

# End-users, recyclers and producers: shaping tomorrow's PGM market and metal prices

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*Trends in PGM demand*—The conference paper will cover a concise analysis of demand trends, which will include the major PGM end-use sectors (autocatalysis, jewellery, glass, petroleum, nitric acid, medical/dental) and will touch on the investment sector. Reference will be made to environmental legislation affecting global emission standards, trends in PGM loadings and the substitutability of platinum and palladium in this end-use sector. Observations will also be made on the jewellery sector, and the development of Chinese and Japanese demand.

*Trends in primary and secondary PGM supply*—Similarly the paper will summarize historic and current global mine supply and primary production trends for PGMs, referencing recent expansions, their deliverability, and other projects coming on line. Consideration will be given to the grade and geology of PGMs worldwide and metallurgical developments. PGMs produced as by-products of base metal production and early PGM recycling estimates will also be appraised. In order to gain a wide-ranging appreciation of the industry's long-term cost trends of producing virgin PGM metals, the paper will look at the cost and profit dynamics of global production on a regional basis (Western Bushveld, Eastern Bushveld, Northern Bushveld, Zimbabwe, USA, Canada and Russia).

*Extrapolating tomorrow's PGM market and forecasting metal prices*—Based on established industry trends and market practices Stephen Forrest will conclude by unveiling a variety of thought-provoking extrapolations of today's and tomorrows platinum, palladium and rhodium markets to conference delegates. Importantly, having highlighted major developing PGM market trends in end-use (specifically on the elasticity of demand to high metal prices), primary and secondary PGM supply trends, in addition to presenting a carefully reasoned forecast of industry supply costs and margin trends, Stephen Forrest will conclude by estimating long-range PGM metal price trends. Other relevant market factors including industrial production, global currency rates and regional political factors will be deliberated.

## Introduction

This conference paper provides a concise analysis of PGM demand trends, including the major end-use sectors, and touches upon the investment sector. Reference is made to environmental legislation affecting vehicle global emission standards, trends in PGM loadings and the substitutability of platinum and palladium in autocatalysts. Observations are also made on the jewellery sector, and the development of Chinese and Japanese demand. Similarly, the paper summarizes current and historical global PGM mine supply and primary production trends, referencing recent expansions, their deliverability, and other projects coming on line. Consideration is given to the grade and geology of PGMs and metallurgical developments worldwide. PGMs produced as by-products of base-metal yield and early PGM recycling estimates are also appraised. To gain a wide-ranging appreciation of the industry's long-term cost trends of producing virgin PGM metals, the paper looks at the cost and profit dynamics of global production on a regional basis.

Based on established industry trends and market practices, the authors unveil a variety of thought-provoking extrapolations of present and future platinum, palladium and rhodium markets. Importantly, having highlighted

trends in major developing PGM end-use markets (specifically on the elasticity of demand to high metal prices) and primary and secondary PGM supply, in addition to presenting a carefully reasoned forecast of industry supply costs and margin trends, the authors conclude by estimating long-range PGM metal price direction. Other relevant market factors, including industrial production and global currency rates, are deliberated.

## Trends in PGM demand

### Platinum

- Notwithstanding platinum's sustained high price, autocatalytic offtake (driven by increasing global regulation of exhaust emissions) remains firm. However, high prices are negatively affecting platinum jewellery sales.
- Global platinum demand is estimated to have grown by 3% in 2005 to 7.5 million oz.

### Autocatalyst sector

The autocatalyst sector is the most important end-user of PGMs. Increasingly stringent environmental legislation and the spread of regulation into more engine sectors globally

have created a huge ongoing market for platinum, palladium and rhodium. Platinum competes with palladium for use in gasoline-powered vehicles, whilst only platinum is suitable for diesel engine systems. Platinum alone has the properties to deliver the required performance under the lean-burn, low exhaust temperatures of the diesel engine exhaust. Sales of platinum-based diesel engine catalysts are steadily increasing as lower running costs make diesel vehicles a more popular car choice. Looking ahead, tightening exhaust emission regulations worldwide for both light and heavy diesel engines will mean increased use of platinum-rich catalysts. Market penetration of diesel light vehicles in some parts of the world, notably North America, has been very low compared to that in Europe, but is expected to rise as fuel economy becomes a more important factor in car purchasing.

Platinum usage for autocatalysts increased by 9% in the past year, with the bulk of this consumption in Europe. Indeed, Europe saw a 17% increase in autocatalyst demand for platinum, reflecting the steep growth in diesel car sales, which is estimated to have made up just over 50% of the European car market for 2005. However, this pattern is not reflected elsewhere in the world. Japanese demand was down 3% at 590 koz in 2005, but this is due to considerable restocking in 2004 inflating the previous year's data. Vehicle production in Japan still increased, owing mainly to new emission legislation affecting the heavy-duty vehicle sector. In North America, platinum demand was up 2.5% to 820 koz. Growth was restricted owing to the substitution of platinum by palladium in gasoline autocatalysts and poor sales from major domestic automobile manufacturers, but was offset by increasing sales of Japanese vehicles, where the diesel market remains very small. Chinese vehicle production was up 15%, along with increases in India, South Korea and Thailand. These output rises, coupled with the parallel tightening of emission standards, contributed to a growth in demand for platinum, up 13% in the rest of the world.

#### ***Jewellery sector***

Global demand for platinum jewellery, accounting for 26% of total platinum utilization, is estimated to have declined by 200 koz in 2005, largely attributable to the sustained high platinum price of over \$800/oz (double that of gold) over the past two years. European consumption (195 koz) has been steady and this is forecast to continue, while demand in China (875 koz), Japan (510 koz) and the USA (275 koz) has become more price elastic, resulting in lower sales. Chinese platinum usage (accounting for around 45% of world demand) has been particularly affected by the substitution of white gold and palladium, falling 13% since 2004. Over the next two years, global jewellery demand is estimated to rise by only a modest 2% (50 koz) annually.

#### ***Electronics sector***

Platinum is used in the magnetic layers of all hard disks and, to achieve higher data densities and faster access times, the levels used in the cobalt-based magnetic alloy continue to increase. With the proliferation of hard-disk devices, such as recordable DVD players and personal digital music players, in addition to the more slowly growing established computer market, platinum usage rose by 20% in 2005 to 360 koz. This trend is expected to continue through 2006.

#### ***Glass and glass fibre manufacture***

Demand for platinum in 2005 has risen by 22% to 355 koz, driven by the consumer products market. In Japan, Taiwan, South Korea and Singapore over 20 new production lines have been constructed for the manufacture of high-quality glass to meet the demand for flat-panel displays. These lines use platinum and rhodium to make stirrers and crucibles for molten glass handling. Continued growth is expected in 2006.

In 2004, new glass fibre production capacity in China also helped to boost the glass sector's requirement for platinum. With the glass fibre industry known to be opaque, verifiable demand figures are hard to come by but, allowing for anticipated growth, combined glass and glass fibre utilization could equate to around 416 koz of platinum by 2008.

#### ***Petroleum refining industry***

Consumption of platinum in the petroleum industry has risen 3% to 155 koz in 2005. Strong global demand and tight supply have meant that petroleum refineries have been operating at or very close to capacity in 2005, so catalyst beds have been topped up more frequently.

The future prospects for platinum in petroleum refining can be seen as stable, with the sector demand steady at around 170 koz per year. Attempts at reducing the platinum (and ruthenium) content of the bi-metallic catalysts used in reforming petroleum have shown that a loss in catalyst performance can occur. Limitations on PGM reduction in this sector have meant that PGM use is assured in the medium term. With no reason to believe that continued use of bi-metallic catalysts will be called into question, platinum's role in this area will be ongoing, without showing extraordinary growth and trailing the fortunes of the petroleum refining industry.

#### ***Investment sector***

In North America and Japan (the major investment sectors), demand for coins and small and large bar investment have fallen because of the ongoing high price regime for platinum. In fact, total investment demand in 2005 reduced from 45 koz to 30 koz, according to Johnson Matthey.

#### ***Palladium***

- Autocatalyst demand remains stagnant from thrifting and increasing diesel car sales, which favour platinum over palladium.
- Palladium usage in jewellery has surged, as consumers take advantage of its lower cost than platinum or gold and higher purity than white gold.
- Jewellery offtake was largely responsible for global demand growth of 8% to 7.7 million oz in 2005.

#### ***Autocatalyst sector***

Naturally, given the price differential between platinum and palladium, there has been extensive R&D activity to substitute platinum with palladium in diesel engine applications. Technology has recently been developed for the oxidation part of the autocatalyst system, which substitutes approximately 25% of the platinum used with palladium. This level of substitution is expected to increase over the coming years, helped considerably by the major fuel producers lowering sulphur levels in diesel, which avoids palladium poisoning. Improvements in engine management systems are also a contributing factor.

Palladium autocatalyst demand increased slightly, up globally 20 koz in the past year. After significant inventory movements in recent years, users are now purchasing palladium directly for end use, so purchases accurately reflect use. In Europe, consumption was down 115 koz (10%), reflecting the shift from gasoline to diesel engine vehicles. North America saw demand decline by 15 koz (1%); the effect of continued thrifting still exceeds the effect of gradual substitution of palladium in place of platinum in this gasoline engine-dominated market.

### Jewellery sector

Global palladium jewellery demand, despite limited promotional and sales infrastructure, has soared by 500 koz (up 54%) to 1.4 moz, due almost entirely to the rapid upsurge in popularity in China. China accounts for 84% (1.2 moz) of the palladium jewellery market. Consumers have taken to palladium because it is perceived as a pure, rare, attractive, precious metal with the potential for long-term price appreciation. Moreover, jewellery fabricators and retailers remain highly incentivised by lower metal inventory costs, higher margins and reduced price volatility compared to platinum. It seems that earlier technical and quality problems in the fabrication of palladium jewellery have been surmounted and the move from Pd950 alloys to Pd990 alloys has been successful, both technically and aesthetically. Palladium jewellery is stocked by an increasing number of stores, often in preference to platinum. While growth is unlikely to continue at current levels, in the long term this is expected to be a significant market.

### Electronics sector

Palladium's wide application in electronic components is thanks to its high electrical conductivity and durability. Demand for palladium in the electronics industry rose 5% in 2005 to 965 koz owing to two significantly different palladium/base metal substitution trends.

Traditionally, palladium has been used extensively in the conductive pastes of multilayer ceramic capacitors (MLCCs). However, intensive research into the use of base metals in response to the palladium price spike in 2000 now means that approximately 70% of MLCCs are nickel based. The continuing trend towards miniaturization also means that in certain conductive pastes where palladium is still used, the total quantities required are reducing.

By contrast, palladium is the beneficiary in the plating sector. Palladium demand grew by 30% in 2005, partly because of the general growth in the production of electronic components, but more particularly from its use as a substitute in the industry drive to remove lead from solder. Additionally, the rising gold price has promoted palladium substitution in the plating compounds used for connectors.

Further minor rises in demand will result from increased production of resistor chips and related components, especially as automotive electronics become more sophisticated.

### Dental sector

Demand for palladium from the dental sector in 2006 is expected to continue rising owing to its low price (relative to gold). State-subsidized treatment using alloys that contain 20% palladium makes Japan the largest market for palladium used in dental alloys. Use of the metal in the Japanese dental sector is expected to continue rising, while consumption in North America is also forecast to increase. Global demand dropped to 845 koz in 2005, a 5-koz decrease on 2004.

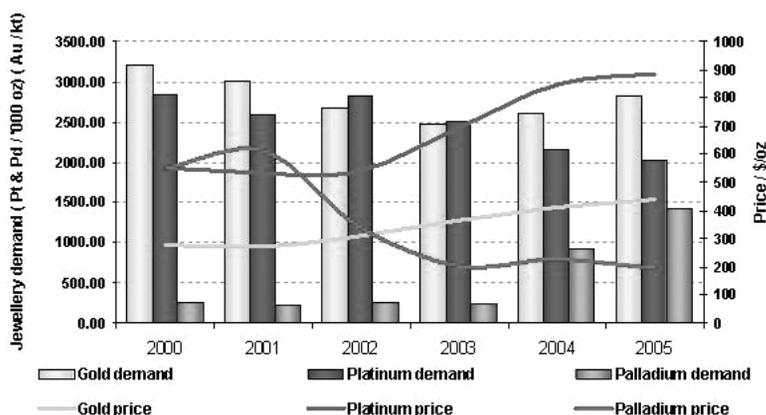
In the long-term, however, dentistry is undergoing technological improvements that will affect on the demand for palladium. Younger generations of patients have a layer of bonding adhesive applied to their newly erupted teeth. Subsequent visits to the dentist involve the reapplication of the adhesive, the dentist's drill becoming increasingly redundant. With dentistry becoming preventative, the only use for PGMs in the surgery will be for reconstruction.

### Rhodium

- Rhodium usage has risen in two key sectors: autocatalyst loadings have increased to meet tighter exhaust emission standards, and manufacturing infrastructure for flat-screen glass production has prompted new tooling requirements.
- Globally, rhodium demand increased by 9% to 949 koz in 2005.

### Autocatalyst sector and glass manufacture

Rhodium consumption in the autocatalyst sector has increased by 62 koz (8%) as loadings have increased to meet tightening NOX emission levels, particularly in the USA. Robust growth of around 4% is expected in this sector for 2006 and beyond. Demand has also grown for



Source: SFA estimates and industry sources, including Johnson Matthey and GFMS

Figure 1. Global jewellery demand trends versus precious metal prices

tooling in the glass industry—up 9 koz (20%)—where rhodium is used with platinum in the manufacture of flat-panel displays. Utilization is expected to continue at around this level.

## Trends in primary and secondary PGM supply

### Primary supply

#### Industry background

More than 75% of the global primary platinum supply comes from South Africa. The PGMs occur within a volcanic intrusion called the Bushveld Igneous Complex (BIC). The BIC is a basin-shaped intrusion of some 370 kilometres across, with only its rim exposed. The intrusion contains numerous distinct layers (magmatically differentiated), three of which contain economic concentrations of PGMs. The main PGM-bearing layers, often referred to as ‘reefs’, are called the Merensky Reef, the Upper Group 2 (UG2) Reef and the Platreef.

The Merensky Reef is located on the Western and Eastern Limbs of the BIC and is historically the preferred target for exploitation and now provides some 29% of the world’s platinum. The Upper Group 2 (UG2) layer is also located on the Western and Eastern Limbs and currently yields 37% of the world’s platinum supply. The UG2 is fast becoming an increasingly important source for PGMs as shallow Merensky orebodies deplete. In fact, numerous Merensky generation shafts now exploit the UG2 along with several new mines and projects in ramp-up. Both layers contain valuable copper and nickel by-products, but base metal concentrations are minor in the UG2 Reef.

On the Northern Limb of the BIC the third reef, known as the Platreef, accounts for 2% of the world’s platinum, with only one mine in operation at present. The Platreef has a number of exploration projects and a relatively high concentration of base-metal credits of nickel and copper.

Other regions of primary PGM supply include Zimbabwe’s Great Dyke region (2%), the Stillwater complex in the USA (3%) and the Sudbury Basin in Canada (6%). Russian PGM output, with the exception of PGMs produced in the Kondyor, Koryak and Urals regions, is mostly generated as a by-product of nickel mining (from Norilsk Nickel) and is the world’s largest source of palladium (50%). Norilsk is also a significant producer of platinum (13%) and rhodium (11%), yielding 28% of the world’s PGM supply.

Since 1995, primary platinum, palladium and rhodium supplies have grown by a yearly average of 3% (155 koz), 4% (160 koz) and 7% (35 koz) respectively. Mine supply growth has mostly prevailed in South Africa, where several producers have developed brownfield mine extensions targeting the UG2 Reef horizon in the Western Limb and/or have developed new greenfield mines in the Eastern Limb, Northern Limb and Zimbabwe.

#### Mining activity

Looking ahead, the significant increase in South African mining activity targeting the UG2 and Platreef orebodies and the planned gradual ramp-up of Zimbabwean supply will result in a change to the ratios of the yield of global PGM. UG2 ores typically contain a higher palladium to platinum ratio, compared to those from the Merensky Reef, whilst in the Platreef and Zimbabwean ores, the platinum to palladium yield is almost one-to-one.

In 2005, primary global platinum supply increased by around 1.5% (94 koz), while palladium output declined by some 4% (310 koz) owing to reduced Russian shipments and the market being oversupplied. Rhodium supply, however, grew by 13% (95 koz), partly as a result of the higher rhodium to platinum yield of UG2 ores but also because of improved processing recoveries in South Africa. A summary of global platinum, palladium and rhodium supply and demand statistics is given below in Table I.

**Table I**  
**Platinum, palladium, and rhodium demand and supply**

Platinum, palladium and rhodium demand															
(000's oz)	2001			2002			2003			2004			2005e		
	Pt	Pd	Rh												
Autocatalysts	2 520	5 090	566	2 590	3 050	599	3 270	3 450	660	3 490	3 720	758	3 820	3 810	821
Jewellery	2 590	230		2 820	260		2 510	250		2 160	920		1 960	1 430	
Electrical	385	670	6	315	760	6	260	900	6	300	920	7	360	965	9
Chemical	290	250	44	325	255	39	320	255	39	325	310	42	335	320	47
Glass & fibreglass	290		41	235		37	210		26	290		47	355		55
Petroleum	130			130			150			150			155		
Dental		725			785			825			850			845	
Other	555	65	10	620	90	10	485	135	13	515	295	14	485	300	17
Total demand	6 760	7 030	667	7 035	5 200	691	7 205	5 815	744	7 230	7 015	868	7 470	7 670	949
Platinum, palladium and rhodium supply															
(000's oz)	2001			2002			2003			2004			2005e		
	Pt	Pd	Rh												
South Africa	4 162	2 010	467	4 457	2 142	507	4 741	2 308	545	4 916	2 456	557	4 963	2 548	665
Zimbabwe	26	21	2	78	63	7	133	107	12	150	120	13	181	144	16
Russia	1 300	4 340	125	980	1 930	90	1 050	2 950	140	850	4 100	105	860	4 272	90
North America	354	790	31	402	967	33	408	1 015	30	408	1 030	30	382	863	27
Primary supply	5 843	7 161	626	5 917	5 102	637	6 332	6 380	726	6 324	7 705	705	6 385	7 827	798
Secondary supply (autocat recycling)	454	253	49	480	314	81	596	427	103	661	466	105	682	791	101
Total supply	6 297	7 414	674	6 397	5 416	718	6 928	6 807	829	6 978	8 145	809	7 093	8 160	900

Source: SFA estimates and industry sources, including Johnson Matthey

## Secondary supply

Higher metal prices have played a major part in enlightening collectors/traders about the potential profitability of recycling catalytic converters. However, despite metal prices continuing to affect the profitability and volumes of recycled PGMs, the effect of newly implemented European directives on recycling practices is likely to mean that PGM prices will have less impact on the levels of recovery, removing much of the price sensitivity associated with recycling autocatalysts. Autocatalyst recovery is directly governed by a vehicle's lifespan, which can differ significantly by region. Regional recovery rates vary between 20% and 40%, with overall PGM losses estimated to be around 10%.

The adoption of tailpipe emission standards worldwide has led to a significant increase in autocatalytic offtake and, consequently, PGM recycling. Since 1995 the average annual growth in recycled platinum, palladium and rhodium has been 8% (36 koz), 22% (39 koz) and 11% (6 koz) respectively.

## Production costs and margins

Globally, for 2005 the average cash costs per 4E oz, including mining, smelting and refining costs and other overhead charges (excluding depreciation and amortization charges), are estimated at \$402/4E oz before the benefit of by-product production credits. Industry cash costs per 4E oz, net of by-product credits, are estimated at a reduced cost of \$238/4E oz. On a similar basis, the global average 4E basket price realized by primary producers is estimated to be \$595/4E oz and, against industry net-cash costs, this computes to a global industry cash margin of \$357/4E oz.

Industry costs and margins vary considerably on a

regional basis. (see Figure 2.) Russian and Canadian producers benefit greatly from a significant yield of nickel and copper by-products. For South African and Zimbabwean producers, which yield PGMs as their main source of revenue, the Western Limb of the BIC is estimated to have the highest net cash margin of \$291/4E oz. The region's higher platinum to palladium ratio, compared to other local regions, achieves the most favourable basket price of \$730/4E oz. Mining operations in Zimbabwe and the Eastern Limb are mostly in ramp-up and not all mines have reached steady state, making direct like-for-like comparisons difficult. However, with greater mining efficiency being achieved by reaching steady-state output, the economics of these regions will improve.

## Extrapolating tomorrow's PGM market and forecasting metal prices

### Factors relating to growth in platinum supply/demand

South African supply of platinum is forecast to grow by 8.7% (432 koz) in 2006 to 5.4 moz, by 7.8% (420 koz) in 2007 and by 5% (289 koz) in 2008 in the face of a strong rand and the usual difficulties associated with starting up new mines. This increase in supply is forecast to move the market, having been in deficit of -403 koz, to a deficit of -310 koz in 2006 before reaching a deficit of just -29 koz in 2007. Thereafter the surplus is projected to widen to 76 koz in 2008 and increase to 122 koz by 2010.

SFA's long-range fundamental analysis of the platinum market to 2020 points to a constructive balance between supply and demand only up to 2011; beyond this a significant market deficit emerges. (Refer to Figure 3). The authors anticipate that for the next six years the rise in

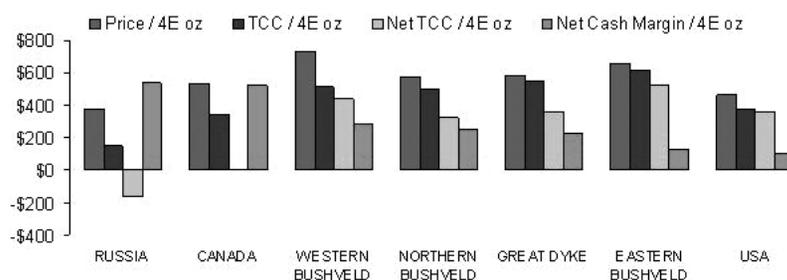
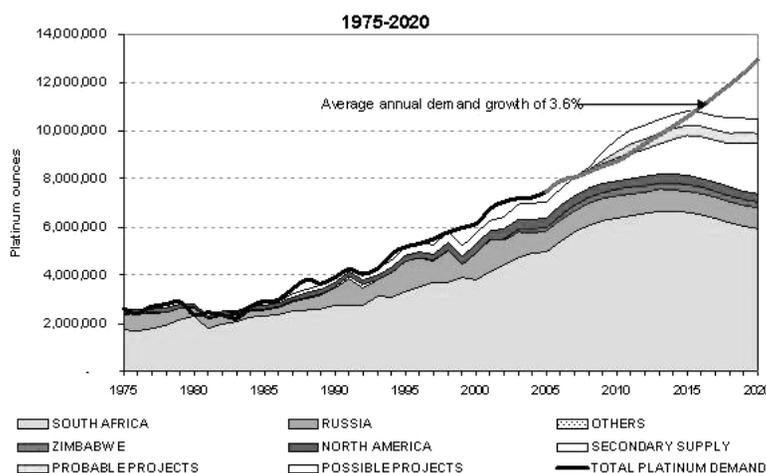


Figure 2. Regional costs and margins—2005—US\$/4Eoz



Source: SFA estimates

Figure 3. Platinum supply/demand to 2020

primary and secondary supply (autocatalytic recycling) will be easily absorbed by growing demand. SFA's market estimates show that new output from possible and probable projects could bring the market back to equilibrium for an additional five years (up to 2016). Annual global demand is expected to rise from roughly 7.47 moz in 2005 to 8.75 moz in 2010, 10.58 moz in 2015 and 12.9 moz in 2020.

The most significant change in the growth of primary supply will be a much closer correlation between platinum and palladium. The reason for this lies in South African producers campaigning for UG2 ores in their new projects in replacement of depleting Merensky Reef shafts. SFA's long-range supply modelling of each producer shows that future supplies (excluding Russian exports from stocks) of platinum, palladium and rhodium are expected to grow by an annual average of 4.6%, 4.0% and 7.4% respectively by 2010, and by an annual average of -0.4%, 0.4% and 0.4% respectively for the period 2015 to 2020. Table II contrasts the growth rates of SFA's extrapolated supply and demand outlook, highlighting the effect of production depletion worldwide. For example, by 2014, North American Palladium's mineable reserves in its open pit and new underground extension will be depleted.

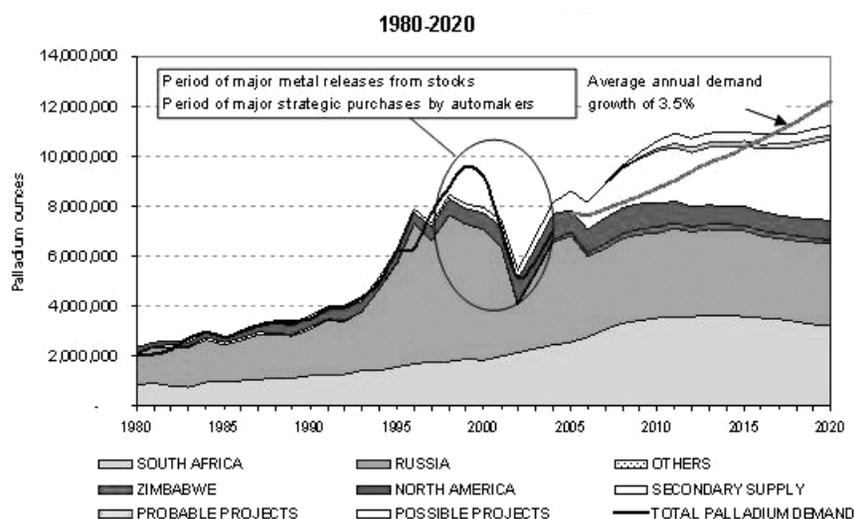
### Factors relating to growth in palladium supply/demand

With secondary supply estimated to increase by 38% to over 1 moz in 2006, the market surplus remains significant. (see Figure 4.) Even at its current price, investor speculation (open interest on NYMEX is significant and long) could mean weaker prices for this metal if funds exit. Vehicle manufacturer demand for palladium is expected to rise by 2% to 3.9 moz in 2006. Altogether, the market will remain in surplus of at least 530 koz in 2006, which is much lower than the surplus market of 950 koz in 2005. This is largely because Russian stock sales in 2006 have not been extrapolated in forward modelling. With increasing recycling and inelastic co-product supply from South Africa, the surplus is, however, expected to grow to more than 1 moz by 2008. It is thought unlikely that in 2006 there will be a repeat of the estimated 1.2 moz purchase of palladium by Chinese jewellery manufacturers seen in 2005, but sales will remain above 2004 levels and continue to grow at a steady rate of around 2% in years to come. Industrial demand for palladium in 2006 will be offset to a degree by continuing miniaturization and thriftiness, especially in the manufacture of multi-layered ceramic capacitors (MLCCs).

**Table II**  
Global supply/demand growth (including probable projects)

Platinum	2005 to 2010		2010 to 2015		2015 to 2020	
	%	oz	%	oz	%	oz
Average annual supply growth	4.6%	356,910	2.5%	236,856	-0.4%	-38,363
Average annual demand growth	3.2%	252,929	3.6%	339,271	4.0%	452,771
Average annual deficit (-) / surplus (+)		103,981		-102,415		-491,134
Palladium	2005 to 2010		2010 to 2015		2015 to 2020	
	%	oz	%	oz	%	oz
Average annual supply growth	4.0%	354,374	1.1%	108,948	0.4%	44,672
Average annual demand growth	3.7%	279,774	3.5%	325,032	3.3%	364,039
Average annual deficit (-) / surplus (+)		74,600		-216,084		-319,367
Rhodium	2005 to 2010		2010 to 2015		2015 to 2020	
	%	oz	%	oz	%	oz
Average annual supply growth	7.4%	71,776	2.5%	32,532	0.4%	5,887
Average annual demand growth	4.6%	44,288	4.6%	56,210	4.5%	68,451
Average annual deficit (-) / surplus (+)		27,488		-23,677		-62,564

Note: # Forecast data excludes any exports from Russian stocks  
Source: SFA estimates



Source: SFA estimates

**Figure 4. Palladium supply/demand to 2020 (oz)**

SFA's long-range analysis of the palladium market to 2020 shows that the market will remain in fundamental surplus until 2016. The resulting combination of the inelastic yield of palladium supply, derived from producers campaigning platinum, and base-metal producers campaigning copper and nickel, together with the recovered recycling yield from processing spent autocatalysts, will outpace consumption growth for the next 11 years. Moreover, the added effect of additional metal produced from possible and probable platinum projects, which are yet to be given the green light, will keep the market in surplus for a further year until 2017. The authors estimate that palladium consumption will rise by an average of 3.6% per year from 2005 to 2015. Despite the potential of the batch process for an escalation in productivity, refinery capacity constraints could restrict the level of palladium recovery beyond 2015. However, the authors' early findings suggest that there is adequate spare capacity to refine 1.5 moz of palladium.

### Factors relating to growth in rhodium supply/demand

Despite a brighter outlook for rhodium consumption, growing at 4.7% over the next ten years, SFA's supply projections (again taking into account the inelastic yield from mining and recycling) show that the market will be in surplus from 2006 to 2013. (see Figure 5.) Greater exploitation of UG2 ores, with a higher rhodium:platinum ratio, dramatically increases rhodium output for every platinum ounce recovered. Additionally, platinum recovery from spent autocatalysts will also affect the rhodium market. Refining capacity constraints in the future are difficult to quantify; nonetheless, SFA's current estimate of idle capacity is around 400 koz. However, with rhodium having a very small market of just under 1 moz, the authors expect that producer marketing initiatives will improve on consumption growth and, with carefully managed sales strategies, will maintain prices above \$1000/oz.

### Modelling long-term PGM prices and exchange rates—supply/demand and the PGM cycle

SFA has examined several methods of estimating long-term PGM price forecasts for use in strategic decision-making. These included:

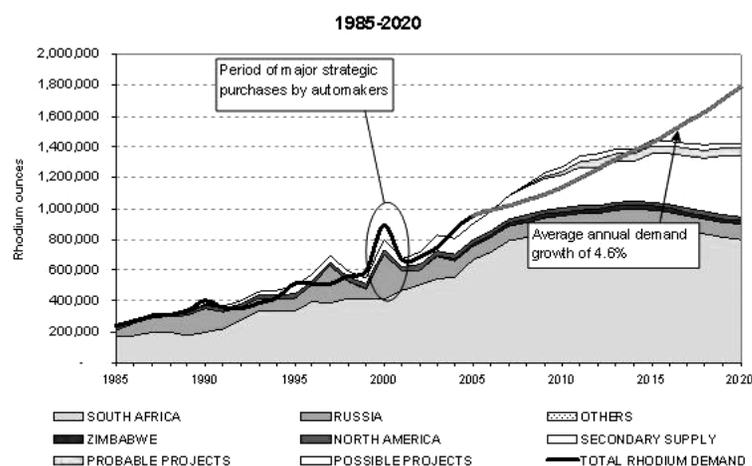
- *PGM price forecasts based on SFA's in-depth modelling of platinum, palladium and rhodium supply-*

*demand fundamentals*—Given the unique nature of platinum-group markets and the evolution of major end uses, particularly in the autocatalyst sector and to a lesser degree in the jewellery sector where thrifting and substitution between platinum group elements often occur, the authors concluded that their supply-demand based price projections became less helpful for forecasting long-term PGM prices beyond 2010. Fundamentally based PGM price forecasts are best suited for near-term predictions only. (see Table III).

- *The combination of five-year fundamentally based PGM price forecasts and a long-range price projection beyond 2030 based on a historically derived series of PGM price trends*—As South Africa is the dominant global producing region and the economic benchmark affecting global PGM supply, the authors considered a weighted South African PGM basket price extrapolation. This shows (see Figure 6) that a historical South African basket price cycle commonly runs for around ten years, from cycle-peak to cycle-peak, with the peaks in 1981, 1991 and 2001. In the same way, cycle-troughs also run some ten years from trough to trough. Based on reason (after a period of high prices and investment in new projects), the trough commonly occurs more or less five years after the cycle peak, as this is the approximate project lead time taken to bring on new mine supply, pushing the market back to equilibrium.

Examining the degree of difference between South African rand and US dollar platinum prices (see Figure 7—a comparison of real rand and real dollar prices for platinum in 2005 money terms) shows that the disparity between the rand and dollar prices of platinum has narrowed significantly, providing a foundation for extrapolating a long-range PGM price forecast out to 2032.

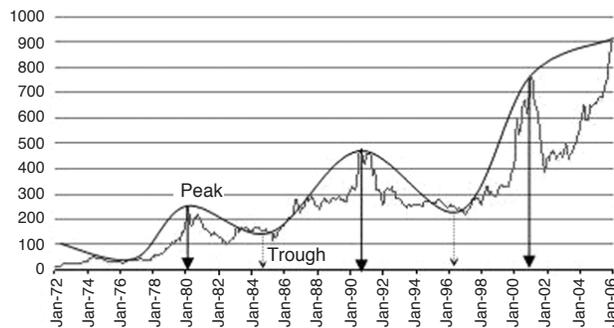
More recently, there has been an early rise in basket prices (2003 to 2006) due to significant constraints in planned South African supply growth. After a more than 40% collapse in South African basket prices (in 2001-2002), prompted by a falling palladium price and the announcement of significant South African expansions, several unforeseen factors have inhibited planned South African supply growth. These factors account for a more than 1 moz lag in supply growth and include:



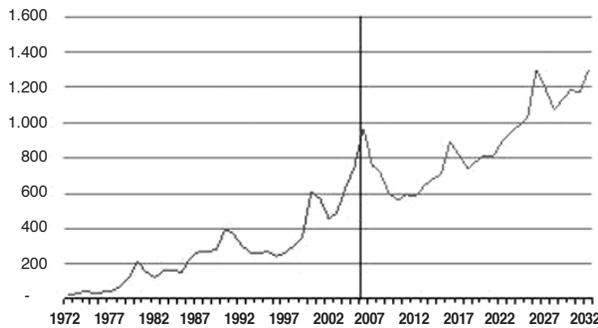
Source: SFA estimates

Figure 5. Rhodium supply/demand to 2020 (oz)

The 4E PGM price cycle based on South African basket prices  
Real price \$/4E oz (extrapolated back to 1972)

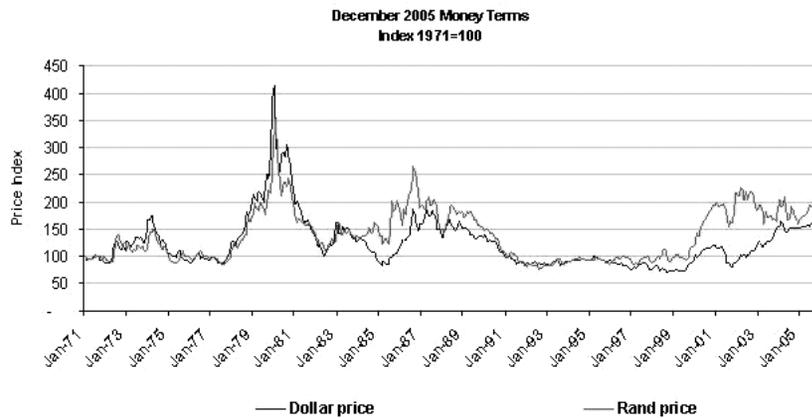


4E PGM basket price forecast  
\$/4E oz (real)



Source: SFA calculations

Figure 6. Modelled 4E South African basket price cycle: historical and forecast



Source: SFA calculations

Figure 7. Platinum prices—Rand and US Dollar

Table III  
PGM prices 2000-2005 and forecasts

		2000	2001	2002	2003	2004	2005	2006 YTD	3-year average to March '06*	5-year average to March '06	Long-term*
Platinum	Average	\$549	\$533	\$543	\$691	\$848	\$906	\$1 037	\$844	\$724	\$850
	High	\$628	\$648	\$610	\$840	\$883	\$1 018	\$1 089			
	Low	\$415	\$418	\$451	\$595	\$763	\$843	\$976			
Palladium	Average	\$692	\$612	\$339	\$203	\$230	\$201	\$285	\$215	\$250	\$220
	High	\$985	\$1,083	\$446	\$272	\$337	\$289	\$318			
	Low	\$439	\$315	\$224	\$149	\$178	\$179	\$266			
Rhodium	Average	\$1 993	\$1,604	\$839	\$531	\$985	\$2 053	\$3 416	\$1 431	\$1 269	\$1 440
	High	\$2 452	\$2,263	\$1,021	\$617	\$1,329	\$3 015	\$3 520			
	Low	\$1 190	\$836	\$598	\$494	\$509	\$1 416	\$3 000			

Note: \*Denotes a hypothetical price range based on R/\$ exchange rate of 6.6x and the influence of accepted supply/demand dynamics forcing a market adjustment to moderate price.

- Difficult geological conditions and inadequate mining planning, preventing a number of new projects from reaching their designed production targets and schedules
- Investment uncertainty relating to the implementation of South Africa's new mineral policy and mining code that has also delayed project finalization and approval
- Rand strengthening, which has significantly undermined the investment returns of newly announced PGM projects, resulting in delays in expansion projects.

Despite PGM demand growth being in line with long-term trends (taking into account autocatalytic substitution—

Pt:Pd, diesel etc.—thriftig, and jewellery developments in China), the rising levels of alarm over South Africa's ability to expand supply have also prompted high levels of speculative interest on TOCOM and NYMEX, forcing prices higher.

Once again, the long-term effects of the above-mentioned factors, together with the unique nature of platinum-group markets and the evolution of major end uses, make it difficult to estimate with a high degree of confidence whether SFA's long-range PGM forecasts, based on the South African PGM basket cycle, specifically timing the next price peak or trough, are robust enough for base-case project valuation purposes.

