DOE Hydrogen and Fuel Cells Program Record		
Record #: 12001	**Date:** May 14, 2012	
Title: H_2 Production and Delivery Cost Apportionment		
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Item:

The hydrogen threshold cost is defined as the untaxed cost of hydrogen (H_2) (produced, delivered, and dispensed) at which hydrogen fuel cell electric vehicles (FCEVs) are projected to become competitive on a $/mile basis with competing vehicles [gasoline in hybrid-electric vehicles (HEVs)] in 2020. As established in Record 11007 [1], this cost ranges from $2.00-$4.00/gge[a] of H_2 (based on $2007). The threshold cost can be apportioned into its constituent H_2 production and delivery costs, which can then serve as the respective cost targets for multi-year planning of the Fuel Cell Technologies (FCT) Program H_2 Production and Delivery sub-programs. As described below, regardless of whether hydrogen is produced at central or distributed sites, the apportionment calculation approximates to a 50-50 split, or $1.00 to $2.00/gge for the cost of H_2 production and $1.00 to $2.00/gge for the cost of H_2 delivery (including CSD).

Data and Assumptions:

The following steps were used to establish the cost target apportionment between H_2 production and H_2 delivery based on the overriding hydrogen threshold cost of $2.00 - $4.00/gge:

1) Set a centralized hydrogen production target using cost projections based on the current lowest cost production technology because all other technologies will have to compete with that one on a cost basis.
2) Calculate a central delivery target (i.e. the threshold cost minus the production cost for the lowest cost technology for centralized H_2) and identify the appropriate delivery scenarios and parameters that can directly or approximately meet that target.
3) Use cost and efficiency information generated in the delivery scenarios identified in Step (2) to set the delivery target for distributed production; namely, the aggregate cost of compression, storage, and dispensing at the station. This step is based on the assumption that consistent technical targets should be used for delivery from both central and distributed production.
4) Calculate a distributed production target; i.e. the threshold cost minus the distributed delivery cost.

Discussed below are the details of this process.

[a] Where 1kg H_2 (LHV) is approximately equal to 1 gasoline gallon equivalent (gge).

Centralized H_2 Production

H_2 Production Cost:

Currently and in the anticipated future large-scale steam methane reformation (SMR) production of H_2 represents the lowest cost baseline against which all other centralized methods of H_2 production can be compared, [2]. That is, to be competitive in the current (and near-term future) market, alternative production technologies must be able to offer a business advantage equal to or greater than SMR.[b] At present, the primary business factor in the market is production cost, or \$/kg of H_2 produced. (In the future, one could argue other business advantages might arise, including hedges against natural gas market volatility, carbon credit, reduction in carbon taxes, or carbon swapping, but at present these mechanisms are not significant business factors.) Thus, the levelized cost of centralized hydrogen production can be set equal to the average cost of H_2 produced at large-scale, centralized SMR plants. In 2007\$ and projected to 2020, this cost is \$1.95/gge based on 2020 technology, using the Annual Energy Outlook 2010 projection for natural gas feedstock cost, and assuming the economies of scale associated with a centralized plant with a production capacity of great than 340,000 kg/day [3].

H_2 Delivery Cost:

Delivery costs, including dispensing costs, are derived from the \$2.00 – 4.00/gge cost threshold range at which H_2 must be produced and delivered to the tank in order to compete with the future cost of gasoline. The upper end of the range, \$4.00/gge, is used to define the maximum cost for H_2 delivery from a central production facility to individual FCEV refueling stations. Subtracting the target cost for production (the levelized cost of centralized H_2 production by SMR, which equals \$1.95/gge) yields a target for delivery from a central production plant of \$2.05/gge.

Distributed H_2 Production On-site at the Station

H_2 Delivery Cost:

The cost for refueling station compression, storage, and dispensing (CSD), or the unit operations carried out at the station end of H_2 delivery path, can be isolated from the Hydrogen Delivery Scenario Analysis Model (HDSAM) scenarios developed to meet the 2020, \$2.05/gge delivery target calculated above. Distributed production by a small-scale reformer, an electrolyzer, or other means is anticipated to generate H_2 at a pressure of 300 – 600 psi. The closest future central delivery analog that meets this technical condition is pipeline delivery, in which hydrogen is assumed to be delivered to the station at 600 psi. A series of future (2020) delivery scenario calculations were made in 2011 using HDSAM v2.3, the results of which are reported in Record #12022, [4]. The CSD costs associated with the 2020 pipeline delivery scenario developed in this model were < \$1.30/gge. However as discussed in Record #12021, adjustments were made to account for differences in seasonal H_2 storage between a central pipeline scenario (wherein variations in summer and winter needs would be met via geologically stored H_2) and an on-site, distributed production scenario (i.e. all storage at the station), [5]. Incorporating these modifications, the final projected 2020 CSD costs are \$1.65/gge (rounded to \$1.70/gge in the 2012 MYRD&D plan).

[b] H2A v3 2020 cost projections for central biomass gasification and central electrolysis indicate that these pathways could achieve H2 levelized costs of \$2.00 if capital costs and feedstock costs can be lowered. While there are currently no central plants operating for these pathways, SMR is an established and widespread production process.

H_2 Production Target:
Distributed production costs are derived from the $2.00 – 4.00/gge threshold established for the cumulative as-produced, delivered, and dispensed cost of H_2. Again, the upper end of the range, $4.00/gge, is used to define the maximum cost for distributed H_2 production by subtracting the target cost for CSD. This calculation yields a target of $2.35/gge.

Production and Delivery Targets

Summarized in Table 1 are the four apportioned costs for centralized and distributed hydrogen production and delivery. Given the uncertainty in the cost projections used in deriving these costs, they can be rounded to two rather than three significant figures.

Table 1. Apportioned costs for centralized and distributed hydrogen production and delivery in 2020.

	Centralized	**Distributed**
H_2 Production Cost *	$1.90/gge	$2.30/gge
H_2 Delivery Cost ***	$2.10/gge	$1.70/gge

*Based on a maximum hydrogen threshold cost of $4.00/gge

** dispensed, but untaxed

Due to the uncertainty of the cost estimates and projections this can be further rounded to a 50-50, or $2.00/gge each, split of the Program's upper level $4.00/gge threshold cost for H_2 fuel. This results in a threshold cost goal of $1-2/gge for hydrogen production and a threshold cost goal of $1-2/gge for hydrogen delivery. Industry representatives, with expertise in both hydrogen production and delivery technologies, have reviewed this record and the assumptions made to ensure reasonable accuracy.

References

1. Program Record #11007, March 25, 2011. "Hydrogen Threshold Cost Calculation," M. Ruth and F. Joseck. http://www.hydrogen.energy.gov/pdfs/11007_h2_threshold_costs.pdf.
2. Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan, Chapter 3.1 Hydrogen Production, November 2012, http://www1.eere.energy.gov/hydrogenandfuelcells/mypp/pdfs/production.pdf
3. Future (2020) Central Hydrogen Production from Natural Gas without CO_2 Sequestration version 3.0; http://www.hydrogen.energy.gov/h2a_prod_studies.html
4. Program Record #12022, November, 2012. "H_2 Delivery Cost Projections - 2011," S. Weil, S. Dillich, and E. Sutherland.
5. Program Record #12021, October, 2012. "Refueling Station Cost Projections - 2011," S. Weil, A. Elgowainy, M. Ruth, S. Dillich, and E. Sutherland.