Precious Metal Availability and Cost Analysis for PEMFC Commercialization

DE-FC04-01AL67601 Topic 6.A
Project Team

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DOE Objectives  PGMs in Fuel Cell Systems

The availability and pricing of platinum group metals (PGMs) is critical to the commercialization of fuel cells.

- Critical to achieving the required levels of performance (power density and efficiency)
- In the stack, primarily platinum and some ruthenium essential to catalysis of anodic and cathodic reactions
- In the fuel processor, important for catalysis of reforming and shift reactions
- Fuel cell stack dominates the demand

PGMs also represent a significant contribution to the overall system cost.
**Relevance**

**Will the successful adoption of fuel cells in transportation applications be threatened by platinum price increases and limitations in platinum supply in the long-term?**

- Given various demand scenarios, can the industry keep supply and demand in balance?
  - What are the factors influencing increases in supply?
  - How fast can supply increase?
- Are resources sufficient to satisfy potential demand?
  - Recycling scenarios?
  - New ore bodies?
  - Technology developments to economically recover deeper deposits?
  - How can recycling reduce demand for primary platinum?
Project Objectives

TIAX LLC is assessing the potential impact of PEM fuel cell commercialization on platinum pricing and availability for the DOE.

- Assess current and projected demand for PGMs exclusive of fuel cell applications
- Estimate the relationships between price and supply/demand for PGMs
- Simulate the impact of fuel cell market growth scenarios on PGM supply and pricing
- Perform sensitivity analysis to critical parameters in the model related to fuel cell markets and technology advances
- Obtain critical feedback from the important participants in the PGM value chain on the model assumptions and projections
- Develop cost projections for the economics of recycling of PGMs from fuel cells and the impact on PGM supply and price
**Project Approach**

We are approximately 90% through the project and currently focusing on Task 5.

**Task 1**
- PGM Data
  - Annual PGM Statistics:
    - Pricing Data
    - Supply Data
    - Demand by Application
    - Reserve Data
  - Completed 12/02

**Task 2**
- Fuel Cell Market Projections
  - Develop projections for stationary, transportation, and portable applications
  - Develop segmentation for each market
  - Scenario-based forecasting model
  - Results Ready for Industry Feedback

**Task 3**
- PGM Value Chain
  - Description of value chain (mine to market)
  - Recycling value chain process scenario
  - Development of high level PGM PEMFC recycling cost model
  - Results Ready for Industry Feedback

**Task 4**
- Econometric Model
  - Market factor assessment
  - Model development
  - Model validation
  - Projection of Pt supply, demand, and price for FCV commercialization scenarios

**Task 5**
- Industry Feedback
  - Solicit feedback from the PGM industry and automotive OEMs
  - Factor feedback into the model, database, PGM market projections, and conclusions
  - Historic Data Analysis Complete 12/02
  - Analysis of Future Scenarios Awaits Industry Feedback (May/June)

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Project Accomplishments

• Econometric analysis of historical platinum price, supply, and demand data
• Compiled platinum resource and market data
• Presented results to Johnson-Matthey and International Platinum Association (IPA) for feedback
• Developed demand scenarios and projection of platinum demand to 2050
  – Will present to South African mining companies and IPA to obtain feedback on potential supply responses, resource projections, and technology assumptions
  – Will present to automotive OEMs for feedback
South Africa’s superior ore deposits have led to its domination of platinum supply.

Russian supplies fluctuated during the 1990s.

**Results**  Platinum Industry Overview  Markets

Autocatalyst and jewelry applications now dominate both market share (80%) and growth in demand for platinum.

- **Demand for Platinum by Application (Mg)**
- **Market Share by Application (%)**


Demand from other applications including chemicals, petroleum, electronics, and glass has been relatively stable.
Results  Platinum Resource Compilation  Basis

Resource data is reported on a geological basis and was used in our study for the assessment of potential long-term platinum availability.

- The platinum resource projection is based on geological information:
  - Significant platinum deposits are located in dense formations and can be detected by aerial magnetic surveys.
  - South African ores are located in well defined layers—the depth of these layers can be accurately estimated.
  - South African resource data is now reported to a depth of 2 km (reported resource data for gold is based on a greater depth).

Reserve data which focuses on near-term available ores, (i.e., 3-5 years), was not used to characterize future platinum availability.
Results  Resource Projections

In the long run stable prices will depend on the amount of economically recoverable platinum resources relative to cumulative demand.

Total Platinum Resource: 76,000 Mg

@ 30 grams per vehicle equals 2.8 billion vehicles

Compiled from a variety of sources, including Cawthorn, Vermaak, Page, Mining Weekly, and Stribyn
Results  Price Behavior  Historical

Statistical tests have shown that historically, real prices have remained at a constant level.

Nominal versus Real Platinum Prices, 1880–2003


*In 1983 dollars, $550 in 2003 dollars

Mean Real Price $303*
Analysis of Historical Platinum Price Data  

Summary of Findings

Our statistical tests support a stationary real platinum price over the last century—particularly since South African supply started.

• Interviews with Englehard and Johnson Matthey confirmed our tests and observation of a stationary real platinum price: it is in the best interest of mines to maintain a stable price to prevent end users from substituting other metals for platinum and ultimately destroying the platinum market.

<table>
<thead>
<tr>
<th>Test</th>
<th>Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual Inspection</td>
<td>• The real price of platinum appears constant (i.e., there is no trend).</td>
</tr>
<tr>
<td></td>
<td>• The price spiked during WW I (due to military demand for platinum), introduction of catalytic converters for cars, and the oil crisis.</td>
</tr>
<tr>
<td></td>
<td>• Following each spike, the real price returned to its long-run mean.</td>
</tr>
<tr>
<td>Slade’s Hypothesis</td>
<td>• The results for platinum are quite different from those found by Slade for other commodities. There is no evidence of a U-shaped pattern and virtually no support for an upward trend in real platinum price.</td>
</tr>
<tr>
<td>Stationarity Test</td>
<td>• 1880–1998</td>
</tr>
<tr>
<td></td>
<td>• 1910-1998</td>
</tr>
<tr>
<td></td>
<td>• 1925–1998</td>
</tr>
<tr>
<td></td>
<td>Not conclusive about stationarity of real platinum price series</td>
</tr>
<tr>
<td></td>
<td>Some support that platinum real price is stationary</td>
</tr>
<tr>
<td></td>
<td>Strong evidence that platinum real price is stationary</td>
</tr>
</tbody>
</table>
Steadily increasing supply since the 1950s, i.e. at approximately 3.5 Mg per year, has been critical to price stability.

- In anticipation of the introduction of catalytic converters in the 1970s in the United States and the 1980s in Europe, South Africa mines expanded production to meet demand.
- In 1980-1990s, South African mines continued to increase supply to meet increasing demand for platinum jewelry from Japan and China.

Data Sources:
- 1901-1957 Die Metallischen Rohstoffe Heinrich Quiring, pp 98-99
Based on this analysis, we have several key expectations for the impact of fuel cell commercialization on platinum pricing:

**Shorter Timeframes**

Over short periods, prices can be volatile—increasing with the introduction of fuel cell technology or other spikes in demand.

**“Longer” Timeframe**

The real platinum price will tend to return to its long-term mean as additional supply and material substitution combine to restore prices.

While anticipated fuel cell demand for platinum may drive higher platinum prices in the short-run, the price will likely return to its long-term mean.
Results Economic Analysis Simulation Illustrative Example

An increase in demand for platinum from fuel cell technology will increase the platinum price in the short-run.

- Based on the estimated parameters from our econometric models of platinum supply and demand and information from automobile industry, we simulated the impact of an increased platinum demand from fuel cell technology on the short-run platinum prices.

<table>
<thead>
<tr>
<th>Year of fuel cell vehicles introduced</th>
<th>Fuel cell vehicle production (million)</th>
<th>Pt demand (g)/vehicle</th>
<th>Fuel cell use of Pt (millions Troy oz)</th>
<th>Increased fuel cell use of Pt in total Pt consumption</th>
<th>Pt price changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.01</td>
<td>100</td>
<td>0.03215</td>
<td>0.50%</td>
<td>0.81%</td>
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<tr>
<td>2</td>
<td>0.25</td>
<td>88</td>
<td>0.7034</td>
<td>10.35%</td>
<td>17.46%</td>
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<tr>
<td>3</td>
<td>0.50</td>
<td>75</td>
<td>1.206</td>
<td>7.02%</td>
<td>22.89%</td>
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<tr>
<td>4</td>
<td>0.75</td>
<td>63</td>
<td>1.507</td>
<td>3.94%</td>
<td>18.90%</td>
</tr>
<tr>
<td>5</td>
<td>1.00</td>
<td>50</td>
<td>1.608</td>
<td>1.26%</td>
<td>9.63%</td>
</tr>
<tr>
<td>6</td>
<td>1.80</td>
<td>46</td>
<td>2.662</td>
<td>13.09%</td>
<td>24.61%</td>
</tr>
<tr>
<td>7</td>
<td>2.60</td>
<td>42</td>
<td>3.511</td>
<td>9.32%</td>
<td>29.94%</td>
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<tr>
<td>8</td>
<td>3.40</td>
<td>38</td>
<td>4.154</td>
<td>6.46%</td>
<td>26.78%</td>
</tr>
<tr>
<td>9</td>
<td>4.20</td>
<td>34</td>
<td>4.592</td>
<td>4.12%</td>
<td>18.10%</td>
</tr>
<tr>
<td>10</td>
<td>5.00</td>
<td>30</td>
<td>4.823</td>
<td>2.10%</td>
<td>10.92%</td>
</tr>
<tr>
<td>11</td>
<td>5.00</td>
<td>30</td>
<td>4.823</td>
<td>0.00%</td>
<td>4.21%</td>
</tr>
<tr>
<td>12</td>
<td>5.00</td>
<td>30</td>
<td>4.823</td>
<td>0.00%</td>
<td>0.99%</td>
</tr>
<tr>
<td>13</td>
<td>5.00</td>
<td>30</td>
<td>4.823</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>
An increase in demand for platinum from fuel cell vehicles will increase the platinum price in the short-run (continued).

**Increased Fuel Cell Use of Pt and Price Changes**

- **Initial increase in Pt demand from fuel cell vehicles**
- **Pt supply catches up to demand, price starts to decline**
- **Greater Pt price increase to respond to increased demand**
- **Pt supply catches up to demand, price starts to decline**
- **Pt price returns to its long-term mean price**

**Results**  Economic Analysis  Simulation  **Illustrative Example**
We have developed vehicle sales estimates based on projected population growth and different vehicle per capita scenarios, but will report these results after we have obtained feedback from industry.

**Population Projection**
- UN Forecast for
  - United States
  - Europe
  - Japan
  - China
  - India

**Total Vehicle Forecast**
- Replacement factor
- New demand
- Vehicle per capita trends
  - US maximum
  - Versus GDP

**Fuel Cell Vehicle Projection**
- Use diffusion model to simulate market penetration
- Define Scenarios
  - Commercialization start date
  - Time to rapid growth
  - Ultimate market penetration
  - Pick delay between developed and developing countries
- IC vehicle market by difference

**Pt Demand vs Time**

**Fuel Cell and IC Powertrain Pt Requirements**
- Fuel Cell - g Pt/kW
- IC vehicle - grams per vehicle
- Timeframe
Next Steps

- Incorporate information and feedback from International Platinum Association (visit to South Africa) into our assessment
  - May
- Present assessment to automobile companies and incorporate their comments
  - June
- Reporting (June/July)
  - Prepare draft final report and supporting appendices for review by concerned parties
  - Prepare Final Report
Next Steps  Visit to South Africa

During our visit, we would like to obtain feedback on preliminary findings and receive critical inputs on supply and resources.

- Discuss project findings to-date with the mining companies
- Develop improved understanding of production processes for platinum group metals
- Obtain platinum industry inputs on supply responses to potential demand scenarios
- Obtain industry inputs on the projection of PGM resources