Precious Metal Availability and Cost Analysis for PEMFC Commercialization

Eric J. Carlson (Primary Contact)
TIAX LLC
Acorn Park
Cambridge, MA 02140-2390
Phone: (617) 498-5903; Fax: (617) 498-7295; E-mail: carlson.e@tiax.biz

DOE Technology Development Manager: Arlene Anderson
Phone: (202) 586-3818; Fax: (202) 586-9811; E-mail: arlene.anderson@ee.doe.gov

ANL Technical Advisor: Bill Cleary
Phone: (202) 586-1570; Fax: (202) 586-9811; E-mail: Bill.Cleary@ee.doe.gov

Objectives

The project objectives include:

- Assessment of current and projected demand for platinum group metals (PGMs) exclusive of fuel cell applications
- Estimation of the relationships between supply capacity/reserves and long-term growth in demand for PGMs
- Development of an econometric model to simulate the impact of fuel cell market growth scenarios on PGM supply and pricing
- Analysis of supply and pricing sensitivity to critical parameters in the model related to fuel cell markets and technology advances
- Solicitation of critical feedback from the important participants in the PGM value chain on the model assumptions and projections
- Development of a cost projection for the economics of recycling PGMs from fuel cells and the impact on PGM supply and price

The overall goal is not only to develop projections of PGM availability and cost, but also to identify and quantify the industry and market drivers influencing these parameters. On the demand side, we will break down the demand between existing markets and the potential applications of fuel cells. We will identify underlying trends in the industrial/chemical and lifestyle markets with attention to growth of demand and potential for substitution of alternative materials. In the fuel cell markets, the impact of technology on PGM demands will also be considered.

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year R,D&D Plan:

- N. Cost
- O. Stack Material and Manufacturing Cost

The overall DOE platinum target for reformate based-systems is 0.2 g Pt/kW.

Approach

The project has been broken into five tasks as follows:

1. Collection of historical PGM supply/demand/pricing and resource data
2. Development of fuel cell market commercialization scenarios
3. Development of a PGM recycling scenario, including a high level PGM proton exchange membrane fuel cell (PEMFC) recycling cost model
4. Development of an econometric model for the simulation of the impact of fuel cell introduction on PGM supply and price
5. Solicitation of feedback from PGM industry and automotive original equipment manufacturers (OEMs)

Tasks 1 and 4 were scheduled for the fiscal years 2001 and 2002. The balance of the tasks will be completed in year 2003.

Accomplishments

- Econometric analysis of historical platinum price, supply, and demand data completed
- Platinum resource and market data compiled
- Results of econometric analysis presented to Johnson-Matthey and International Platinum (IPA) for feedback
- Market demand scenarios developed for fuel cell vehicles and platinum catalyst out to 2050; scenarios presented to South African mining companies, IPA, and automotive OEMs to obtain feedback on market projections, potential supply responses, resource projections, and technology assumptions

Future Directions

- The platinum and automotive industry feedback will be integrated to develop conclusions on the potential impact of PEMFC commercialization on price and availability of platinum
- Final report will be issued

Introduction

Platinum group metals (PGMs) are critical to the commercialization of fuel cells because of their role in supporting critical levels of performance (power density and efficiency), but they also represent a significant contribution to overall system cost. Depending on operating design parameters, platinum would represent between 10 and 20% of the system cost of a gasoline fuel cell system produced in high volume. PGMs (primarily platinum and some ruthenium) are critical to catalyzing reforming/shift reactions in the fuel processor and electrochemical oxidation and reduction in the fuel cell, with the fuel cell requirements presently dominating the demand. Successful adoption of fuel cells in transportation applications in the long term could create markets on the order of ten million vehicles, leading to significant pressure on PGM suppliers to increase production capacity and supply. Consideration of stationary and portable applications for fuel cells further increases the demands on PGM supplies. Clearly, the combination of stationary, portable and transportation markets for fuel cells will create pressure on the PGM industry to increase supplies and might cause skyrocketing prices (thereby threatening fuel cell market viability) unless action is taken to guide the process. In addition to price, the

commercialization of fuel cells will also depend on the amount of economically mineable PGM resources and the ability of the PGM value chain to supply the PGM materials in the needed forms and at reasonable markups above the London Metals Exchange (LME) price.

Econometric analysis and modeling were applied to understand and simulate the relationships between supply, demand, and price for historical markets. An understanding of the basis for platinum resource projections was developed and used to compile a future platinum resource estimate. Inputs from the platinum and automotive industries are being obtained to project future fuel cell vehicle platinum demand and the ability of the mines to respond to these demands. The impact on price of platinum will be assessed using the econometric model.

Approach

The modeling approach starts with construction of an econometric model based on historic supply, demand, and price data. A simulation will then be run to study the impact of introduction of fuel cell vehicles on the supply and price of platinum. Automotive catalysts and jewelry are the two dominant markets for platinum (approximately 80%); hence, they will be important elements in the econometric model. The investment industry consumes a minor amount of material but can exert significant influence on short-term price. However, over long periods of time, investment should have zero impact on supply and demand.

After completion and validation of the econometric model, future demand scenarios will be input into the econometric model to project the impact of fuel cell commercialization on supply and pricing. The scenarios for stationary, portable, and transportation applications of fuel cells will range from optimistic to pessimistic and contain volume and time estimates. Economic growth, catalyst technology development, and shifts in automotive powertrain technology will be some of the factors considered in development of the demand scenarios. The model and the scenarios can be used to conduct sensitivity analyses to the various factors. Recycling will play a significant role as platinum consumption increases further. The high value of recycled platinum drives a high level of recovery today.

Inputs from the platinum and automotive industries have been and are being solicited to obtain data, feedback on assumptions, and reactions to projections of fuel cell technology and commercialization. The two industries worked together to introduce platinum-based catalytic converters in the 1970's, and similar efforts of even larger scale (e.g., expansion in mining capacity and capital investments) will be called for in the commercialization of fuel cells. Consequently, input from the industry drivers is essential to development of conclusions.

Results

Use of the econometric model to simulate the impact of fuel cell vehicle commercialization indicates that the platinum price will increase in the short-run until increased production restores balance between supply and demand. As production catches up to demand, the platinum price will return to its long-term mean price. Table 1 contains an illustrative case of fuel cell vehicle (FCV) introduction and platinum demand. Figure 1 illustrates the results from the simulation model for short-run and longer-run price.

The total platinum demand projection was built up from total vehicle projections for the U.S., Japan, Western Europe, China, and India; fuel cell vehicle market penetration scenarios; and a vehicle platinum requirement scenario. The selected countries represent approximately 80% of worldwide vehicle

Table 1. Illustrative Fuel Cell Vehicle Introduction Scenario and Simulated Impact on Platinum Price

Year	FCV Production (million)	Pt /veh (g)	FCV Pt (millions Troy oz)	Change in total Pt consumption due to FCVs	Pt price changes
1	0.01	100	0.03215	0.50%	0.81%
2	0.25	88	0.7034	10.35%	17.46%
3	0.50	75	1.206	7.02%	22.89%
4	0.75	63	1.507	3.94%	18.90%
5	1.00	50	1.608	1.26%	9.63%
6	1.80	46	2.662	13.09%	24.61%
7	2.60	42	3.511	9.32%	29.94%
8	3.40	38	4.154	6.46%	26.78%
9	4.20	34	4.592	4.12%	18.10%
10	5.00	30	4.823	2.10%	10.92%
11	5.00	30	4.823	0.00%	4.21%
12	5.00	30	4.823	0.00%	0.99%
13	5.00	30	4.823	0.00%	0.00%

sales. Vehicle projections were based on population projections for the respective countries and assumed vehicles per capita. For the mature markets in the developed countries, the vehicles per capita have reached asymptotic values, while for the emerging transportation markets in developing countries, the vehicles per capita will show significant growth. For this reason, we developed vehicle per capita scenarios for the latter regions. We also assumed a time lag for fuel cell vehicle introduction into the emerging markets. In the developed countries, a moderate to declining population growth leads to a modest vehicle sales increase driven by the U.S. Large populations along with increasing vehicles per capita in China and India lead to significant new vehicle markets. In 2050, we estimated sales in the developed countries would be 47 million vehicles, while the developing countries would add an additional 25, 46, or 86 million vehicles depending on the market growth scenario (i.e., slow, moderate, or high).

Preliminary fuel cell market introduction scenarios are shown in Figure 2. The ANL (Argonne National Laboratory, Ref 1) penetration curve was used to estimate fuel savings in the U.S. from fuel cell vehicle commercialization. In the ANL scenario, used as our bounding case, commercialization starts with rapid adoption in 2018 and a market penetration of 100% by 2037. The more moderate scenarios assume a slower adoption and penetrations of 80% and 50%. Overlaying these scenarios, we assume technology advances that result in reduced platinum loadings per vehicle of 20 grams in 2015 and 15 grams by 2025.

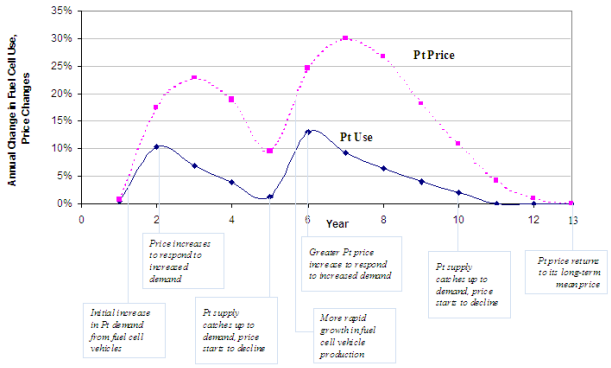

Figure 1. Simulation of platinum price response to increased platinum demand from fuel cell vehicle introduction.

Combining the vehicle projections, fuel cell vehicle market projections, platinum loading assumptions, and growth in traditional platinum markets leads to the primary platinum curves shown in Figure 3 for the moderate and slow growth fuel cell vehicle scenarios. Figure 4 highlights the critical role that recycling will play in reducing the demand for primary platinum. In the moderate growth

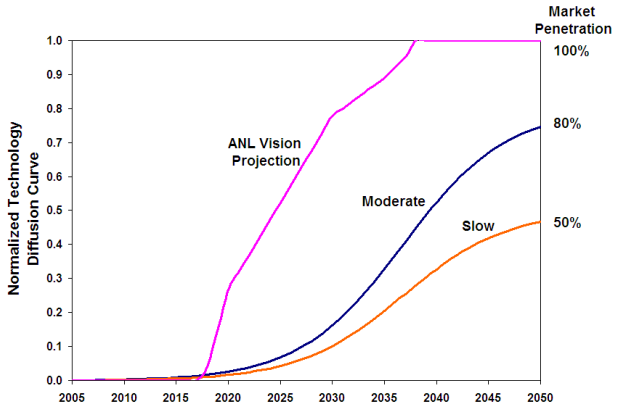

Figure 2. Fuel cell vehicle market penetration scenarios for developed and developing countries. The latter countries have 10- and 15-year time lags for the moderate and slow scenarios.

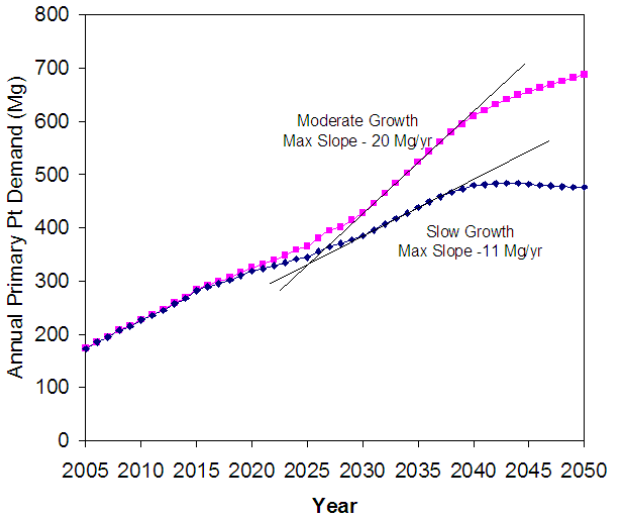

Figure 3. Total primary platinum demand needed to supply vehicle and other platinum market needs. The vehicle demand includes both the developed and developing countries.

scenario, recycled platinum used in fuel cell vehicles exceeds primary platinum after 2045. Figure 5 shows the platinum demand for the moderate commercialization scenario relative to historical platinum production data. The integration of the primary platinum demand out to 2050 shows the cumulative production represents approximately 30% of projected resources.

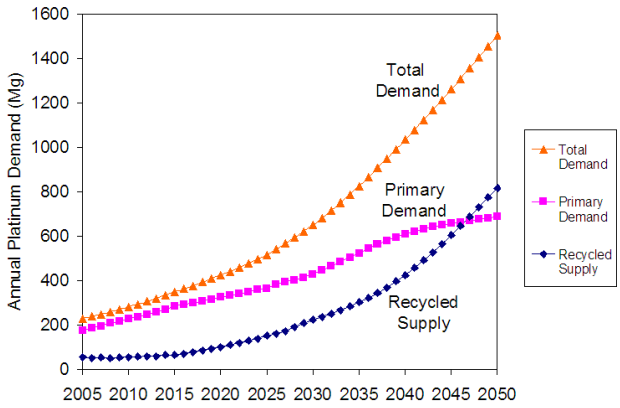

Figure 4. Overall annual platinum demand for the moderate growth scenario with the primary and recycled supply shown. Platinum from recycling exceeds primary supply after 2045.

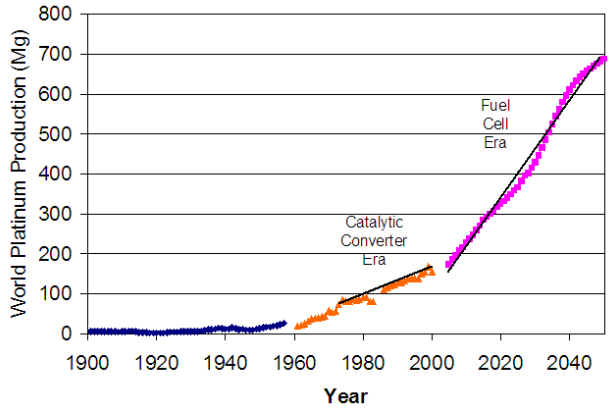

Figure 5. Moderate vehicle and fuel cell commercialization scenario platinum demand plotted relative to historical growth in platinum production.

Conclusions

The results presented in this report still require the final feedback from the platinum and automotive industries.

- Short-run spikes in platinum price may occur, dependent on the balance between demand and supply. Traditionally, the platinum industry has tried to maintain a constant real price to sustain traditional markets for PGMs while promoting growth of new applications. The expectation is that the platinum industry will continue to increase production to keep supply and demand in balance.
- The platinum industry will have to increase their rate of new production capacity to satisfy increased demand.
- High levels of recycling will be critical to reducing demands on primary platinum and are expected to exceed primary production.
- The combination of recycling and advances in mining technology to economically recover deeper sources of PGM ore will be needed to maintain reserves of platinum.

References

1. M.K. Singh, "VISION: a spreadsheet energy use model developed by ANL for the U.S. DOE", ANL, December 2002 run for DOE/OHFCIT2

FY 2003 Presentations

1. 2003 U.S. DOE Hydrogen, Fuel Cells & Infrastructure Technologies Program Merit Review and Peer Evaluation in Berkeley, California.
2. 2002 Fuel Cell Seminar in Palm Springs, California.