Opportunities for downstream value addition in the platinum group metals value chain: Fuel cells

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Department of Research and Information
Despite the serious challenges facing South Africa’s mining industry, the country remains by far the world’s dominant producer of platinum group metals (PGMs). Based on 2011 figures, South Africa produces approximately 75% of global platinum, 35% of palladium and over 80% of rhodium.

South Africa has over 80% of global PGM reserves (value at ca. R50 000 billion), with Zimbabwe holding a further 7% and Russia 8%, with the three countries claiming 95% of global reserves. Russia’s share of global production is 50% of palladium and 15% of platinum refined by a single company, with sales controlled by the state.

In 2011, global platinum production amounted to 6.4 million ounces, palladium output totalled 7.4 million ounces and rhodium production reached 768 000 ounces. Four mining and refining companies control more than 95% of global PGMs supply. Recycling, which is an increasing component of the PGMs supply chain, amounted to 2 million ounces for platinum, 2.1 million ounces for palladium and 260 000 ounces for rhodium.

The practical or real demand for PGMs is made up of two components: autocatalysts (39%) and industrial applications (22%). Jewellery represents a further 31% of demand, whilst investment demand (8%), particularly through exchange traded funds (ETFs), has grown in significance as investors sought to gain from rising commodity prices.

Five international companies purchase from PGM refiners to fabricate more than 85% of PGMs for applications. The fabricators constantly work to minimise PGM content, also called thrifting, due to high prices and supply uncertainty. They hold the intellectual property that is key to the use of PGMs.

South Africa has a substantial base of international autocatalyst manufacturers with a capacity of 27.1 million units per annum, which equates to approximately 830 000 ounces (1.2 m³ or R10 billion p.a.) of platinum. The domestic autocatalyst manufacturing industry has an approximate 19% share of the global market at full capacity. It was established in 1990 at the behest of the automotive OEMs, having created 5 000 direct and more than 30 000 indirect jobs.

The wide scale adoption and commercialisation of emerging fuel cell technologies potentially provide a new growth phase in PGMs demand, as it is a key catalyst in the production of fuel cells and hydrogen. Powered by electricity generated from hydrogen and oxygen, fuel cells emit only water, while generating electricity at 50% efficiency levels, twice those of conventional engines or turbines. Fuel cell electric vehicles (FCEVs) are considered complementary to today’s battery-electric vehicles and to expand the range of zero-emission transportation options available to consumers.

Although current FCEVs contain 50 times the PGM input than that of an autocatalysts exhaust system, over the medium- to long-term this should reduce to about 5 times. A number of projections show that fuel cells will become the dominant automotive technology (linked to electric motors and batteries for short range) as they become cost competitive with diesel hybrids and offer far greater global warming gas reduction potential. All the major automotive OEMs have joint venture partnerships aimed at the commercial rollout of FCEVs over the medium to long-term.

South Africa is part of the global effort to support commercial applications through PGM based hydrogen fuel cells. In 2007, Cabinet adopted the HySA strategy of the Department of Science and Technology, which promotes the domestic PGM catalysis value chain. Centres of competence have been established at the University of the Western Cape, the University of Cape Town, Mintek and the CSIR. Anglo Platinum has launched a demonstration rural generation project in Lepalale and locomotives with fuel cells at Rustenburg.

A number of opportunities exist to further investigate the potential for establishing a new industrial sector in South Africa based on the PGMs fuel cell catalysis value chain. This could be through engagements with Hydrogen South Africa participants to understand the progress with regard to the various technologies under consideration.
INTRODUCTION

The platinum group metals (PGMs) consist of six elements that are characterised by similarity, namely platinum, iridium, osmium, rhodium, ruthenium and palladium. Based on their densities, the first three are categorised as heavy, while the last three are regarded as light.

PGMs are superb catalysts in addition to other characteristics like corrosion resistance, high melting points and chemical stability. It is precisely these characteristics that make PGMs highly desirable in many applications.

Currently, the single largest market for the three most important PGMs (i.e. platinum palladium and rhodium) is the automotive sector, specifically the catalytic converter industry. In addition, the three PGMs also find application uses in other areas like electronics, fuel refinery and chemical industries. A further key application for platinum and palladium in particular is the jewellery market. PGMs are also used in dental alloys, fuel cells and as bars and coins for investment purposes.

PGM resources are rare and 80% of the world’s platinum reserves are located in South Africa. The history of platinum mining in South Africa dates back to the mid-1920s. The industry has since grown in leaps and bounds over the decades to become one of the prime foreign exchange earners in the mining sector. South Africa is among the richest countries when measured by mineral reserves, which are valued currently at about USD 2.5 trillion. It is estimated that about 85% of the minerals in value terms are PGMs.

This research report investigates downstream opportunities for domestic value addition associated with the platinum group metals (PGMs) value chain. It focuses in particular on the trends in downstream application markets associated with major PGMs, specifically platinum and palladium, and, to a certain extent, rhodium.

The research has found that, whilst petrol and diesel catalysts still represent the largest market demand for PGMs, platinum-based catalysts in fuel cells represent the next major growth opportunity for South Africa’s platinum resource base. Consequently, the report provides an overview of the forces that shape world demand for and supply of PGMs. It further examines developments in the global fuel cells industry, focusing in particular on the associated opportunities. The report concludes with an outlook for the global fuel cells industry.

INDUSTRIAL CLASSIFICATION

The mining and beneficiation of PGMs are grouped under the Standard Industrial Classification (SIC) codes Division 24, Group 2424: Mining of PGMs and the dressing, beneficiating and otherwise preparing of the ore. This report focuses particularly on platinum, palladium and rhodium. Rhodium is not mined for its own sake, but occurs together with platinum and palladium.

The manufacturing of catalysts, in turn, is grouped under Division 24, Group 3359: Manufacture of other chemical products not elsewhere classified.

PLATINUM DEMAND AND SUPPLY OVERVIEW

For the most part of the last decade the platinum market tended towards balance, with the supply of platinum more or less correlated with total net demand (i.e. total gross demand less recycling), as illustrated in Figure 1.

Between 2002 and 2010, demand averaged 6.34 million ounces, whilst supply averaged 6.31 million ounces. An exception occurred in 2009, when demand fell to 5.39 million ounces, mainly due to the negative impact of the global financial crisis. Total net demand recovered to 6.05 million ounces in 2011, driven largely by industrial demand.
The platinum market is estimated to have recorded a deficit in the order of 410 000 ounces in 2012, since demand increased further to 6.25 million ounces whilst supply contracted by 10% to 5.84 million ounces due principally to production stoppages in South Africa.

**Figure 1: Platinum supply and demand balance**

![Platinum supply and demand balance](image)

**Platinum demand dynamics**

The practical demand for platinum is made up of three components, namely autocatalysts, industrial demand and jewellery. Whilst autocatalysts (39%) and jewellery (31%) demand account for the largest shares of gross platinum demand, industrial demand (22%), particularly for chemical and glass related applications, as well as investment demand (8%), are increasingly becoming important drivers of platinum demand.

**Figure 2: Changing patterns of platinum demand**

![Changing patterns of platinum demand](image)
As shown in Figure 2, industrial applications dominated platinum demand in 1980. However, autocatalysts had become the dominant component of platinum demand by 2008. Since then, demand for autocatalysts has dropped off substantially due to the impact of the global economic crisis on the vehicle industry. On the other hand, jewellery demand has almost doubled, driven mainly by China and other higher growth developing regions.

**Figure 3: Growth in the demand for platinum from various sectors**

- **Autocatalyst demand**: Between 2002 and 2010, autocatalyst net demand recorded modest growth of only 2% per annum (refer to Figure 2). Platinum is used primarily in diesel autocatalytic converters. Approximately 3.6 million ounces of platinum are used annually in autocatalytic converters. In Europe, there has been increasing substitution of platinum by palladium in light duty diesel vehicles. On the other hand, Japanese auto manufacturers still prefer to use platinum in light duty petrol vehicles. North American demand for platinum-based autocatalytic converters is expected to rise due to an increase in the production of diesel driven heavy duty and light duty vehicles.

- **Jewellery demand**: Over the same period, jewellery demand contracted by 2% per annum, most probably with the renewed glitter of gold as a precious metal of choice playing a role, as well as in reaction to price increases (demand for platinum jewellery is highly price-elastic). Approximately 2.4 million ounces of platinum are consumed annually in jewellery manufacturing. However, demand has been relatively flat recently in the key markets of Europe, North America and Japan. China and India provide the best prospects for growth going forward. In China, consumers increasingly prefer gem-set pieces, whilst growth in India comes off a relatively low base, as consumers still prefer gold to platinum jewellery.

- **Industrial demand**: Industrial demand, comprising chemicals, glass, electronics and petroleum related applications, has grown by 3% annually over the past decade. Approximately 2 million ounces of platinum are consumed in industrial processes and applications annually. Whilst electronics demand contracted by 4% per annum, glass grew by 6%, chemicals by 4% and petroleum by 3% per annum over the same period. With respect to glass related applications,
platinum is used in glass melting tanks to manufacture liquid crystal display (LCD) screens. In the case of petroleum, platinum is used in the refining process.

- **Investment demand**: Investment demand, in the form of platinum bars and physically-backed exchange traded funds (ETFs), exploded over the last decade. It grew, on average, by 22% per annum as investors increasingly sought to make quick returns through speculation. However, the current sovereign debt crisis in Europe, the on-going debt deleveraging by households and businesses in developed economies, as well as concerns over the strength of the Chinese economy, have contributed to the emergence of gold as the safe haven and precious metal of choice for investors. Over the past few months, platinum prices have recovered mainly on concerns over the labour strife in South Africa during the second half of 2012, as well as other serious challenges facing its platinum mining industry.

**Platinum supply dynamics**

South Africa remains by far the world’s dominant producer of platinum, contributing approximately 75% of global production (refer to Figure 4). Russia is the second largest producer, contributing 13% to global production, followed by North America and Zimbabwe, contributing 6% and 5%, respectively.

**Figure 4: Platinum supply by major producing region/country**

![Platinum supply by major producing region/country](image)

However, production growth in most of the world’s major platinum producing regions has been rather flat over the last decade. Since 2002, South African supplies onto global markets grew by only 1% due to a number of factors, including the introduction of a new mineral rights regime, the depletion of ore bodies, production stoppages due to safety issues and intermittent labour action, rising platinum recycling and thrifting, as well as the progressive maturation of key demand markets.

Russia and North America fared no better, with production in these regions contracting by 2% and 1%, respectively, over the same period.
Zimbabwe proved to be the exception - its supply has grown at 14% per annum since 2005 as the country’s political environment began to normalise. However, recent legislation pertaining to economic empowerment and indigenisation may yet derail any further expansion in the country’s mineral sector.

In the near term, Zimbabwe and North America are expected to record above average output performance, whilst production in South Africa is expected to increase slightly above its long-term trend when industrial and motor vehicle demand begins to recover and demand for new technological applications such as fuel cells increases.

**Recycling:** Recycling has become an increasingly important and cost effective source of alternative platinum supply. In 2011 alone, 1.8 million ounces of platinum are expected to be recycled. This represents approximately 29% of total mined platinum supplies. Scrapped motor vehicles, particularly those with diesel autocatalytic converters, as well as jewellery, are the two major sources of scrapped platinum supplies. It is expected that increased recycling, without a concomitant jump in demand, would put downward pressure on platinum prices in the near to medium term. Over the long-term, with the promise of rising fuel cell demand, recycling may play an important and even necessary secondary supply source to supplement ever tightening primary sources of platinum supply.

**Figure 5: Growth trend in recycled platinum**

![Graph showing growth trend in recycled platinum](source: Johnson Matthey)

**Palladium demand and supply overview**

As a relatively cheaper alternative to platinum, particularly in the use of catalytic converters, palladium demand has recorded much stronger growth than platinum over the past decade.

Between 2002 and 2011, the average annual demand for palladium was approximately 7.7 million ounces, whereas total supply, including recycled material, averaged about 8.6 million ounces per annum (refer to Figure 6). This growth can be largely explained by the emergence of the large Chinese motor vehicle market for petrol vehicles.

With tighter supply conditions presently unfolding, fuelled by the growth of vehicle ownership in China, palladium prices are set to follow an upward trend in the near- to medium-term.
Palladium demand dynamics

The practical demand for palladium comprises three segments: autocatalysts; jewellery; and industrial (chemical, electrical and dental). Whilst autocatalysts account for 57% of total palladium demand, industrial demand (particularly chemical and electrical), is increasingly becoming an important source of future palladium demand (refer to Figure 7).
Palladium demand and supply overview contd.

- **Autocatalyst demand**: Between 2002 and 2011, palladium use in autocatalytic converters (as an alternative to platinum) grew relatively strongly at 8% per annum, in contrast to platinum’s modest growth of only 2% per annum. Currently, approximately 5.9 million ounces per annum of palladium are used in autocatalysts. The key drivers of autocatalyst demand for palladium are the North American and Chinese markets, which prefer petrol vehicles.

- **Jewellery demand**: Jewellery demand has been flat in recent times, particularly in China where high palladium prices have suppressed demand. However, palladium has gained ground in the Eurozone and North America, where it has become popular in the men’s wedding band segment.

- **Industrial demand**: Industrial demand for palladium totals around 2.65 million ounces, having recovered to pre-recession levels. The electrical sector has made the largest contribution at 1.49 million ounces, particularly for use in computer hardware components. The balance is used as inputs into consumer products, particularly textiles and packaging.

- **Investment demand**: Investment demand has been on a downward trend, mainly due to the concerns over economic growth prospects for the advanced economies, particularly Japan, the Eurozone and the United States. However, current tight supply conditions may push palladium prices higher, which should fuel investment demand, particularly palladium ETFs.

**Figure 8: Growth in demand of palladium from various sectors**

![Graph showing growth in demand of palladium from various sectors]

**Source:** Johnson Matthey, IDC calculations

**Palladium supply dynamics**

Russia remains the world’s dominant supplier, contributing 46% to global palladium supplies (refer to Figure 9). In addition, the Russian state holds substantial stocks of palladium, approximately 750 000 ounces, which it sells into global markets from time to time. South Africa is the second largest producer, accounting for 35% of global supplies, followed by North America with 13%. Improving ore grades in North America should see a substantial increase in production from this region. Zimbabwe accounts for only 4% of global supplies, although expanding operations in this country should result in higher output levels.
Recycling: As is the case with platinum, recycling is becoming an increasingly important addition to global palladium supplies. Stocks from recycling are expected to increase by 19% in 2011 or 2.2 million ounces, which is approximately 25% of mined supplies. The main sources of recycled supply are increasing recovery from autocatalysts and electronic scrap. There has also been an increase in recovery from the Chinese jewellery sector.

Figure 9: Palladium supply by major region

LESSTER PGMS: RHODIUM DEMAND AND SUPPLY OVERVIEW

Over the past decade, rhodium demand averaged 872 000 ounces per annum, whilst supply was slightly higher at 918 000 ounces per annum. Between 2002 and 2011, the demand for rhodium grew on average by 3% per annum.

Figure 10: Rhodium demand and supply balance
Rhodium demand dynamics

The key components of rhodium demand are autocatalysts, glass, chemicals and, to a lesser extent, electrical demand. Autocatalysts account for over 80% of rhodium demand. However, autocatalyst demand for rhodium is expected to decline due to thrifting of metal loads in autocatalysts, although the outlook for demand remains positive over the long-term (see insert on thrifting). Nevertheless, demand from the glass sector is expected to rise by 25% over the next year, mainly due to expansions in LCD production and the increasing use of rhodium in glass fibre manufacturing.

Figure 11: Rhodium demand by application in 2010

Whilst demand from the autocatalyst sector grew by only 2% per annum over the past decade, glass and chemicals related demand recorded the highest growth rates, at 10% and 7% per annum, respectively, over the same period (refer to Figure 12). On the other hand, demand growth from the electrical sector was relatively flat over this period.

Figure 12: Growth trends in rhodium demand from various sectors
The announcement by Nissan (in July 2007) of its plans to introduce new, lower PGM, autocatalyst technology on its gasoline vehicles in late 2008 or early 2009 gathered considerable attention from market commentators and from the media. In October 2007, Mazda also announced new technology which it also believes will allow it to cut its autocatalyst metal loadings. In January 2009, the company again announced that it will fit its ‘Single Nanocatalyst Technology’ to the new Mazda3 vehicle to be launched later this year. However, it is important to note that this technology is being used solely on the underfloor catalysts used on this vehicle and not across the entire aftertreatment system. This suggests that the PGM savings made will not be as great as may be implied by the recent announcement.

Importantly, the catalysts mentioned in both of these announcements use platinum group metals as the active component and we do not expect that their introduction will affect automotive sector PGM usage.

There are three competing trends relating to platinum group metal usage in the automotive industry:

i. Emissions legislation is continuing to tighten all around the world. Whenever new regulations are enacted somewhere, average precious metal loadings on catalysts tend to rise in response. If this were the only trend, it would lead to continual increases in metal usage for this application.

ii. Over the long term the number of vehicles manufactured globally is also rising. As almost every vehicle now fits at least one catalyst, rising production volumes drives the number of catalysts higher, and increases the amount of precious metal required by the car industry.

iii. Opposing these two trends, all of the car companies, in partnership with Johnson Matthey and other catalyst manufacturers, are continually working to improve the performance of automotive catalytic converters. This equates to designing catalysts that convert the same amount of pollutants but require a lower precious metal content to do so. Many of the announcements on new, lower-loaded catalyst technology are simply a recognition of the effectiveness of this thrifting process which has been on-going since the first autocatalysts were used in the 1970s.

This third trend has the opposite effect from the others and this cost control or thrifting process (the removal of precious metal) has been able to keep the growth in platinum group metal requirements from the automotive industry to manageable levels. Mazda’s ‘nanotechnology’ is a new name, not necessarily a new concept. Catalyst manufacturers’ attempts to thrift are on-going and Johnson Matthey expects them to continue in coming years. Our view on all of these recent announcements is therefore that they represent something like the degree of thrifting that could be possible over a short to medium term timescale. However, we do not expect them to materially affect the positive outlook for increasing platinum group metal demand in the automotive sector.

Source: Johnson Matthey

Rhodium supply dynamics

South Africa is by far the world’s largest supplier of rhodium, accounting for over 80% of global supplies (i.e. approximately 650 000 ounces). Russia is the world’s second largest supplier, but only contributes 9% to global supplies (i.e. only about 68 000 ounces). Zimbabwe is a distant third, contributing only 4%, or 28 000 ounces, to global supplies. Recycling currently accounts for about 25% of global supply, mainly due to increased recoveries from spent autocatalysts.
DEMAND FOR PGMs IN SOUTH AFRICA

As previously noted, with the exception of palladium, South Africa dominates the global supply of PGM mineral alloys. However, this domination of upstream PGMs production is not matched by an equally significant value-added PGMs manufacturing base. Data from the Department of Mineral Resources (DMR) shows that less than 3% (as a percentage of export sales) of major PGMs, specifically platinum and palladium, is sold into the domestic market (refer to Figure 14). The same applies to lesser PGMs such as rhodium.

South Africa’s catalytic converter industry

Five international companies purchase from PGM refiners to fabricate more than 85% of their purchases of PGMs for automotive applications. The fabricators constantly work to minimise PGM content, also called thrifting, due to high prices.
and supply uncertainty. They hold the intellectual property that is key in the use of PGMs, particularly in the manufacture of autocatalysts or catalytic converters.

The local catalytic converter industry was established in 1990, ostensibly at the request of the automotive OEMs. Over the last 15 years, the industry experienced 14% annual compounded growth in production volumes. Installed production capacity stands at approximately 27.1 million units per annum, equating to an estimated 830,000 ounces of PGMs. This amount, however, conflicts directly with DMR’s data on local sales of PGMs. Whilst DMR statistics suggest that only 1.5% of mined PGMs is sold locally, the Catalytic Converter Interest Group states that it is more like 15% of global autocatalytic converter annual production at peak. In addition, the industry consumes almost 40% of domestic stainless steel production equating to approximately 50,000 tons per annum. This suggests that the industry is a beneficiation success story, as it consumes significant volumes of South Africa’s key minerals, PGMs and chrome (used in the production of stainless steel).

The industry directly employs 5,000 people and over 30,000 estimated indirect jobs associated with both upstream and downstream inputs suppliers into the industry. Approximately 50 manufacturing plants, mainly owned by multinational suppliers to automotive OEMs, comprise the core of the South African industry. At full capacity, the domestic industry represents 19% of the global market, with peak export revenues of over R20 billion.

In recent times, the industry has come under pressure due to the prevailing adverse global market conditions for motor vehicles, particularly in Europe. Current production capacity utilisation is down to 70%, or 18.8 million units. This is expected to fall further as a revision of the Motor Industry Development Plan (MIDP) to the Automotive Production Development Programme (APDP) will remove incentives for automotive OEMs to rely on component exports to offset motor vehicle imports. Nevertheless, the industry is in discussions with government in order to establish an appropriate incentive scheme that will further entrench the domestic auto catalytic converter industry by focusing on further value-added manufacturing, such as substrates, particle filters for diesel and petrol engines, heavy duty catalysts and full exhaust systems.

**OPPORTUNITY FOR DOWNSTREAM BENEFICIATION: FUEL CELLS**

**Background**

Although fuel cell technology was first developed in 1839, the technology lay dormant for over 130 years until the US space agency, NASA, began developing fuel cells for space missions. NASA’s Gemini space programme was the first to incorporate platinum as a catalyst for fuel cell membranes. Fuel cells were also used on the Apollo mission to provide electric power and drinking water to the astronauts. The Soviet Union also used fuel cells on their space programmes as well as for military applications.

Commercial organisations also began to experiment with fuel cell technology from the 1960s onwards. General Motors developed the first fuel cell driven electric vehicle in the 1960s. The oil crisis in the 1970s stimulated further experimentation by major US, German and Japanese motor manufacturers with fuel cell electric vehicles (FCEVs). These vehicles used hydrogen as a fuel source, which generated no harmful emissions.

In the early 1980s, as oil prices increased, there was a major push to commercialise fuel cell technologies, especially for public transport, particularly buses, and municipal power generation through small-scale power stations. However, despite the major push, commercial applications gained little foothold as the technologies did not achieve the levels of performance needed for market acceptance, whilst oil prices dropped in real terms for the most part of the 1990s and early 2000s.

In the 1990s, government policies on harmful emissions became more stringent, particularly in the USA and Europe, due to increasing concerns around global warming. For the first time vehicle emission standards called for alternative energy sources rather than a reliance on making improvements to the internal combustion engine. This led to further research by the large automakers, such as DaimlerChrysler, General Motors and Toyota, into fuel cell driven electric vehicles. Nevertheless, the commercialisation of fuel cell technologies failed to gain market traction.
With the increasing spectre of global warming in the 2000s and increasing oil prices, fuel cell technologies are once again under consideration as a viable source of alternative energy that would reduce humanity’s dependence on harmful fossil fuels. Consequently, both private sector and government funding earmarked for fuel cell research have increased markedly. In addition, actual demonstration projects highlighting the benefits of fuel cells began to proliferate. There was also wide-scale deployment of fuel cell driven buses, particularly in Europe, China and Australia.

In 2007, fuel cell technologies gained some commercial traction in the market. For the first time, manufacturers offered warranties and aftermarket services based on codes and standards in the markets they served. Increasingly, fuel cell technologies found their way into auxiliary power units in boats, caravans, toys and military communications equipment. In addition, fuel cell technologies offered a more reliable alternative to diesel generators as back-up power systems, particularly during natural disasters. This is particularly relevant in the context of the diesel generator failures during hurricane Katrina and the Fukushima nuclear disaster in Japan, following the March 2011 tsunami.

The power provision and back-up capabilities of fuel cells are also being increasingly adopted in the mobile telecoms sector, particularly in remote regions on the African continent, where domestic power grids cannot cope with increasing power demands. This alternative is more economical than diesel generators, with less risk of fuel theft, as is the case with diesel.

Therefore, despite some challenges with regard to costs, the establishment of codes, standards and aftermarket service capabilities by manufacturers have contributed positively to the increasing adoption of fuel cells in everyday applications. Increasing scaleability of different applications such as power generation and electric vehicles should also lead to further commercialisation and market adoption.

**How fuel cells work**

A fuel cell combines hydrogen and oxygen to generate electricity, whilst discharging only water and heat as a by-product, with relatively high efficiency levels (ca. 50% for electricity as opposed to 25% for the internal combustion engine).

**Figure 15: How a fuel cell works**

These two features make fuel cells the ideal technologies in the fight against greenhouse gas emissions. Both the anode and cathode contain platinum catalysts, which increase the rates of the oxidisation process as well as of the reduction process in the anode.
**Fuel cell technologies**

There are currently at least seven fuel cell technologies, each with a unique acronym and varying technical characteristics and applications (refer to Table 1 below). These include:

- **Proton Exchange Membrane Fuel Cells (PEMFC):** This is by far the most commercially successful fuel cell technology and it contains PGM catalysts. It uses a water-based acidic polymer membrane with platinum catalytic electrodes. PEMFCs mostly use hydrogen as a fuel source and can operate at both low and elevated temperatures of up to 200°C. They are used in fuel cell electric motor vehicles, transport and small scale consumer products.

- **Direct Carbonate Fuel Cells (DMFC):** This technology is similar to PEMFC. It uses a platinum-ruthenium catalyst, which draws hydrogen from liquid methanol and is in the very early stages of commercial use.

- **Molten Carbonate Fuel Cells (MCFC):** This technology uses a molten carbonate salt (not PGMs) at the electrolyte. It operates at very high temperatures and can use coal-bed methane or natural gas as a fuel source. It is in the early stages of commercial use in the power generation industry.

- **Phosphoric Acid Fuel Cells (PAFC):** Using a platinum catalyst with a phosphoric acid electrolyte, these fuel cells are moderately efficient and can be used in co-generation plants with natural gas as a fuel source. The technology is currently in commercial use on a limited scale, with efficiencies of up to 85% in co-generation plants. It is also used in back-up generators and heavy vehicles.

- **Solid Oxide Fuel Cells (SOFC):** This technology operates at very high temperatures with zirconium oxide as an electrolyte (not PGMs). It can be used together with other hydrocarbon fuels such as coal-bed methane gas. Currently, 25 kilowatt cells are in use for power generation, whilst the 100 kilowatt cells are in the developmental phase.

- **Alkaline Fuel Cells (AFC):** This technology uses alkaline electrolyte (not PGMs) and pure hydrogen as a fuel source. Generally, such fuel cells operate at low temperatures but with high levels of efficiency. First used in NASA’s space programme, but very expensively, the technology is now mostly used in military and space programme applications.

Table 1: Fuel cell technologies and applications

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In terms of growth dynamics, PEMFC is by far the dominant commercial fuel cell technology, followed by DMFC (refer to Figure 16). All other technologies are either in an experimental stage or have not yet received any commercial traction. Units demand of PEMFC has recorded compounded growth of 201% since 2007, whilst DMFC uptake has remained largely flat. Since PEMFC technologies use platinum catalysts, present growth rates suggest they would have an enormously positive impact on platinum demand (and prices) over the next decade.
Fuel cell applications

Fuel cell applications are categorised into three broad segments, namely portable, stationary and transport. To date, the portable segment has received the largest market adoption in terms of unit sales, when compared to the stationary and transport segments (refer to Figure 17). Between 2007 and 2011, total unit sales recorded compounded growth of 122% per annum. These high growth trends suggest an increasing adoption of fuel cell technologies for commercial purposes as manufacturers overcome costs and technical challenges.

At the segmental level, the portable segment, where increasing market acceptance is evident, grew by 132% per annum over the same period. The transport segment recorded the second highest growth at 52% annually, followed by the stationary segment at 50% per annum, albeit both from a very low base.

Demand was estimated at US$355.3 million in 2011 and is projected to reach US$910.3 million by 2018, growing at a compound annual growth rate (CAGR) of 15% from 2013 to 2018. The Asia-Pacific and North American regions dominate the global market in terms of demand, but Europe is seen as the most promising future market. Japan and South Korea
Fuel cells contd.

Portable segment

The portable segment refers to fuel cells used in very small applications that can deliver power of between 2 to 100 watts. These include toys and educational fuel cells, auxiliary power units and consumer electronics. It should be noted that the portable segment only accounts for approximately 2.6% of global fuel cell energy supply of 82.6 MW.

Nevertheless, it serves as an important point of entry for many fuel cell companies and also to popularise the everyday use of fuel cells in various applications. A promising market under the portable segment is the auxiliary power unit (APU), where fuel cells are integrated into vehicles, particularly in leisure vehicles such as boats and caravans. In this regard, the heavy duty truck market is seen as potentially lucrative for the fitment of APU units, since emissions legislation, particularly in the EU, prevents the idling of heavy duty trucks parked overnight.

Presently, consumer electronics remain the ‘holy grail’ for portable fuel cell applications. The main issue appears to be with developing fuel cells being small enough to fit into electronic components, but able to provide extended running times that would exceed any battery pack, particularly in laptops, tablets and other mobile devices. Presently, fully integrated fuel cell applications for consumer electronics appear to be a number of years away.

Stationary segment

The stationary segment comprises micro combined heat and power (micro-CHP), uninterruptable power supply systems (UPS) and stand-alone small-scale power stations.

- **Micro-CHP**: Residential micro-CHPs have gained some traction in the Japanese market, aided by government subsidies. The subsidies have promoted larger adoption of the technologies, which has seen unit costs come down. The subsidies will eventually be phased out as increasing production eventually leads to economies of scale and cost competitiveness. Following the Japanese example, South Korea also offer subsidies for residential micro-CHPs to be phased out once economies of scale have been achieved. Denmark has also embarked on a large domestic rollout.

- **UPS**: Presently, the USA is the largest market for UPS systems, which provide back-up power to particularly large telecommunication systems. Fuel cell UPS systems can provide back-up power for up to 72 hours. This has the potential to replace large and expensive diesel generator plants typically used for back-up in large plants such as nuclear power stations, refineries and even hospitals. The recent failure of the diesel generators leading to a near meltdown of the reactor core at the Fukushima nuclear plant in Japan, after the tsunami struck in March 2011, underscores the need for more reliable sources of back-up power during disasters. Fuel cell based UPS systems are increasingly attracting investments and gaining market traction as companies begin to realise economies of scale and overcoming initial manufacturing glitches.

- **Small-scale power stations**: The world’s largest players in the power equipment market have all adopted renewable generation capabilities in their product portfolios. In this regard, POSCO Power of South Korea has developed a small-scale fuel cell driven power plant with more than 40 MW of generation capacity. POSCO further intends to build a 60 megawatt fuel cell power station by 2013, which will be the largest in the world. In the USA and Japan, smaller fuel cell power stacks, between 100 and 400 kilowatts, are sold to provide power to large buildings, office blocks and residential blocks. The fuel supply systems to the fuel cells generate hydrogen, which could be used to provide fuel to buses during the day. In this regard, US-based Bloom Energy is presently selling power generated by fuel cells to industrial customers at 20% below grid prices by using natural gas as a fuel source. There are also plants using methane (natural gas) and other fuels.
Opportunity for downstream beneficiation:
Fuel cells contd.

gas) extracted from biogas (typically 60% methane) as fuel sources. The company hopes to expand to residential markets as the technologies eventually gain full market acceptance.

Transport segment

Fuel cell applications in the transport sector focus on completely replacing the internal combustion engine with four times more efficient electric motors and/or hybrid technologies which are able to extend the range of battery operated systems. Key sub-segments include materials handling vehicles, light duty vehicles, buses and other transport. The overall market for Li-ion batteries in light duty vehicles is projected to grow from US$1.6 billion in 2012 to almost US$22 billion in 2020.

- **Materials handling vehicles**: Materials handling equipment is by far the largest sub-segment, accounting for about 50% of total fuel cell activity under the transport segment. The key application is replacing battery operated forklifts with hydrogen fuel cells. Fuel cell operated forklifts have many advantages over battery operated models, including performance, recharging times and extended working range. Fuel cell technologies are also used in hybrid battery operated models, where they complement the range of batteries. Almost all new distribution centres in the USA already use fuel cell vehicles, as these are 24x7 operations unsuited to batteries.

- **FCEVs**: The major global auto manufacturers have all committed to the full commercialisation of fuel cell electric vehicles by 2015. Major cities in Europe are in the process of ramping up the necessary hydrogen fuel infrastructure in anticipation of wide-scale fuel cell electric vehicle adoption by 2015 and beyond. It is expected that the initial uptake of fuel cell vehicles will run into tens of thousands in 2015, largely limited by available hydrogen refuelling infrastructure. As both auto manufacturers and hydrogen fuel providers achieve economies of scale, costs are expected to fall dramatically, accelerating the adoption of FCEVs by consumers. A typical FCEV contains about 80 grams of PGMs or 25 times more than current exhaust catalytic converter systems. The target is to reduce the PGM content to between 10 and 20 grams per car, or 4 to 8 times current catalytic converter systems.

- **Buses**: Despite being increasingly available as a means of public transportation in cities around the world, fuel cell buses remain expensive compared to conventional buses. Very few are produced globally and demand is currently centred on high profile events such as the Olympic games and other major sporting events. However, as governments increasingly turn to greener public sector transport, it is hoped that further demand will be stimulated, which will increase economies of scale in production and make hydrogen buses more affordable. A few cities in the world already have fleets of fuel cell buses running.

- **Other transport applications**: Fuel cell technologies are also applied to scooters, trains, boats and military vehicles. Fuel cell driven motorcycles are potentially a huge global market, with the Chinese market alone estimated at 20 million per year.
Regional developments

Fuel cell demand has reported astronomical growth in the world’s major developed economic regions in the past 3 to 5 years. Whilst the European region has the highest uptake in terms of unit sales, its compounded annual growth of 114% per annum lags behind North America’s 143% annual growth. The Asian region has also recorded healthy growth of 112% per annum. The rest of the world also lags the major regions. However, it is expected that as fuel cell technologies mature and gain wider global acceptance in major developed economic regions, they should stimulate demand in the rest of the world.

Figure 18: Fuel cell demand by region

![Fuel cell demand by region graph](source)

Key industry players

Table 2 lists companies that are active in global fuel cell research and in the commercialisation of fuel cell technologies.

Table 2: List of fuel cell producers

<table>
<thead>
<tr>
<th>Firm</th>
<th>Country</th>
<th>Technology</th>
<th>Presence in South Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bloom Energy Servers</td>
<td>USA</td>
<td>Energy Servers</td>
<td>No</td>
</tr>
<tr>
<td>Aditya</td>
<td>USA</td>
<td>Portable fuel cell generation systems</td>
<td>Yes</td>
</tr>
<tr>
<td>Panasonic Ene Farm</td>
<td>Japan</td>
<td>Residential fuel cells</td>
<td>Yes</td>
</tr>
<tr>
<td>Toshiba Dynario</td>
<td>Japan</td>
<td>Portable fuel cells</td>
<td>Yes</td>
</tr>
<tr>
<td>Daimler Benz</td>
<td>German</td>
<td>FCEV</td>
<td>Yes</td>
</tr>
<tr>
<td>Toyota</td>
<td>Japan</td>
<td>FCEV</td>
<td>Yes</td>
</tr>
<tr>
<td>Nissan</td>
<td>Japan</td>
<td>FCEV</td>
<td>Yes</td>
</tr>
<tr>
<td>FuelCell Energy</td>
<td>USA</td>
<td>Stationary fuel cell power plants</td>
<td>No</td>
</tr>
<tr>
<td>Antig</td>
<td>Taiwan</td>
<td>Fuel cell stacks</td>
<td>No</td>
</tr>
<tr>
<td>CMR Fuel Cells</td>
<td>UK</td>
<td>DMFC</td>
<td>No</td>
</tr>
<tr>
<td>Nomadic Fuel Cells</td>
<td>USA</td>
<td>DMFC and PEMFC</td>
<td>No</td>
</tr>
<tr>
<td>Samsung</td>
<td>South Korea</td>
<td>Fuel cell batteries</td>
<td>Yes</td>
</tr>
<tr>
<td>Horizon Fuel Cell Technologies</td>
<td>Singapore</td>
<td>PEMFC</td>
<td>No</td>
</tr>
<tr>
<td>myFC</td>
<td>Sweden</td>
<td>Portable fuel cell</td>
<td>No</td>
</tr>
<tr>
<td>Volvo</td>
<td>Sweden</td>
<td>FCEV</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Source: Fuel Cell Today Industry Review 2011
Other key participants, such as Ballard Power, Clearedge, Toshiba, Panasonic, Plug Power Inc. and Hydrogenics Corporation have set up in South Africa.

**DEVELOPMENTAL IMPACT**

**Employment potential**

With much of the fuel cell industry still in an experimental phase, most of the present employment opportunities are limited to highly skilled research and development (R&D) jobs. These jobs are presently located in universities and innovative small- and medium-sized companies.

However, it is expected that once fuel cell technologies transcend the initial experimental phase and move into the early phases of commercialisation, employment opportunities, particularly in manufacturing and sales, will begin to materialise. Further employment opportunities in R&D should also occur as commercialisation takes off.

The US Department of Energy has listed the following job categories as being associated with fuel cell technologies: mechanical engineers; chemists; chemical engineers; electrical engineers; materials scientists; laboratory technicians; factory workers; machinists; industrial engineers; power plant operators; power plant maintenance staff; bus, truck and other fleet drivers; vehicle technicians; fuelling infrastructure installers; and hydrogen production technicians.

According to Fuel Cell 2000, there are approximately 39 000 jobs (about 13 000 direct and 26 000 indirect) currently in the global fuel cell industry (refer to Figure 19 below). Most of these jobs are currently located in Australia-Asia. The African continent does not feature in the present job estimates.

**Figure 19: Fuel cell industry job estimates, 2011**

Fuel Cell Today and Fuel Cell 2000 estimate that approximately 700 000 direct jobs will have been created by 2020 in fuel cell manufacturing. When servicing and maintenance is included, the direct job estimates could exceed 1 million. This implies a compounded job growth of between 65% and 75% per annum over the next 8 years.
South Korea, for example, aims to provide 20% of the world’s fuel cells by 2020, creating 560,000 jobs in the process. This implies a figure of 2.8 million jobs in the global fuel cell industry by 2020, with global sales estimated at US$126 billion.

Cynthia Carrol, outgoing CEO of Anglo American, believes that a home-grown fuel cell industry has the potential to generate hundreds of thousands of jobs in South Africa, whilst at the same time generating carbon-free energy. The hydrogen fuel cell strategy, HySA, aims to supply 25% of the catalyst demand for fuel cells by 2020. This could generate additional jobs in the platinum mining sector.

**Research and development**

With platinum as a key catalyst in the anodes and cathodes of PEMFC, DMFC and PAFC fuel cell technologies, the Department of Science and Technology (DST), the Anglo American Growth Metals Development Fund and Altergy Systems have established a joint venture known as Clean Energy Investments to manufacture Altergy fuel cells in South Africa.

With the appropriate levels of investment, fuel cell technologies also have the potential to create an entirely new export-oriented industrial sector in South Africa. The participation of Anglo American in promoting hydrogen fuel cell technologies suggests, perhaps, a concern over future platinum demand on the company’s part. As noted elsewhere in the report, platinum catalytic converters have grown by only 2% over the last decade, whilst recycling has substantially increased.

In contrast, platinum-based fuel cell catalysts used in PEMFC have grown by 132% per annum over the past decade, albeit from a very low base. Of the 6.5 million ounces in global platinum demand, about 50,000 ounces are currently used globally in fuel cells. However, this figure could potentially reach 16 million ounces by 2050 if fuel cell technologies become commercially sustainable — that is, a three-fold increase in demand for PGMs.

**HySA**

HySA is the national strategy of DST to develop local technology and skills for the establishment of a hydrogen fuel cell industry in the country. The 15-year programme was approved by Cabinet in 2007 with the key objective of promoting a domestic-based PGM catalysis value chain, which aims to supply 25% of the catalyst demand for the global hydrogen fuel cells market by 2020. DST established three centres of competence:

- HySA Systems (hosted by the University of Western Cape),
- HySA Catalysis (co-hosted by the University of Cape Town and MINTEK);
- HySA Infrastructure (co-hosted by the North West University); and
- Centre for Scientific and Industrial Research (CSIR).

The HySA centres are tasked with developing three key technologies, namely CHP, portable power systems and hydrogen-fuelled vehicles.

**Backward linkages in the PGMs value chain**

PGM minerals have many desirable qualities that make them suitable for a variety of applications, ranging from the treatment of cancer to hydrogen fuel cells as a source of clean energy. A report commissioned by the now defunct Platinum Beneficiation Committee lists the desirable properties of PGMs as: hardness and density; corrosion resistance and durability; resistance to high temperatures; catalysis; electrical conductivity; aesthetics; bio-compatibility; and investment value. Figure 20 illustrates the successive stages of value addition to PGMs, specifically:

- **1st stage - basic fabricated products**: Divided into metals (including ingot, sheet, wire rod and tubing) and chemicals.
- **2nd stage - semi-manufactured products**: Includes, among others, dental alloys, semi-manufactured jewellery, thermocouple wire and gauze. Chemicals at this stage include coated substrates, membranes, anodes and cathodes, which are particularly relevant for fuel cells.
• **Final stage - manufactured products**: Includes finished jewellery, glass furnaces and micro-machined parts flowing from value addition to metals. On the chemical side, this includes catalysts used in fuel cells, autocatalysts, diesel particulate filters and pharmaceuticals (refer to Table 3 below for a list of downstream applications of PGMs).

**Figure 20: The downstream PGMs value chain**

**Table 3: Downstream applications of PGMs**

<table>
<thead>
<tr>
<th>Application</th>
<th>Platinum</th>
<th>Palladium</th>
<th>Rhodium</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrical</strong></td>
<td>• Electrical contacts and electrodes</td>
<td>• Consumer electronics</td>
<td>• Thermocouples</td>
</tr>
<tr>
<td></td>
<td>• Hard disk drives</td>
<td>• Ceramic capacitors</td>
<td>• Electrical contacts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Spark plugs (aircraft)</td>
<td>• Spark plugs (aircraft)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Electrical contacts</td>
<td>• Hard disk drives</td>
</tr>
<tr>
<td><strong>Medical</strong></td>
<td>• Chemo-therapy</td>
<td></td>
<td>• Menthol production</td>
</tr>
<tr>
<td></td>
<td>• Micro-machined implants</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>High performance alloys</strong></td>
<td>• Glass making</td>
<td>• Surgical instruments</td>
<td>• Optical instruments</td>
</tr>
<tr>
<td></td>
<td>• Resistance thermometers</td>
<td></td>
<td>• Glass fibre production</td>
</tr>
<tr>
<td><strong>Catalysis</strong></td>
<td>• Autocatalysts</td>
<td>• Autocatalysts</td>
<td>• Alloying agent</td>
</tr>
<tr>
<td></td>
<td>• Fuel cells</td>
<td>• Petroleum cracking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Nitric acid production</td>
<td>• Hydrogenation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Silicon production</td>
<td>• Hydrogen gas purification</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Petroleum refining</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>• Jewellery</td>
<td>• Jewellery</td>
<td>• Jewellery</td>
</tr>
<tr>
<td></td>
<td>• Investment bars</td>
<td>• White gold production</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Carbon monoxide detection</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Platinum Beneficiation Committee)
## SWOT ANALYSIS

<table>
<thead>
<tr>
<th>STRENGTHS</th>
<th>WEAKNESSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>• South Africa has the world’s largest in-situ platinum reserves, over 75% of the global reserve base.</td>
<td>• Weak skills base in scientific research.</td>
</tr>
<tr>
<td>• Public-private partnership venture to develop PEMFC, DMFC and PAFC technologies under the direction of DST.</td>
<td>• Engineering per capita ratio lags significantly behind peer countries.</td>
</tr>
</tbody>
</table>

### OPPORTUNITIES

<table>
<thead>
<tr>
<th>OPPORTUNITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>• To develop, or support and partner the development of platinum based fuel cell technologies to the level of commercial scaleability.</td>
</tr>
<tr>
<td>• To eventually capture a significant share of the global fuel cell market.</td>
</tr>
<tr>
<td>• To establish an entirely new and sustainable export-oriented industry with opportunities.</td>
</tr>
<tr>
<td>• Potential for generating significant employment opportunities in the hundreds of thousands.</td>
</tr>
<tr>
<td>• Fuel cells will potentially mean massive demand growth for PGMs, with associated price and revenue increases.</td>
</tr>
<tr>
<td>• With fuel cell research currently in the early stage development phase, international development companies are interested in setting up manufacturing facilities in attractive locations, including South Africa.</td>
</tr>
<tr>
<td>• Fuel cell demand is currently driven by increasing energy efficiency needs, emission reduction and energy security.</td>
</tr>
</tbody>
</table>

### THREATS

- Cheaper metals replacing platinum as catalysts in fuel cells.
- South African efforts to develop fuel cell technologies to commercial scaleability may be eclipsed by other countries.
- Perceived supply constraints due to challenges faced by the mining industry such as rising costs, increased mining depths, labour unrest and the social licence to operate.
- Protracted recovery of global markets.

## COMPETITIVE PLATFORM

### Factor conditions

- South Africa is well endowed with platinum reserves (+)
- Weak scientific and engineering skills base (-)

### Firm strategy, structure and rivalry

- South African firms lag behind the rest of the world in exploiting fuel cell technologies (-)
- Minimal involvement of South African firms in developing fuel cell technologies (-)

### Demand conditions

- Global and domestic demand for commercially scaleable fuel cell technologies potentially unlimited (+)
- Fuel cell growth has the potential to stimulate further platinum demand and the value of platinum exports (+)

### Related supporting industries

- Large auto assembler footprint in the country (+)
- Significant domestic capacity in auto catalytic manufacturing, with opportunities to advance further value addition and home-grown technologies (+)
- Universities involved in developing fuel cell knowledge and research capacity (+)
- CSIR involved in developing chemical, materials and engineering expertise for fuel cell research

### Government

- DST recognises the potential of developing commercially scaleable fuel cell technologies (+)
- Establishment of green industries prioritised in National Development Plan, New Growth Path and IPAP (+)
- Development financing available for green projects (+)

### Key

| + | Positive |
| 0 | Neutral  |
| - | Negative |
DEVELOPMENT OPPORTUNITIES

PGMs are an enabler of and their demand is driven by cleaner and greener production. The move to reduce urban smog from vehicles, which started in California in the late 1980s and subsequently moved to Europe, followed by Japan and the rest of USA and then the world at large, drove autocatalyst demand for platinum up toward 50% of the total at peak, and has also driven price and interest in jewellery and investment. This had tremendous benefits for South Africa where PGM exports are concerned, doubling demand and increasing prices by over 200% in real terms. The clean air related market has slowed recently, since recycling has grown to more than 30% and autocatalyst demand growth has stagnated, as maturity has been reached in developed countries with respect to tail pipe emission standards.

The next key area for PGM demand is fuel cells and the hydrogen economy that has shown annual growth of ca. 130% (in terms of MW and units produced) over the past five years. This trend is expected to continue, thus requiring a move from pilot (development) units to first line commercial. This has the potential to more than double the current total annual demand for PGMs and hence, by itself (i.e. without any beneficiation), could potentially result in a 400% increase in the direct contribution to the South African economy with respect to platinum mining and refinery aimed principally at export markets.

PGMs have represented the largest export revenue item for South Africa in the past 10 years, with major implications for the economy at large. The fuel cell industry is roughly where the solar photo-voltaic industry was 10 years ago, when scale was low and prices were very high. However, with the development of a significant off-take in Germany, global PV production capacity has increased 100-fold and prices have dropped by a factor of 10. Projections of fuel cells show a similar 10-fold reduction in costs being possible for a 100 times scale up.

Current auto fuel cell systems cost about R800 000 per unit, whilst a fuel cell stack costs R250 000 (in turn with ca. R18 000 platinum content at current prices). These costs are projected to drop once the technology is fully commercial and a significant scale of production has been achieved, possibly towards the usage of R2 000’s worth of platinum at today’s prices in a R10 000 fuel stack within a R50 000 fuel cell vehicle unit. It is clear that at least five-fold value addition is possible by going downstream into fuel cell stack manufacture.

Key for fuel cells (and PGMs) demand is enabling commercialization through increased volumes and reduced costs. Europe is spending more than R40 billion on automotive fuel cell developments over the next five years, and the USA (California), Japan and Korea all have large development programmes. They are doing this primarily to go green as regards transport (energy), since green electricity technologies are well established commercially, and these countries not only have limited expensive diesel electricity generation, but also intend to reduce fossil fuel usage in transport.

In addition, this enables electric cars to have ranges and refuelling times similar to those of internal combustion engines. Two of the primary concerns stated by industry players are the availability and price of platinum. However, with the platinum component of the fuel cell stack cost being 20%, 5% of the vehicle fuel cell system and less than 2% of the total vehicle price, this is probably not significant. Notwithstanding this, fuel cell companies continue pushing for alternatives (i.e. substitutes for platinum). Investment in manufacturing in South Africa can reduce this concern and thus the likelihood of alternatives becoming commercial, as the platinum cost is projected at 20% of the overall fuel stack cost at current prices.

Engagement with Hydrogen South Africa

It would appear that platinum-based fuel cell catalysts provide a real opportunity for the establishment of a new industrial sector in the medium- to long-term. Currently, technological development in South Africa is in the experimental phase under the banner of Hydrogen South Africa (HySA).

Consolidation among junior and marginal platinum miners

With miners facing increasing operational cost pressures, especially energy and wage costs, exacerbated by a sometimes strong and volatile currency, junior and marginal miners may find their projects not economically viable or sustainable on a long-term basis. Consequently, the consolidation of junior or marginal players should be encouraged in order to derive economies of scale and drive down the cost of production.
Explore the electricity and co-generation capabilities of fuel cell technologies

As noted above, Phosphoric Acid Fuel Cells (PAFC) technology has been successfully used on a commercial basis in co-generation plants, with natural gas as a fuel source achieving efficiencies of up to 85%. Therefore, the possibility exists for the deployment of fuel cell based cogeneration plants in large industrial plants, such as ferrochrome, steel, cement and petrochemical plants, where there are suitable hydrogen or hydrogen rich fuel sources.

For off-grid remote applications such as cell-phone masts, there is current use, with the viability thereof either matching or exceeding diesel generator sets, using various fuels such as methanol (possibly ex biomass), ammonia and methane/biogas. This presents a market potential that could stimulate the local production of PGM coated fuel stacks, which could also serve a growing global demand.

Explore the viability of expanding and deepening domestic autocatalytic manufacture

As noted above, South Africa already has a substantial catalytic converter industry, which at its peak represented 19% of the global market. However, going forward this industry faces significant challenges, particularly the continued uncertainty in the global economy and the increasing off-shoring by multinational OEMs of catalytic converter manufacturing.

Nevertheless, the emergence of China, as one of the world’s largest automotive markets, as well as continued strength in vehicle growth in other BRICS countries and the USA, suggest much upside potential in the global automotive market once the current economic difficulties have run their course.

Consequently, the South African catalytic converter industry could be well placed to capitalise on future growth in the automotive market. This would require continued investment and rejuvenation of existing operations, as well as exploring opportunities in niche markets such as:

- Manufacturing of substrates, which would require a feasibility study to consider the respective potential;
- Particle filters, for both diesel and petrol fuelled motor vehicles;
- Catalysts and filters for the growing global heavy duty vehicle market segment;
- Full exhaust systems, which add further value to PGMs and chrome ore through increasing demand for stainless steel.

Green commuter transport (buses) pilot programme in the Platinum Belt

The potential for the introduction of a fuel cell bus pilot programme in Rustenburg should be investigated as both a symbolic and marketing gesture to highlight the potential and benefits of fuel cell driven transport. Rustenburg is considered as an ideal location given its centrality in the South African Platinum Belt. It should be noted that grant funding may be available to fund the difference between a conventional bus and a more expensive fuel cell bus in support of such a project. The project will also include the establishment of refuelling stations.

Such a project may have significant symbolic value, particularly given the current troubles in the platinum mining industry. It could assist in refocusing the social partners, government, business and labour, leading them to consider the potential of the country’s platinum windfall, instead of labouring on the current ills affecting the industry. For government, it highlights the issue of beneficiation and green energy, whilst for business it highlights future demand, and for labour it underscores the job creation potential of manufacturing fuel cells and buses locally.
Table 4: Summary of development funding opportunities

<table>
<thead>
<tr>
<th>Market gaps</th>
<th>Financing opportunities</th>
<th>Risks</th>
<th>Development returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigate the commercialisation potential of domestically or internationally developed fuel cell technologies</td>
<td>Providing funding for pre-feasibility and feasibility studies to investigate commercial potential</td>
<td>Minimal – appointment of specialist consultants and partners to undertake studies</td>
<td>Specialist technical opinion of industry/sector potential</td>
</tr>
<tr>
<td>Localisation of production of domestically or internationally developed fuel cell technologies (medium- to long-term)</td>
<td>Project development: establishing local manufacturing capacity and capabilities associated with proven fuel cell technologies</td>
<td>Commercial risk in the establishment of yet unknown domestic industry/sector</td>
<td>Establishment of new domestic industry</td>
</tr>
<tr>
<td>Consolidation of junior and marginal platinum miners</td>
<td>Assist junior miners and marginal players in achieving economies of scale</td>
<td>Commercial risk</td>
<td>Domestic job creation</td>
</tr>
<tr>
<td>Investigate fuel cell electricity and cogeneration potential</td>
<td>Possibility of alternative energy generation for large plants and niche applications</td>
<td>Minimal – appointment of technical specialist</td>
<td>Specialist technical opinion on viability of fuel cell cogeneration</td>
</tr>
<tr>
<td>Expanding and deepening local manufacturing of autocatalysts</td>
<td>Project development: investigate feasibility of new manufacturing facilities for substrates and particle filters for light and heavy duty vehicles</td>
<td>Market risk – increasing offshoring of autocatalysts manufacture</td>
<td>Promote further beneficiation of PGMs and chromium (stainless steel)</td>
</tr>
<tr>
<td>Green commuter transport (bus) pilot programme</td>
<td>Project development: introduction of new green technologies that has potential for future localisation</td>
<td>Securing grant funding to fund gap between conventional and more expensive fuel cell buses</td>
<td>Symbolic – shows the future potential of South Africa’s PGMs windfall.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Get social partners to refocus energies beyond current crisis.</td>
</tr>
</tbody>
</table>
MARKET OUTLOOK

Platinum group metals

The aftershocks of the 2008/09 global financial and economic crises, coupled with the subsequent sovereign debt and fiscal crises in certain countries within the Eurozone, which led to renewed recessionary conditions in that region, have continued to undermine the world economy's recovery momentum. The slowdown in major BRICS economies in 2012, specifically China, India and Brazil, suggests that, in addition to their own structural challenges, the very fragile global economic environment has begun taking its toll even on fast-growing emerging powers.

Consequently, commodity prices retreated somewhat, as investors sensed a weakness in underlying demand. With more than USD200 billion of capital expenditure under review by major global mining houses in mid-2012, it would appear that some of the majors have developed serious doubts over China's ability to sustain the robust pace of commodities consumption. Others feel that Chinese demand for commodities is nowhere near peak levels, considering the current negativity as just a minor glitch driven more by global sentiment than real demand fundamentals.

Considering such opposing sentiments, this report takes a more 'middle of the road' view over the short- to medium-term prospects, recognising the underlying weaknesses in the global economy on the one hand, but also that it is highly unlikely that the Chinese growth phenomenon will come to an abrupt halt. Nevertheless, the domestic mining industry faces a number of significant challenges of its own, some of which are structural in nature, that continue to undermine its development and are preventing it from reaching its true potential.

Demand weakness has been reflected in softer PGM prices, although a partial rebound accompanied the labour strife and resulting production stoppages in the South African mining industry in the second half of 2012. Together with rising production costs, including substantially higher wage settlements, these developments have put the local PGMs mining industry under considerable strain.

Although the weaker rand has provided some relief, certain miners have opted to close down marginal operations, with those at Aquarius Platinum’s Marikana mine having been suspended indefinitely. More disconcerting has been the major restructuring announcement by platinum major Angloplats, which includes the winding down of operations at four mine shafts, affecting 14 000 employees. Other industry players have also indicated that they are reviewing some of their operations.

Hence, the industry appears to be restructuring its operations in order to extract greater value from the mineral assets, implying the shutting-down, temporarily or permanently, of some of their non-profitable operations and a focus on those that are clearly profitable under the current global market conditions. It is also likely that certain large players may cut back on their capital spending plans, although still aiming to improve cost efficiencies.

Regardless of the challenges facing the domestic PGMs mining industry, its future prospects hinge largely on a sustainable recovery in global demand, particularly in the Eurozone, which is a critical market for autocatalyst-related demand from the South African perspective, particularly where platinum is concerned. However, the rapid development of the Asian market, particularly in China and India, will play an increasing role in years to come.

Domestic supply disruptions due to labour strife contributed to taking the platinum market closer to a balanced position in the latter part of 2012, whilst Chinese jewellery demand and investor interest in platinum ETFs provided further price support. Solid vehicles sales in China and other emerging markets, a continued recovery in North American and Japanese demand (whilst a rebound in Europe is likely to lag), and stronger emission standards worldwide should favour the platinum and palladium markets going forward.

The normalisation of South African production (although significant industrial relation risks prevail) should widen the surplus in the global platinum market to some extent in 2013, but a tightening trend is anticipated towards the latter part of the
forecast period. With respect to palladium, the deficit in global markets is likely to persist throughout the period 2013 to 2017, being particularly pronounced in later years. Accordingly, modest average price increases are anticipated in the case of platinum, but substantially stronger where palladium is concerned.

However, the European car market will be the key factor behind a recovery in global platinum demand. With vehicle sales plummeting across key Eurozone markets, the near term outlook remains bleak. The poor performance of the Eurozone’s auto sector is obviously closely related to the continuing economic woes of the region.

Consequently, without an imminent recovery in key markets, South African platinum producers will attempt to keep the market in balance in order to prevent an outright collapse in prices, firstly by rationalising operations and, secondly, by cutting back on production. The recent announcement by Anglo Platinum of the major restructuring of its operations, which will effectively remove 400 000 ounces of platinum annually from global supply, can be understood in this context.

The picture for palladium looks rosier. Record vehicle sales in China and a recovery in North American sales for the year ending 2012 are pushing palladium prices upwards. The tight supply situation for this metal could push palladium production growth to 7% annually over the forecast period.

Investments under way in the platinum mining industry include the Royal Bafokeng and Anglo American Merensky phases 1 and 3 projects worth R13 billion, Angloplats’ R1.6 billion Amandelbult expansion, Implats’ shaft 17 and 20 projects valued at R17.7 billion, Northam Platinum’s R2.5 billion Booysendal project, the Wesizwe Frischgewaagd-Ledig project worth R7.9 billion and Afplats at R3 billion. Smaller platinum projects include Tharisa Minerals’ worth R1 billion and Lesego Platinum’s R150 million project.

**Fuel cells**

The commercial uses of platinum-based fuel cells are increasingly gaining market traction, as evidenced by the stellar growth of 122% per annum in delivered fuel cell products over the last five years. The portable segment has registered the highest compounded growth of 132% per annum over the period, followed by the transport segment at 52% and the stationary segment at 50% per annum.

The increasing drive towards greener industries and renewable fuels will be the main driver behind sustained growth in fuel cell technologies. Fuel cells represent a real alternative energy source to fossil fuels because of their zero emissions. Increasingly, governments are deploying mechanisms such as carbon taxes to price in the true costs of burning fossil fuels.

At the same time, it is expected that, with increasing commercialisation and scaleability, the cost and price of fuel cell technologies will come down, which should increase its market growth and PGMs consumption. It has been shown that a 15% reduction in costs is possible with a doubling of capacity, with this expected to continue until significant (major) commercial scale is reached.

The increasing availability of electric vehicles should further enhance growth in the fuel cell industry. The world’s largest vehicle OEMs have undertaken to launch an array of electric vehicle models from 2015. It is estimated that, under a best-case scenario, the global fuel cell industry would generate revenues of approximately US$126 billion by 2020, creating about 2.8 million jobs in the process.

Becoming part of the global fuel cell supply chain represents a unique opportunity for South Africa to develop a new industry, whilst at the same time promoting higher value addition to the country’s mineral base, as well as scientific knowledge and skills development.
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