PLATINUM ESSENTIALS

Palladium's five-year supply/demand outlook and its role in liberating platinum for the hydrogen economy

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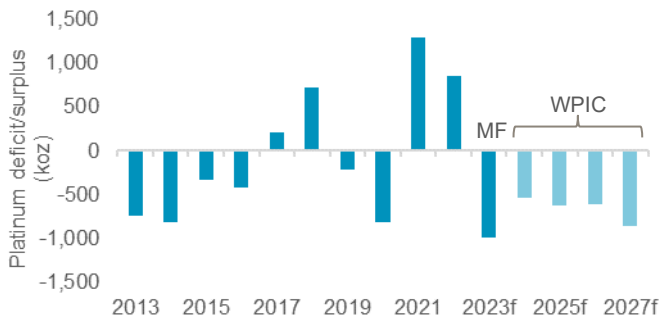
Platinum is expected to transition into a supply deficit from 2023, with consecutive deficits sustained throughout our two- to five-year market outlook to 2027. Multi-year platinum deficits, accentuated by ongoing substitution of platinum for palladium in automotive end uses, will draw-down above ground platinum stocks and tighten markets at a time of rapid acceleration in the growth of the hydrogen economy. This report introduces the WPIC's five-year palladium outlook alongside an examination of how PGM demand eventually self-solves for market imbalances to account for the fixed primary supply dynamics of polymetallic ore bodies. We expect growth in platinum for palladium substitution to continue until there is a closing of the price differential, but to eventually reverse as platinum posts ongoing market deficits and palladium moves into a surplus. Importantly, this will free up platinum supply to be made available for the rapid growth in the hydrogen economy expected in the mid to late 2020s, meaning platinum will not be a bottleneck in the development of this key energy transition technology.

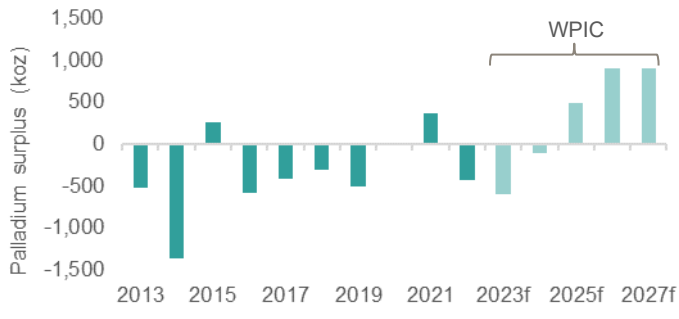
Palladium demand peaked in 2019, with the metal then reporting 8-years of consecutive supply deficits. Following automotive production impacts during COVID that resulted in palladium supply surpluses, deficits rematerialised in 2021 and 2022 despite ongoing demand challenges caused by supply chain disruptions (semi-conductor shortages), rising BEV penetration rates and, substitution for platinum. Looking ahead, we expect automotive palladium demand to stabilise as absolute vehicle sales recover to pre-pandemic levels by 2025f. However, palladium will transition to surplus markets from 2025f reaching 897 koz by 2027f, due to a 1.2 Moz increase in palladium recycling supply between 2022 and 2027. Palladium surpluses will be consecutive and increasing. In contrast, platinum is forecast to enter sustained material market deficits, reaching 851 koz by 2027f. We see diverging market balances as an incentive for reverse substitution of platinum for palladium in autocatalysts in the second half of the 2020's, freeing up platinum supply for the hydrogen economy.

Figure 1: Platinum forecast to move into market deficit from 2023



Source: Metals Focus 2013-2023f, WPIC Research 2024 onwards

Figure 2: Palladium market surplus forecast from 2025



Source: Metals Focus 2013-2022, WPIC Research 2023 onwards

**WPIC in-house supply research is based solely on published supply data, including forward looking guidance, with any adjustments noted. It does not represent the views of any WPIC members or those of Metals Focus which independently prepare our Platinum Quarterly reports. Demand data is based on public data but includes WPIC in-house analysis.*

WPIC's palladium outlook supports our platinum projections to provide an overview of the synergies between PGM's.

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Figure 3: WPIC Palladium Supply/ Demand outlook for 2023 to 2027

	METAL FOCUS ESTIMATES†			WPIC PALLADIUM ESTIMATES‡				
	2020	2021	2022	2023f	2024f	2025f	2026f	2027f
PALLADIUM SUPPLY								
Refined mine production				Production at mid-point of aggregate guidance ranges				
- South Africa	2,002	2,726	2,238	2,323	2,578	2,598	2,577	2,582
- Zimbabwe	382	407	404	376	467	471	468	471
- North America	994	897	822	705	819	855	889	906
- Russia	2,826	2,617	2,790	2,485	2,485	2,777	2,777	2,777
- Other	229	236	234	225	225	225	225	225
- Producer inventory movement								
Total mining supply	6,434	6,882	6,487	6,114	6,574	6,925	6,936	6,961
Total recycling	3,151	3,374	2,792	3,082	3,198	3,528	3,734	3,921
Total supply	9,585	10,256	9,280	9,196	9,773	10,454	10,670	10,882
PALLADIUM DEMAND								
Automotive	7,997	8,048	8,061	8,107	8,259	8,379	8,260	8,472
Jewellery	175	209	224	224	224	224	224	224
Industrial	1,526	1,572	1,504	1,465	1,394	1,362	1,289	1,289
Total investment	-104	59	-74	1	1	1	1	1
- Bar & coin	12	23	18	1	1	1	1	1
- ETF	-116	36	-92	0	0	0	0	0
Total demand	9,595	9,889	9,715	9,796	9,878	9,966	9,773	9,985
Supply/demand balance	-10	367	-435	-600	-106	487	897	897

Source: Metals Focus from 2020 to 2022, WPIC Research 2023 onwards

We forecast palladium to remain in deficit in 2023 and 2024 before moving into surpluses from 2025.

Palladium substitution for platinum supports flat demand, despite the decline in ICE production.

The surplus is a function of significant growth in palladium recycling supply.

Figure 4: WPIC Platinum Supply/ Demand outlook for 2024 to 2027

	PUBLISHED PLATINUM QUARTERLY ESTIMATES†				WPIC ESTIMATES‡			
	2020	2021	2022	2023f	2024f	2025f	2026f	2027f
PLATINUM SUPPLY								
Refined mine production					Production at mid-point of aggregate guidance ranges			
- South Africa	3,298	4,678	3,915	3,873	4,262	4,304	4,257	4,227
- Zimbabwe	448	485	480	502	502	603	603	603
- North America	337	273	263	284	311	321	331	336
- Russia	704	652	663	647	624	624	624	624
- Other	202	208	201	205	204	205	204	204
- Producer inventory movement	-84	-93	43	0	0	0	0	0
Total mining supply	4,906	6,204	5,565	5,511	5,902	6,056	6,019	5,993
Total recycling	1,997	2,079	1,691	1,682	1,869	1,832	1,868	1,861
Total supply	6,903	8,283	7,256	7,193	7,771	7,888	7,886	7,854
PLATINUM DEMAND								
Automotive	2,324	2,555	2,897	3,255	3,605	3,713	3,708	3,845
Jewellery	1,830	1,953	1,899	1,861	1,831	1,829	1,860	1,886
Industrial	2,018	2,538	2,245	2,628	2,406	2,508	2,461	2,513
Total investment	1,536	-56	-640	433	460	460	460	460
- Bar and coin	571	324	225	403	310	310	310	310
- ETF	507	-241	-558	30	150	150	150	150
- Stocks held by exchanges	458	-139	-307	0	0	0	0	0
Total demand	7,709	6,990	6,401	8,176	8,302	8,510	8,489	8,705
Supply/demand balance	-806	1,293	854	-983	-531	-621	-602	-851

†The Platinum Quarterly report and data are prepared independently for the WPIC by Metals Focus

‡WPIC estimates and analysis are based upon publically available information

Source: Metals Focus from 2020 to 2023, WPIC Research 2024 onwards

In contrast, platinum is expected to remain in deep and sustained deficits from 2023 onwards.

Introduction

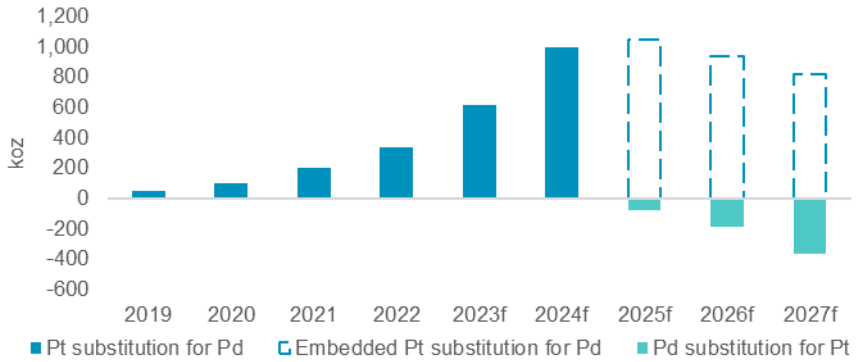
This Palladium outlook serves as a supportive piece to our Platinum Essentials two- to five-year platinum outlook and describes both the historical synergies between platinum and palladium, as well as the key role that palladium will play in supporting platinum's critical role in enabling the hydrogen economy. With a multi-year series of platinum market deficits forecast, existing above ground stocks of platinum are expected to be rapidly depleted, potentially leading to tighter market conditions that could act as a brake on the pace of growth of the hydrogen economy. Fortunately, there are existing end uses of platinum where substitution with other PGMs could free up availability of platinum to ensure it is not a bottleneck for green hydrogen. These opportunities include palladium substitution for platinum in catalytic converters, and palladium catalysts instead of platinum catalysts in select industrial applications.

We focus on automotive substitution in this report, but it is worth noting that palladium catalysts can substitute for platinum in some industrial applications, but the potential volumes are hard to estimate and unlikely to be that material.

This report analyses palladium market drivers in coordination with the outlook for platinum. Broadly speaking, we expect continued growth in automotive platinum substitution for palladium until price parity, but as we project the palladium market to enter a surplus from 2025, it seems probable that this balance will switch, and we will begin to see substitution of palladium for platinum in catalytic converters.

As already noted, this will liberate platinum for the hydrogen industry, albeit in small volumes initially as the substitution process is a lengthy one given it only occurs quickly on new models and is then locked in for the lifetime of those models, typically seven years. It will therefore take a long time to even unwind the platinum for palladium substitution we have seen and are projecting to 2025. Even so, by 2027 we forecast palladium for platinum substitution to have already reached 366 koz, which will continue to grow thereafter.

Figure 5: We expect palladium substitution for platinum to commence in 2025, but it will take time to reverse out the embedded platinum substitution for palladium that will have occurred by then



Source: Metals Focus 2019-2023, WPIC Research 2024 onwards

Platinum:Palladium auto-catalyst history

Platinum and palladium are co-products in polymetallic ores, typically found in association with the other PGMs, including rhodium, as well as gold, nickel and copper. Platinum and palladium, along with rhodium are key constituents in auto-catalysts for curbing vehicle emissions. Although there are some physiochemical differences, as part of the PGM group, they are similar enough to be interchangeable, to a point, in many applications, and specifically in catalytic converters.

A quick overview of how substitution works

Before explaining some of the main historical trends in substitution, it is worth providing a high-level overview of the process. Being closely grouped transition elements, PGMs have similar physiochemical properties, meaning that to a greater or lesser degree they can perform similar roles in different applications with variable effectiveness. Some are better suited to some applications, and others to other applications. In the case of platinum and palladium used in vehicle emissions control, platinum used in catalysts is far less prone to sulphur poisoning, while the use of some palladium in catalysts enhances stability at higher temperatures. With the declining sulphur content of fuels over the past two decades, platinum and palladium in catalysts are interchangeable on a 1:1 basis.

PGM's have many physiochemical similarities and can, to a point, be interchanged in many applications.

Setting the relative ratio of the PGMs in a catalytic converter occurs during the development of the emissions controls system for the engine of a new vehicle model or new emissions control level, to achieve subsequent regulatory certification. At which point, those ratios are locked in for the lifetime of that vehicle platform, typically seven years. Even though subsequent price movements might move the economics of the catalytic converter in an unfavourable direction, it is extremely unlikely that redesigning the emissions control system and going through the certification process again justifies the cost or risk, particularly in passenger cars. We estimate that around 15% of vehicles produced in any given year are new models where substitution during development can easily occur. As a consequence, the ebb and flow of the substitution process plays out over an extended period of time and, for example, the platinum for palladium substitution currently underway is going to be locked in for many years to come (see figure 5).

In our previous platinum quarterly, we noted projected platinum for palladium substitution in catalytic converters of 615 koz in 2023. Based upon our own two-to-five-year platinum supply demand outlook, we expect platinum substitution for palladium to continue to grow, peaking at over 1 Moz per annum by 2025. However, historical precedent reveals that substitution of platinum for palladium, and vice versa, is not a new phenomenon in either gasoline or diesel drivetrains, with the bidirectional ebb and flow a function of metal availability, security of supply, and economics (relative pricing and catalytic effectiveness).

615 koz of Platinum for Palladium substitution is projected for 2023 and over 1 Moz in 2025.

We expect platinum substitution for palladium to continue until there is a closing of the price differential.

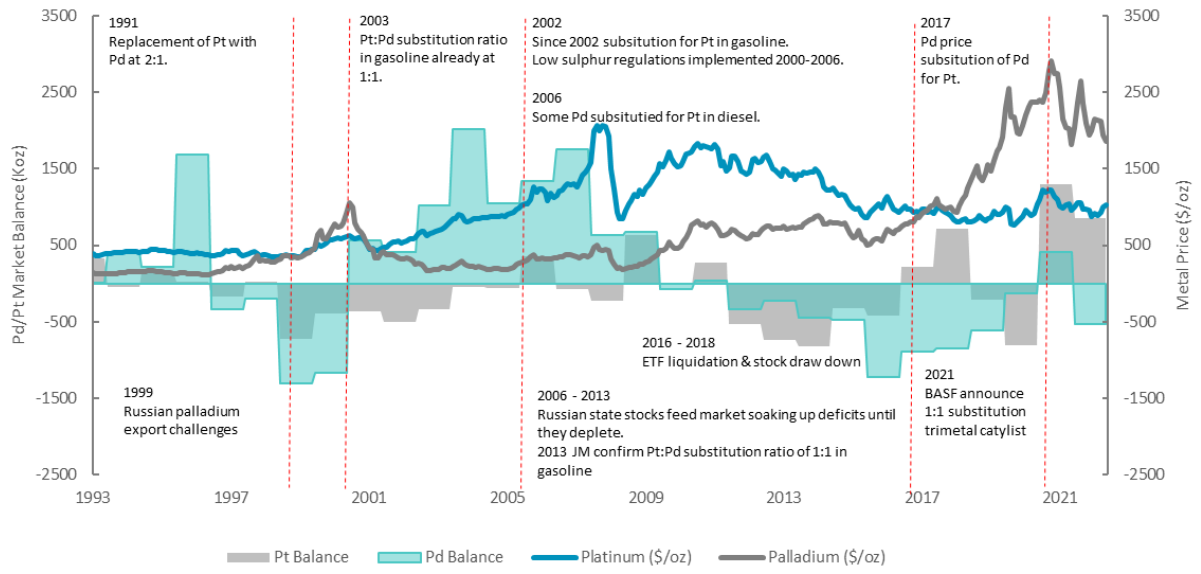
Commodity prices are impacted by supply demand/imbalances. In the event of oversupply, the price of a commodity would normally be expected to fall until uneconomic supply is curtailed, or the price falls to a level that attracts new demand into the market. Conversely, in the event of a market being in undersupply, the price of a commodity is expected to increase until new supply is attracted to the market, or demand is priced out of the market.

The polymetallic nature of PGM bearing orebodies means that there are multiple price inputs establishing the economics of production. Thus, supply is unlikely to react to the changing fortunes of any one specific commodity. Primary mine supply is therefore highly (but not totally) price inelastic.

However, the substitutability of platinum and palladium helps balance the market, to an extent, over time with the automotive sector historically switching between PGMs when market imbalances arise.

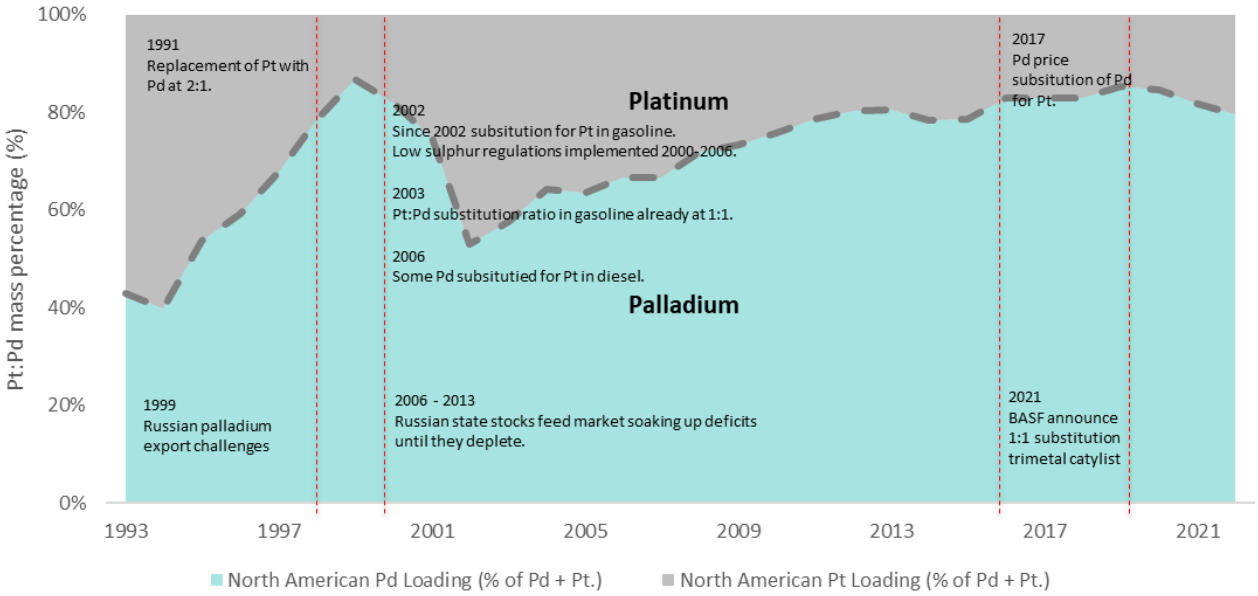
In the following section, we unpack the timing of historical substitution in coordination with underlying supply/demand fundamentals (figure 6), as well as the ratio of Platinum to Palladium used in the vehicle fleet, using the US as an example (figure 7). Significant substitution has occurred in the late 1990s, early 2000s, and since 2017. Exploring this history reveals valuable insights for the current market landscape and the next 5 years.

Figure 6: Historical precedent reveals bidirectional substitution in gasoline and diesel drivetrains based on metal availability and economic viability. Substitution of platinum & palladium has occurred following a material surplus or deficit where security of supply and subsequent price movements incentivised the change.



Source: Bloomberg, Johnson Mathey, Metals Focus, WPIC Research

Figure 7: North American markets are some of the quickest to react to changing price related economics. North American vehicles have some of the largest engine capacities, which leads to large cost savings when substitution opportunities arise.



Source: OICA, Johnson Mathey, Metals Focus, WPIC Research

1991 – 1997: Price incentivised Pd for Pt substitution

Different exhaust pollutants necessitate different temperatures for effective conversion to less harmful emissions. Palladium, platinum, and rhodium each excel in specific catalytic temperature ranges. Initially, in the 1980s, platinum-rhodium catalysts dominated NO_x reduction and CO/HC oxidation. Platinum's resistance to catalytic poisoning by sulphurous oxides was needed when fuels contained a higher sulphur content, until regulations limiting sulphur emerged in the late 1990s. To compensate for its fallibility to sulphur poisoning, palladium initially replaced platinum at a 2:1 ratio in the early 1990s. Substitution occurred due to platinum's price premium to palladium (2.8x palladium from 1993-1997) and a sustained market surplus of palladium.

1999 – 2002: Palladium export challenges reduces availability, Pt for Pd substitution.

In the late 1990's a period of bureaucratic inertia over export quotas resulted in annual Russian palladium exports halving over a three-year period. This resulted in a significant palladium deficit emerging in 1999, which in combination with a significant short-term palladium price increase prompted aggressive and significant reverse substitution with platinum being used to avoid palladium price risk. This reverse substitution was using platinum at a 1:2 ratio to replace palladium. This process was far faster than substitution in recent years as there was less integration of the engine firing electronics in emissions control and emissions limits were appreciably lower for all pollutants.

Historical precedents highlight the substitution opportunities between platinum and palladium.

2002 – 2007: Palladium surplus and lower sulphur fuels drive increased palladium use in new vehicle catalysts.

The development of lower sulphur fuels in the West, in combination with Russian export restrictions easing in 2002, resulted in palladium beginning to be reintroduced in gasoline catalytic converters and slowing the significant rate of reverse substitution in the preceding years. During this time, as diesel passenger cars were becoming more popular in Europe, it was more widely recognised that platinum's use was primarily in diesel vehicles and palladium in gasoline. This was due to the lower operating temperature of a diesel engine where palladium sulphur poisoning was accentuated. However, it was possible to introduce limited amounts of palladium in diesel emissions control, primarily in the diesel dominated heavy-duty market but also in some passenger vehicles to benefit from the depressed palladium price.

2007 – 2016: Palladium sales from Russia state reserves keep market adequately supplied.

Continuing the easing of export controls from Russia, the period 2007-11 was characterised by ongoing palladium sales from Russian state reserves (held by state agency Gokhran). This kept the market more than adequately supplied, which resulted in further palladium for platinum (reverse) substitution in gasoline vehicles, as well as to a lesser extent increased use in diesel vehicles. From 2012 onward, the palladium market switched into a period of sustained undersupply. However, the palladium price failed to react to this imbalance, and while Gokhran sales tailed off and officially ended in 2013, rumours abounded that the remaining Russian reserves had been transferred to Switzerland and were continuing to feed into the market. In combination with palladium ETF disinvestment from 2015, this maintained the substitution swing towards palladium through 2016.

2016 – present: Russian above ground stocks depleted and automakers adjust to material palladium deficit, Pt for Pd substitution.

Following nine years of consecutive palladium deficits, which exhausted Russian and Swiss palladium inventories, which in combination with a gradual drying up of the pace of palladium ETF disinvestment through the 2010s the palladium price eventually responded to significantly tightened market. The palladium price exceeded the platinum price in 2017 and with ongoing palladium deficits forecast, the expectation of substitution returned. Hints of early substitution of platinum for palladium in 2018 emerged but automakers would neither confirm nor deny any details. This was understandable as even aggressive substitution would not solve the palladium shortage, but it would provide clarity of platinum demand growth and risk an associated platinum price increase adding to the severe cost impact as palladium had risen from around $300 /oz to near $3,000/oz. We believe significant substitution by platinum for palladium occurred quickly, despite no confirmation of this, but occurred on new models which due to regulatory limit tightening for China 5/6 and Euro 6d, already necessitated system redesign, enabling manufacturers to avoid costly catalyst composition change decisions yet achieve cost effective substitution.

The announced development of a 'new' Tri-metal catalyst for gasoline aftertreatment systems further increased substitution of platinum for palladium. Significant bottom-line profit incentives of palladium savings at a 1:1 substitution ratio, as well as palladium security of supply concerns, have continued to drive this shift, increasing at least an identified 615 koz of platinum demand in 2023 and a cumulative total of over 1,300 koz to date.

Price differentials and security of supply concerns have driven platinum for palladium substitution to over 1,300 koz, cumulative to date.

With platinum continuing to trade at a discount to palladium, we expect continued growth in platinum for palladium substitution to a peak of over 1.1 Moz per annum from 2025. It is important to remember that with substitution occurring only on new vehicle models, which only account for around 15% of vehicle production in any given year, the substitution that is forecast to occur will be take a long time to unwind. However, as described below, that process will help to slowly liberate platinum for the hydrogen economy.

Reverse Substitution

As platinum heads into a series of sustained market deficits from this year (2023) and palladium heads towards a series of market surpluses from 2025, we would anticipate an eventual closure of the platinum/palladium pricing differential. Consequently, we expect the trend of platinum for palladium substitution to slow, and eventually cease with a period of palladium for platinum reverse substitution to begin from 2025. Even though we expect the substitution trend to begin to switch from 2025, we still expect 2025 to be the peak year for platinum substitution for palladium as substitution will continue to occur almost exclusively on new vehicle models with existing 7-year life platforms gradually achieving the change.

Sustained surpluses are expected in the palladium market from 2025 due to increased recycling of higher-grade palladium auto scrap (reflecting the higher palladium loadings over time to meet tighter emissions limits), and inelastic primary supply. In a surplus market, supply typically adjusts to meet demand. However, palladium supply, being a co-product of other metals, displays relative price inelasticity. For instance, although Nornickel supplies ~40% of palladium mine supply globally, in comparison to its core nickel production, palladium is not a significant enough sustainable revenue generator to be a major driver of its longer-term production plans. Conversely, while in some South African operations, at recent prices, palladium has been a significant revenue driver, which in combination with elevated rhodium prices, lead to record profitability, there were no collective efforts to expand production. Thus, the palladium supply-side response potential is limited, and we see more potential for a demand-side reaction as palladium availability increases. In

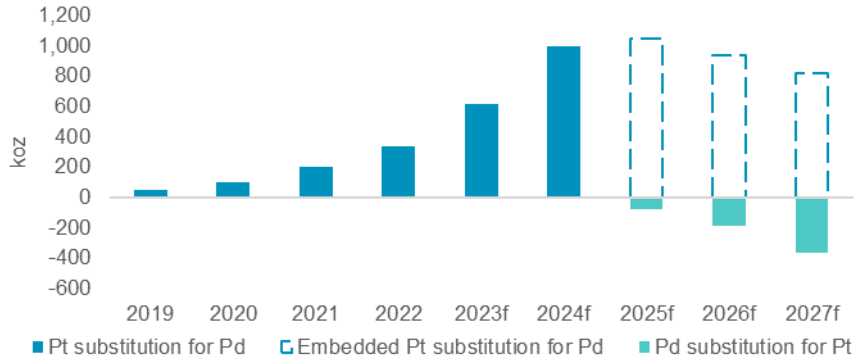
Palladium mined supply, being a co-product in polymetallic orebodies, displays relative price inelasticity. We see a demand response to palladium oversupply as being more likely.

contrast, the platinum market is forecast to face sustained deficits, supported by continued growth in demand from automotive and industrial applications, as well as the rapid growth in demand linked to green hydrogen (Fuel Cell Electric Vehicles (FCEVs), electrolysers etc), albeit off a small starting base.

Platinum for palladium substitution in automotive end uses is expected to peak at over 1 Moz in 2025.

As the platinum market tightens but palladium moves into oversupply, automakers are likely to reverse the substitution trend in new vehicle models. Our base case assumes reverse substitution to occur at a rate limited to new vehicle models, which as mentioned is estimated to be around 15% of annual vehicle production. We expect this to result in aggregate resulting in approximately 366 koz of additional annual palladium demand by 2027, which will continue to grow thereafter.

Figure 8: Platinum substitution for palladium has risen to 615koz p.a. it is expected to peak in 2025, following this we have taken the view that palladium availability will incentivise reverse substitution.



Source: Metal Focus 2018-2023, WPIC Research 2024 onwards

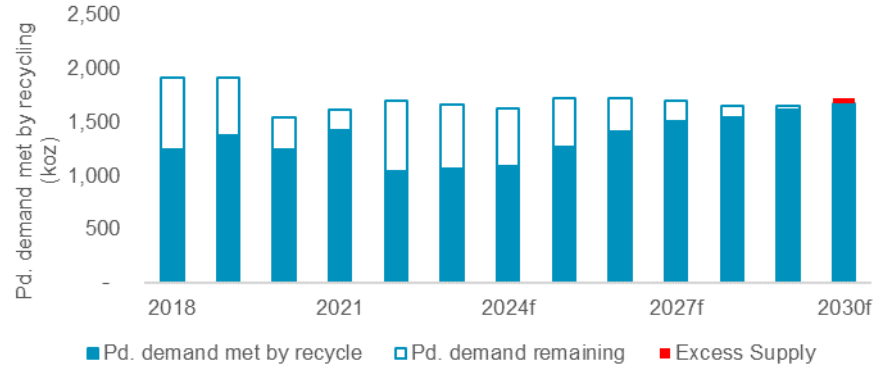
Palladium for platinum substitution estimated to reach 366koz by 2027 - a reversal of recent trends.

Security of supply concerns allayed by recycling mix

One of the other factors behind recent and ongoing platinum for palladium substitution has been security of supply concerns given the magnitude of Russian supply to the global palladium market (40% of mined palladium supply vs. 11% of mined platinum supply), especially in the wake of Russia's invasion of Ukraine.

This is a valid concern for the next couple of years, but looking ahead, we expect a significant increase in the recycling supply of palladium. With reference to figure 9 and considering the average age of scrapped vehicles being around 12 years, the increased supply of recycled palladium is a function of the vehicles being recycled over next few years being increasingly palladium heavy, particularly in North America and Europe. Indeed, our research suggests that by 2029 and 2030, Europe and North America palladium recycling supply will surpass identified automotive demand.

Figure 9: The North American palladium market achieves circularity by 2030 with recycling supply outpacing identified demand.



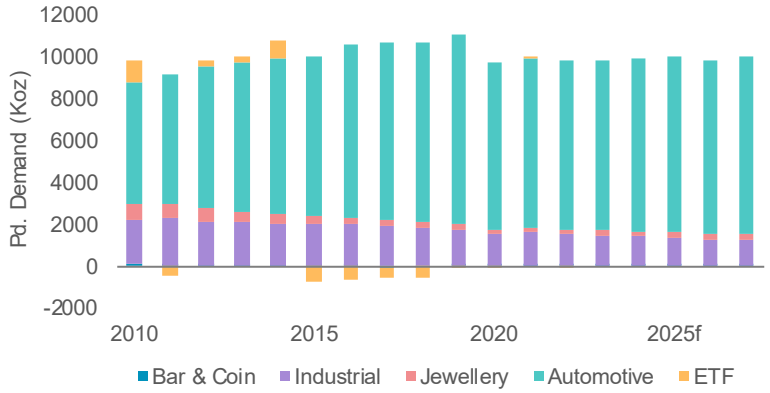
Source: WPIC Research, Johnson Matthey, SFA (Oxford) 2013 – 2018, Metals Focus 2019 – 2022, WPIC research 2023 onwards

Increasing palladium scrap supply can provide increased in-country critical metal security as supply surpasses identified automotive demand in North America by 2030.

Palladium supply/demand outlook 2023-2027

The 5-year WPIC palladium outlook is characterised by a shift from a decade long palladium deficit to sustained market surpluses. Automotive demand for palladium grows modestly, which rises to a high of 8,500 koz, albeit remaining some way below the pre-COVID record of 9,000 koz. This is partially offset by declining industrial demand and flat jewellery demand.

Figure 10: Industrial and jewellery demand decline offset automotive growth resulting in a flat overall demand profile below that of pre-COVID records.



Source: Johnson Matthey, SFA (Oxford) 2013 – 2018, Metals Focus 2019 – 2022, WPIC research 2023 onwards

Supply-side drivers define the forecast, increasing cumulatively over the forecast period by over 1.2Moz. The biggest driver of supply growth is scrap supply, supported by the end-of-life vehicles being scrapped in the outlook period typically having higher palladium loadings, coming from a period of increasingly stringent emission standards being imposed on vehicle fleets, and therefore overall higher PGM loadings. Total supply is additionally supported through increased mine supply as Russian and South African supply returns to historic output levels, based upon the mid-point of aggregated public company guidance. This may represent a challenging collective target given the impact of sanctions on Russian companies, and the sociopolitical, basket price, and electricity shortage challenges in South Africa.

The key takeaways for the period 2023-2027 are presented below (all figures are presented as the growth/decline from 2022 to 2027f):

- **Total Mining Supply** is forecast to rise by 7% driven by Russian and South African mine supply normalisation post smelter maintenance. Risks involve South African load shedding and Russian adaptation to Western sanctions affecting OEM suppliers.
- **Recycling Supply** is forecast to be 40% higher by 2027, attributable to vehicles with high palladium loadings reaching end of life across regions with mature emissions legislation.
- **Automotive demand** is forecast to increase by 5% by 2027. This growth comes from palladium for platinum reverse substitution in catalytic converters, as well as higher loadings due to more stringent emission standards and increased drivetrain hybridisation.
- **Industrial Demand** is forecast to be 14% lower over the period as electronic and medical applications continue thrifting and substitution trends for cheaper ceramics and base metals.

We forecast the palladium market to remain in a substantial deficit of 600 koz in 2023, owing to smelter maintenance and electricity shortages impacting supply, coupled with a flat demand profile. We expect the deficit to ease to 106 koz in 2024, before entering a period of growing and sustained year-on-year palladium surpluses, which are the result of the compounding effect of

secondary supply growth outpacing demand-side gains. Palladium enters a sustained surplus whilst concurrently platinum enters sustained deficits.

Figure 11: WPIC Palladium Supply/ Demand outlook for 2023 to 2027

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Total recycling	**3,151**	**3,374**	**2,792**	**3,082**	**3,198**	**3,528**	**3,734**	**3,921**
Total supply	**9,585**	**10,256**	**9,280**	**9,196**	**9,773**	**10,454**	**10,670**	**10,882**
PALLADIUM DEMAND								
Automotive	**7,997**	**8,048**	**8,061**	**8,107**	**8,259**	**8,379**	**8,260**	**8,472**
Jewellery	**175**	**209**	**224**	**224**	**224**	**224**	**224**	**224**
Industrial	**1,526**	**1,572**	**1,504**	**1,465**	**1,394**	**1,362**	**1,289**	**1,289**
Total investment	**-104**	**59**	**-74**	**1**	**1**	**1**	**1**	**1**
- Bar & coin	12	23	18	1	1	1	1	1
- ETF	-116	36	-92	0	0	0	0	0
Total demand	**9,595**	**9,889**	**9,715**	**9,796**	**9,878**	**9,966**	**9,773**	**9,985**
Supply/demand balance	**-10**	**367**	**-435**	**-600**	**-106**	**487**	**897**	**897**

Source: Metals Focus from 2020 to 2022, WPIC Research 2023 onwards

Figure 12: WPIC Palladium Supply/ Demand outlook for 2023 to 2027

	PUBLISHED PLATINUM QUARTERLY ESTIMATES†				WPIC ESTIMATES‡			
	2020	2021	2022	2023f	2024f	2025f	2026f	2027f
PLATINUM SUPPLY								
Refined mine production					Production at mid-point of aggregate guidance ranges			
- South Africa	3,298	4,678	3,915	3,873	4,262	4,304	4,257	4,227
- Zimbabwe	448	485	480	502	502	603	603	603
- North America	337	273	263	284	311	321	331	336
- Russia	704	652	663	647	624	624	624	624
- Other	202	208	201	205	204	205	204	204
- Producer inventory movement	-84	-93	43	0	0	0	0	0
Total mining supply	**4,906**	**6,204**	**5,565**	**5,511**	**5,902**	**6,056**	**6,019**	**5,993**
Total recycling	**1,997**	**2,079**	**1,691**	**1,682**	**1,869**	**1,832**	**1,868**	**1,861**
Total supply	**6,903**	**8,283**	**7,256**	**7,193**	**7,771**	**7,888**	**7,886**	**7,854**
PLATINUM DEMAND								
Automotive	**2,324**	**2,555**	**2,897**	**3,255**	**3,605**	**3,713**	**3,708**	**3,845**
Jewellery	**1,830**	**1,953**	**1,899**	**1,861**	**1,831**	**1,829**	**1,860**	**1,886**
Industrial	**2,018**	**2,538**	**2,245**	**2,628**	**2,406**	**2,508**	**2,461**	**2,513**
Total investment	**1,536**	**-56**	**-640**	**433**	**460**	**460**	**460**	**460**
- Bar and coin	571	324	225	403	310	310	310	310
- ETF	507	-241	-558	30	150	150	150	150
- Stocks held by exchanges	458	-139	-307	0	0	0	0	0
Total demand	**7,709**	**6,990**	**6,401**	**8,176**	**8,302**	**8,510**	**8,489**	**8,705**
Supply/demand balance	**-806**	**1,293**	**854**	**-983**	**-531**	**-621**	**-602**	**-851**

†The Platinum Quarterly report and data are prepared independently for the WPIC by Metals Focus

‡WPIC estimates and analysis are based upon publically available information

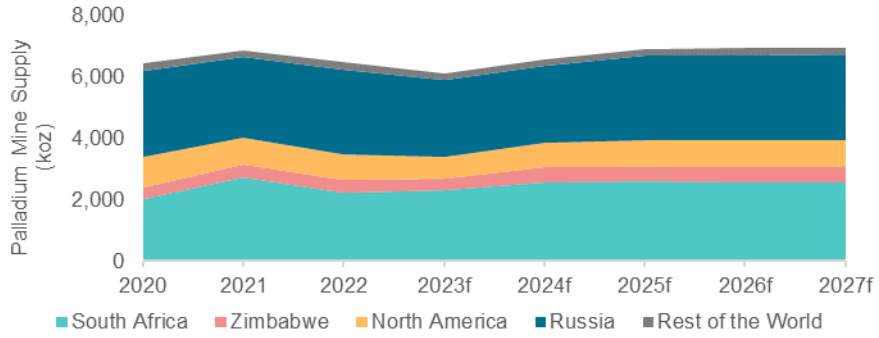
Source: Metals Focus from 2020 to 2023, WPIC Research 2024 onwards

Palladium Supply Outlook

Primary Mine Supply

Using the mid-point of published public guidance for all producers globally suggests palladium mine supply is forecast to drop 6% in 2023. This reflects a number of mining companies having made downgrades to public guidance due to regional refinery maintenance and operational challenges such as the electricity shortage in South Africa. As things stand at present, aggregate company guidance indicates that production is expected to normalise, with the 4-year average (2024-2027) at 6,849 koz, within 1% of the trailing 5-year average of 6,770 koz.

Figure 13: Global palladium mine supply outlook



Source: Metals Focus from 2020 to 2022, WPIC Research 2023 onwards.

Power disruptions continue to impact South African mine supply, but is not necessarily fully baked into 2024 and longer-term guidance.

The guidance for South African refined palladium mine supply in 2023 indicates a 10% reduction compared to the average production between 2015 and 2019 (pre-COVID). While primary supply is expected to recover to near pre-COVID levels between 2024 and 2027, output is likely to plateau from 2025. Capital investments in the region are primarily focused on maintaining existing production levels due to basket price volatility and inflationary and recessionary risks weighing on investment decisions. Rising interest rates also present challenges for new projects, impacting expected returns unless there is a corresponding increase in commodity prices.

Russian (Nornickel) annual mine production guidance forecasts an 11% decrease year-on-year in 2023 due to planned smelter maintenance. Despite sanctions against Russia, Nornickel has managed to maintain output at planned levels so far. The smelter re-build will occur without Western OEM expertise and Nornickel's project execution amid sanctions could offer insights into future production expectations. The smelter rebuild is currently scheduled to be completed in 2024. Nornickel has previously spoken to expansion plans, driven by its desire to increase output of the class I nickel needed for lithium-ion batteries, which would in turn boost the output of palladium (and to a lesser extent platinum). In the wake of the sanctions applied since Russia's invasion of Ukraine, the company has pulled medium- and long-term guidance, leaving a lack of clarity regarding its expansion plans. However, sanctions in combination with Indonesia's ramping up of NPI to battery grade nickel conversion capacity have likely changed the economics of Nornickel's plans, which may call them into doubt.

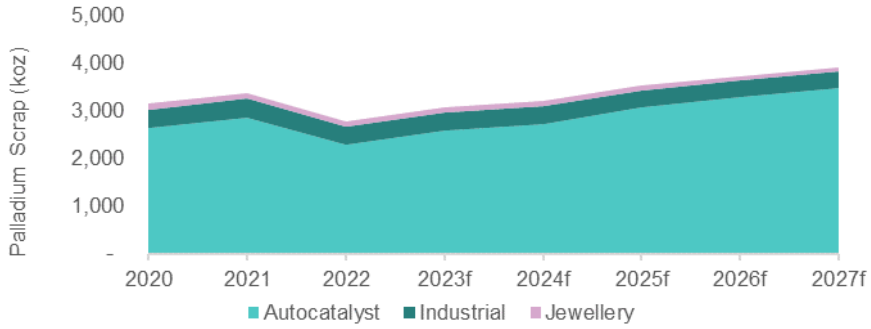
Elsewhere, Zimbabwean mine production is expected to grow over the forecast period (2023–2027) by 95koz and could see further upside as miners favour its shallow operating depths, more consistent electricity supply. North American guidance highlights a rise in palladium production of 201koz following the planned repair of shaft damage at the Stillwater mine and expanded byproduct output from Canadian nickel operations.

Secondary Supplies

We expect growth in secondary palladium scrap additions, primarily from autocatalyst recycling partially offset by declining industrial and jewellery segments. We have used a methodology of projecting recycling output based upon historical trends in vehicle models, loadings and average vehicle age at the point of scrappage. We do not attempt to adjust for changes observed in recovery rates driven by moves in PGM prices as a) we think the economics of the car breaking and scrappage industry likely only allows for short-term efforts to game pricing, and b) we do not forecast PGM prices.

As already highlighted, the increasing palladium loadings applied to vehicles during the 2010's are beginning to flow through to the recyclers and will be a major factor behind the increase in recycled palladium supply. In contrast for platinum, during this period its use in catalytic converters was increasingly biased to diesel vehicles, the silicon carbide substrates of which are, we understand, subject to processing constraints, limiting recycling rates.

Figure 14: Globally palladium output from auto catalyst recycling is forecast to rise 52% on 2022 levels, rising by 1.2 Moz to 3.5Moz in 2027.

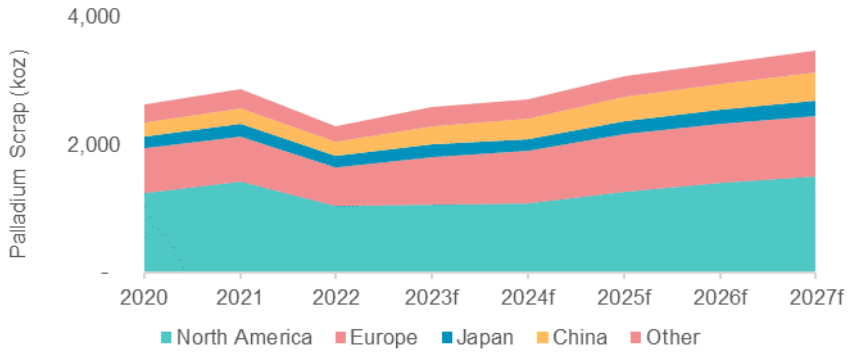


Palladium scrap supply to rise 52% on 2022 levels by 2027.

Source: Metals Focus from 2020 to 2022, WPIC Research 2023 onwards.

The increase in palladium recycling supply from end-of-life catalytic converters is particularly acute in Europe and North America, with recycling forecast to reach record highs in 2027 at 1,500 koz and 950 koz respectively. Vehicle recycling rates in Western markets is expected remain steady due to their well-established secondary supply chains. China's recycling sector is evolving, and its rate is projected to rise by 7% over the forecast period, leading to a doubling of its auto scrap recycle supply from 213 koz in 2022 to 444 koz in 2027. This in part reflects the end-of-life vehicles coming through in China now being the first to have emissions control systems containing meaningful levels of PGMs, mainly palladium.

Figure 15: Recycling palladium supply is dominated by Europe and North America; however, China's sector is quickly evolving.



Source: Metals Focus from 2020 to 2022, WPIC Research 2023 onwards.

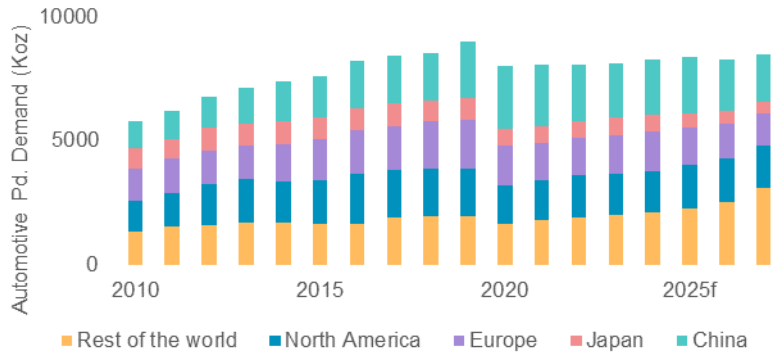
Palladium Demand Outlook

Automotive Demand

PGM demand in the automotive sector will be shaped by regional dynamics. Mature automotive markets in North America, Europe and China are expected to steadily transition towards electric mobility, although not all vehicle roles and geographies, even in these markets, will be suitable for battery electrification with current technologies. We also expect electrification to be a feature in emerging economies (captured as part of 'Rest of the World'), but at the same time we forecast an overall growth in traditional internal combustion engine vehicles on increasing total vehicle ownership. Additionally, the adoption of increasingly stringent emission legislation in these regions will contribute to a steady overall increase in automotive PGM demand even as EV penetration increases. Palladium demand is forecast to rise at 1.2% CAGR over a 5-year period to a post COVID high in excess of 8,500 koz by 2027.

Geographic production trends

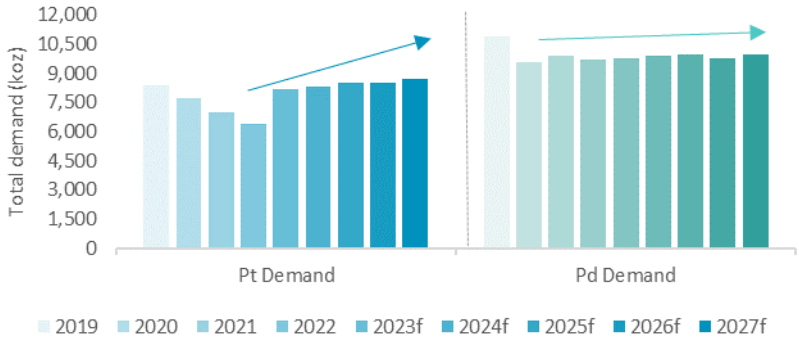
Figure 16: Automotive demand for palladium rises 6% versus the post COIVD depression by 2027 driven by regionally divergent trends.



Source: Johnson Matthey, SFA (Oxford) 2013 – 2018, Metals Focus 2019 – 2022, WPIC Research 2023 onwards.

Despite ongoing drivetrain electrification trends, increasingly stringent emission regulations in emerging economies will contribute to a steady increase in palladium automotive demand.

Figure 17: Rising platinum demand above pre-COVID levels contrasts with a flat outlook for palladium.



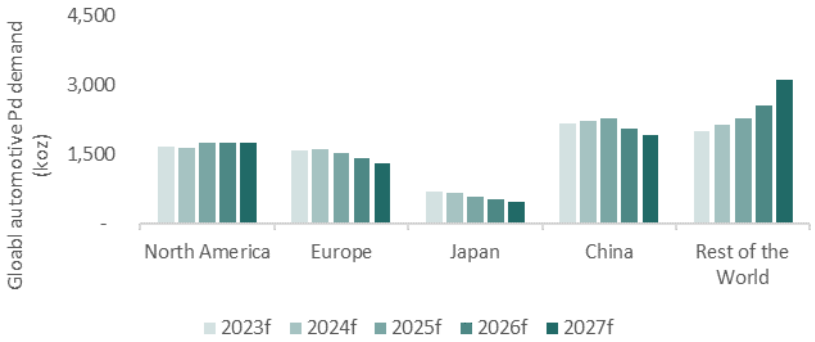
Source: Metals Focus 2019 – 2022 (Pd) and 2019 – 2023 (Pt), WPIC research onwards.

Vehicle production is poised for growth through 2027, despite downward revisions to forecasts due to higher long-run interest rates and eroded purchasing power. Light vehicle production is forecast to once again exceed pre-covid levels of ~93M by 2027, with a CAGR of 2.8% outpacing pre-2018 5-year growth of 2.3%. We believe this growth in the near term will be driven by pent up demand for replacement vehicles following a period of under-production during COVID and the semi-conductor crisis. Furthermore, with automaker inventories still running at historically reduced levels, we expect some automaker and dealer restocking to occur, bolstering vehicle production.

While this is our base case outlook, financing costs given elevated interest rates present a significant risk to this outlook that cannot be ignored. That said, financial pressures should abate as interest rates fall, as they are forecast to do from 2024.

Although total vehicle numbers rise, PGM demand growth is more nuanced and will be defined regionally according to the changing drivetrain mix. Palladium demand will benefit primarily from gasoline light duty vehicle growth in the 'Rest of the World' and increasing hybridisation (hybrid vehicles require higher PGM loadings than conventual ICE vehicles to meet emissions targets at lower exhaust temperatures), offsetting growing levels of BEV penetration in China and the West.

Figure 18: Palladium demand in the rest of the world rises 62% on increased ICE sales and stricter loadings. North America retains elevated levels of palladium demand across the forecast with increasing levels of hybridisation. Whilst China and Europe are on a trajectory of increasing BEV penetration.



North America and the 'rest of the world' support automotive demand through increased hybridisation and light duty gasoline vehicle growth.

Source: Metals Focus from 2020 to 2022, WPIC Research 2023 onwards, OICA.

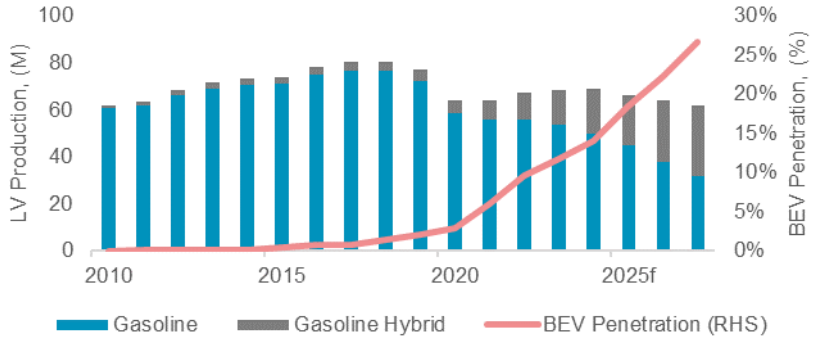
Vehicle Electrification, FCEV and PGM Demand

The accelerating shift towards battery electric vehicles (BEVs) has raised concerns about the future demand for palladium, particularly in light of its heavy demand reliance on the exhaust treatment systems for internal combustion engines (~80% of total palladium demand). This stands in contrast to the more diverse end markets for platinum (only ~40% automotive). Battery electric vehicle (BEV) production increased by 73% year-on-year in 2022. We expect BEV production to increase by a 26% CAGR between 2022 to 2027 to 25M units to reach a global penetration of 27%. However, it is well documented that not all vehicle roles or geographies are suitable for battery electrification with current technologies.

Hybrids provide an intermediatory solution in hard to electrify regions. Containing 10% to 15% more PGM's than traditional ICE equivalents; their broader adoption provides a boost to automotive palladium demand.

Hybrids offer a transitional solution towards full electrification and are likely to witness strong adoption rates in regions with limited charging infrastructure or large travel distances. North America will see the highest gasoline hybrid penetration rates, rising to 55% and contributing to a +78 koz rise in total automotive demand for palladium through to 2027, despite falling traditional internal combustion sales. Globally, the combined gasoline ICE and gasoline hybrid vehicle outlook remains flat in 2027 compared to 2020 levels, as increased hybrid uptake offsets declining pure ICE vehicle sales. It is worth noting this is not at odds with increasing BEV penetration as we expect continued aspirational vehicle ownership to drive total light vehicle production higher. Importantly, hybrids typically contain PGM loadings 10% to 15% higher than their traditional ICE equivalents, in order to meet emissions limits when operating at lower and less efficient exhaust temperatures (a function of the temperature variations that come with stop-start use of an hybrid ICE engine). On a separate note, while not factored into our base-case drivetrain forecasts, we reported that there is a risk that a potential lithium shortage could constrain BEV production levels.

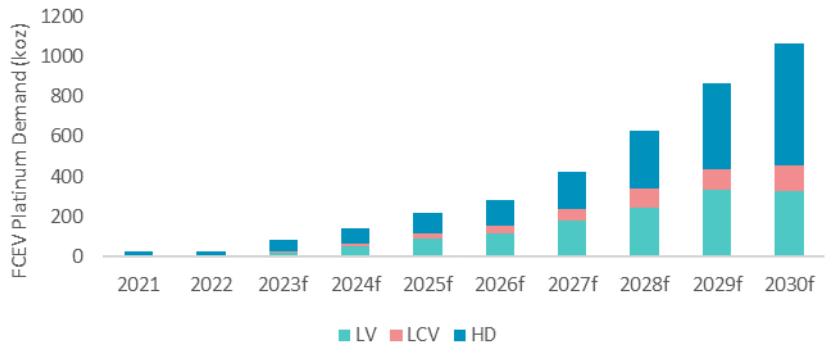
Figure 19: Automotive demand for palladium is expectation to be sustained for some time to come. Higher palladium loadings for hybrid vehicles offset an ongoing decline in traditional ICE vehicles production.



Source: WPIC Research, OICA.

Fuel cell electric vehicles (FCEVs) are poised for rapid growth, expected to reach nearly 1.5 million units by 2030. Although this represents less than 2% of the vehicle market share at that time, FCEVs will excel in high-capacity and high-utilisation areas. Their comparatively lighter drivetrain (versus an equivalent BEV vehicle) minimises the loss in load capacity to battery weight, while quick refuelling suits long-distance and high capacity-utilisation transportation. These advantages position them as a cost-effective green transportation solution, predominantly in commercial and heavy-duty sectors. Heavy-duty fuel cells can contain up to eight times more platinum than diesel counterparts, and by 2030 FCEV demand for platinum is expected to reach around 1,000 koz p.a. Unlike platinum and iridium, palladium is currently not used in FCEV catalysts due to its lower catalytic activity at PEM fuel cell operating temperatures, and lesser resistance to catalyst poisoning. While palladium sees usage elsewhere in the hydrogen economy, assuming no significant change to current technologies, it won't receive the same automotive demand surge as platinum.

Figure 20: Over 1,000 koz will be added to Platinum automotive demand by 2030 from FCEV applications, with HD being the main driver.



Source: Metals Focus (2021 – 2022), WPIC Research 2023 onwards.

FCEV growth will spur platinum demand growth. Palladium does not receive the same benefit, but it will see usage elsewhere in the hydrogen economy.

Legislation

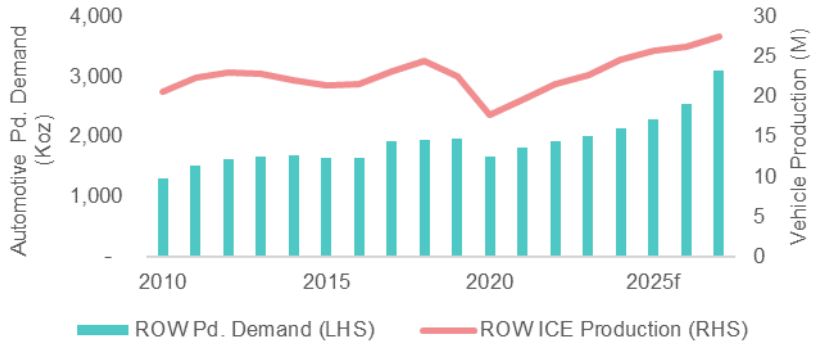
Emission standards will continue to shape demand dynamics as countries strive to strengthen their legislation and testing protocols. For example, India's adoption of Bharat Stage 6 standards and the US phasing in Tier 3 will bolster demand, leading to incremental gains as new vehicle models adhere to these higher standards. On the other hand, the widely speculated delay of Euro 7 standards until post 2027, is projected to result in a decrease of 216 koz in European automotive demand for palladium over the forecast period.

Increasingly stringent emissions standards in developing vehicle economies such as India, lag the West and now also China (where standards have caught the West and, in some areas, overtaken). Nonetheless, the evolution of

emissions legislation and growth of vehicle demand, biased towards ICE, in countries like India mostly parallels China's historical journey. This trend serves as a guide for palladium demand growth in the "Rest of the World", which is projected to experience a significant 10.1% compound annual growth rate (CAGR) and become the largest demand geography over the forecast period to 2027.

A 10.1% CAGR is projected in 'the rest of the world' automotive demand segment as emerging economies develop their emission legislation and become the largest demand geography over the forecast period.

Figure 21: Growing emission standard compliant ICE vehicle production in the 'Rest of the World' bolsters Palladium demand by 62% (2022 to 2027).



Source: OICA, WPIC Research, Johnson Matthey, SFA (Oxford) 2013 – 2018, Metals Focus 2019 – 2022, WPIC Research onwards.

In the United States, the Tier 3 emission standards are being gradually phased in to reduce vehicle emissions and improve air quality. By setting tighter limits on pollutants, these regulations necessitate the use of more effective catalytic converters, positively impacting palladium demand as new vehicles are designed to comply with these standards. Despite increasing BEV penetration, levels of ICE hybridisation North American sustains automotive demand for palladium demand growth over the forecast period.

However, the European Union's Euro 7 emission standards, initially planned for introduction around 2025 have been watered down, and are expected to face delays due to technical and legislative complexities, as well as industry opposition. On the one hand, delays reduce the potential future loadings on ICE vehicles, on the other, future ICE affordability is significantly improved which is likely to result in higher ICE vehicle production numbers. On balance, we think that continued BEV penetration in Europe will continue to be the main driving factor, gradually reducing European automotive demand for palladium.

In summary, the introduction of more stringent emission standards will continue to play a pivotal role in shaping the outlook for the palladium demand for years to come, through the long tail of declining ICE production. Within this demand shift from Europe, North America and China, toward the emerging economies and regions difficult to electrify.

Industrial demand

Total industrial demand is poised to decrease by 14% by 2027, hitting around 1,300 koz. This drop is fuelled by the contraction in consumer electronics demand for palladium and substitution across applications like multi-layer ceramic capacitors (MLCC) and dental usage. Palladium is vital for high-reliability MLCC applications (such as within defence tech.) and semiconductor lead frames. However, elevated metal prices have led to thrifting and substitution efforts. Palladium's use in lead frames remains stable; its high-cost drawback is surpassed by its closest substitute gold, which trades at a premium as of 2023. Electrical demand decline is driven by diminishing MLCC use, with total electrical demand estimated to fall at a -5.0% CAGR from 2023 to 2027.

Palladium demand for electrical and medical applications is forecast to be lower as substitution for cost effective base metals and ceramics increases.

Dental demand is steadily dropping despite improved global access to dental healthcare. The availability of cheaper substitutes, such as base metal alloys, ceramics, and resins have facilitated the decline. Japan, the largest dental

market, includes palladium alloys in state health insurance coverage. However, the price exceeding the subsidy threshold has led to outstanding payments by dental practitioners. Reluctantly, dental practices are shifting to lower cost substitutes, which are fully covered by insurance schemes, resulting in a projected demand decrease in the forecast period.

Chemical demand is set to surge by 8% YoY in 2023, approaching 500 koz and maintaining momentum into 2024. This growth is linked to the legacy of China's 13th five-year plan in 2016, driving bulk chemical capacity additions in a previously underdeveloped industry. PGMs, particularly palladium, are crucial catalysts for various bulk chemicals like PTA, VAM, and Nitric Acid. Initial industrial plant capacity additions drive the bulk of demand, followed by internal recycling with minor annual additions. As the petrochemical sector capacity additions slows down due to market saturation, we project chemical demand to peak at 490 koz in 2023 and then stabilise at around 420 koz over the medium to long term.

Palladium chemical demand is set to peak in 2023, followed by a tail of as capacity additions in China slow down.

Table 1: Chemical products for which palladium-based catalysts are critical:

Precursor Product	Product
Purified Terephthalic Acid (PTA)	Polyester
Vinyl Acetate Monomers (VAM)	Polyvinyl acetate and polyvinyl alcohol
Nitric Acid	Fertiliser

Jewellery demand

Today, jewellery accounts for a negligible amount of palladium demand, accounting for only about 2% of total annual demand, which is not expected to change materially going forwards.

Hydrogen: Palladium industrial demand potential

Although green hydrogen is a platinum biased storey, there *are* palladium opportunities within the hydrogen economy. Palladium can serve as a catalyst for hydrogen purification, hydrogen storage, and for hydrogen carriers. Additionally, it will play a role in reducing harmful nitrous oxides from ammonia combustion, a zero-emission fuel that is an option for maritime decarbonisation.

Hydrogen purification is essential due to remove impurities present in hydrogen produced from different sources. Clean hydrogen is crucial for fuel cells and other applications. Palladium, platinum, and Pt/Pd alloys catalyse this purification process, much as they do in exhaust treatment systems.

Meanwhile, liquid organic hydrogen carriers (LOHC) are emerging as a solution for safe hydrogen transportation and storage. Palladium and platinum catalyse the hydrogenation and dehydrogenation of LOHC, facilitating hydrogen absorption and release. Palladium initially dominated this technology but lost ground to lower-priced platinum, given their interchangeability.

While palladium comprises just 1% of hydrogen PGM demand in 2023 (per Metals Focus), its market is nascent, with applications largely in early development. Platinum holds a dominant 67% share in PGM hydrogen demand, particularly in high-volume applications like FCEVs due to its optimal activity in harsh operational conditions. Yet, palladium exists as a price-sensitive viable alternative for some processes like LOHC and purification. With growing palladium surpluses and deepening platinum deficits, mirroring the auto catalyst trend, we anticipate an upswing in industrial palladium chemical demand in the medium to long term.

Appendix: Palladium demand history

Understanding past drivers assists in applying context and understanding to the outlook for the metal. Palladium's catalytic properties, relative abundance, and historical price discount to platinum, have resulted in it being used in a multitude of end uses. These span from automotive catalytic converters to industrial applications such as hydrogen peroxide and petrochemical production, to semi-conductor manufacturing in electronics and medical applications.

However, even though palladium has a variety of uses, total demand is exceptionally concentrated, with ~80% of demand accounted for by auto-catalysts. This is a trend that has run for the last decade with industrial demand for palladium having declined from 25% in 2010 to only 15% today. Palladium's fundamentals and therefore outlook, are inherently intertwined with trends in the automotive sector, and it's use within it.

For the automotive sector, palladium's catalytic properties make it an essential component in gasoline-powered vehicle catalytic converters, helping to reduce harmful emissions. It facilitates reactions such as oxidation of carbon monoxide (CO) to carbon dioxide (CO2) and conversion of nitrogen oxides (NOx) into nitrogen and oxygen, reducing the emission of these harmful pollutants into the atmosphere. Palladium is also used in diesel-vehicles, albeit in small quantities with platinum being the preferred catalyst due to its resistance to sulphur poisoning.

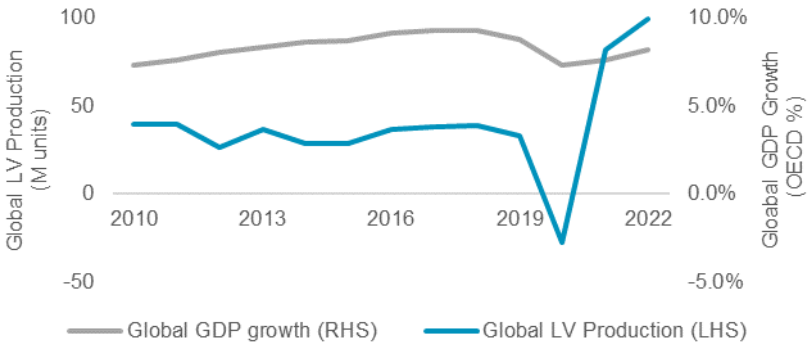
The past decade has been characterised by record rising palladium demand, which peaked at an all-time high of 11 Moz in 2019 before turning sharply lower due to COVID. Thereafter, palladium' demand has flat-lined, due to COVID, the semi-conductor crisis and the increasing market share of battery electric vehicles, as well as platinum substitution for palladium in gasoline vehicles limiting automotive demand for platinum.

Palladium demand drivers

Palladium autocatalyst demand is determined by four primary drivers.

Firstly, in the short term the greatest influence on automotive palladium demand is global vehicle production output; simply put, more palladium containing vehicles being produced leads to higher demand. However, tighter emissions regulations over the long term have driven palladium demand growth far more than vehicle production growth. Between the period of 2010 to 2019 vehicle production increased from 77.5 M units to 92.3 M units, an increase of 19%. This significant increase in production along with increased vehicle loadings (more on this later) drove palladium to its all-time peak demand of 11,000 koz.

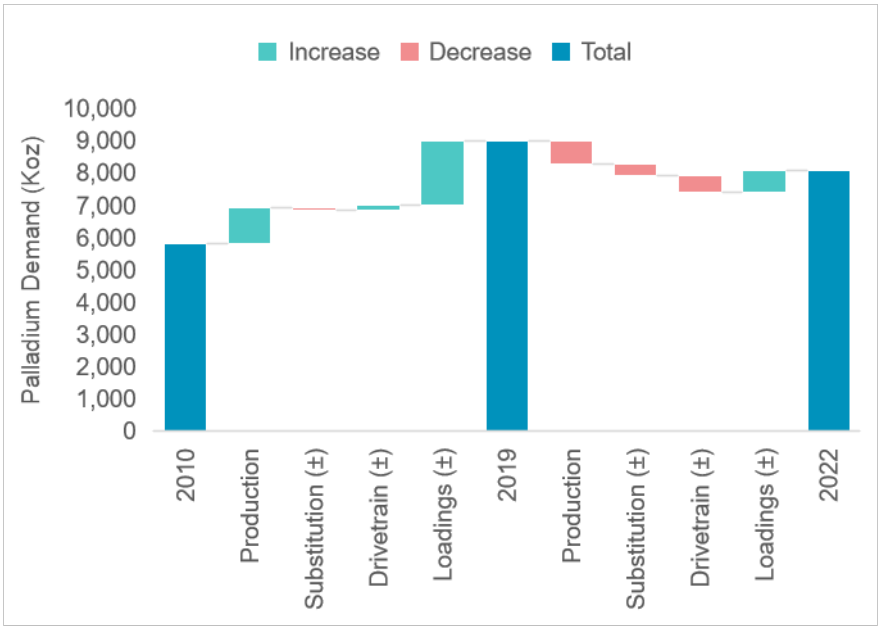
Figure 22: GDP (Gross Domestic Product) and vehicle production are closely related. Strong GDP projections indicate high economic output and consumer purchasing power.



Source: OEDC, OICA, WPIC research.

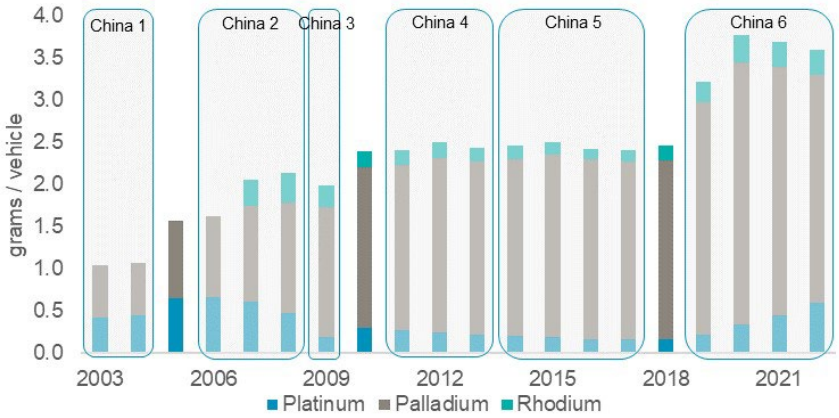
Secondly, the introduction of stricter emission controls are a key driving force of palladium demand. Emission's regulations such as US Tier 3, Euro 6 and China 6 (see fig 19) and their derivatives implemented around the world have resulted in increased PGM loadings across all vehicle types. Whilst some of this has been offset through thrifting, it has mostly translated to increased loadings of PGM's per vehicle. To put this in perspective, China, the globe's largest automaker, witnessed a remarkable uptick of around 60% in palladium loadings per vehicle since 2010. On a global scale, these elevated loadings have played a pivotal role, contributing a substantial 2,000 koz to annual demand compared to levels in 2010.

Figure 23: Vehicle production numbers and increased palladium loadings drove automotive demand for palladium to a record level to 2019. Figure shows drivers and total automotive palladium demand for years 2010, 2019 & 2022.



Source: OICA, WPIC Research, Johnson Matthey, ICCT, SFA (Oxford) 2013 – 2018, Metals Focus 2019 – 2022, WPIC research.

Figure 24: China PGM loadings increased c.60% since 2010, with a largely gasoline fleet Palladium has been the primary beneficiary.



Source: OICA, WPIC Research, Johnson Matthey, ICCT, SFA (Oxford) 2013 – 2018, Metals Focus 2019 – 2022, WPIC research.

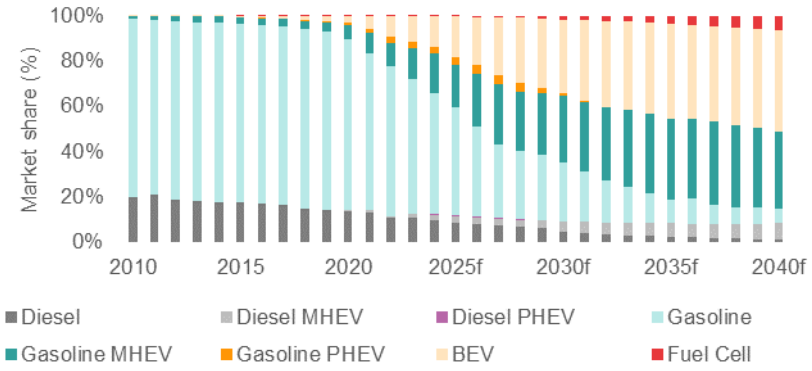
Thirdly, the PGM loadings to meeting emission standard vary from vehicle to vehicle. Palladium is primarily contained in gasoline, and gasoline hybrid vehicles, whilst diesel vehicles contain minor amounts of the metal. Historically, the mass of palladium contained in a vehicle is proportionate to its engine size, whereby a 3.0L vehicle would have twice as much palladium as a 1.5L vehicle to meet emission regulations. Therefore, growth in the light commercial sector and consumer trends for premium and larger vehicles and a consumer preference for gasoline over diesel, especially post-diesel-gate, positively impact palladium's demand dynamics. Typically, we expect smaller

engines in China and emerging markets, with larger engines and therefore higher PGM loadings in Western markets.

North America exemplifies this trend. Consumers favour large gasoline pick-up trucks and SUV's, with the average light vehicle engine size being 3.1L (2019-2021) vs. 1.6L for China. Despite lower annual vehicle production, North America had the largest share of palladium demand until 2018 when China introduced stricter emissions regulations, and overtook it.

Indeed, drivetrain preferences since 2015 have been heavily influenced by the fallout from 'dieselgate'. In Europe, this pushed consumers away from diesel and towards gasoline, which reduced platinum demand by 161 koz and increased palladium demand by 295 koz (between 2015 and 2019). More recently, the growth in BEV market share at the expense of ICE has reduced global palladium demand by around 500 koz (between 2019 and 2022), but the rise of hybrid vehicles could offset further BEV penetration due to their need for 10-15% higher PGM loadings to meet emission standards. This is due to increased temperature variability as the internal combustion engine is not operating on a continuous basis.

Figure 25: Increasing levels of hybridisation and BEV adoption has occurred up to 2023. We forecast this trend to continue through 2027.



Source: OICA, WPIC Research

As a final point, technological developments serve as the last pillar of palladium fundamental demand. In 2019 BASF announced the development of a tri-metal catalyst, improving wash coat formulation and demonstrating that the 1:1 substitution ratio was still possible commercially in gasoline vehicles in the lower-temperature portion of the exhaust treatment system. Palladium has been in a sustained market deficit since 2012, as a result of which, it has traded at price premium to platinum since 2017. This price differential incentivised fabricators to start substituting palladium for platinum, reducing demand. To date we estimate 1,300 koz of platinum for palladium substitution has occurred, partially offsetting higher loadings, and recovering vehicle production.

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