DOE Hydrogen and Fuel Cells Program Record		
Record #: 12024	**Date:** September 19, 2012	
Title: Hydrogen Production Cost Using Low-Cost Natural Gas		
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Item:

Hydrogen produced and dispensed in distributed facilities at high-volume refueling stations using current technology and DOE's Annual Energy Outlook (AEO) 2009 projected prices for industrial natural gas result in a hydrogen levelized cost of $4.49 per gallon-gasoline-equivalent (gge) (untaxed) including compression, storage and dispensing costs. The hydrogen production portion of this cost is $2.03/gge.

In comparison, current analyses using low-cost natural gas with a price of $2.00 per MMBtu can decrease the hydrogen levelized cost to $3.68 per gge (untaxed) including compression, storage and dispensing costs. The production cost portion of hydrogen produced at distributed retail stations could decrease to $1.21 per gge.

Reference:

This Record provides further information on the effects that currently low (as of 2012) natural gas prices can have on the resulting cost of hydrogen produced from natural gas using steam methane reformation (SMR) technologies in distributed facilities at refueling stations. DOE's Fuel Cell Technologies Program assesses the cost of hydrogen using the H2A Production Model, a model developed to provide a consistent and transparent analysis methodology for a variety of hydrogen production pathways.[1] The H2A Production model is a discounted cash flow model that calculates the resulting levelized cost of hydrogen on a dollar per kilogram basis, taking into account capital costs, operating costs, and energy and feedstock costs.[2]

In addition to the H2A model itself, DOE has published a number of case studies of various hydrogen production pathways using the H2A model.[3] Standard H2A analyses of forecourt (distributed) hydrogen production consider hydrogen produced and dispensed at high utilization, 1,500 kg/day stations. The H2A forecourt case studies further assume a 20-year facility life, with repairs and replacements made as needed. For

[1] H2A Production Model, Version 3. http://www.hydrogen.energy.gov/h2a_production.html.

[2] 1 kg of hydrogen is approximately equivalent to 1 gallon-gasoline-equivalent (gge) on an energy content basis (LHV). For the purposes of this Record, 1 kg of hydrogen is assumed to be equal to 1 gge. The resulting "levelized cost" provided by H2A can be thought of as the minimum selling price (excluding taxes) needed to recoup all capital, operating, and energy costs and provide a 10% after-tax rate of return on investments (though the actual price of hydrogen will be driven by the market). All hydrogen costs cited in this Record represent the levelized cost of hydrogen, as determined through H2A analysis.

[3] http://www.hydrogen.energy.gov/h2a_prod_studies.html

energy feedstocks used in the production of hydrogen, the H2A model and case studies use AEO 2009 energy price estimates as cost inputs.[4]

In comparison to the AEO 2009 energy prices used in standard H2A analyses, the latest AEO 2012 price predictions for industrial natural gas are lower, reflecting the availability of shale gas. In recent years, the abundance of shale gas has been driving down prices of natural gas, which might drop even further than AEO 2012 estimates. For instance, prices as low as $2/MMBtu have been found in various spot markets for natural gas.

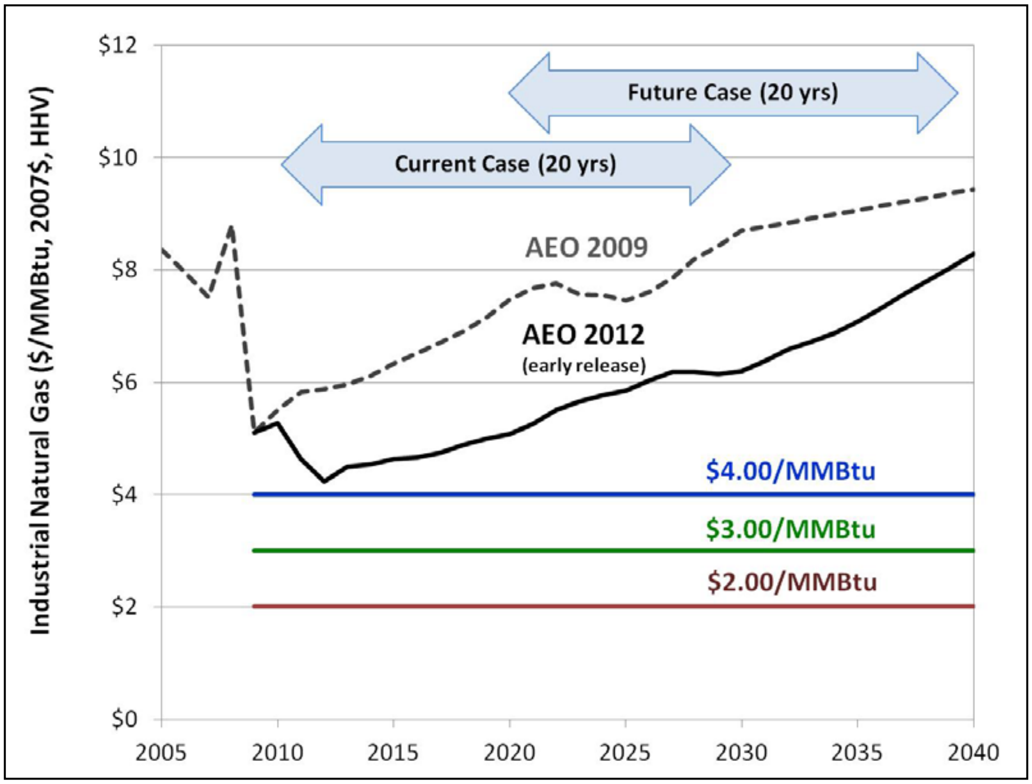
<u>Approach and Assumptions:</u>

This Record describes an analysis of the effect that lower natural gas costs can have on the resulting cost of hydrogen. Hydrogen costs were developed using the H2A Production model. In particular, the analysis assumed all cost inputs, except for the price of natural gas, remain the same as those presented in the "Current Forecourt (Distributed) Hydrogen Production from Natural Gas 1500 kg per day version 3.0" published H2A case study.[3]

In addition to the analysis of hydrogen production via natural gas SMR using current technologies, an analysis of distributed hydrogen production via natural gas SMR using future technologies was also conducted. Similar to the current technology analysis, the future case analysis assumed all cost inputs, except for the price of natural gas, remain the same as those presented in the "Future Forecourt (Distributed) Hydrogen Production from Natural Gas 1500 kg per day version 3.0" published H2A case study.[3]

Tracking standard case studies assumptions on plant life and start-up year, this analysis assumes a start year of 2010 (extending through 2029) for evaluations of current production technologies, and a 2020 start year (extending through 2039) for evaluations of future technologies.

[4] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2009*, "An Updated Annual Energy Outlook 2009 Reference Case Reflecting Provisions of the American Recovery and Reinvestment Act and Recent Changes in the Economic Outlook," April 2009, SR/OIAF/2009-03. Table 3. Energy Prices by Sector and Source.



Notes: The values shown reflect the AEO 2009 and AEO 2012 (early release) prices for industrial natural gas. The flat prices of $4.00, $3.00 and $2.00 per MMBtu were used to conduct sensitivity analyses and are not associated with AEO data. Prices beyond AEO projections are extrapolated using AEO data and the results of the Pacific Northwest National Laboratory's MiniCAM model for 2035 and 2050.

Figure 1. Industrial Natural Gas Prices Used in the Hydrogen Levelized Cost Analysis

As noted, the published H2A case studies set natural gas feedstock costs equal to the AEO 2009 prices for industrial natural gas. To better understand the effect of varying natural gas prices on the resulting price of hydrogen, and to explore the sensitivity of hydrogen levelized cost on natural gas in general, an analysis was conducted using AEO 2012 price predictions for industrial natural gas, which are lower than the AEO 2009 predictions. The analysis also incorporated sensitivity evaluations, assuming constant natural gas costs of $2, $3, and $4 per MMBtu.

Though very low price natural gas has been found periodically in spot markets, it is not expected that natural gas prices in real terms would remain at $2/MMBtu or $4/MMBtu through 2030 or 2040. However, a constant $2/MMBtu or $4/MMBtu price might reflect the terms of a long-term contract that locks in pricing over a 20-year contract lifetime. While such low-price, long-term contracts may not be likely for distributed hydrogen production facilities, analyses of the effects that very low natural gas prices can have on hydrogen production cost are useful in exploring the sensitivity of hydrogen costs to feedstock energy costs.

Analysis Results:

Using AEO 2009 prices for industrial natural gas as a production feedstock, the standard H2A case study for current forecourt hydrogen production via natural gas SMR estimates a dispensed hydrogen cost of $4.49/kg. The production cost alone without on-site compression, storage, and dispensing (CSD) costs is $2.03/kg (see Figure 2). Using the standard future case for forecourt SMR production and AEO 2009 natural gas prices, H2A estimates a dispensed hydrogen cost of $3.75/kg for stations built in 2020, with a production cost (not including CSD) of $2.10/kg (higher than the current case, due to higher predicted natural gas feedstock costs over the plant's analysis period).

Replacing the standard AEO 2009 natural gas costs with AEO 2012 natural gas price projections into the H2A analysis yields a total dispensed hydrogen cost of $4.20/kg for current production technologies, with a production cost (not including CSD) of $1.74/kg. Similarly, using AEO 2012 natural gas price projections in an H2A analysis of the future case yields a dispensed hydrogen cost of $3.41/kg, with the production cost accounting for $1.77/kg.

As discussed above, sensitivity analyses were conducted for both the current technology case and the future technology case using constant natural gas feedstock prices of $2/MMbtu, $3/MMBtu, and $4/MMBtu. By way of comparison, the standard H2A case studies use AEO 2009 price projections for industrial natural gas, which average $7.37/MMBtu and $8.81/MMBtu for the current and future cases, respectively.

Using a constant natural gas feedstock cost of $4/MMBtu, hydrogen can be produced in the current case for $1.57/kg, with the total cost of dispensed hydrogen of $4.03/kg. In the future case using $4/MMBtu natural gas prices, hydrogen can be produced for $1.43/kg, and fully dispensed at $3.08/kg.

For the very low cost natural gas case, using a constant natural gas feedstock cost of $2/MMBtu, hydrogen can be produced in the current case for $1.21/kg, with the total cost of dispensed hydrogen of $3.68/kg. In the future case using $2/MMBtu natural gas prices, hydrogen can be produced for $1.10/kg, and fully dispensed at $2.75/kg.

Note that the potential effects that low natural gas prices might have on electricity prices are not incorporated into these analyses.

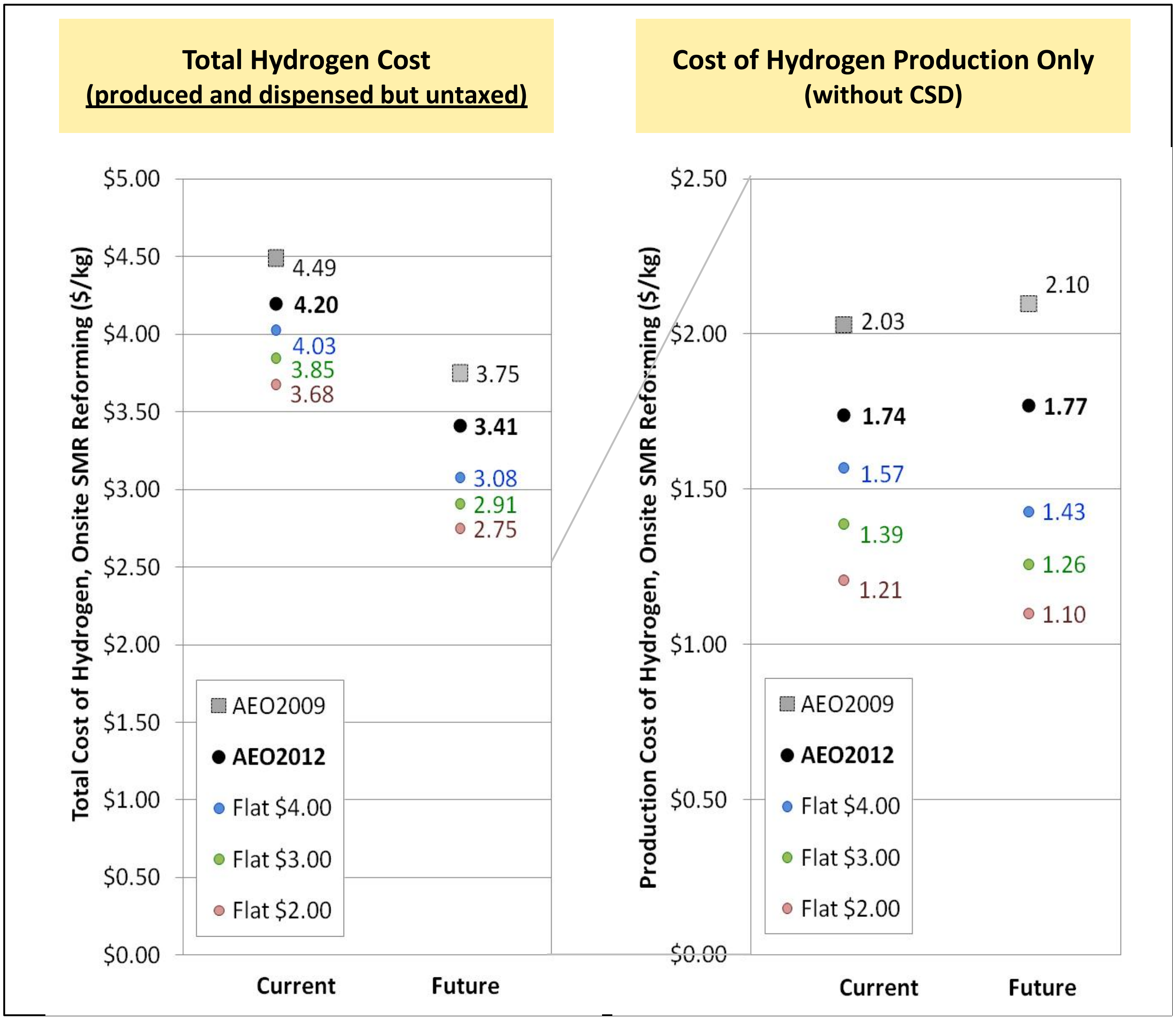


Figure 2. Hydrogen Levelized Cost Results for Forecourt Hydrogen Production Using Natural Gas

References:

[1] H2A Production Model: http://www.hydrogen.energy.gov/h2a_production.html

[2] H2A Current and Future Forecourt (Distributed) Hydrogen Production from Natural Gas case studies (version 3): http://www.hydrogen.energy.gov/h2a_prod_studies.html