Hydrogen Cost Estimates via Steam Methane Reforming

The following table summarizes the estimated "all-in" cost of hydrogen produced by reforming natural gas at the fueling station, including compression, storage, and dispensing.

			Hydrogen Cost From On-Site Steam Methane Reformer System ($/kg)			**FCEV Hydrogen Cost per Mile Traveled** ($/gallon of gasoline equivalent, untaxed)	
	Hydrogen Production Capacity	Equipment Production Quantities	Production Cost	Compression & Storage Cost	Total Cost ($/kg)	Relative to Hybrid Electric Vehicle	**Relative to Conventional Car**
Today HGM2k (20 cars/day)	**115 kg/day**	**> 10**	5.92	3.37	9.29	$5.68/ggre	**$3.92/ggre**
Today HGM3k (30 cars/day)	**172 kg/day**	**> 10**	4.60	2.74	7.34	$4.49/ggre	**$3.10/ggre**
Today HGM10k (100 cars/day)	**578 kg/day**	**> 10**	3.53	1.87	5.40	$3.30/ggre	**$2.28/ggre**
~4 Years HGM10k (100 cars/day)	**578 kg/day**	**> 200**	3.20	1.47	4.67	$2.85/ggre	**$1.97/ggre**
~6 Years (250 cars/day)	**1,500 kg/day**	**>500**	2.35	0.99	3.34	$2.04/ggre	**$1.41/ggre**

Assumptions: Annual Capital Recovery factor = 19.1%; Capacity Factor = 70%; Natural Gas = $8/MBTU
Electricity = 8 cents/kWh; FCV fuel economy = 2.4 X ICEV; HEV fuel economy =1.45 X ICEV

H2Gen:Markets4.XLS, Tab'H2 Cost Table' M23;10/16/2009

These hydrogen costs include a 10% real, after-tax return on investment for all equipment, plus fuel costs and operation and maintenance (O&M) costs, with an average fueling system capacity factor of 68.6%.

The first three rows correspond to hydrogen costs available today for three different SMR capacities based on commercial units, with production quantities of just 10 fueling systems.

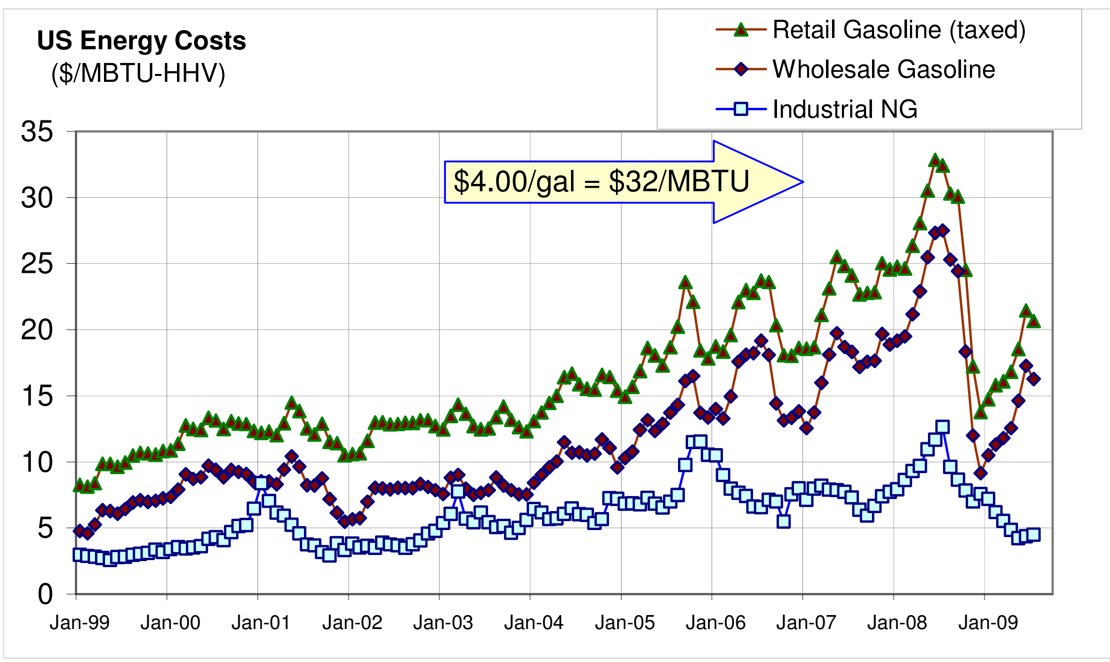
The last two columns show the cost of hydrogen in $/gallon of gasoline on a *range-equivalent* basis ($/ggre). That is, these estimates take into account the improved fuel economies of the FCEV relative to a hybrid electric vehicle and relative to a non-hybrid (conventional vehicle.)

These range-equivalent costs are proportional to the fuel cost per mile. For example, for the HGM-10K with 578 kg/day capacity, the "all-in" cost of hydrogen would be $5.40/kg, which is equivalent on a cents per mile basis to $2.28/gallon of gasoline, meaning that the owner of a FCEV would pay the same fuel cost per mile as the owner of a conventional car with gasoline selling at $2.28/gallon. Alternately, the FCEV owner would pay the same fuel cost per mile as the owner of a higher fuel economy hybrid electric vehicle with gasoline at $3.30/gallon.

The last two rows show the estimated costs with higher SMR production volumes and for a 1,500 kg/day fueling system, where hydrogen cost could be less than $2/ggre. This 1,500 kg/day system has not been built, but its costs were estimated as part of a DOE cost shared contract to demonstrate the potential to make compressed hydrogen at $3/kg.

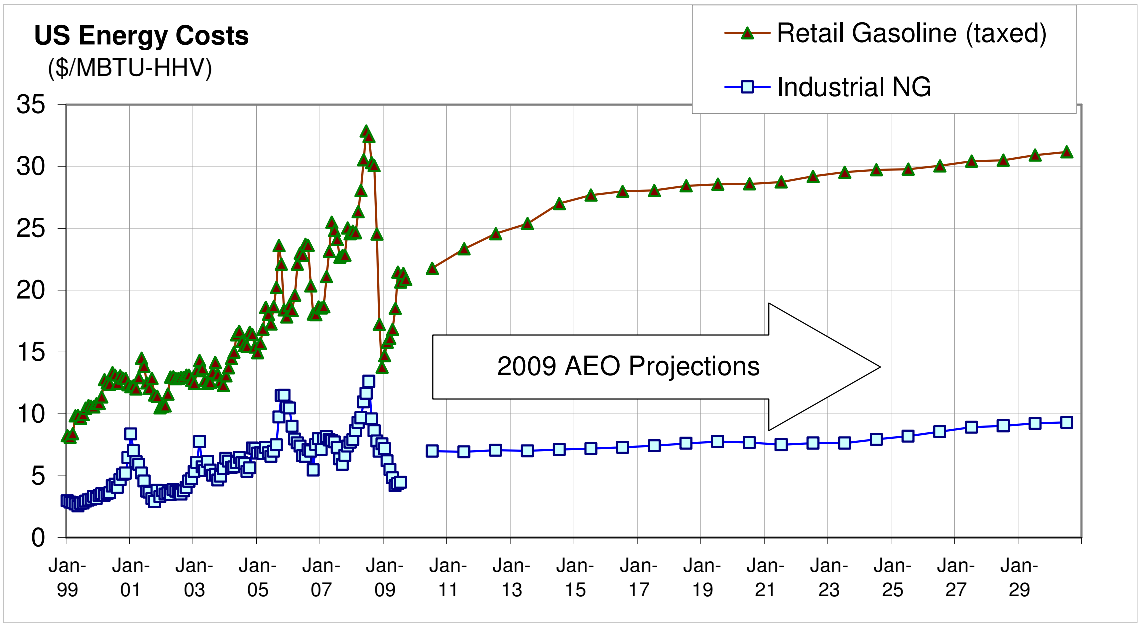
These hydrogen costs depend on the cost of natural gas, taken as $8/MBTU in these calculations. Note that Henry Hub is now selling below $3/MBTU (as of October 2009). Adding $1 to $2/MBTU for transmission and distribution would bring the current price of industrial natural gas to at most $5/MBTU.

Of course gasoline prices have fluctuated wildly in the 2008-2009 time period too. The appropriate benchmark is the price of natural gas compared to the price of gasoline. As shown below, the price of gasoline began diverging from the price of natural gas in the 2006-2007 time period. By the summer of 2008, with crude oil hitting $147/bbl, gasoline was selling at three times the price of natural gas on a $/MBTU basis. The crash in the fall of 2008 plunged gasoline close to parity with natural gas, but has since diverged rapidly again, while industrial natural gas prices continue to fall.



H2Gen: NG-Price.XLS; Tab 'Gasoline-NG' T100- 10 / 16 / 2009

Given these historical data on natural gas and gasoline prices, we can estimate what the relative fuel costs per mile would have been for ICVs, HEVs, and FCEVs. We also use the Energy Information Administration's 2009 Annual Energy Outlook projections for fuel costs to project how gasoline and hydrogen derived from natural gas might evolve through 2030. They are projecting that gasoline will cost three times as much as natural gas. These gasoline prices include highway taxes. We assume that hydrogen made from natural gas would not be taxed initially to encourage the use of this clean fuel. Eventually, however, it will have to be taxed to maintain our highway systems.



H2Gen: NG-Price.XLS; Tab 'Gasoline-NG' T182- 10 / 19 / 2009

To calculate the gasoline and hydrogen costs per mile, we assume these vehicle fuel economies:

- Conventional ICE vehicle: 25 mpg
- Hybrid electric vehicle: 36.3 mpg (1.45X ICV)
- Fuel cell electric vehicle: 60 mpgge (2.4X ICV)

We estimated the hydrogen fuel costs for two cases:

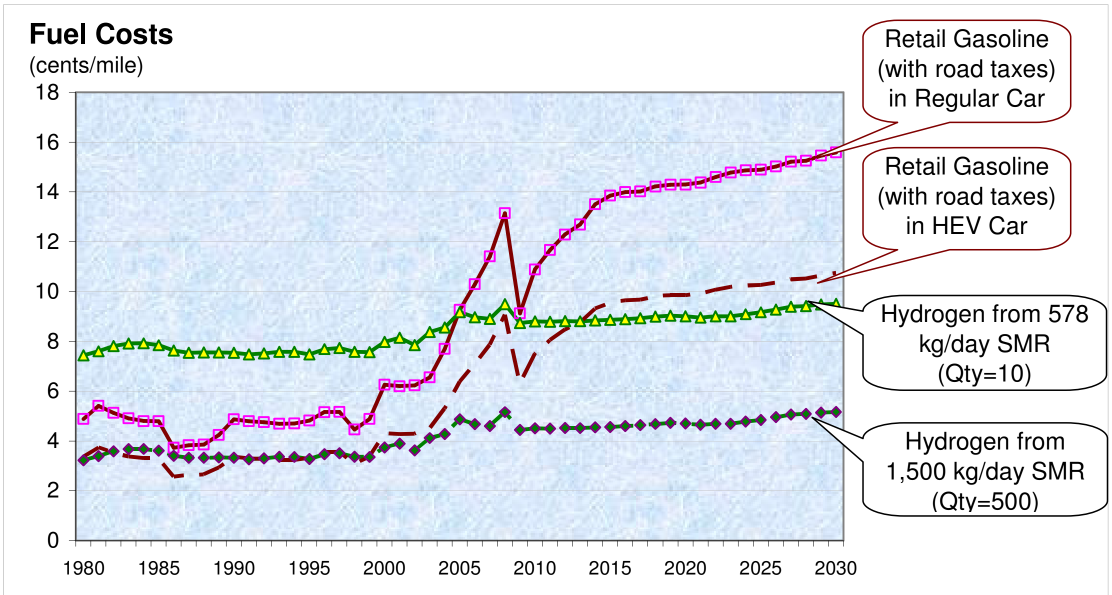
- The commercial HGM-10,000 SMR (578 kg/day capacity) in production quantities of just 10 units, combined with the required compression, storage and dispensing (CSD) equipment
- An SMR with 1,500 kg/day capacity plus associated CSD in production quantities of 500 units, the system analyzed for the DOE under a cost-shared contract with H_2Gen. This represents our best judgment on the likely cost of on-site hydrogen fueling systems once in moderate scale production.

The results show that hydrogen from the existing commercial SMR system in very low production volume is already competitive on a cents/mile basis with a conventional ICV using 2009 gasoline and natural gas prices. With the 2009 AEO fuel price projections, hydrogen in a FCEV would be competitive with gasoline in an HEV by 2013.

As shown below, the larger 1,500 kg/day fueling system in 500 production quantities would have been competitive with HEV gasoline cents/mile historically, and with AEO fuel price projections, would be much less expensive than gasoline in either an ICV or HEV.

Fuel Costs (cents/mile traveled) for Fuel Cell Vehicles and Conventional Cars

(Based on Historical Prices for Natural Gas and Gasoline in the US & AEO 2009 Projections to 2030)



HEV = Hybrid Electric Vehicle; SMR = steam methane reformer (the method of making hydrogen from natural gas and water)
FCV fuel economy = 60 mpgge; HEV fuel economy = 36.2 ICEV fuel economy = 25 mpg; Capital Recovery Factor =0.1919
Electricity = 8 cents/kWh; SMR efficiency (HHV/HHV) = 78%; 4-stage Compressor Isentropic Efficiency = 65%;
Output pressure = 7,000 psia; Input pressure = 235 psia; HFA Capacity Factor = 68.6%
578 kg/day system costs $1790K; 1,500 kg/day system costs $2773K

H2Gen: NG-Price.XLS; Tab 'Gasoline-NG' T102- 10 / 19 / 2009