Platinum

Autocatalyst

Demand for platinum in autocatalysts reached an all-time high in 2001, rising by 33 per cent to 2.52 million ounces. In Europe, demand exceeded 1 million oz and was driven by a strong rise in sales of diesel cars. Tighter emissions regulations and a move back towards platinum from palladium by several auto makers also had a significant effect worldwide; North American demand, for example, jumped 27 per cent despite a sharp fall in new vehicle output.

Europe

Use of platinum in autocatalysts surged by 375,000 oz or 55 per cent last year in Europe to 1.055 million oz. This remarkable increase was achieved even though Western European production of new vehicles rose by only 1 per cent. The leading factor behind the rise in platinum demand was the strong growth in production and sales of diesel cars. In 2001, diesel catalysts accounted for over 70 per cent of auto demand for platinum in the region.

Diesel car sales climbed by 11 per cent to 5.33 million vehicles in Western Europe last year, and increased their market share to 36 per cent. The superior fuel efficiency of diesel-powered vehicles compared with gasoline is a strong selling point in Europe, where fuel costs are relatively high. The improved performance of the latest generation of diesel cars has also contributed to the rise in sales.

For technical reasons diesel autocatalysts use only platinum, whereas gasoline autocatalysts generally use platinum or palladium, in combination with rhodium. The increase in diesel car production, therefore, had a direct influence on platinum demand. In addition, platinum loadings on diesel autocatalysts were increased significantly in order to ensure compliance with European Stage III emissions legislation, which applied to all new vehicles from January 2001.

The price of palladium tripled between the third quarter of 1999 and January 2001. This, coupled with concerns about the stability of supply, caused auto companies to examine their use of palladium in autocatalysts for gasoline vehicles. Several subsequently favoured the use of platinum over palladium, reversing the trend that started in the mid 1990s. New platinum-rich catalysts entered the production stream last year, boosting demand significantly. The switch back towards platinum, however, was by no means universal and many auto makers continue to use palladium based catalyst technology.

In 2002 we expect European autocatalyst demand for platinum to increase as diesel cars gain further market share. The move from palladium to platinum in gasoline catalysts will also continue to influence demand this year.

Platinum Demand: Autocatalyst
'000 oz

	2000	2001
Europe	680	1,055
Japan	290	345
North America	620	790
Rest of the World	300	330
Total	**1,890**	**2,520**

Japan

Japanese demand for platinum in autocatalysts defied a fall in vehicle production and increased by a fifth to 345,000 oz, the highest level since 1992. Japanese emissions regulations came into force in October 2000 for new models and will be extended to encompass all existing models from September 2002. The stricter regulations resulted in a significant boost to autocatalyst pgm loadings in 2001, increasing platinum demand accordingly.

The Japanese Environmental Agency (JEA) has published technical guidelines that propose even greater reductions in emissions. Auto manufacturers have responded by inceasing autocatalyst pgm loadings further on some models for the domestic market, in order to achieve emissions ratings 50 per cent below the current legal limits. This trend is likely to continue in 2002.

In 2001, Japanese car manufacturers reacted to concern about the long term supply and price stability of palladium by using more platinum-intensive catalytic converters on new models. This also contributed to the growth in demand.

All Japanese cars exported to the USA now have to meet the national LEV standards, and some voluntarily meet the higher Californian ULEV (ultra low emission vehicle) limits. As with the domestic market, a higher proportion of export models used platinum based catalysts in 2001.

These positive factors for platinum demand far outweighed a 3 per cent decline in Japanese car production to 8.12 million units.

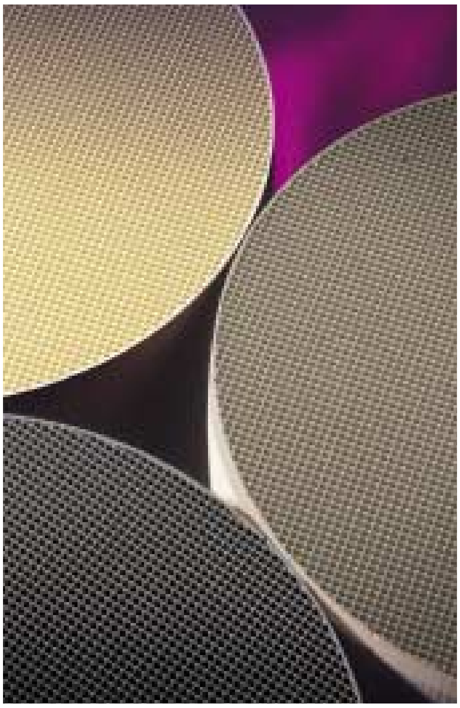
Platinum is used to increase the data storage capacity of computer hard disks

North America

The impact of reduced economic activity on US light vehicle production was pronounced in 2001 – US output slid by more than 10 per cent to 11.49 million cars and light duty trucks, as manufacturers drew down inventories of finished vehicles and imports gained market share.

Despite the weakened vehicle market, total North American demand for platinum in autocatalysts grew impressively, climbing by more than a quarter to 790,000 oz. The move in favour of catalysts utilising platinum in gasoline vehicles had a strongly positive effect on consumption. On top of this, several US-based automakers added to their platinum inventories during the year.

Car manufacturers are already working to meet more stringent US Federal emissions standards for light vehicles (Tier 2) that will start to take effect from 2004, and it is probable that higher loadings of pgm on autocatalysts will be required in some instances. Tighter regulations are also likely to necessitate the widespread use of platinum catalysts on heavy-duty diesel vehicles. This is expected to make a significant contribution to future demand for platinum in the longer term.



Coated and uncoated (top left) diesel autocatalysts

Rest of the World

The increasing control of automobile exhaust emissions had a growing impact on autocatalyst pgm demand in developing countries in 2001. This, combined with rising car sales in China and Brazil, produced a 10 per cent rise in platinum use to 330,000 oz.

Vehicle emission regulations (known as Bharat II) were introduced in nine major Indian cities in late 2000 and 2001, and enforce limits similar to those set by the Euro Stage II standards. Car manufacturers have largely adopted platinum-rich catalyst systems to meet the new limits. In March 2001, a government task force recommended the countrywide adoption of Bharat II standards and the introduction of the next stage of regulation in the seven largest urban conurbations by April 2005. If the proposals are adopted as legislation, this would further boost Indian pgm demand.

China has required all new vehicles to meet Euro Stage I limits since January 2001 and offers incentives for vehicles that meet Euro Stage II rules. As else-where, tighter regulations have increased autocatalyst demand for pgm. The Chinese autocatalyst market also benefited from strong sales of light vehicles last year – production and sales rose 16 per cent and 13 per cent respectively, both exceeding 2 million vehicles.

Implementation of South Korean LEV regulations has been deferred from January 2001 until 2003. The Korean legislation will require gasoline cars to conform to the US LEV standards, while diesel cars will have to meet Euro III emissions limits. This is expected to increase platinum loadings on autocatalysts.

South American pgm demand was lifted by the continued recovery in the Brazilian car market. Car sales rose 10 per cent to 1.29 million and production increased by 7 per cent to 1.35 million units. The Mexican car industry, however, was affected by the downturn in the US market. After rising by 29 per cent in 2000, production last year was static at 1.85 million light vehicles.

Platinum Demand: Autocatalyst Recovery
'000 oz

	2000	2001
Europe	(40)	(55)
Japan	(60)	(70)
North America	(350)	(370)
Rest of the World	(20)	(25)
Total	**(470)**	**(520)**

Autocatalyst Recovery

The volume of platinum recovered from the recycling of autocatalysts is estimated to have increased 11 per cent in 2001 to 520,000 oz. North America is by far the leading source of recovered pgm from autocatalysts, returning 370,000 oz of platinum to the market last year.

Higher pgm prices encouraged recyclers to increase collection rates in 2001 and recovery of platinum rose 6 per cent as a result. The rate of increase in platinum recovery is slowing, however, as cars fitted with palladium-rich catalytic converters are being scrapped in increasing numbers in the USA.

Platinum recovery from autocatalysts in Europe reached 55,000 oz in 2001, an improvement of 15,000 oz on the previous year. Compared to the USA, autocatalyst recycling is largely in its infancy in the region. However, European legislation that will require at least 85 per cent of a car's weight to be recycled by 2005 is likely to stimulate greater efforts to recycle autocatalysts.

Higher pgm prices saw platinum recovery increase by 10,000 oz in Japan and 5,000 oz in the Rest of the World region in 2001.

DIESEL CARS & PLATINUM DEMAND

Demand for diesel powered cars in Western Europe has grown remarkably over the last decade. Across the region as a whole, diesels now account for over one third of all new cars sold. Both gasoline and diesel cars are subject to strict limits on pollutant emissions, and both use autocatalysts containing pgm to reduce emissions. However, because diesel and gasoline engines operate under very different conditions, they utilise different pgm-based catalysts. Gasoline autocatalysts utilise platinum and/or palladium in combination with rhodium, whereas diesel autocatalysts currently only use platinum. The increased market penetration of diesels in Europe, therefore, has important implications for future pgm use in the region.

European Diesel Car Sales Have Been Rising Rapidly

The market for diesel cars in Western Europe has experienced phenomenal growth in recent years. In 1995 diesels accounted for 22.6 per cent of new car sales in the region, by 2001 this had risen to 35.9 per cent, equivalent to 5.33 million cars. In Austria, Belgium, France and Spain the penetration of diesel automobiles already exceeds 50 per cent.

The growth in popularity of diesels has been driven by several factors:

- **Performance.** Major technical developments in engine design and engine management systems have vastly improved the overall performance of modern diesel engines for light vehicles. They now compete effectively with gasoline engines in terms of noise and driveability, and offer a feeling of 'power' resulting from high torque at low speeds. As a result of increased demand, car manufacturers are offering a greater number of models with diesel engines.
- **Economy.** The fuel efficiency of diesel engines is significantly higher than comparable gasoline engines. The relatively high cost of both diesel and gasoline in the EU makes fuel efficiency an important consideration for European drivers. For example, in January 2002 the average price of a litre of unleaded gasoline in the region was equivalent to $3.07 per US gallon; in the USA it was around $1.15 per gallon – over 60 per cent cheaper. *

  **Source: The Automobile Association Ltd, UK, and the European Road Information Centre, Switzerland.*
- **Tax incentives.** Many European governments tax diesel fuel at a lower rate than gasoline, which reinforces the running cost advantage of diesel cars. In August 2001 diesel fuel was on average 23 per cent cheaper than gasoline in Western Europe, primarily due to taxation differentials.

Diesels also retain their traditional advantages of long life and low maintenance requirements. Although the purchase cost of new diesel cars can be higher than comparable gasoline models, they tend to retain their value better.

Why Do Diesel & Gasoline Autocatalysts Differ?

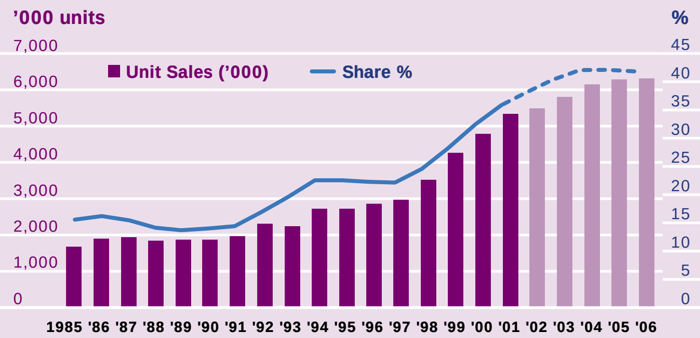
The amounts of air and fuel burnt in a gasoline engine are usually in chemical balance, there being no excess of either. This stoichiometric air:fuel ratio is typically 14.7 parts air to 1 part gasoline.

Under these conditions, and at the quite high temperatures (350-750°C) of the gasoline exhaust gas, platinum and/or palladium oxidise the pollutants carbon monoxide (CO) and hydrocarbons (HC), while rhodium catalyses the reduction of nitrogen oxides (nitric oxide and nitrogen dioxide, termed NOx) to nitrogen. Auto companies, therefore, use catalysts containing platinum and rhodium, palladium and rhodium, or a mixture of all three to meet current gasoline vehicle emissions regulations. These catalytic converters are known as three-way catalysts because they efficiently and simultaneously convert the three pollutants to harmless gases.

In marked contrast a diesel engine always operates with a large excess of air (the air:fuel ratio is typically ~30:1), often referred to as lean-burn operation; three-way catalysts cannot perform under these conditions. It has therefore been necessary to restrict NOx emissions by sophisticated diesel engine control measures and to use an oxidation catalyst to convert excess HC and CO to water and carbon dioxide.

An additional complication comes from the operating conditions of diesel engines that result in low exhaust gas temperatures (120-350°C). To date, only platinum based catalysts have been able to deliver the required

Diesel Passenger Car Sales in Western Europe



Source: DRI-WEFA Global Automotive Group performance under these operating conditions.

The low temperature of diesel engine exhaust gas also means diesel oxidation catalysts may have to contain higher loadings of platinum than their gasoline equivalents to achieve the necessary conversions of HC and CO.

Future Emissions Legislation May Benefit Platinum

As with gasoline-powered vehicles, diesel cars are subject to increasingly stringent exhaust gas emissions legislation, which drives development of improved combustion processes and increasingly efficient autocatalysts.

The Euro III legislation (effective from January 2000 for new models, and from January 2001 for all existing models) introduced stringent new limits for diesel vehicle emissions for HC, CO, and NOx, as well as for particulate matter (PM).

The permissible limits will be further reduced by the Euro IV regulations, due to enter legislation from January 2005 (see table), and by future Euro V regulations that are currently under discussion.

To meet the lower NOx and PM emissions limits set by Euro IV, and those likely to be introduced under future Euro V regulations, it may be necessary for some diesel cars to be equipped with additional pollution abatement technology. Several options that utilise the catalytic properties of platinum are being developed to meet the challenge.

Technology for Control of Particulate Matter

The nature of the diesel combustion process results in the formation of particulate matter (PM) or 'soot'. Improved engine control and combustion engineering have in recent years dramatically lowered the amount of PM formed by modern light duty diesel engines. Nevertheless, there are some concerns about the health effects of very small particles, and ways of completely eliminating them are being sought.

It is possible to remove virtually all of the PM from diesel exhaust by using a porous ceramic filter. However, the challenge is then to remove the trapped soot from the filter. One means of achieving this is to burn it but the direct reaction of diesel soot with oxygen (air) requires temperatures above 550°C, which do not normally occur in the exhaust gas of diesel cars. However, platinum catalysts can be used to oxidise additional fuel that is injected into the exhaust gas periodically, raising the temperature sufficiently to initiate combustion of the trapped soot.

A more elegant approach for the combustion of trapped soot involves the oxidation of nitric oxide (NO), which is already present in the exhaust gas, to nitrogen dioxide (NO_2) over a platinum based catalyst. The NO_2 produced is a much more powerful oxidant than oxygen, and it starts to burn PM at temperatures as low as 250°C. This concept has been commercialised as the continuously regenerating trap (CRT™) and has already been fitted to many thousands of heavy duty diesel trucks and buses in Europe. In North America and other industrialised regions, these devices are involved in several inner city trials, and sales are growing as their benefits become recognised more widely.

In future, both these approaches to PM reduction may become widely used on diesel cars, and both make use of platinum oxidation catalysts.

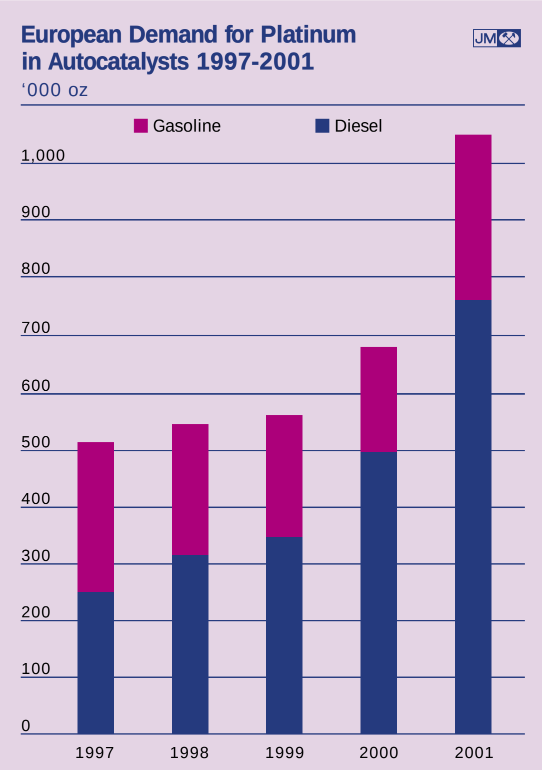
Technology for NOx Control

The oxygen rich environment of a diesel engine's exhaust gas favours the catalytic oxidation of CO and HC to water and CO_2 over the reduction of NOx to nitrogen, but all three emissions must be within the appropriate legislative limits. To date, NOx emissions from diesel cars have been reduced below these thresholds through

European Union Passenger Car Emissions Regulations

	1997 – Euro II		2000 – Euro III		2005 – Euro IV	
Pollutant (g/km)	**Gasoline**	**Diesel**	**Gasoline**	**Diesel**	**Gasoline**	**Diesel**
HC	–	–	0.20	–	0.10	–
NOx	–	–	0.15	0.50	0.08	0.25
HC+NOx	0.50	0.70*	–	0.56	–	0.30
CO	2.20	1.00	2.30	0.64	1.00	0.50
PM	–	0.88†	–	0.05	–	0.025

**Limit was 0.90 for direct injection diesels until 30 Sept 1999 †Limit was 0.10 for direct injection diesels until 30 Sept 1999*
HC = Hydrocarbons; NOx = Oxides of Nitrogen; CO = Carbon Monoxide; PM = Particulate Matter



developments in diesel engine design and combustion technology. These include the use of very high-pressure fuel pumps in sophisticated direct injection systems, which precisely control the volume of fuel injected into the cylinder and produce a finely atomised spray. The delivery of fuel at very high pressure leads to a lower average combustion temperature that moderates the formation of NOx.

A second important way of reducing the amount of NOx formed is the use of exhaust gas recirculation (EGR), where partially oxygen-depleted exhaust gas is mixed with the fresh air that enters through the inlet manifold. This lowers the oxygen content of air in the cylinder, again lowering the peak combustion temperature and so reducing the amount of NOx formed.

There are practical limits, however, to what can be achieved by engine design and by improving the combustion process. In the future, measures such as these may not be able to reduce the formation of NOx to sufficiently low levels. To meet the lower NOx limits set by Euro IV, and those that may be introduced under future Euro V regulations, it might be necessary for some diesel cars to be equipped with additional pollution abatement technology.

One of the most likely catalytic ways of controlling NOx emissions is to chemically retain NOx as nitrate in what is sometimes called a 'NOx-trap'. During normal, lean operation of the diesel engine, NO is oxidised to NO_2 by platinum as the exhaust gas flows through the trap. The NO_2 is then retained in the trap in nitrate form. Periodically, the diesel engine is run richer than normal (with a higher proportion of fuel) for a short time. This produces exhaust conditions under which the nitrate is catalytically reduced to harmless nitrogen and released, regenerating the trap.

In NOx control, therefore, as in PM control, platinum is likely to have a key role. Already NOx-trap technology is used on some lean running gasoline engines. There are challenges for its practical implementation on diesel cars, but good progress is being made in this area.

US Market Yet to Follow European Growth

In the last quarter of 2001, diesels represented 39.8 per cent of Western European car sales. The impact of the growth in diesel car production on platinum demand is clear from the accompanying bar chart. With fuel costs unlikely to decrease significantly in the foreseeable future, the appeal of diesel cars to European consumers seems certain to increase further. Current estimations for the potential penetration of diesels across Western Europe range from 42 to 50 per cent by 2006, exceeding sales of 6 million vehicles annually.

In marked contrast, diesel cars accounted for less than 1 per cent of US light vehicle sales in 2001. US consumers were put off diesel cars in the early 1980s because the first models sold in the USA suffered from poor performance. This negative public perception persists today. However, advances in modern diesel engine performance are not yet recognised widely.

In addition, because gasoline in the USA is typically less than half the price of fuel in Western Europe, fuel economy is not an important consideration for most American consumers when purchasing a new car.

An increase in US national fuel efficiency standards could help to increase the appeal of diesel light vehicles but the Senate rejected the most recent proposals in March 2002.

The penetration of diesels into the US market is further hindered by current Federal vehicle emission regulations. These do not make a distinction between gasoline and diesel automobiles, and require significantly lower NOx levels than those applied under Euro III legislation.

Despite these hurdles, inroads are being made into the US market by the latest diesel cars, and the modern high speed diesel engine is well suited for use in the very popular sports utility vehicles. Nevertheless opinion is divided, even among the leading car manufacturers, about the level of market share that diesels could achieve.

Jewellery

Global demand for platinum in jewellery dropped by 10 per cent to 2.55 million oz in 2001. Demand from China increased to a record 1.3 million oz, a rise of 18 per cent year on year, but high platinum prices in the first half of the year, combined with lower economic activity, had a major impact on fabrication levels in Japan and the USA. Platinum lost market share to white gold in the lower priced sections of these markets, whilst demand in Japan was further affected by substantial liquidation of inventories. European demand fell 11 per cent overall but Swiss and UK fabricators increased sales.

Europe

European demand for platinum in jewellery fabrication slid to 170,000 oz in 2001, affected by the metal's high price in the first half of the year and economic weakness, particularly in export markets. Demand from German and Italian manufacturers fell sharply but UK bridal jewellery fabricators and the Swiss watch industry enjoyed healthy order levels.

Sales in the German jewellery market as a whole were depressed in 2001, reflecting a weaker economy. The platinum sector was further affected by a general move towards the use of cheaper jewellery materials. With the price of platinum relatively high in the first half of the year, there was a significant amount of substitution of platinum with white gold, as well as increased use of non-precious metals such as titanium and stainless steel.

The Italian platinum jewellery industry is largely export led, particularly for manufacturers of lightweight chain products. Orders from the USA and Japan fell substantially in 2001 due to depressed retail demand.

UK demand for platinum for jewellery manufacture increased almost 10 per cent in 2001. Whilst the number of pieces hallmarked grew only moderately, the average weight of platinum per article continued the rise seen in 2000. The UK platinum jewellery market is dominated by bridal products, which are generally less sensitive to price increases.

Swiss fabricators produced considerably more platinum jewellery for export in 2001, boosting platinum demand. The Swiss watch making industry also had a strong year, despite the slowing global economy. The number of platinum watches produced increased by 25 per cent, and sales in Europe – the main initial destination for Swiss-made watches – were particularly strong.

Chinese jewellery accounted for 1.3 million oz of platinum demand in 2001

Japan

Demand for platinum from the Japanese jewellery industry dropped by a third in 2001, falling from over 1 million oz in 2000 to 710,000 oz last year – the lowest level since the mid 1980s. The slump was primarily due to a combination of intensive efforts to reduce inventories of platinum jewellery by both fabricators and retailers, as well as reduced consumer spending.

The situation was exacerbated by the high price of platinum, which averaged over ¥2,300 per gram during the first half of 2001. As the economy worsened and retail sales declined, it became harder for platinum jewellery to compete in the lower price ranges. Wholesalers and retailers responded by focusing increasingly on white gold as a substitute for platinum to satisfy the public's demand for inexpensive white jewellery. Whilst the overall Japanese jewellery market was stable in 2001 in terms of number of pieces sold, platinum's share of the market fell by a fifth to 27 per cent. In contrast, sales of white gold items rose by 21 per cent and those of yellow gold by 10 per cent.

Consumer spending on jewellery in Japan is heavily biased towards pieces under ¥37,500. Platinum items only accounted for 15 per cent of all jewellery bought in this price bracket in the key sales month of December 2001 compared to 20 per cent the previous year. Even in higher value sectors of the market (¥100,000 to ¥400,000 per piece), which had previously been price resilient, sales in 2001 dropped by 10 per cent.

Lower consumer spending had the greatest effect on sales of platinum fashion jewellery – the number of

Platinum Demand: Jewellery '000 oz		
	2000	**2001**
Europe	190	170
Japan	1,060	710
North America	380	280
Rest of the World	1,200	1,390
Total	**2,830**	**2,550**

necklaces sold fell 26 per cent, bracelet demand dropped 30 per cent, and sales of platinum earrings fell by 26 per cent.

Platinum jewellery manufacturers, wholesalers and retailers all made strenuous efforts to reduce inventories in 2001, in the face of continuing economic uncertainty and consumers' reluctance to buy more expensive jewellery. The amount of old jewellery being returned for melting increased as a result. The impact of stock reductions was to cut demand for platinum alloys for new jewellery fabrication substantially.

With little immediate prospect of a sustained recovery in the Japanese economy, retail sales are unlikely to improve in 2002. Platinum demand from jewellery fabricators, however, may benefit from lower recycling of old stock.

North America

After nine years of steady growth, North American demand for platinum in jewellery fell by 100,000 oz to 280,000 oz in 2001, a drop of over 26 per cent. As in Japan, a weakened economy that undermined retail sales and inventory reductions, in this case by retailers, were the main negative influences.

The high price of platinum relative to white gold contributed to the decline, with the latter taking market share as the amount spent per sales transaction diminished. This was also true of the bridal sector, which accounts for the majority of platinum sales in the USA, and which is traditionally not very sensitive to price movements.

Sales of platinum jewellery during the Christmas season in 2000 were lower than had been expected, which resulted in large stocks being carried over into 2001. This cut demand for new platinum jewellery from fabricators. To this was added the slide in US equities during the first nine months of 2001 and the stagnation of the economy in the second half of the year, which combined to dampen consumer spending on luxury items. In anticipation of lower sales, retailers streamlined their platinum product lines and reduced inventories. The net result was a further reduction in new metal demand.

Platinum jewellery sales over the 2001 Christmas period in the USA, however, were better than many retailers expected and demand to date in 2002 has been encouraging. US consumer confidence has shown some signs of improvement, increasing the likelihood that spending will rise this year. Much depends on the strength and pace of the US economic recovery from its brief recession, but indicators such as industrial output and employment levels were positive in the first quarter of 2002.

Rest of the World

The Chinese appetite for platinum jewellery remained healthy in 2001; sales of platinum to jewellery manufacturers rose by 200,000 oz (18 per cent) to 1.3 million oz. Higher retail sales were driven by GDP growth of over 7 per cent last year (according to government figures), while the affluence of urban areas continues to increase.

In late 2000 and during the first half of 2001, when the price of platinum was over $600 per oz, Chinese jewellery fabricators found their profit margins on platinum articles reduced. Most were unable to pass on their extra costs in full to retailers, and many increased their production of white gold items as a result. The fall in the platinum price in the second half of 2001 rapidly enabled manufacturers to regain their margins on platinum products and fabricator demand for the metal increased significantly. Despite retail price increases, the Chinese public remained very enthusiastic about platinum jewellery throughout.

Figures from the first quarter of 2002 suggest that platinum jewellery demand this year will show further strong growth. Consumption has been helped by the spread of retail outlets outside of the major cities and the greater choice of products and designs available. Platinum is also gaining a wider consumer base and is not just the preserve of affluent younger buyers.

Platinum consumption in the remainder of the Rest of the World region fell 10 per cent in 2001 to 90,000 oz. Almost all other Asian countries producing platinum jewellery rely heavily on exports to Japan, the USA and Europe and so were affected by the downturn in demand in these areas.

The economic slowdown in the USA cut short growth in the emerging platinum jewellery manufacturing business in India. In recent years, Indian manufacturers have taken advantage of their established position as exporters of gem set gold jewellery to develop sales of platinum products to major wholesalers in the USA. Domestic demand for platinum jewellery in India offers the potential for long-term growth but is currently very modest.

Thai jewellery manufacturers have been hit hard by the fall in the Japanese market, as well as the downturn in the USA. Output in the South East Asian region is generally from fabricators that rely on low production costs to be able to sell into niche markets. Future production will be largely dependent on increased export sales as the key European, US and Japanese economies expand.

Platinum Jewellery Alloys

Platinum jewellery is rarely manufactured from 100 per cent platinum because the pure metal is too soft to withstand the rigours of daily wear. Most is typically produced using platinum of 85 to 95 per cent purity, alloyed with small amounts of other metals to increase its hardness. The platinum purity or "fineness" is nearly always measured in parts per thousand (ppt). A hallmark showing "Pt950" certifies that the metal is composed of 950 ppt (95 per cent) platinum and 50 ppt (5 per cent) other metals.

As well as determining how well a piece of jewellery will resist scratching in use, the hardness of a platinum alloy also affects how easily a piece of jewellery can be shaped and finished by hand. It is also important in the automated manufacture of products such as chains because softer alloys place less wear on the forming machinery. Components such as spring catches, however, have to be made from harder alloys that can withstand the stresses placed upon them in use.

In addition to hardness, the choice of alloy for a particular application depends on several other factors that are influenced by the alloying metal, including purity, melting range and casting behaviour, reactivity, and workability (the ability of the platinum alloy to be shaped, rolled or drawn without becoming brittle and cracking). Cost and appearance are also key considerations but, in general, particular alloy types have tended to dominate in different countries due to manufacturers' long-standing familiarity with their individual characteristics.

Platinum-palladium alloys are widely used in Japan and China. The most common alloys are Pt900/Pd (100 ppt palladium) Pt850/Pd and Pt950/Pd. Pt900/Pd is the general purpose alloy of choice in Japan, offering a good combination of hardness, workability, and suitability for casting, welding and soldering. Chain manufacturers prefer Pt850 because its softness and ductility minimise tool wear and are also very well suited to the chain making process.

The alloy compositions used by Chinese manufacturers tend to vary considerably. Diamond set jewellery is typically produced in Pt900/Pd but other platinum jewellery is produced from alloys containing copper, cobalt or nickel. Pt950/Pd is sometimes used in Europe and Asia for castings requiring fine detail.

Platinum alloys containing up to 5 per cent **cobalt** (particularly Pt950/Co) are extensively used in Europe and Japan, and have gained popularity in the USA. The addition of cobalt produces a fluid alloy that is well suited to the casting process, that can reproduce very fine detail, and which produces hard, durable jewellery.

The alloy Pt900/Ir, containing 10 per cent **iridium**, has very good all round manufacturing characteristics: it can be cast, welded, machined and stamped; it is ductile and malleable; can be hardened through working; and does not readily oxidise. Because of these advantages, Pt900/Ir has traditionally been one of the most important jewellery alloys used in the USA, although there has recently been a swing toward alloys of 950 fineness. Some manufacturers in Germany and Japan also prefer this alloy. Pt800/Ir is very hard and dense, and is used in Germany for the production of fine wirework.

Platinum-copper alloy systems offer several general purpose jewellery alloys for machining and hand-working applications. Casting, however, can be difficult with some copper-containing alloys. The most common compositions contain 30 or 50 ppt copper, sometimes in combination with 50 to 100 ppt palladium.

Ruthenium is used to produce a Pt950/Ru alloy that has good all-round machining properties and is well suited to high volume manufacturing processes. It is widely used for the manufacture of wedding bands, particularly in the USA. Platinum-ruthenium alloys are also commonly used by Swiss watch manufacturers.

Other platinum alloys containing metals such as tungsten, gold and gallium are also produced for the jewellery industry, and can offer advantages for specific applications. Speciality alloys, however, only account for a very small proportion of those used – the great majority of platinum jewellery is manufactured from platinum alloyed with a combination of palladium, iridium, ruthenium, cobalt or copper.

Hallmarking

Jewellery is usually marked to record the platinum content of individual pieces. When backed by consumer protection laws, a hallmark (or assay or standard mark) is a guarantee that the article contains the specified minimum purity of platinum. Some countries permit the composition of the alloy to fall below the standard by a set amount, for example 0.5 per cent, which is known as negative tolerance.

In many countries, platinum is identified by the accepted international abbreviations of "Pt" or "Plat", either preceded or followed by the fineness number. In the USA, alloys of 950 fineness or above may be marked with the word "platinum". In the UK, platinum is identified by a 5-sided shape (a rectangle surmounted by a triangle) within which the fineness number is stamped. In 1975, the European Hallmarking Convention introduced a "Common Control Mark" for platinum that is recognised by each of the signatory countries. This is a diamond shape containing a balance, which in turn surrounds the fineness number.

Europe: for platinum, the finenesses set under the Hallmark Convention are 999, 950, 900, and 850. No negative tolerance is accepted. The countries that have adopted the convention to date are Austria, the Czech Republic, Denmark, Finland, Ireland, the Netherlands, Norway, Portugal, Sweden, Switzerland and the UK.

Most other countries in Europe apply a single platinum 950 standard, with Italy permitting a small negative tolerance. France, Spain and Italy also allow iridium to be counted as platinum. Germany permits use of alloys with 999, 960, 950, 900 and 800 fineness.

Japan: Japanese regulations cover the finenesses 1000, 950, 900, and 850, and permit a negative tolerance of up to 0.5 per cent. This enables manufacturers of 1000 alloy to add small quantities of other elements in order to increase the hardness of the pure platinum.

USA: products manufactured in the USA from platinum with a fineness of 950 or above may be marked "Platinum" or "PLAT". Alloys above 850 fineness can be marked with the abbreviations "Plat" or "Pt" as long as they are preceded by the fineness number. Alloys containing a minimum platinum content of 500 ppt are permitted if the total pgm content is at least 950 ppt. Hallmarks for these alloys have to state the fineness of each metal, for example: "650Plat300Irid".

China: the mainland Chinese jewellery industry has a national hallmarking standard that covers platinum articles, and this is policed by retailers who send incoming goods from manufacturers to approved testing centres. Most alloys used have a platinum fineness of 900 or 950 and are marked accordingly.

Platinum jewellery manufactured in Hong Kong is covered by trade descriptions orders, under which any product described as being "platinum" must have a fineness of at least 850. Similar to Europe and Japan, the hallmarks Pt850, Pt900, Pt950 and Pt990 are used to denote the platinum content of alloys used.

Outline Properties of Common Platinum Jewellery Alloys

Composition % Alloying elements	Pt/pgm Fineness	Melt temp. °C	Hardness Hv	Applications/Notes	Countries of major use
5% Copper	950	1,745	120	General purpose	Europe
5% Cobalt	950	1,765	135	Fluid for hard castings	Europe, USA
3-5% Cobalt/ 5-10% Palladium	850–950	1,730–1,765	125(C)–150(C)	Hard castings	Japan
5% Iridium	950	1,790	80	General purpose	Europe, Japan, USA
10% Iridium	900	1,800	110	General purpose	USA
15% Iridium	850	1,820	160	Catches, pins, springs	Japan
20% Iridium	800	1,830	200	Spring applications & fine wirework	Germany
5% Palladium	950	1,765	60, 68(C)	Castings, delicate settings	Japan
10% Palladium	900	1,755	80, 72(C)	General purpose	China, Japan
15% Palladium	850	1,750	90, 64(C)	Chain making	Japan
5% Ruthenium	950	1,795	130	Machining	Europe, USA
5% Tungsten	950	1,845	135	Hard for springs	Europe

NOTES: 1. Melt temperature is the liquidus value – the temperature at which the alloy becomes fully liquid 2. Hardness values are for the annealed state except those marked (C), which are for the as-cast state 3. Pt/pgm finenesses are in ppt.

Platinum Demand: Chemical '000 oz		
	2000	2001
Europe	100	105
Japan	20	20
North America	100	100
Rest of the World	75	65
Total	**295**	**290**

Chemical

Global demand for platinum in the chemical industry was largely stable during 2001, demand declining marginally compared with the previous year to 290,000 oz. Silicone output was broadly similar to the year before and there were no significant additions to paraxylene capacity – the manufacture of both products uses platinum.

Predictions of strong growth for the speciality silicones sector did not materialise during 2001, as demand was hit by slower economic growth in Europe and the recession in the USA.

Speciality silicones are primarily used in the manufacture of adhesives, synthetic rubbers, sealants for construction applications, and a range of consumer goods such as personal care products. As most of the catalyst used is lost during the production process, platinum demand is closely related to silicone output.

Paraxylene is a chemical precursor to purified terephthalic acid (PTA). This in turn is the feedstock for the production of polyester fibres and the plastic polyethylene terephthalate (PET). The manufacture of paraxylene is catalysed using platinum but metal losses during the process are small, so demand is mostly linked to construction of new manufacturing capacity. Several new paraxylene units came on stream in 1999 and 2000, reducing the need for investment in additional capacity last year. This led to a decline in demand for platinum catalysts.

Demand for platinum based process catalysts in other sectors of the chemicals industry is small in comparison to silicones and paraxylene. Demand was broadly similar to 2000 in 2001, although the pharmaceutical industry remains a growth sector.

The nitric acid industry suffered from lower demand and prices for nitrogen fertilisers in 2001 due to weak crop prices, reduced economic growth, and a wet spring planting season in Europe and North America. The deterioration in the fertiliser market meant that there was little significant investment in nitric acid capacity in 2001 and demand for platinum catalysts was broadly similar to the year before.

Electrical

Use of platinum in electrical and electronic applications fell 15 per cent to 385,000 oz in 2001, primarily due to a sharp downturn in the global electronics industry, and in sales of personal computers in particular. Demand for platinum in thermocouples also declined, reflecting lower industrial output in Japan, North America and Europe.

Platinum Demand: Electrical '000 oz		
	2000	2001
Europe	80	65
Japan	90	80
North America	145	120
Rest of the World	140	120
Total	**455**	**385**

Computer hard disks are the largest single electrical application for platinum and demand almost doubled between 1998 and 2000. The rapid growth was due to soaring sales of personal computers and the increase in disk storage capacity through the use of a layer of a platinum-cobalt alloy. In 2001, however, sales of personal computers faltered – worldwide sales dropped by 4 to 5 per cent and shipments in the large US market dropped by 11 to 12 per cent compared to the previous year.

In addition, by the start of 2001, over 90 per cent of all hard disks produced incorporated a platinum alloy layer, reducing the opportunities for further market share gains. Whilst the greater use of platinum in hard disks has increased their data storage density, this has also enabled manufacturers to reduce the number of disks in each hard drive – the average fell from 1.8 disks per

PEM fuel cells power advanced prototype vehicles such as DaimlerChrysler's NECAR 5 and Jeep Commander 2 drive in 2000 to 1.6 in 2001. The net result of lower PC sales and fewer disks per hard drive was a fall in platinum demand of around 15 per cent last year.

There is optimism amongst PC manufacturers that last year's fall in total PC sales will be short-lived, and order levels will recover this year.

Demand for platinum in thermocouples weakened in 2001 as a result of lower levels of production in the key industrial sectors of steel and semiconductor manufacturing. Crude steel output fell by over 11 per cent in the USA and by around 3 per cent in the European Union and Japan in 2001. Sharp declines in semiconductor production reduced the number of semiconductor fabrication units that came on-line last year.

Use of platinum in fuel cells amounted to less than 2 per cent of overall total electrical demand in 2001 but the technology is moving towards commercialisation in several applications. Important developments in 2001 are highlighted in the accompanying panel.

Glass

Demand for platinum in glass manufacturing applications increased by 30,000 oz to 285,000 oz in 2001. Substantial growth in China was driven by construction of new television glass and fibreglass furnaces, and investment in high quality LCD glass capacity continued in Japan and South Korea. These increases heavily outweighed decreased demand in North America and Europe.

FUEL CELLS

The era of commercialisation begins

Fuel cells generate electricity and heat from a simple electrochemical reaction in which oxygen and hydrogen combine to form water. A solid or liquid electrolyte carries electrically charged particles between an anode and a cathode. A catalyst, usually platinum, is used to speed up the reactions at the electrodes. This process produces much less pollution than burning the fuel in a combustion engine or generator and is also more efficient, making it economically and environmentally attractive.

There are several types of fuel cell, utilising different electrolytes and fuels. The proton exchange membrane (PEM) type of fuel cell always employs platinum as a catalyst on the electrodes. Alkaline and phosphoric acid fuel cells also commonly use platinum-containing electrodes. Other types of fuel cell may use pgm to catalyse the conversion of the fuel (such as natural gas, methanol or gasoline) to hydrogen to feed the cell itself. Most current development work is focused on PEM fuel cells.

Present demand for platinum in fuel cells is low; a few thousand ounces annually. Commercial production to date has been mainly of large, typically 200kW, phosphoric acid fuel cells for stationary power generation applications. Smaller PEM units, however, are now under development. For example, Plug Power has already started field trials of PEM fuel cell systems designed to supply electricity and heat to individual homes.

Other organisations in Europe, Japan and North America are expected to follow this lead and units for domestic use should be commercially available within five years. On a shorter timescale, Coleman Powermate expects to launch a small, portable PEM fuel cell generator during 2002.

The automotive sector, however, remains the most exciting area for this technology due to its huge size. Almost every car manufacturer has a fuel cell programme and most have built and exhibited prototypes, with many already entering into pre-commercial partnerships.

Ballard Power Systems, for example, has been developing PEM fuel cell components and systems for automobiles via joint ventures with DaimlerChrysler and Ford. In November 2001 Ballard took full control of the joint venture companies, Xcellsis and Ecostar; in return, DaimlerChrysler and Ford increased their direct ownership of Ballard.

Meanwhile, UTC Fuel Cells (previously known as International Fuel Cells) has forged alliances with companies including Hyundai, Nissan and Renault, to advance development of PEM fuel cell powered automobiles.

A third major grouping is composed of General Motors (GM) together with Toyota. In 1999 the two companies signed a 5 year agreement to work together to develop alternative vehicle propulsion technologies. In early 2002, GM exhibited a new concept car, AUTOnomy, which is specifically designed to be fuel cell powered. Although GM does not intend to manufacture a product based on AUTOnomy for some years, Toyota has announced that it will sell fuel cell cars from 2003.

Honda, meanwhile, has been developing fuel cell technology since 1989 and, like Toyota, intends to introduce a production fuel cell vehicle next year. These are perhaps the most significant developments of the last twelve months as they may mark the beginning of the commercial era for fuel cells.

Up-to-date news and information about the global fuel cell industry can be found on the web site **www.fuelcelltoday.com**.

The Chinese market for fibreglass is expanding strongly, and several major manufacturers in China have scheduled or undertaken expansions in capacity. In contrast, the European and North American fibreglass markets are mature and demand was weakened by the economic slowdown. Nevertheless, there is growth in several applications, including construction and lightweight fibreglass reinforced products in the automotive industry.

The LCD glass market suffered from falling prices due to oversupply in 2001, as demand for consumer electronics such as laptop computers, personal organisers and mobile phones fell. This caused some manufacturers to scale back their expansion plans but construction of several new furnaces did proceed. Renewed investment in this sector should materialise from the second half of 2002, if economic growth in the USA and Europe regains momentum, stimulating demand for equipment manufactured from platinum.

Demand for traditional CRT (cathode ray tube) screens for televisions and desktop computers remained healthy in emerging Asian markets in 2001. Demand for platinum-rhodium alloys used in the manufacturing process was boosted by capacity additions in China and India. In contrast, the CRT glass industry in the USA is battling tough competition from Asian imports, and is not expected to invest in new furnaces in the foreseeable future.

Platinum Demand: Glass
'000 oz

	2000	2001
Europe	20	15
Japan	65	85
North America	50	30
Rest of the World	120	155
Total	**255**	**285**

Petroleum Refining

Platinum based catalysts are used in several stages of petroleum refining, particularly during the reforming of naphtha into downstream petrochemical products. Demand for platinum from the petroleum refining industry increased by 15,000 oz to 125,000 oz in 2001 as incremental additions were made to existing capacity.

The petroleum markets in North America and Western Europe are mature, and large-scale refinery construction is unlikely for both environmental and economic reasons. Demand for platinum catalysts was stable in Europe, China and Japan in 2001 and increased moderately in North America.

Platinum consumption in Latin America and South East Asia is forecast to grow over the next 2 years, with the installation of several new reforming, hydrocracking and isomerisation units.

Platinum Demand: Petroleum Refining
'000 oz

	2000	2001
Europe	15	15
Japan	5	5
North America	35	40
Rest of the World	55	65
Total	**110**	**125**

Other

Demand for platinum in other applications increased by 16 per cent in 2001 to 435,000 oz. The use of platinum in dental alloys grew significantly as the high price of palladium at the beginning of the year caused a strong move towards alternative materials. Gains were also made in applications such as oxygen sensors for cars and platinum electrode spark plugs.

European Stage III auto emissions legislation brought about a significant increase in demand for oxygen sensors in 2000 and 2001. These are an essential part of engine management systems for vehicles fitted with catalytic converters. The new European regulations resulted in manufacturers installing additional sensors to ensure emissions limits are met. The number of sensors per vehicle is expected to stabilise in 2002, and so demand will more closely follow changes in vehicle production.

In North America, the 10 per cent fall in light duty vehicle production in 2001 offset any gains made from the use of greater numbers of sensors per vehicle, and platinum demand was unchanged from the previous year.

The key component of a spark plug is the central electrode that carries the electric charge to the tip. Platinum electrodes have a higher durability than traditional copper electrodes. This enables manufacturers to reduce electrode diameter, which in turn decreases the voltage required. The high durability of platinum can also improve combustion performance over the life of the spark plug, reducing emissions. These advantages have led to a growing proportion of new cars in Europe being fitted with platinum based spark plugs and demand in 2001 increased as a result.

In North America, where platinum spark plugs are already specified as original equipment by all the major auto makers, the decline in automobile production reduced platinum demand. Japanese demand for platinum spark plugs is being eroded by iridium tipped products. The use of electrodes manufactured from iridium or iridium-rhodium alloy facilitates further reductions in electrode diameter and gains in durability.

Platinum Demand: Other '000 oz	2000	2001
Europe	105	120
Japan	35	40
North America	210	250
Rest of the World	25	25
Total	**375**	**435**

The dental industry made a substantial switch away from palladium based alloys in 2001, accelerating the trend of the year before. The main beneficiaries were high-gold alloys containing an average of 10 per cent platinum but demand for base metal formulations also increased. This resulted in platinum consumption rising by more than 20 per cent compared to 2000. The change was most noticeable in the North American market, which is sensitive to metal price movements because most dental treatment is not subsidised.

Biomedical applications for platinum components continued to increase in 2001, particularly for catheters and stents used in arterial surgery, and for pacemakers. The trend towards miniaturisation of medical devices, however, is moderating growth in platinum demand.

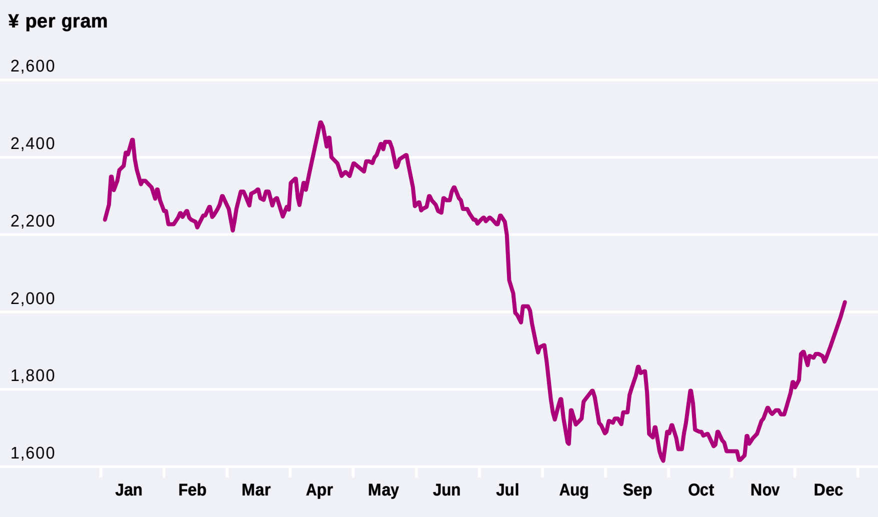
Use of the platinum based drug, Carboplatin, to combat cancer continues to increase, but in many cases at the expense of Cisplatin (also based on platinum). Production of a new drug, Oxaliplatin, used to fight prostate cancer, is increasing rapidly but total output – and therefore demand for platinum – is still very small.

Investment

The sharp fall in the platinum price between June and August stimulated strong interest in platinum investment products in both the USA and Japan. Sales of platinum coins from the US Mint increased rapidly in the second half of 2001 and lifted the net demand for small bars and platinum coins by 10,000 oz to 50,000 oz. Similarly, Japanese purchases of investment bars increased from July onwards and for the year as a whole outweighed disposals by a net 30,000 oz.

Demand for the US Mint's platinum Eagle series of proof and bullion coins fell year-on-year during the first six months of 2001 as the platinum price averaged almost $600 per oz. However, sales climbed steeply as the price began to fall, and increased by 70 per cent during the second half of 2001 compared to the year before. The investment attraction of platinum bullion coins was further enhanced by the fall in US equity prices during the first 9 months of the year. Sales of US Eagle coins continued at strong levels during the first quarter of 2002, increasing by 14 per cent compared to the first quarter of 2001.

Platinum Price in Japanese Yen in 2001



Platinum Demand: Investment '000 oz	2000	2001
Coins and small bars		
Europe	0	0
Japan	5	5
North America	35	45
Rest of the World	0	0
	40	**50**
Large bars in Japan	**(100)**	**30**
Total	**(60)**	**80**

A loan of 196,000 oz of platinum to the US Mint by the DLA has now been repaid, although the Mint is believed to have purchased a proportion of the metal borrowed. The Mint is expected to maintain its working stock of platinum by making annual purchases of metal on the spot market in future, as demand dictates.

The first few months of 2001 saw Japanese sales of large bars back to the market far outweigh new purchases as the price exceeded ¥2,300 per gram. The Japanese market for 500g and 1kg bars is highly price sensitive, therefore as the platinum price began to fall, buying accelerated. From late July onwards, purchases of investment bars jumped dramatically as the price dropped under ¥2,000 per gram, resulting in net demand of 30,000 oz during 2001.