DOE Hydrogen and Fuel Cells Program Record	
Record #: 5038	**Date:** May 22, 2006
Title: Hydrogen Cost Competitive on a Cents per Mile Basis - 2006	
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Approved by: JoAnn Milliken	**Approval Date:** May 22, 2006

Item:

Lower the cost of hydrogen from natural gas to be competitive on a cents per mile basis with conventional gasoline vehicles.

Supporting Information:

The results of a 2003 economic analysis were used to estimate the cost of hydrogen produced from distributed natural gas reforming at $5 per gallon of gasoline equivalent (gge) (See U.S. DOE Record 5030: Hydrogen Baseline Cost of $5 per gge in 2003; available at http://www.hydrogen.energy.gov/program_records).

Since the original analysis, DOE-sponsored R&D has resulted in significant cost reductions, largely attributable to engineering improvements that include:

- Reduced cost of hydrogen purification technology
- Improved systems integration
- Integrated thermal management
- Improved catalyst performance

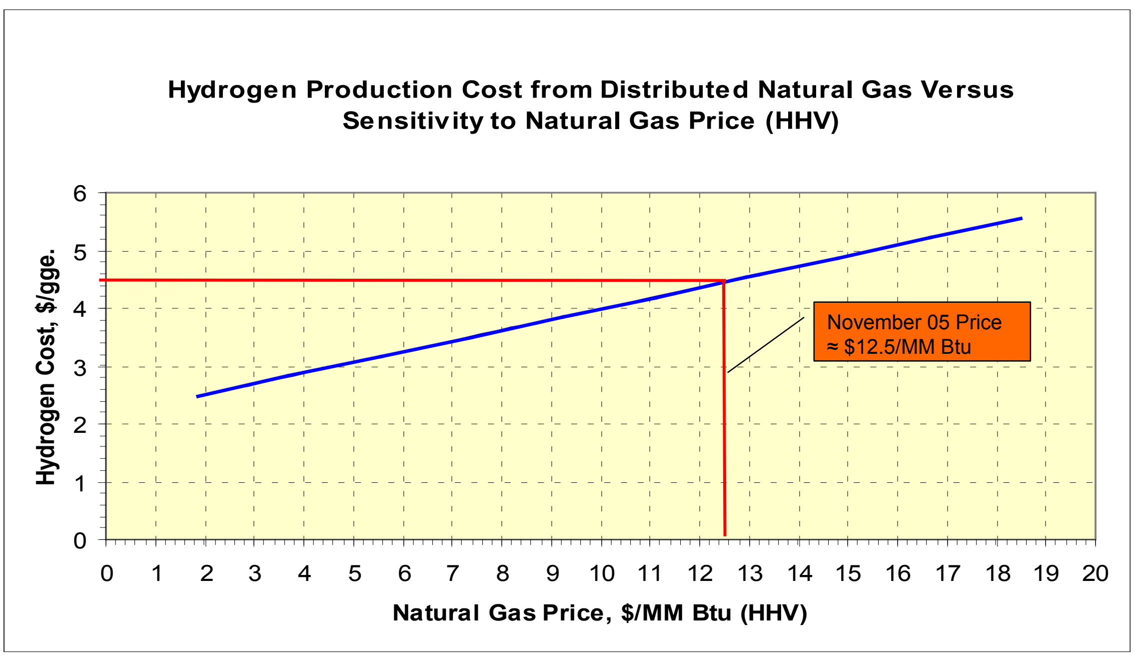
These improvements were used to conduct another analysis in 2005 using the H2A model, a model developed to provide consistent analysis methodology for a variety of hydrogen production pathways (http://www.hydrogen.energy.gov/h2a_analysis.html). The model was developed in conjunction with national laboratory and industry experts, and has been peer reviewed and beta tested using several hydrogen production and delivery pathways. The results of the 2005 analysis have shown a 40% reduction (to $3.10 per gge) in the cost of hydrogen produced from distributed natural gas reforming. The cost analysis and methodology were independently verified in 2006 by a panel of experts to evaluate progress of research efforts in hydrogen production cost reduction (see http://www.hydrogen.energy.gov/peer_review_production.html for details). The next step will be to take the best available technology from the laboratory and build and validate a system.

The cost analysis assumes that a small-scale natural gas steam reformer is added to an existing fueling station, and the analysis includes the cost of hydrogen production, compression, storage, and dispensing to the vehicle. Energy Information Administration (EIA) prices for natural gas were used in the model: $4.40 per million British thermal units (MMBtu) in the 2003 analysis (based on the lower heating value), and $5.24 per MMBtu in the 2005 analysis. (The difference between the EIA's 2003 and 2005 natural gas price is less than the rate of inflation, indicating that the 2005 hydrogen production cost analysis is a conservative estimate.)

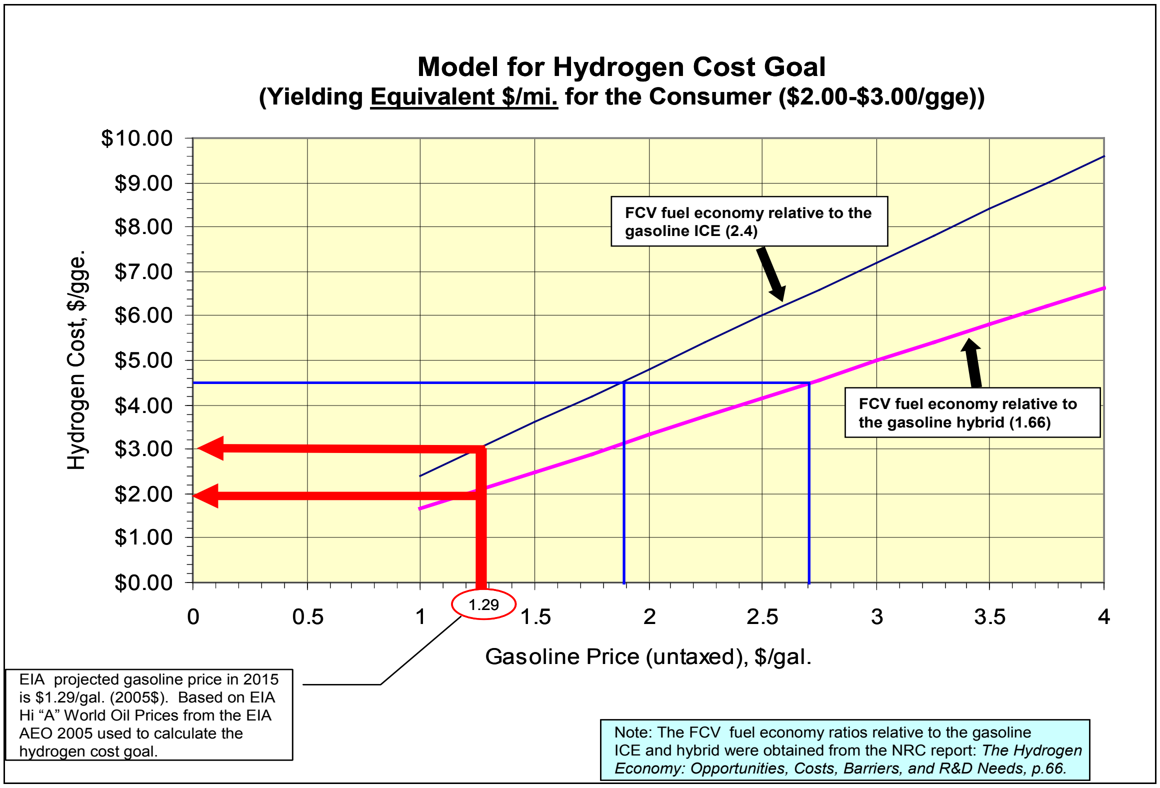
The EIA typically underestimates energy prices. Therefore, the DOE Hydrogen Program conducts sensitivity analysis on hydrogen cost. For example, natural gas at $12.50 per MMBtu (the actual November 2005 cost) would yield a hydrogen cost of $4.50 per gge. Because of the higher efficiency of hydrogen fuel cell powered cars compared to conventional gasoline vehicles, hydrogen at a cost of $4.50 /gge is competitive on a cents per mile basis to gasoline at $1.90 per gallon, untaxed.

Understanding Effects of Feedstock Volatility

Distributed natural gas/renewable liquid reforming and on-site electrolysis (promoting renewable electricity) strategies are advantageous for the transition to the hydrogen economy because they obviate the need for a new delivery infrastructure. Current delivery methods (high pressure tube trailers and "liquid" trucks) are very energy intensive and not cost effective for distances over 100 miles. The distributed reforming approach is an enabling technology to produce hydrogen not only from natural gas, but from a portfolio of options such as methanol, ethanol and other renewable liquids. In a steady state hydrogen economy, where diverse domestic resources are used, volatility of hydrogen price should not be an issue. However, natural gas prices are known to be volatile and this is an important consideration for planning the transition. The chart below shows this sensitivity:



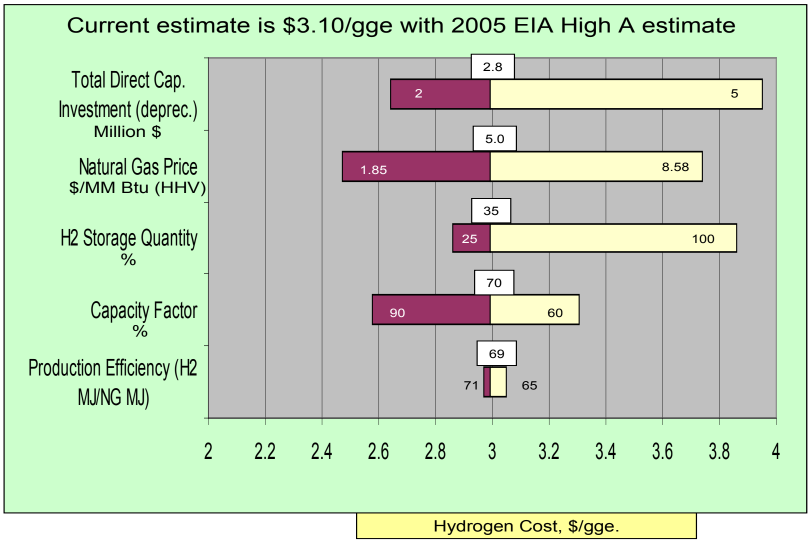
For example, using a weekly data point in November 2005 for an industrial natural gas price of $12.50 per million Btu, hydrogen would currently cost $4.50 per gallon-gasoline-equivalent (gge). This cost is calculated using the H2A financial model which calculates hydrogen costs based on the current technology development status. The H2A model is a cash flow model that allows us to understand the cost of various hydrogen production and delivery pathways on a consistent basis. This portfolio analysis tool provides a levelized cost of hydrogen for a given rate of return (input) and accounts for capital costs, construction time, taxes, depreciation, O&M, inflation, and feedstock prices. See http://www.hydrogen.energy.gov/h2a_analysis.html. As shown in the chart below, hydrogen at $4.50/gge would make hydrogen fuel cell vehicles competitive on a "cents per mile" basis with gasoline vehicles (ICE) at gasoline prices of $1.90/gge (untaxed) and gasoline hybrid-electric vehicles at gasoline prices of $2.70/gge (untaxed).



The impact of the volatility of natural gas prices will continue to be evaluated to ensure the viability of this hydrogen production pathway. Feedstock price volatility will significantly influence investment decisions.

The chart below shows the major variables that influence natural gas-based hydrogen costs.

Sensitivity Analyses for Distributed Hydrogen Production from Natural Gas



The pie chart below shows the composition of costs contributing to the current estimate of producing hydrogen from distributed natural gas. This estimate is based on the best available research, projected to high volume, but not yet validated under real-world operating conditions by the Program's Technology Validation Sub-Program. This estimate is based on the 2005 EIA High A estimate for natural gas in 2015.

Cost Breakdown of Hydrogen from Distributed Natural Gas ($3.10/gge)