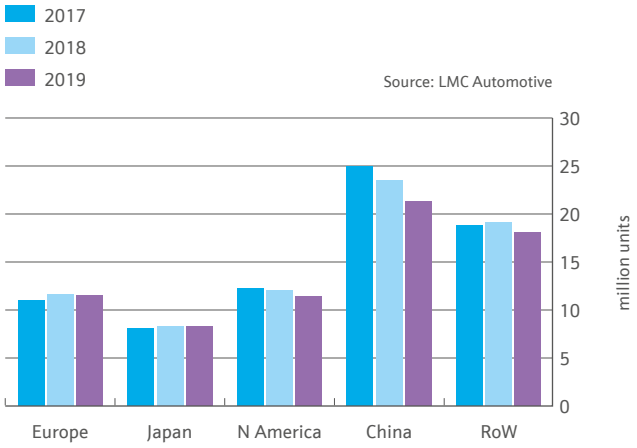


Figure 16 Light duty gasoline vehicle production by region

Supply '000 oz	2017	2018	2019
South Africa	2,547	2,543	2,626
Russia	2,452	2,976	2,987
Others	1,452	1,487	1,456
Total primary supply	**6,451**	**7,006**	**7,069**

Gross demand '000 oz	2017	2018	2019
Autocatalyst	8,465	8,830	9,635
Jewellery	167	148	135
Industrial	1,820	1,926	1,764
Investment	-386	-574	-87
Total gross demand	**10,066**	**10,330**	**11,447**
Recycling	-2,861	-3,116	-3,428
Total net demand	**7,205**	**7,214**	**8,019**
Movements in stocks	-754	-208	-950

Table 5 Palladium supply and demand

"Last year saw a 14% rise in global average palladium loadings on gasoline cars, with double-digit growth in both Europe and China"

Tightening emissions legislation and stricter vehicle testing regimes boosted the average content of three-way catalysts in most major vehicle markets. Last year saw a 14% rise in global average palladium loadings on gasoline cars, with double-digit growth in both Europe and China. This propelled automotive demand for palladium to a new all-time high of 9.64 million ounces, a 9% gain versus 2018 despite falls in gasoline vehicle production in most regional car markets.

In China, car sales were affected by slowing economic growth, with consumers becoming more cautious about purchasing big-ticket items. In addition, the termination of government incentive schemes continued to affect the market, particularly in

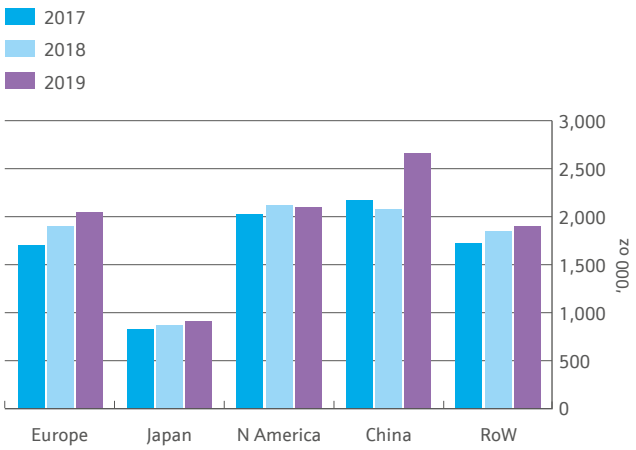


Figure 17 Autocatalyst demand for palladium (gross)

some lower-tier cities where sales had been inflated by vehicle tax reductions during the 2016–2017 period. As a result, Chinese light duty vehicle output slumped by nearly 9% in 2019, while gasoline cars also lost market share to battery electric vehicles.

Car production and sales were also temporarily impacted by the mid-year introduction of China 6 emissions legislation in 16 provinces and cities, which together account for around 70% of annual Chinese car sales. However, consumer demand for China 6 models was much higher than this would suggest, with the result that some automakers were left with excess inventory of China 5 vehicles and a shortage of China 6 variants. By the final quarter of 2019, inventories of older vehicles had been reduced, and most production lines had been switched to China 6 models.

Ultimately, we estimate that China 6 vehicles accounted for about 70% of new gasoline vehicles produced in China in 2019. As a result, and despite a fall in total car production volumes, palladium consumption on Chinese cars leapt by over 20%.

Palladium also saw a marked increase in use in heavy duty vehicles in China last year. In this region, there is a small market for trucks powered by compressed natural gas (CNG), some of which were equipped with China VI catalyst systems last year. These vehicles use three-way catalyst technology but typically require much heavier palladium loadings compared to gasoline vehicles, due to the methane content of the exhaust gas stream. Because methane is particularly unreactive, relatively large amounts of palladium are required to catalyse the chemical process that converts it to water and CO_2.

Gross demand '000 oz	2017	2018	2019
Europe	1,704	1,903	2,052
Japan	829	876	911
North America	2,028	2,124	2,099
China	2,179	2,080	2,669
Rest of World	1,725	1,847	1,904
Total	**8,465**	**8,830**	**9,635**

Table 6 Palladium demand: Autocatalyst

The European market also saw further strong growth in the palladium content of gasoline aftertreatment systems, primarily due to the rollout in of Euro 6d-TEMP emissions legislation. The new standards were extended to all new cars in September 2019, requiring vehicles to demonstrate NOx and particle number emissions compliance in real driving emissions (RDE) testing as well as in laboratory tests.

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

The technical difficulty of achieving this, and the commercial risk of not doing so, have had a very significant impact on average pgm loadings on three-way catalysts: between 2017 and 2019, the average pgm content of a European gasoline car rose by over a quarter. As a result, despite lacklustre conditions in the European automotive industry, we estimate that palladium demand in this region rose by 8% to a record 2.05 million oz in 2019.

Demand in industrial applications fell by 8% last year. Most of palladium's industrial applications are relatively insensitive to price, but consumption in the dental industry has been affected by high prices, which make palladium dental alloys less competitive compared with alternative materials such as resins and ceramics, and even platinum-containing gold alloys. Palladium consumption in the dental sector fell by 13% last year.

Palladium use in electronics also declined, but this was primarily for reasons unrelated to metal prices. Plating applications are palladium's largest demand segment in the electronics industry. Palladium plating salts are typically used to apply a thin palladium layer, usually as part of a 'sandwich' between layers of nickel and gold, on electronic components such as connectors, lead-frames and printed circuit boards (PCBs). In 2019, world demand for these components dropped, as trade disputes and tariff increases impacted economic activity, especially in China.

"Ultimately, we estimate that China 6 vehicles accounted for about 70% of new gasoline vehicles produced in China in 2019. As a result, and despite a fall in total car production volumes, palladium consumption on Chinese cars leapt by over 20%"

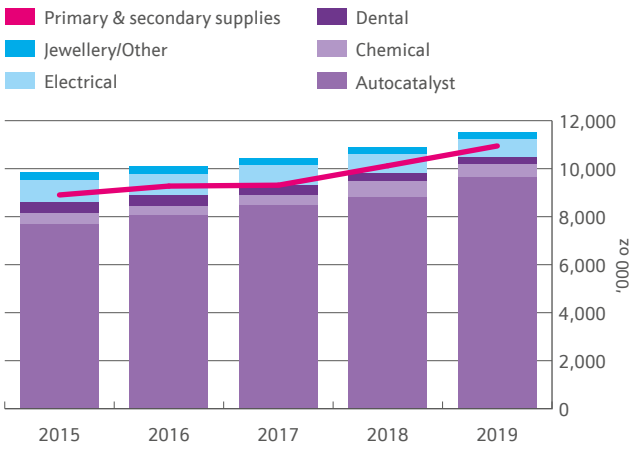


Figure 18 Palladium demand in consuming applications (excluding investment)

"At the start of 2019, only just over 700,000 oz of palladium remained in ETF vaults (down from a peak of nearly 3 million ounces in 2015); by August, this had fallen to a low of 590,000 oz"

Consumption of palladium in the chemicals industry remained at unusually high levels in 2019, albeit below the previous year's record total. Purchasing of palladium process catalyst by Chinese chemicals companies was exceptionally strong, stimulated by capacity additions for purified terephthalic acid (PTA), a feedstock in the manufacture of polyethylene terephthalate (PET) which is widely used in the packaging and textiles industries. There was also further investment in new monoethylene glycol (MEG) plants, which in China typically use coal as a feedstock and involve a palladium catalyst.

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

Demand '000 oz	2017	2018	2019
Chemical	442	626	545
Dental	391	358	313
Electrical	843	768	729
Other	144	174	177
Total	**1,820**	**1,926**	**1,764**

Table 7 Palladium demand: Industrial

Palladium supplies rose marginally in 2019, with Russian sales stable and a slight increase in shipments from South Africa. Russian quarterly production volumes have been particularly volatile in recent years, due to changes in the company's process flowsheet that have contributed to significant variations in work-in-progress inventories. Output of pgm was exceptionally strong during the first six months of 2019, due to the release of work-in-progress from the Krasnoyark refinery where most of Norilsk Nickel's pgm is treated. For the year as a whole, Norilsk's palladium output rose by 7%, but sales from refined inventory were lower than in 2018, leaving Russian primary supplies broadly unchanged.

Inventory fluctuations played an important role in the secondary sector, where the industry is facing capacity constraints following the closure of two European refineries at a time of rising autocatalyst recycling volumes and ongoing changes in material feedstocks. This resulted in rising lead-times across the sector; we allow for this in our estimate of recycling volumes. Nevertheless, secondary palladium recoveries rose by 10% last year, leaving combined primary and secondary supplies up 4%. This was a better supply-side performance than we had previously anticipated, but it did little to improve the overall picture of severe deficit: with the annual shortfall in palladium supplies approaching 1 million ounces, the price climbed from $1,260 in January to over $1,900 at the year end (and set a new all time record of over $2,800 in February 2020).

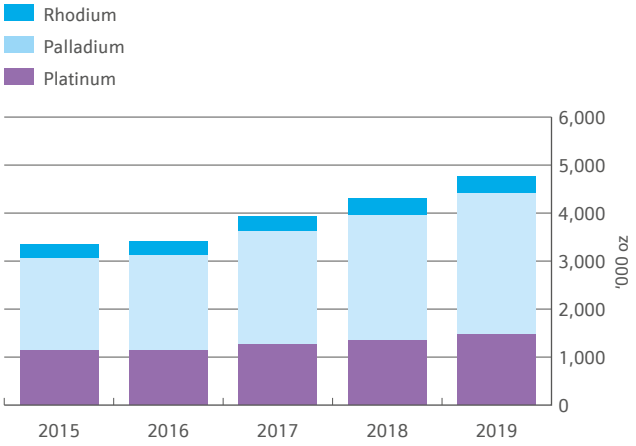


Figure 19 Autocatalyst recovery by metal

Rhodium summary

Supply and demand in 2019

Rhodium moved into deficit in 2019, with auto demand up 14% and primary supplies flat.

Market liquidity tightened dramatically, as automakers sought to secure their future rhodium needs.

Metal availability was inconsistent, due to electricity shortages in South Africa and capacity issues in secondary refineries.

Exceptionally tight market conditions propelled the price to $6,000 in December 2019 and to all-time highs in early 2020.

Global consumption of rhodium on autocatalysts leapt by 14% in 2019, following a step-change in loadings on Chinese vehicles as the phase-in of China 6 legislation got underway. Car companies in other regions also used more rhodium, in response to tighter emissions standards and more stringent testing. These gains offset a sharp fall in rhodium use in the glass industry, as capacity expansion slowed after two years of exceptionally strong activity. Although combined primary and secondary supplies rose by 3%, this was not enough to prevent the market moving into deficit.

Supply '000 oz	2017	2018	2019
South Africa	611	618	624
Russia	78	69	68
Others	70	70	65
Total primary supply	**759**	**757**	**757**

Gross demand '000 oz	2017	2018	2019
Autocatalyst	834	883	1,008
Other	207	170	137
Total gross demand	**1,041**	**1,053**	**1,145**
Recycling	-310	-335	-363
Total net demand	**731**	**718**	**782**
Movements in stocks	28	39	-25

Table 8 Rhodium supply and demand

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

While the primary driver for these price gains was a surge in buying by car companies, supply factors also played a role. Rhodium shipments from South Africa rose marginally in 2019, but supply volumes fluctuated during the year as a combination of 'load-shedding' (rolling cuts in electricity supply), stock-takes and routine or emergency plant maintenance periodically affected refinery operations. In a very small and illiquid market, small variations in supply may have a noticeable impact on price.

Secondary supplies grew by 8%, as greater volumes of scrapped autocatalyst entered the recycling network. However, the rate of increase was lower than for platinum and palladium, reflecting historic thrifting of the rhodium content of autocatalysts, combined with capacity constraints within the secondary refining sector. Capacity issues have disproportionately affected rhodium, because its chemistry means that the refining process takes longer than for platinum or palladium. Over the past two years, the refining sector has accumulated higher than normal semi-processed inventories of all the pgm, but the impact on rhodium has been particularly significant.

Total rhodium demand rose by 9%, as lower demand from glassmakers was offset by surging demand from the automotive sector. With emissions legislation tightening in most major markets, the average rhodium content of a gasoline car rose by over 20%, greatly outweighing a 5% fall in world light duty gasoline vehicle production. The largest changes were seen in Europe, as a result of more stringent testing of passenger vehicles, and in China, where a new phase of legislative tightening got underway.

From September 2019, all new passenger cars sold in Europe were required to meet Euro 6d-TEMP standards, which require vehicles to demonstrate NOx and particle number (PN) emissions compliance in real driving emissions (RDE) on-road testing, as well as in the laboratory. At the same time, automakers have also been facing new in-service conformity regulations, which were introduced in January 2019 and are intended to ensure

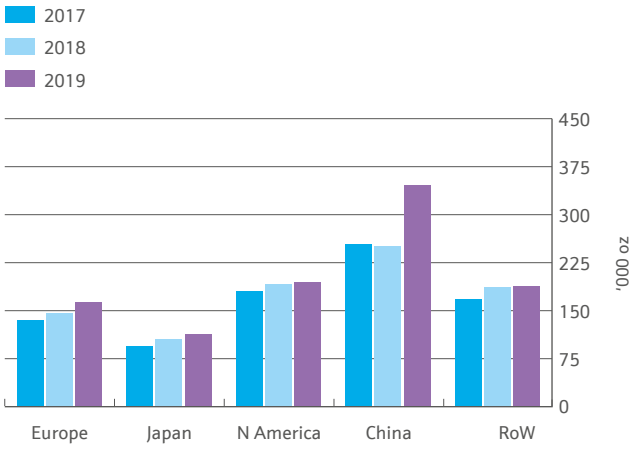


Figure 20 Autocatalyst demand for rhodium (gross)

that catalyst systems meet RDE standards not just at the point that the vehicle is put into service, but for most of its lifetime.

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

In China, some cities and provinces began to implement China 6 legislation in July 2019, a year ahead of the nationwide implementation schedule. We estimate that over two-thirds of gasoline cars sold in 2019 were China 6 vehicles and that the majority of these were equipped with catalysts capable of meeting the stricter China 6b standards. Compared with China 5 systems, the catalysts used on China 6b models have significantly higher loadings for palladium and, particularly, rhodium.

Consumption of rhodium in industrial applications weakened in 2019, primarily due to lower purchasing from the Chinese glass industry, where increased economic uncertainty and overcapacity in the domestic market has resulted in some fibreglass expansions being deferred. In addition, high rhodium prices had some impact on demand. Glassmakers have some scope to make short-term adjustments to their rhodium usage in response to price, by reducing the rhodium content of the platinum alloys used in glassmaking. Alloys with a lower rhodium content are less durable, but as rhodium's premium over platinum rises, thrifting can make economic sense even if this reduces the working life of the equipment.

Demand '000 oz	2017	2018	2019
Chemical	72	67	65
Electrical	5	5	6
Glass	110	111	52
Other	20	-13	14
Total	**207**	**170**	**137**

Table 9 Rhodium demand: Industrial

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

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

Three factors which are not fully captured by our supply and demand measurements may have contributed to unusual market tightness. Firstly, when step-changes in legislation occur, our figures may underestimate physical demand in any single annual period, because we consider autocatalyst demand to occur at the time of vehicle production. In reality, during periods of sharply rising loadings, manufacturers may see significant increases in their work-in-progress inventories of pgm some weeks or even months ahead of vehicle production.

"Total rhodium demand rose by 9%, as lower demand from glassmakers was offset by surging demand from the automotive sector"

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

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

The combined impact of these factors led to a general tightening of rhodium availability during 2019, pushing prices to levels not seen since 2008. Rhodium ended the year at around $6,000 per ounce, as further electricity shortages caused disruption to South African mining and processing operations, before moving to all time highs above $13,000 during February and early March 2020.

Platinum supply and demand

Troy ounces

Supply '000 oz[1]	2014	2015	2016	2017	2018	2019
South Africa	3,546	4,572	4,392	4,450	4,467	4,398
Russia[2]	700	670	714	720	687	721
North America	340	339	353	346	330	324
Zimbabwe[3]	401	400	489	466	474	451
Others[3]	167	158	162	157	152	139
Total supply	**5,154**	**6,139**	**6,110**	**6,139**	**6,110**	**6,033**

Demand '000 oz[4]	2014	2015	2016	2017	2018	2019
Autocatalyst[4]	3,062	3,273	3,339	3,224	3,033	2,876
Chemical	576	502	476	462	677	700
Electrical[4]	225	228	232	233	240	224
Glass	143	227	247	314	501	409
Investment	277	451	620	361	67	1,131
Jewellery[4]	2,839	2,746	2,413	2,385	2,258	2,052
Medical and biomedical[5]	214	215	218	220	222	229
Petroleum	172	140	186	227	372	250
Other	468	494	535	575	599	588
Total gross demand	**7,976**	**8,276**	**8,266**	**8,001**	**7,969**	**8,459**

Recycling '000 oz[6]	2014	2015	2016	2017	2018	2019
Autocatalyst	-1,255	-1,136	-1,146	-1,268	-1,347	-1,471
Electrical	-28	-30	-32	-35	-38	-40
Jewellery	-762	-574	-738	-746	-699	-650
Total recycling	**-2,045**	**-1,740**	**-1,916**	**-2,049**	**-2,084**	**-2,161**

Total net demand[7]	**5,931**	**6,536**	**6,350**	**5,952**	**5,885**	**6,298**
Movement in stocks[8]	-777	-397	-240	187	225	-265

Platinum gross demand by region

Troy ounces

Gross demand '000 oz		2014	2015	2016	2017	2018	2019
Europe	Autocatalyst	1,476	1,672	1,786	1,707	1,455	1,314
	Chemical	111	120	122	118	122	124
	Electrical	12	13	13	10	11	12
	Glass	11	11	11	11	11	13
	Investment	-73	-88	109	36	-102	566
	Jewellery	204	203	177	176	191	190
	Medical and biomedical	72	71	71	70	68	69
	Petroleum	22	-4	3	7	29	15
	Other	127	136	154	172	182	181
	Total	**1,962**	**2,134**	**2,446**	**2,307**	**1,967**	**2,484**

Gross demand '000 oz		2014	2015	2016	2017	2018	2019
Japan	Autocatalyst	448	384	360	358	364	359
	Chemical	41	43	42	37	40	42
	Electrical	31	33	32	31	31	29
	Glass	-96	4	2	25	7	9
	Investment	19	700	543	171	220	32
	Jewellery	313	314	310	303	293	290
	Medical and biomedical	16	16	15	15	16	16
	Petroleum	3	3	3	2	2	2
	Other	71	80	77	79	79	78
	Total	**846**	**1,577**	**1,384**	**1,021**	**1,052**	**857**

Gross demand '000 oz		2014	2015	2016	2017	2018	2019
North America	Autocatalyst	356	379	360	325	337	344
	Chemical	113	114	103	112	116	118
	Electrical	18	22	26	33	37	30
	Glass	10	10	29	45	18	18
	Investment	7	-32	109	127	66	156
	Jewellery	218	227	221	225	224	201

Gross demand '000 oz		2014	2015	2016	2017	2018	2019
North America	Medical and biomedical	85	85	87	88	89	93
	Petroleum	21	40	35	18	15	17
	Other	141	138	146	147	156	154
	Total	**969**	**983**	**1,116**	**1,120**	**1,058**	**1,131**

Gross demand '000 oz		2014	2015	2016	2017	2018	2019
China	Autocatalyst	130	136	151	157	143	152
	Chemical	155	131	121	83	215	282
	Electrical	39	38	42	44	51	48
	Glass	144	178	135	111	388	283
	Investment	0	0	0	0	0	0
	Jewellery	1,935	1,796	1,510	1,470	1,316	1,119
	Medical and biomedical	18	19	19	20	21	22
	Petroleum	30	32	76	120	254	156
	Other	53	59	72	83	87	82
	Total	**2,504**	**2,389**	**2,126**	**2,088**	**2,475**	**2,144**

Gross demand '000 oz		2014	2015	2016	2017	2018	2019
Rest of World	Autocatalyst	652	702	682	677	734	707
	Chemical	156	94	88	112	184	134
	Electrical	125	122	119	115	110	105
	Glass	74	24	70	122	77	86
	Investment	324	-129	-141	27	-117	377
	Jewellery	169	206	195	211	234	252
	Medical and biomedical	23	24	26	27	28	29
	Petroleum	96	69	69	80	72	60
	Other	76	81	86	94	95	93
	Total	**1,695**	**1,193**	**1,194**	**1,465**	**1,417**	**1,843**
	Grand total	**7,976**	**8,276**	**8,266**	**8,001**	**7,969**	**8,459**

Platinum supply and demand

Tonnes

Supply tonnes[1]	2014	2015	2016	2017	2018	2019
South Africa	110.3	142.2	136.6	138.4	138.9	136.8
Russia[2]	21.8	20.8	22.2	22.4	21.4	22.4
North America	10.6	10.6	11.0	10.8	10.3	10.1
Zimbabwe[3]	12.5	12.4	15.2	14.5	14.7	14.0
Others[3]	5.2	4.9	5.0	4.9	4.7	4.3
Total supply	**160.4**	**190.9**	**190.0**	**191.0**	**190.0**	**187.6**

Demand tonnes[4]	2014	2015	2016	2017	2018	2019
Autocatalyst[4]	95.2	101.7	103.9	100.3	94.3	89.5
Chemical	18.0	15.6	14.8	14.4	21.0	21.8
Electrical[4]	7.1	7.1	7.2	7.3	7.5	7.0
Glass	4.4	7.0	7.7	9.8	15.6	12.7
Investment	8.6	14.1	19.3	11.2	2.1	35.2
Jewellery[4]	88.3	85.5	75.1	74.1	70.2	63.8
Medical and biomedical[5]	6.6	6.7	6.8	6.8	6.9	7.1
Petroleum	5.3	4.3	5.8	7.1	11.6	7.8
Other	14.6	15.4	16.6	17.9	18.6	18.3
Total gross demand	**248.1**	**257.4**	**257.2**	**248.9**	**247.8**	**263.2**

Recycling tonnes[6]	2014	2015	2016	2017	2018	2019
Autocatalyst	-38.9	-35.3	-35.6	-39.4	-41.9	-45.7
Electrical	-0.9	-0.9	-1.0	-1.1	-1.2	-1.3
Jewellery	-23.7	-17.9	-23.0	-23.2	-21.7	-20.2
Total recycling	**-63.5**	**-54.1**	**-59.6**	**-63.7**	**-64.8**	**-67.2**

Total net demand[7]	**184.6**	**203.3**	**197.6**	**185.2**	**183.0**	**196.0**
Movement in stocks[8]	-24.2	-12.4	-7.6	5.8	7.0	-8.4

Platinum gross demand by region

Tonnes

Gross demand tonnes		2014	2015	2016	2017	2018	2019
Europe	Autocatalyst	45.9	52.0	55.6	53.1	45.3	40.9
	Chemical	3.5	3.7	3.8	3.6	3.8	3.9
	Electrical	0.4	0.4	0.4	0.3	0.3	0.4
	Glass	0.3	0.3	0.3	0.3	0.3	0.4
	Investment	-2.3	-2.7	3.4	1.1	-3.2	17.6
	Jewellery	6.3	6.3	5.5	5.5	5.9	5.9
	Medical and biomedical	2.2	2.2	2.2	2.2	2.1	2.1
	Petroleum	0.7	-0.1	0.1	0.2	0.9	0.5
	Other	4.0	4.2	4.8	5.3	5.7	5.6
	Total	**61.0**	**66.3**	**76.1**	**71.6**	**61.1**	**77.3**

Gross demand tonnes		2014	2015	2016	2017	2018	2019
Japan	Autocatalyst	13.9	11.9	11.2	11.1	11.3	11.2
	Chemical	1.3	1.3	1.3	1.2	1.2	1.3
	Electrical	1.0	1.0	1.0	1.0	1.0	0.9
	Glass	-3.0	0.1	0.1	0.8	0.2	0.3
	Investment	0.6	21.8	16.9	5.3	6.8	1.0
	Jewellery	9.7	9.8	9.6	9.4	9.1	9.0
	Medical and biomedical	0.5	0.5	0.5	0.5	0.5	0.5
	Petroleum	0.1	0.1	0.1	0.1	0.1	0.1
	Other	2.2	2.5	2.4	2.5	2.5	2.4
	Total	**26.3**	**49.0**	**43.1**	**31.9**	**32.7**	**26.7**

Gross demand tonnes		2014	2015	2016	2017	2018	2019
North America	Autocatalyst	11.1	11.8	11.2	10.1	10.5	10.7
	Chemical	3.5	3.6	3.2	3.5	3.6	3.7
	Electrical	0.6	0.7	0.8	1.0	1.2	0.9
	Glass	0.3	0.3	0.9	1.4	0.6	0.6
	Investment	0.2	-1.0	3.4	4.0	2.1	4.9
	Jewellery	6.8	7.1	6.9	7.0	7.0	6.3

Gross demand tonnes		2014	2015	2016	2017	2018	2019
North America	Medical and biomedical	2.6	2.6	2.7	2.7	2.8	2.9
	Petroleum	0.6	1.2	1.1	0.6	0.5	0.5
	Other	4.4	4.3	4.5	4.6	4.8	4.8
	Total	**30.1**	**30.6**	**34.7**	**34.9**	**33.1**	**35.3**

Gross demand tonnes		2014	2015	2016	2017	2018	2019
China	Autocatalyst	4.0	4.2	4.7	4.9	4.4	4.7
	Chemical	4.8	4.1	3.8	2.6	6.7	8.7
	Electrical	1.2	1.2	1.3	1.4	1.6	1.5
	Glass	4.5	5.6	4.2	3.5	12.1	8.8
	Investment	0.0	0.0	0.0	0.0	0.0	0.0
	Jewellery	60.2	55.9	47.0	45.7	40.9	34.8
	Medical and biomedical	0.6	0.6	0.6	0.6	0.6	0.7
	Petroleum	0.9	1.0	2.4	3.7	7.9	4.8
	Other	1.6	1.9	2.2	2.6	2.7	2.6
	Total	**77.8**	**74.5**	**66.2**	**65.0**	**76.9**	**66.6**

Gross demand tonnes		2014	2015	2016	2017	2018	2019
Rest of World	Autocatalyst	20.3	21.8	21.2	21.1	22.8	22.0
	Chemical	4.9	2.9	2.7	3.5	5.7	4.2
	Electrical	3.9	3.8	3.7	3.6	3.4	3.3
	Glass	2.3	0.7	2.2	3.8	2.4	2.6
	Investment	10.1	-4.0	-4.4	0.8	-3.6	11.7
	Jewellery	5.3	6.4	6.1	6.5	7.3	7.8
	Medical and biomedical	0.7	0.8	0.8	0.8	0.9	0.9
	Petroleum	3.0	2.1	2.1	2.5	2.2	1.9
	Other	2.4	2.5	2.7	2.9	2.9	2.9
	Total	**52.9**	**37.0**	**37.1**	**45.5**	**44.0**	**57.3**
	Grand total	**248.1**	**257.4**	**257.2**	**248.9**	**247.8**	**263.2**

Palladium supply and demand

Troy ounces

Supply '000 oz[1]	2014	2015	2016	2017	2018	2019
South Africa	2,126	2,683	2,570	2,547	2,543	2,626
Russia[2]	2,589	2,434	2,781	2,452	2,976	2,987
North America	893	872	911	935	959	954
Zimbabwe[3]	327	320	396	386	393	379
Others[3]	160	144	129	131	135	123
Total supply	**6,095**	**6,453**	**6,787**	**6,451**	**7,006**	**7,069**

Demand '000 oz[4]	2014	2015	2016	2017	2018	2019
Autocatalyst[4]	7,518	7,691	8,043	8,465	8,830	9,635
Chemical	313	449	413	442	626	545
Dental	464	468	429	391	358	313
Electrical[4]	970	903	872	843	768	729
Investment	943	-659	-646	-386	-574	-87
Jewellery[4]	272	220	189	167	148	135
Other	111	134	157	144	174	177
Total gross demand	**10,591**	**9,206**	**9,457**	**10,066**	**10,330**	**11,447**

Recycling '000 oz[6]	2014	2015	2016	2017	2018	2019
Autocatalyst	-2,117	-1,931	-1,986	-2,361	-2,628	-2,945
Electrical	-474	-475	-481	-479	-475	-471
Jewellery	-89	-46	-21	-21	-13	-12
Total recycling	**-2,680**	**-2,452**	**-2,488**	**-2,861**	**-3,116**	**-3,428**

Total net demand[7]	**7,911**	**6,754**	**6,969**	**7,205**	**7,214**	**8,019**
Movement in stocks[8]	-1,816	-301	-182	-754	-208	-950

Palladium gross demand by region

Troy ounces

Gross demand '000 oz		2014	2015	2016	2017	2018	2019
Europe	Autocatalyst	1,583	1,622	1,637	1,704	1,903	2,052
	Chemical	-25	74	74	75	72	73
	Dental	77	70	65	60	51	42
	Electrical	113	101	99	96	91	88
	Investment	-74	-200	-269	-287	-141	-56
	Jewellery	60	59	58	53	49	43
	Other	25	27	24	23	30	26
	Total	**1,759**	**1,753**	**1,688**	**1,724**	**2,055**	**2,268**

Gross demand '000 oz		2014	2015	2016	2017	2018	2019
Japan	Autocatalyst	794	759	787	829	876	911
	Chemical	16	15	15	17	17	17
	Dental	205	227	200	174	156	140
	Electrical	214	231	227	221	199	188
	Investment	-2	4	-3	-3	-1	1
	Jewellery	67	66	64	57	52	45
	Other	9	9	9	9	9	9
	Total	**1,303**	**1,311**	**1,299**	**1,304**	**1,308**	**1,311**

Gross demand '000 oz		2014	2015	2016	2017	2018	2019
North America	Autocatalyst	1,963	2,039	1,992	2,028	2,124	2,099
	Chemical	71	76	73	75	76	73
	Dental	156	145	138	131	125	106
	Electrical	140	131	128	124	112	105
	Investment	-205	-181	-71	-19	-87	-5
	Jewellery	44	39	36	29	27	27
	Other	43	60	46	44	43	47
	Total	**2,212**	**2,309**	**2,342**	**2,412**	**2,420**	**2,452**

Gross demand '000 oz		2014	2015	2016	2017	2018	2019
China	Autocatalyst	1,608	1,654	2,038	2,179	2,080	2,669
	Chemical	160	209	156	181	269	265
	Dental	8	8	7	7	7	6
	Electrical	169	158	156	155	141	134
	Investment	0	0	0	0	0	0
	Jewellery	78	34	10	9	2	1
	Other	16	17	45	51	72	71
	Total	**2,039**	**2,080**	**2,412**	**2,582**	**2,571**	**3,146**

Gross demand '000 oz		2014	2015	2016	2017	2018	2019
Rest of World	Autocatalyst	1,570	1,617	1,589	1,725	1,847	1,904
	Chemical	91	75	95	94	192	117
	Dental	18	18	19	19	19	19
	Electrical	334	282	262	247	225	214
	Investment	1,224	-282	-303	-77	-345	-27
	Jewellery	23	22	21	19	18	19
	Other	18	21	33	17	20	24
	Total	**3,278**	**1,753**	**1,716**	**2,044**	**1,976**	**2,270**
	Grand total	**10,591**	**9,206**	**9,457**	**10,066**	**10,330**	**11,447**

Palladium supply and demand

Tonnes

Supply tonnes[1]	2014	2015	2016	2017	2018	2019
South Africa	66.1	83.5	79.9	79.2	79.1	81.7
Russia[2]	80.5	75.7	86.5	76.3	92.6	92.9
North America	27.8	27.1	28.3	29.1	29.8	29.7
Zimbabwe[3]	10.2	10.0	12.3	12.0	12.2	11.8
Others[3]	5.0	4.5	4.0	4.1	4.2	3.8
Total supply	**189.6**	**200.8**	**211.0**	**200.7**	**217.9**	**219.9**

Demand tonnes[4]	2014	2015	2016	2017	2018	2019
Autocatalyst[4]	233.8	239.1	250.2	263.4	274.6	299.6
Chemical	9.7	14.0	12.9	13.6	19.5	16.9
Dental	14.4	14.6	13.3	12.2	11.2	9.8
Electrical[4]	30.3	28.1	27.2	26.3	23.9	22.7
Investment	29.3	-20.5	-20.1	-12.0	-17.8	-2.7
Jewellery[4]	8.5	6.9	5.9	5.2	4.6	4.1
Other	3.5	4.2	4.8	4.5	5.3	5.5
Total gross demand	**329.5**	**286.4**	**294.2**	**313.2**	**321.3**	**355.9**

Recycling tonnes[6]	2014	2015	2016	2017	2018	2019
Autocatalyst	-65.9	-60.1	-61.7	-73.4	-81.7	-91.5
Electrical	-14.8	-14.8	-15.0	-15.0	-14.8	-14.7
Jewellery	-2.7	-1.4	-0.7	-0.6	-0.4	-0.3
Total recycling	**-83.4**	**-76.3**	**-77.4**	**-89.0**	**-96.9**	**-106.5**

Total net demand[7]	**246.1**	**210.1**	**216.8**	**224.2**	**224.4**	**249.4**
Movement in stocks[8]	-56.5	-9.3	-5.8	-23.5	-6.5	-29.5

Palladium gross demand by region

Tonnes

Gross demand tonnes		2014	2015	2016	2017	2018	2019
Europe	Autocatalyst	49.2	50.4	50.9	53.0	59.2	63.8
	Chemical	-0.8	2.3	2.3	2.3	2.2	2.3
	Dental	2.4	2.2	2.0	1.9	1.6	1.3
	Electrical	3.5	3.1	3.1	3.0	2.8	2.7
	Investment	-2.3	-6.2	-8.4	-8.9	-4.4	-1.7
	Jewellery	1.9	1.8	1.8	1.6	1.5	1.3
	Other	0.8	0.8	0.7	0.7	0.9	0.8
	Total	**54.7**	**54.4**	**52.4**	**53.6**	**63.8**	**70.5**

Gross demand tonnes		2014	2015	2016	2017	2018	2019
Japan	Autocatalyst	24.7	23.6	24.5	25.8	27.2	28.3
	Chemical	0.5	0.5	0.5	0.5	0.5	0.5
	Dental	6.4	7.1	6.2	5.4	4.9	4.4
	Electrical	6.7	7.2	7.1	6.9	6.2	5.8
	Investment	-0.1	0.1	-0.1	-0.1	0.0	0.0
	Jewellery	2.1	2.1	2.0	1.8	1.6	1.4
	Other	0.3	0.3	0.3	0.3	0.3	0.3
	Total	**40.6**	**40.9**	**40.5**	**40.6**	**40.7**	**40.7**

Gross demand tonnes		2014	2015	2016	2017	2018	2019
North America	Autocatalyst	61.1	63.4	62.0	63.1	66.1	65.3
	Chemical	2.2	2.4	2.3	2.3	2.4	2.3
	Dental	4.8	4.5	4.3	4.1	3.9	3.3
	Electrical	4.4	4.1	4.0	3.9	3.5	3.3
	Investment	-6.4	-5.6	-2.2	-0.6	-2.7	-0.2
	Jewellery	1.4	1.2	1.1	0.9	0.8	0.8
	Other	1.3	1.9	1.4	1.4	1.3	1.5
	Total	**68.8**	**71.9**	**72.9**	**75.1**	**75.3**	**76.3**

Gross demand tonnes		2014	2015	2016	2017	2018	2019
China	Autocatalyst	50.0	51.4	63.4	67.8	64.7	83.0
	Chemical	5.0	6.5	4.8	5.6	8.4	8.2
	Dental	0.2	0.2	0.2	0.2	0.2	0.2
	Electrical	5.3	4.9	4.9	4.8	4.4	4.2
	Investment	0.0	0.0	0.0	0.0	0.0	0.0
	Jewellery	2.4	1.1	0.3	0.3	0.1	0.0
	Other	0.5	0.5	1.4	1.6	2.2	2.2
	Total	**63.4**	**64.6**	**75.0**	**80.3**	**80.0**	**97.8**

Gross demand tonnes		2014	2015	2016	2017	2018	2019
Rest of World	Autocatalyst	48.8	50.3	49.4	53.7	57.4	59.2
	Chemical	2.8	2.3	3.0	2.9	6.0	3.6
	Dental	0.6	0.6	0.6	0.6	0.6	0.6
	Electrical	10.4	8.8	8.1	7.7	7.0	6.7
	Investment	38.1	-8.8	-9.4	-2.4	-10.7	-0.8
	Jewellery	0.7	0.7	0.7	0.6	0.6	0.6
	Other	0.6	0.7	1.0	0.5	0.6	0.7
	Total	**102.0**	**54.6**	**53.4**	**63.6**	**61.5**	**70.6**
	Grand total	**329.5**	**286.4**	**294.2**	**313.2**	**321.3**	**355.9**

Rhodium supply and demand

Troy ounces

Supply '000 oz[1]	2014	2015	2016	2017	2018	2019
South Africa	470	611	615	611	618	624
Russia[2]	80	80	85	78	69	68
North America	24	22	24	23	22	20
Zimbabwe[3]	36	36	44	42	43	40
Others[3]	7	5	5	5	5	5
Total supply	**617**	**754**	**773**	**759**	**757**	**757**

Demand '000 oz[4]	2014	2015	2016	2017	2018	2019
Autocatalyst[4]	771	760	806	834	883	1,008
Chemical	90	73	64	72	67	65
Electrical	3	3	4	5	5	6
Glass	49	52	85	110	111	52
Other	38	30	41	20	-13	14
Total gross demand	**951**	**918**	**1,000**	**1,041**	**1,053**	**1,145**

Recycling '000 oz[6]	2014	2015	2016	2017	2018	2019
Autocatalyst	-297	-277	-275	-310	-335	-363
Total recycling	**-297**	**-277**	**-275**	**-310**	**-335**	**-363**

Total net demand[7]	**654**	**641**	**725**	**731**	**718**	**782**
Movement in stocks[8]	-37	113	48	28	39	-25

Rhodium supply and demand

Tonnes

Supply tonnes[1]	2014	2015	2016	2017	2018	2019
South Africa	14.6	19.0	19.1	19.0	19.2	19.4
Russia[2]	2.5	2.5	2.6	2.4	2.2	2.1
North America	0.8	0.7	0.7	0.7	0.7	0.6
Zimbabwe[3]	1.1	1.1	1.4	1.3	1.3	1.2
Others[3]	0.2	0.2	0.2	0.2	0.2	0.2
Total supply	**19.2**	**23.5**	**24.0**	**23.6**	**23.6**	**23.5**

Demand tonnes[4]	2014	2015	2016	2017	2018	2019
Autocatalyst[4]	24.0	23.6	25.1	25.9	27.5	31.4
Chemical	2.8	2.3	1.9	2.3	2.1	2.0
Electrical	0.1	0.1	0.1	0.2	0.2	0.2
Glass	1.5	1.7	2.6	3.3	3.4	1.6
Other	1.2	0.9	1.3	0.6	-0.4	0.4
Total gross demand	**29.6**	**28.6**	**31.0**	**32.3**	**32.8**	**35.6**

Recycling tonnes[6]	2014	2015	2016	2017	2018	2019
Autocatalyst	-9.2	-8.6	-8.5	-9.6	-10.4	-11.3
Total recycling	**-9.2**	**-8.6**	**-8.5**	**-9.6**	**-10.4**	**-11.3**

Total net demand[7]	**20.4**	**20.0**	**22.5**	**22.7**	**22.4**	**24.3**
Movement in stocks[8]	-1.2	3.5	1.5	0.9	1.2	-0.8

Notes to tables

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

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

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

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

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

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

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

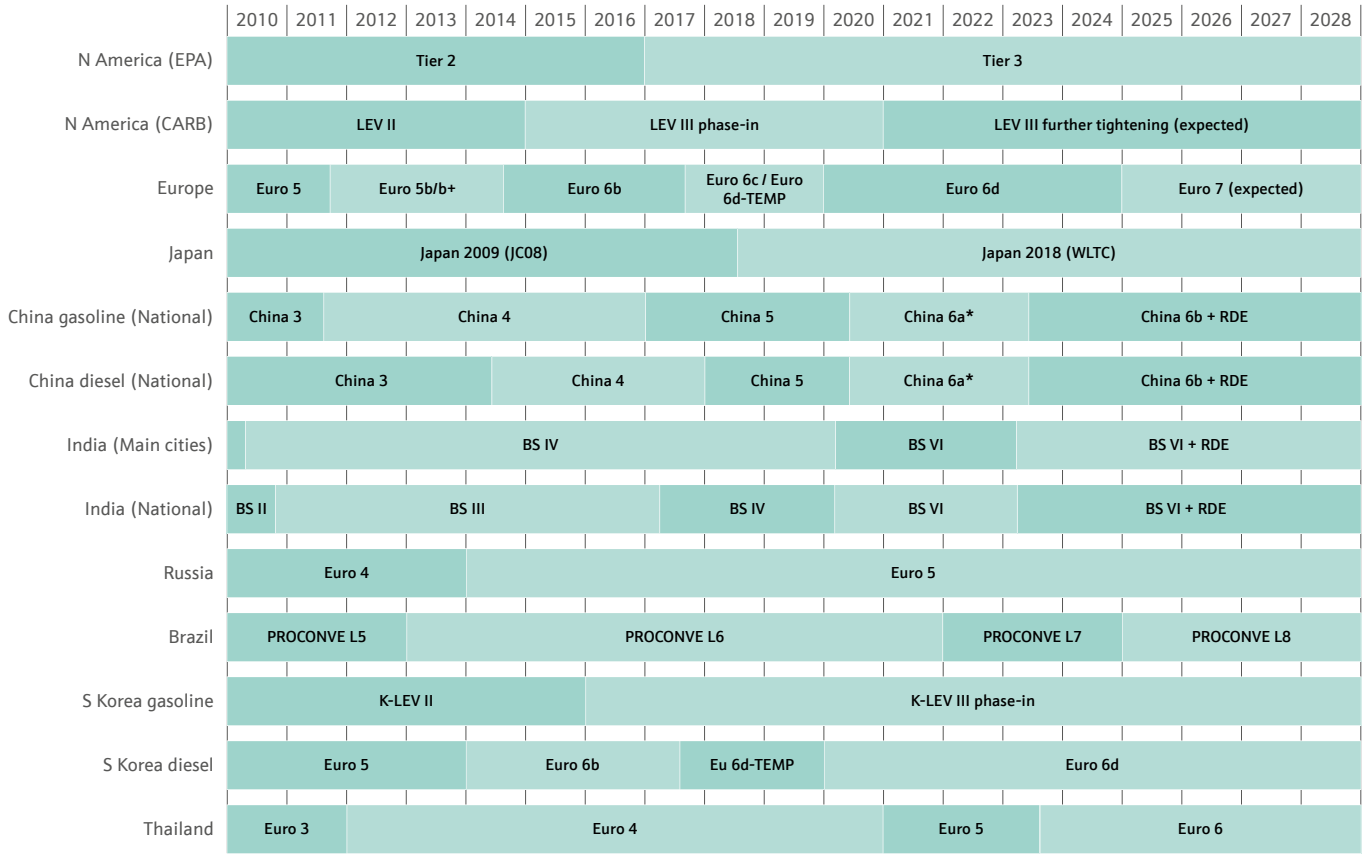
[8]**Movements in stocks** in any given year reflect changes in stocks held by fabricators, dealers, banks and depositories but excluding stocks held by primary refiners and final consumers. A positive figure (sometimes referred to as a 'surplus') reflects an increase in market stocks. A negative value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

Glossary

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

Emissions legislation

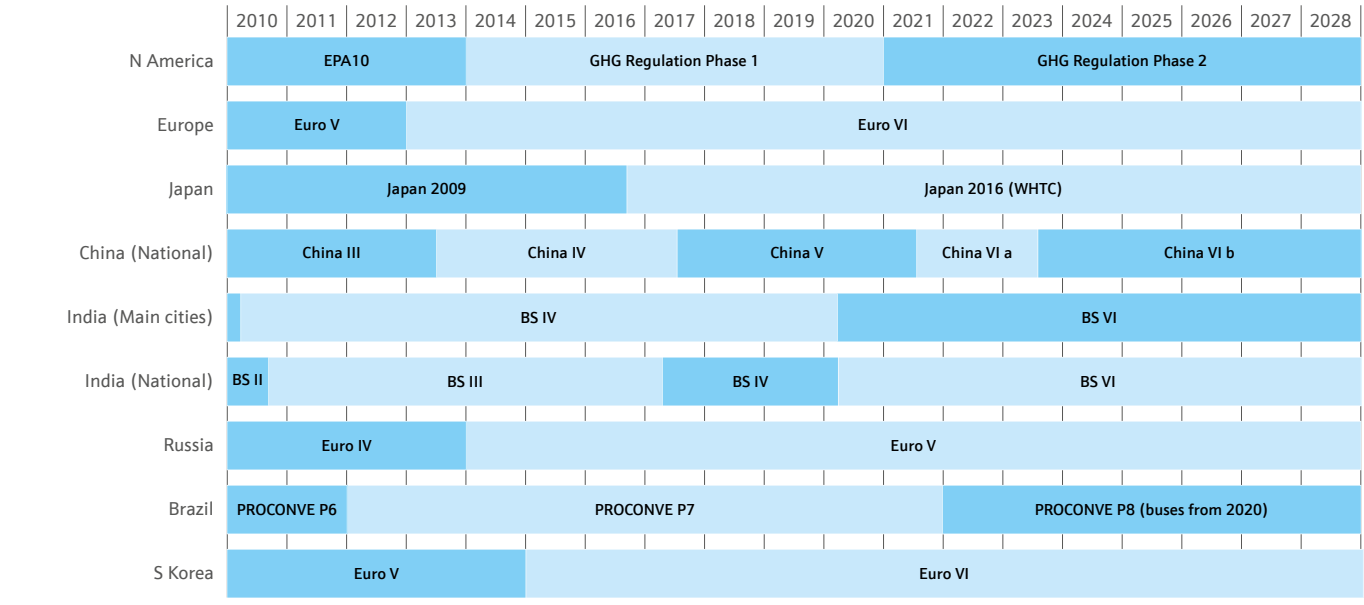
Light duty



Dates shown are for New Vehicle Type Approvals for passenger cars

*Introduction of China 6a particle number limit delayed by six months, to 1st Jan 2021

Heavy duty



Euro 6 emissions legislation

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

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

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

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

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

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

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

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

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

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

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