



Precious Metal Availability and Cost Analysis for PEMFC Commercialization

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**2003 Hydrogen and Fuel
Cells Merit Review Meeting**

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TIAX LLC
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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.

Barriers
N. Cost (Fuel-Flexible Fuel Processor) O. Stack Material and Manufacturing Cost

Technical Targets	
Reformate Based-System	gPt/kW
	0.2



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?

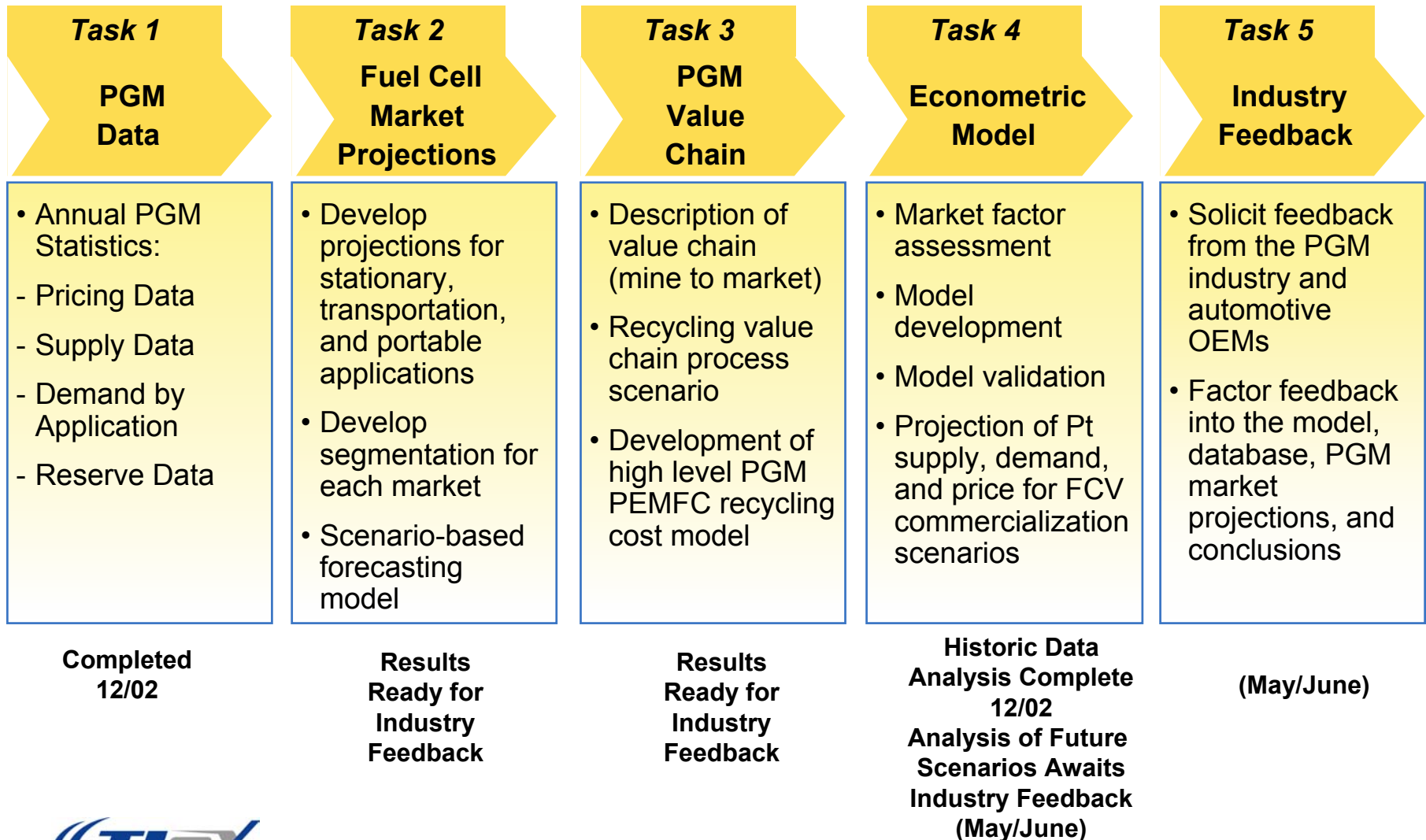
Project Objectives

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

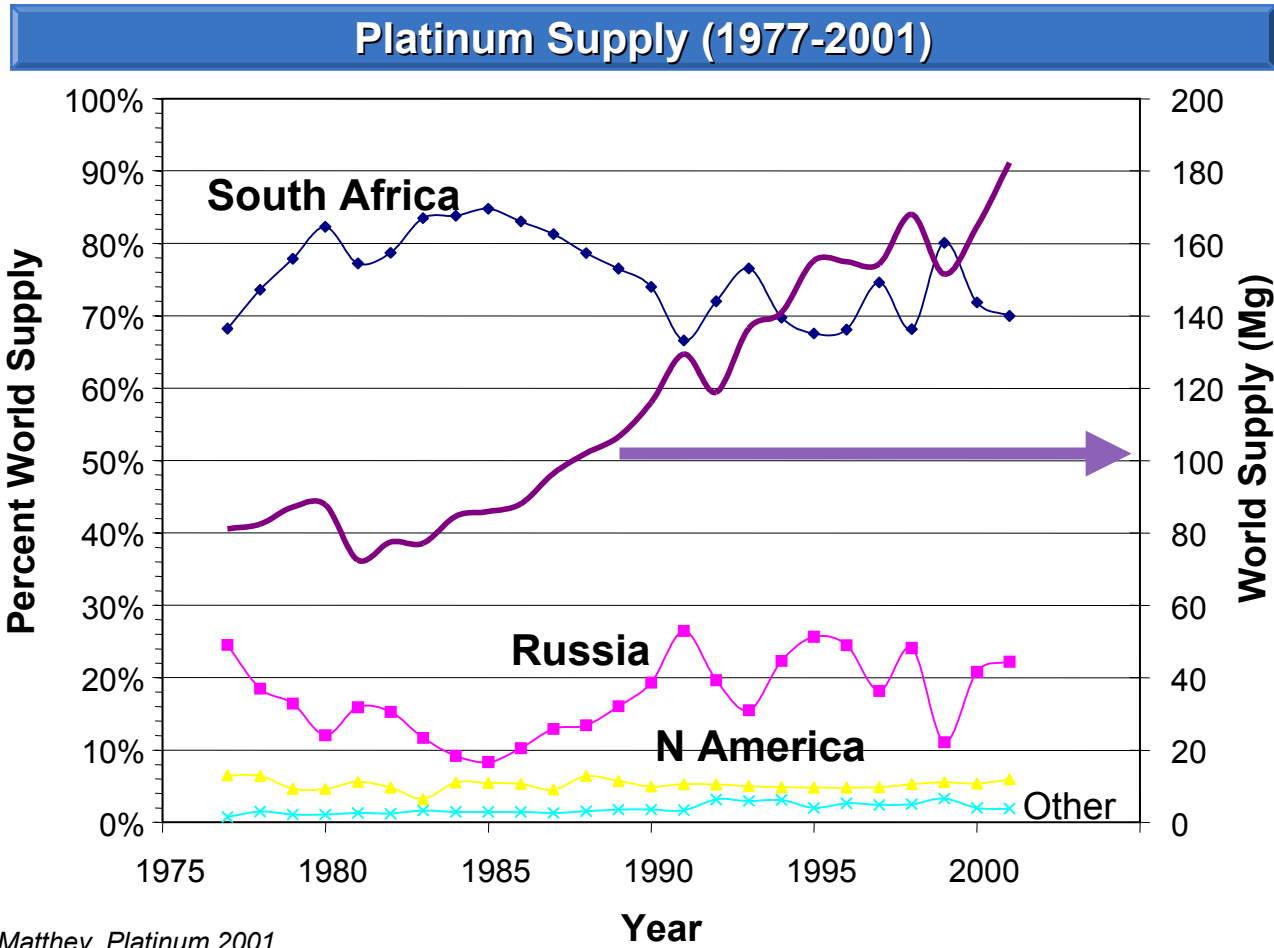
We are approximately 90% through the project and currently focussing on Task 5.



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.

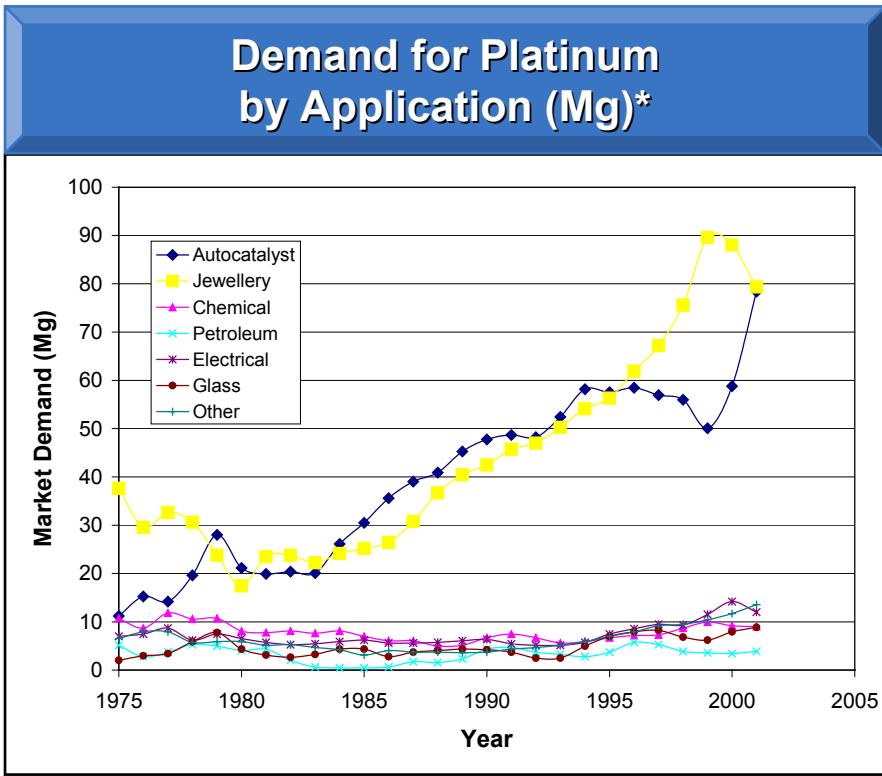


Source: Johnson Matthey, Platinum 2001.

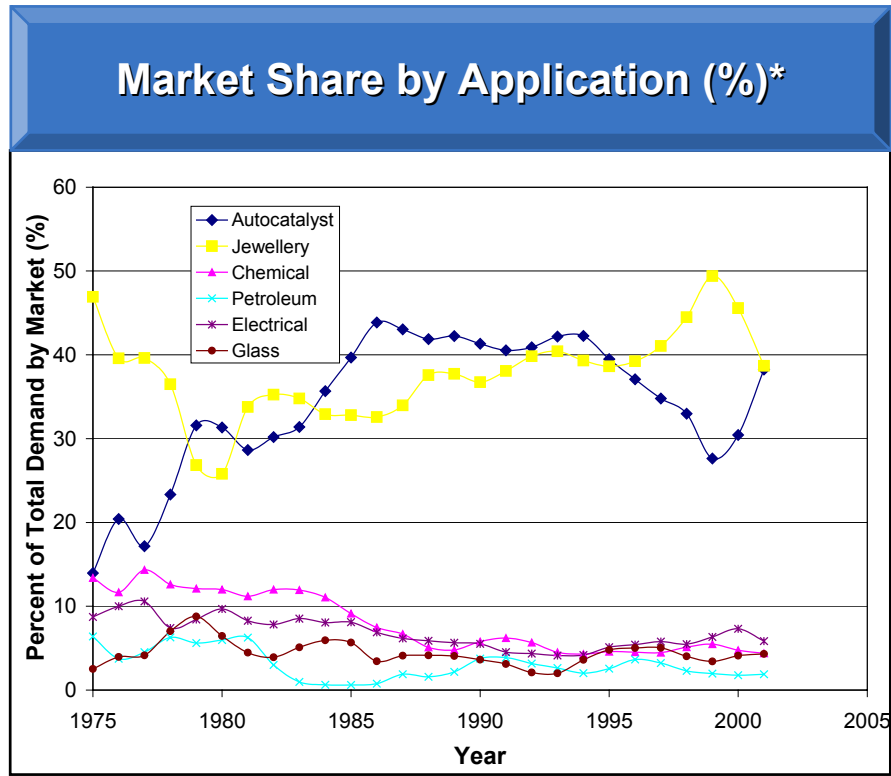
Russian supplies fluctuated during the 1990s.



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



Source: Johnson Matthey, Platinum 2001.



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Demand from other applications including chemicals, petroleum, electronics, and glass has been relatively stable.

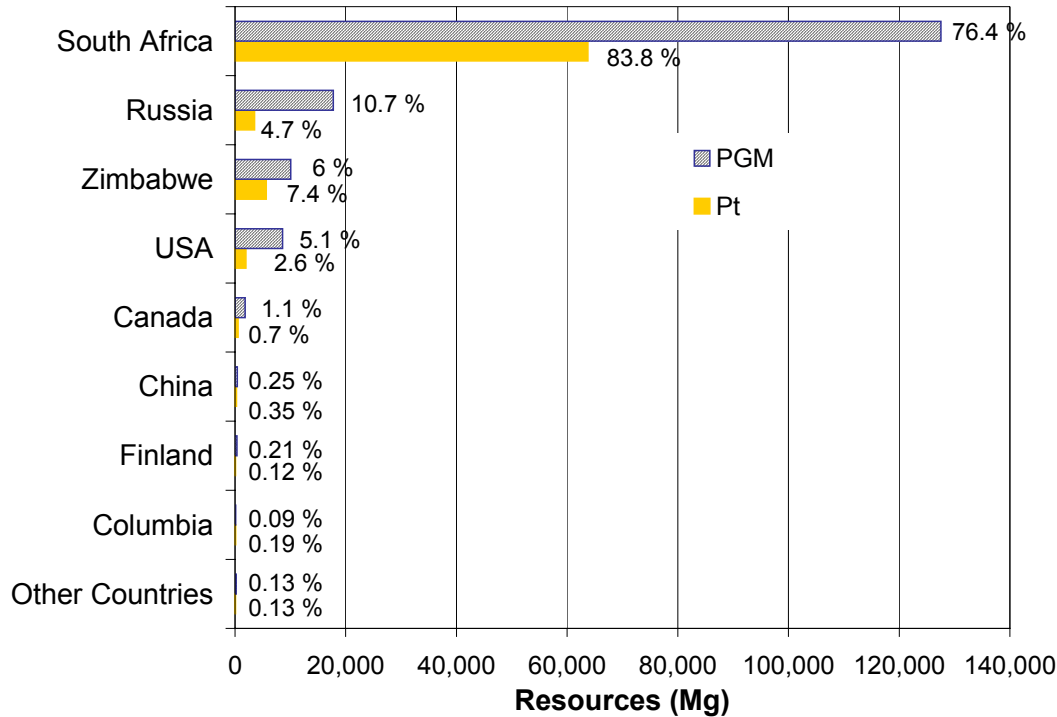


Resource data is reported on a geological basis and was used in our study for the assessment of potential long-term platinum availability.

- 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.

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



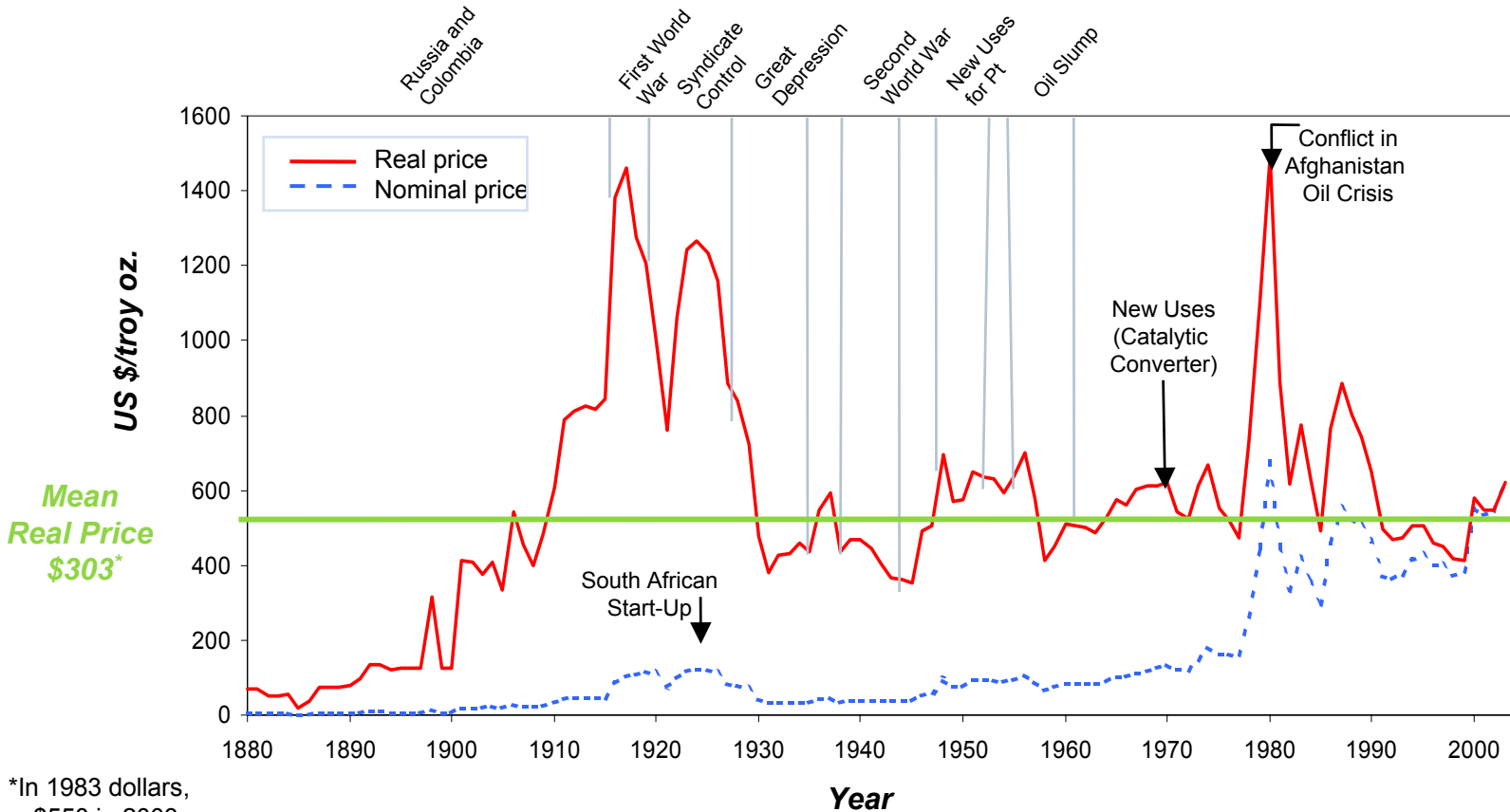
Compiled from a variety of sources, including Cawthorn, Vermaak, Page, Mining Weekly, and Stribyn

**Total Platinum Resource:
76,000 Mg**

@ 30 grams per vehicle
equals 2.8 billion vehicles

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

Data Sources: U.S. Geological Survey, Vermaak, C.F., "The Platinum-Group Metals," pp. 110



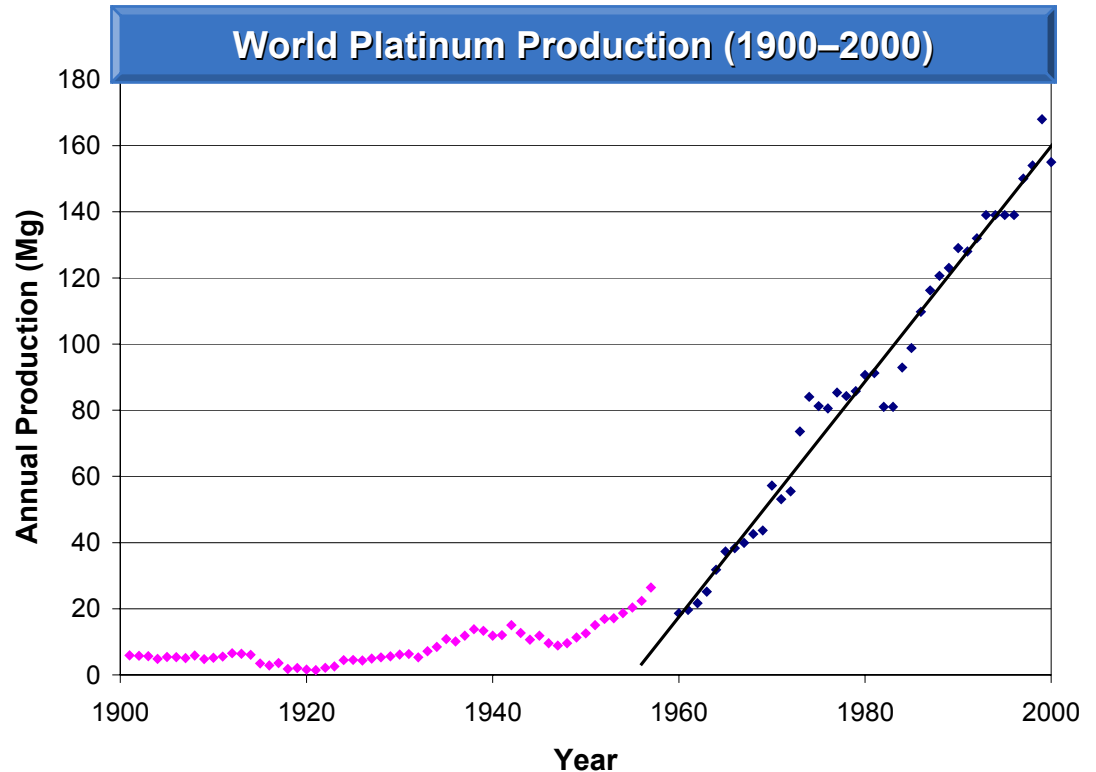
Our statistical tests support a stationary real platinum price over the last century- particularly since South African supply started.

- 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.

Test	Finding	
<p>Visual Inspection</p>	<ul style="list-style-type: none"> • The real price of platinum appears constant (i.e., there is no trend). • The price spiked during WW I (due to military demand for platinum), introduction of catalytic converters for cars, and the oil crisis. • Following each spike, the real price returned to its long-run mean. 	
<p>Slade's Hypothesis</p>	<ul style="list-style-type: none"> • 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. 	
<p>Stationarity Test</p>	<ul style="list-style-type: none"> • 1880–1998 • 1910-1998 • 1925–1998 	<p>Not conclusive about stationarity of real platinum price series</p> <p>Some support that platinum real price is stationary</p> <p>Strong evidence that platinum real price is stationary</p>

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
1963 -1983 Mineral Facts and Problems, U.S. Bureau of Mines
1986-2000 Mineral Yearbook, U.S. Geological Survey

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.

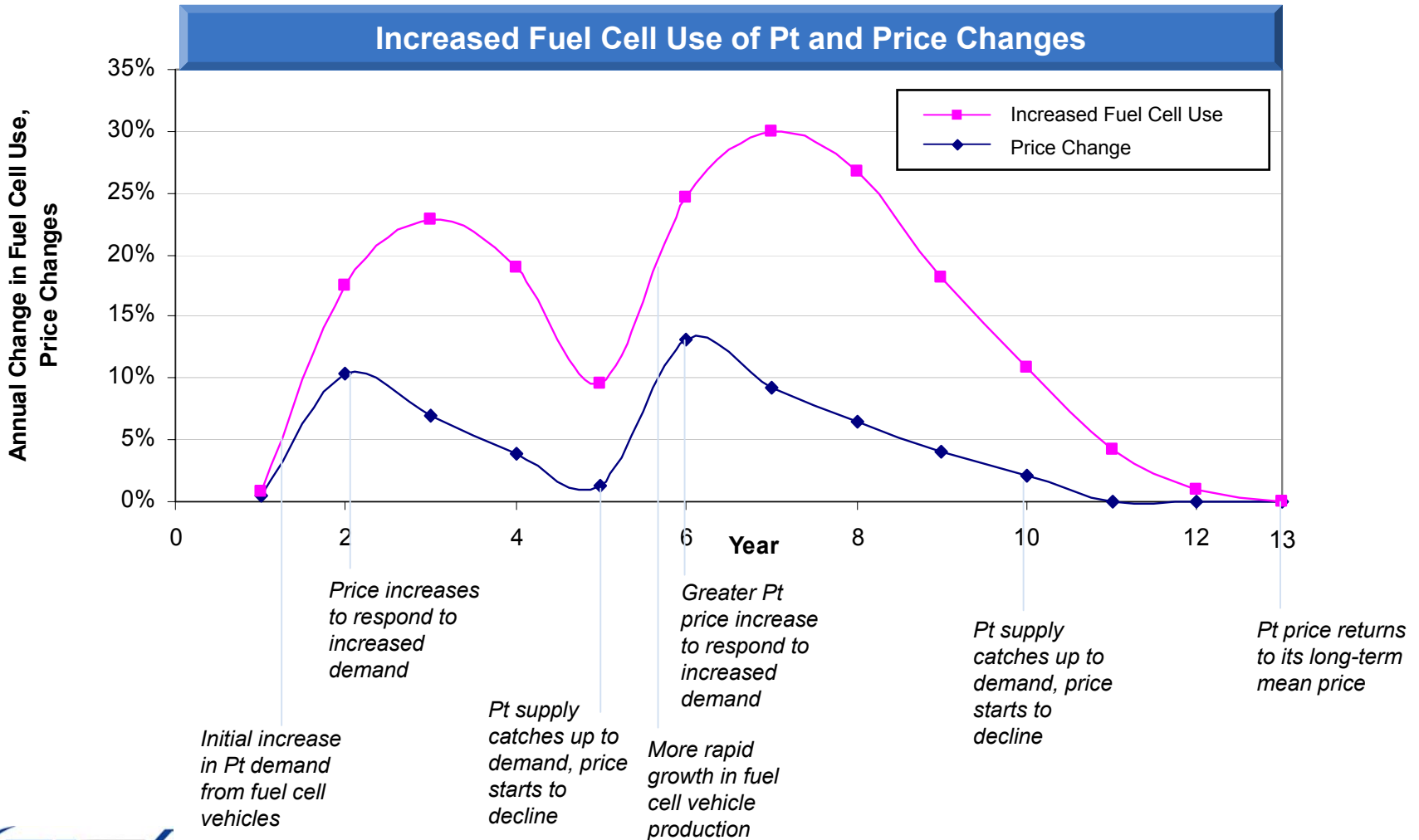
While anticipated fuel cell demand for platinum may drive higher platinum prices in the short-run, the price will likely return to its long-term mean.

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

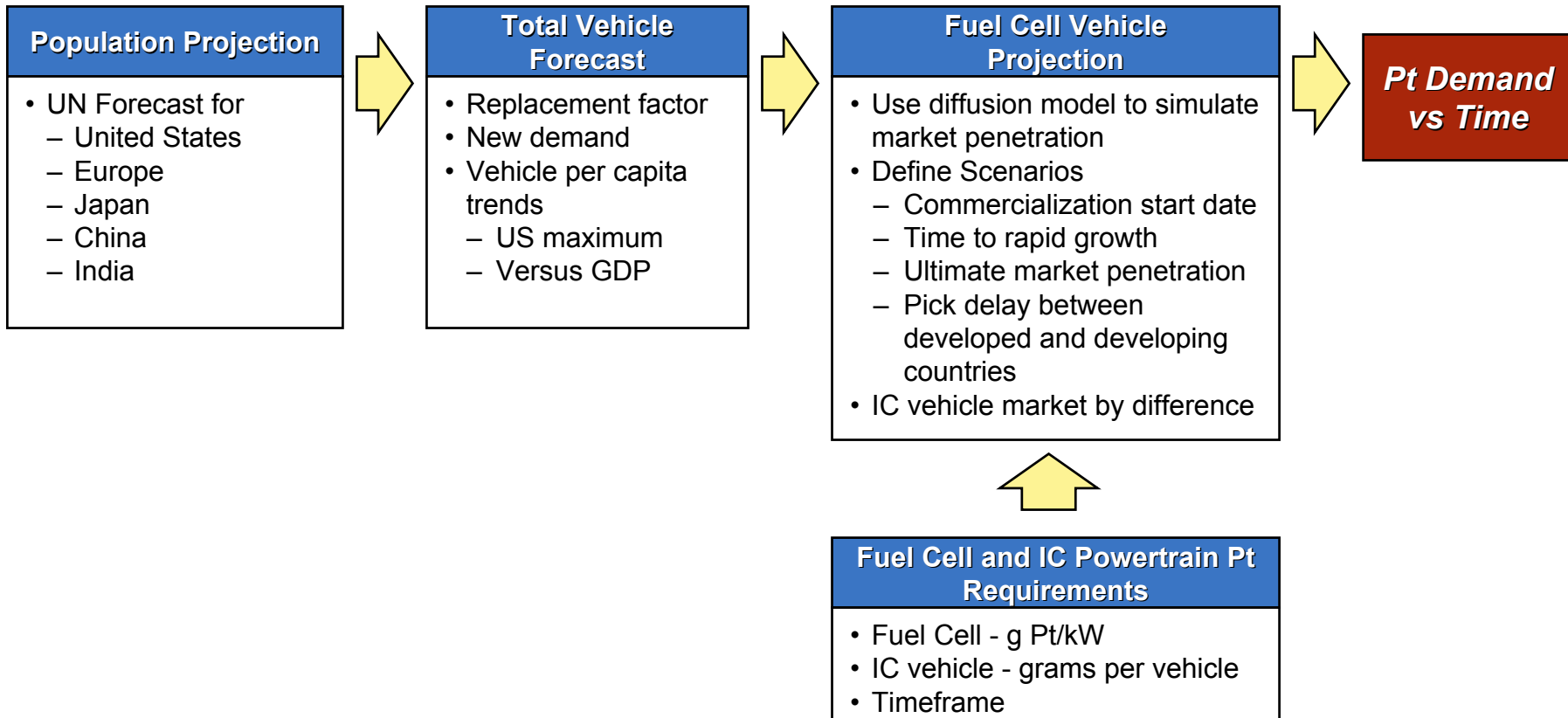
- Based on the estimated parameters from our econometric models of platinum supply and demand and information from automobile industry, we simulated the impact of an increased platinum demand from fuel cell technology on the short-run platinum prices.

Year of fuel cell vehicles introduced	Fuel cell vehicle production (million)	Pt demand (g)/vehicle	Fuel cell use of Pt (millions Troy oz)	Increased fuel cell use of Pt in total Pt consumption	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%

An increase in demand for platinum from fuel cell vehicles will increase the platinum price in the short-run (continued).



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.



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

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