
U.S. Department of Energy Hydrogen Program

Hydrogen Production & Delivery

Rick Farmer

**2008 DOE Hydrogen Program
Merit Review and Peer Evaluation Meeting**

June 9, 2008





Goal and Objectives

GOAL: Research and develop low-cost, clean, highly efficient hydrogen production technologies from diverse domestic resources, including fossil, nuclear, and renewable sources

- Reduce the cost of hydrogen to \$2.00 - \$3.00/gge (Untaxed & Delivered)

Near-term: Distributed Production

(produced at station to enable low-cost delivery)

- *Natural gas reforming*
- *Renewable liquid reforming*
- *Electrolysis*

Longer-term: Centralized Production

(large investment in delivery infrastructure needed)

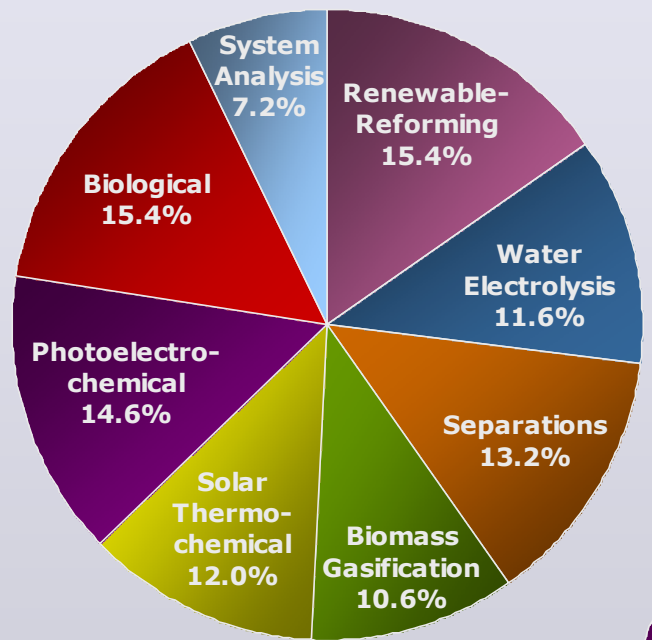
- *Biomass gasification*
- *Coal with sequestration*
- *Wind, solar, and nuclear-driven electrolysis*
- *Solar/nuclear high-temperature thermochemical water splitting*
- *Photoelectrochemical, biological production*

- Reduce total hydrogen delivery cost to < \$1.00/gge

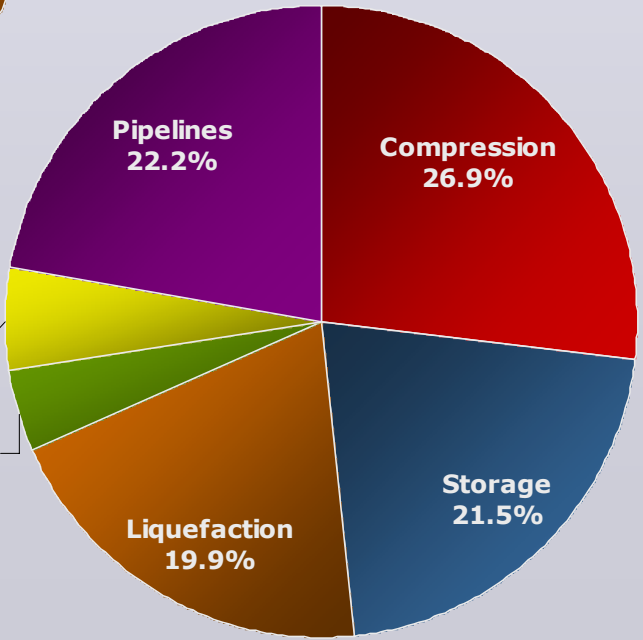


EERE H₂ Production and Delivery Budget

FY2008 Budget = \$39.6 M



Production FY 2008 (\$28.9M)



Delivery FY 2008 (\$10.7M)

- ### FY2008 Emphasis
- Initiate 8 new projects
 - Electrolysis
 - Compression
 - Off-board storage
 - Liquefaction
 - Identify renewable reforming pathways to achieve <\$3.80/gge by 2012
 - Complete solar thermochemical down selection to 1-2 cycles



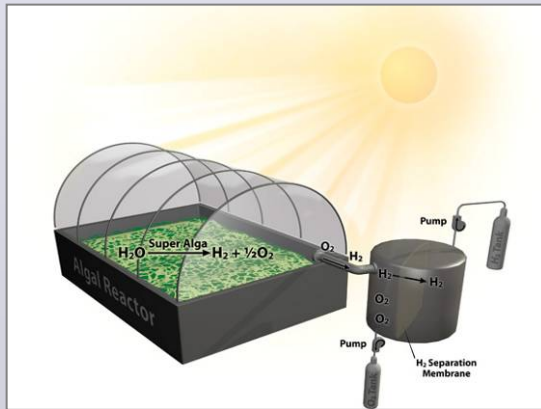
Challenges – H₂ Production & Delivery



Biomass Gasifier

Production

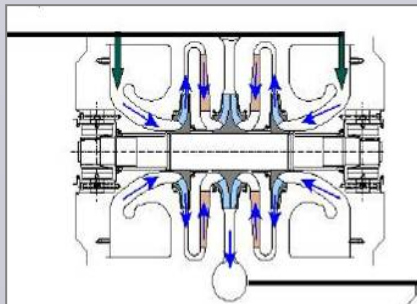
- Biomass Based Processes
 - Catalyst efficiency and durability
 - Capital equipment cost
 - Feedstock cost and handling
- Electrolysis
 - Capital equipment cost
 - Integration with renewable electricity
- Biological, PEC, Solar Thermochemical
 - H₂ production rate
 - Materials efficiency
 - Reactors and process development



Biohydrogen

Delivery

- Capital cost
- Materials
- Energy efficiency



Compressors



2008 Production Accomplishments



Demonstrated significant improvements in electrolyzer performance

- Achieved 67% stack efficiency
 - Verified by NREL
- Produced H₂ at 1200 psig
- Demonstrated an advanced high efficiency membrane
- Developed lower cost fabrication methods for two key cell components

(Giner Electrochemical Systems, LLC)



2008 Production Accomplishments

Continued to Improve Aqueous Phase Reforming of Bio-derived Liquids

- Cost of H₂ reduced 10X since 2005
- Catalyst lifetimes now exceeding 1 year
- Increased hydrogen productivity by 50% through chemical control of feedstock and catalyst improvement

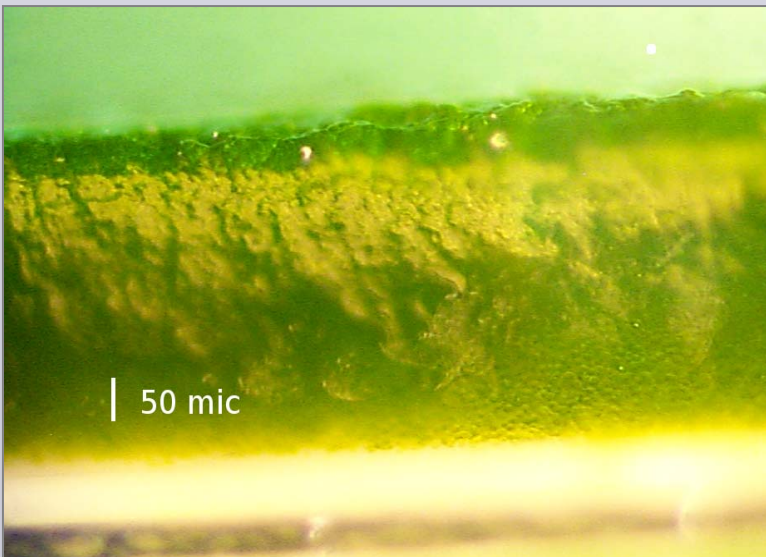
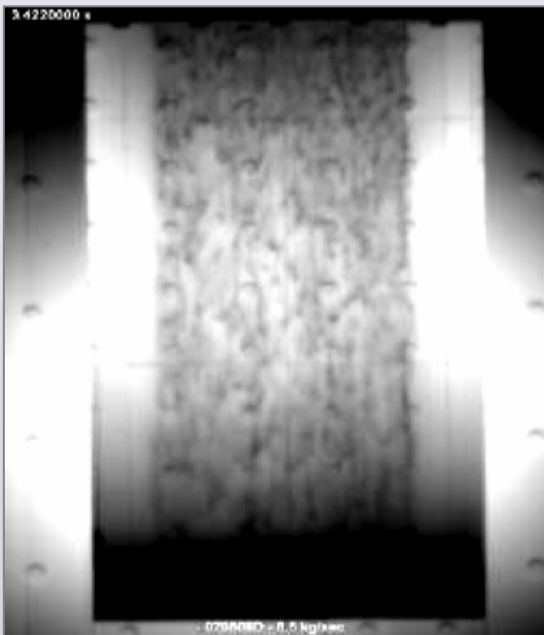
(PNNL and Virent)



**10 kg/day H₂
Pilot Plant**



2008 Production Accomplishments



Demonstrated falling particle receiver/heat transfer system

(Sandia National Lab)

Completed first experimental determination of the electronic surface structure of a PEC material (WO_3)

(UNLV and U. of Hawaii)

Cloned a novel hydrogenase using environmental DNA samples and expressed a functional hydrogenase in an organism

(J. Craig Venter)



2008 Delivery Accomplishments



**Electrochemical
Hydrogen Compressor
(EHC)**

Developed Prototype Electrochemical Hydrogen Compressor

- Peak compression of 4000 psi
- Continuous operation for 1500 hours
- No seal leakage

(FuelCell Energy)

Identified APCI Liquid Hydrocarbon as a Promising Carrier

- Developed novel carrier evaluation and down select tool
- Planned integration into H2A V.3

(TIAX, LLC)





2008 Delivery Accomplishments

Identified Low Cost & Low Permeability Fiber Reinforced Polymer

- 1 psi per day or
 - $\ll 0.1\%$ hydrogen per day
- Developed & verified test bed for ASME compliance testing

(Oak Ridge and Savannah River)

Photo courtesy of Fiberspar, LLC





Summary

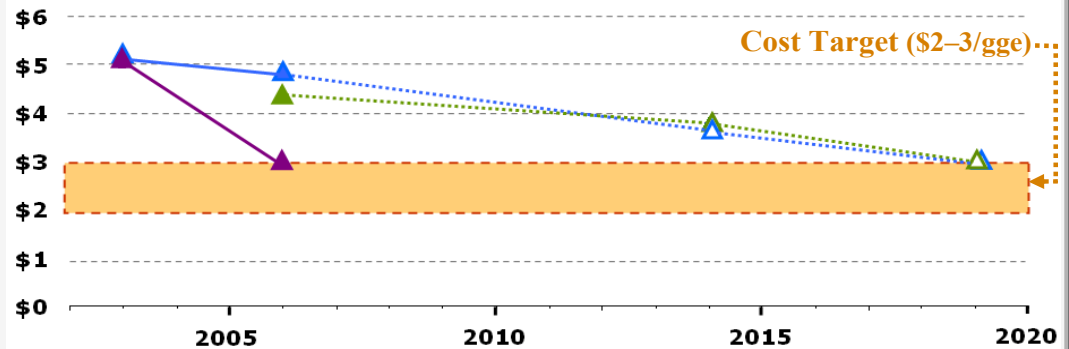
The Program has reduced the cost of producing hydrogen from multiple pathways.

Cost of Hydrogen (Delivered) – Status & Targets (in \$/gallon gasoline equivalent (gge), untaxed)

NEAR TERM: Distributed Production

→ Hydrogen is produced at station to enable low-cost delivery

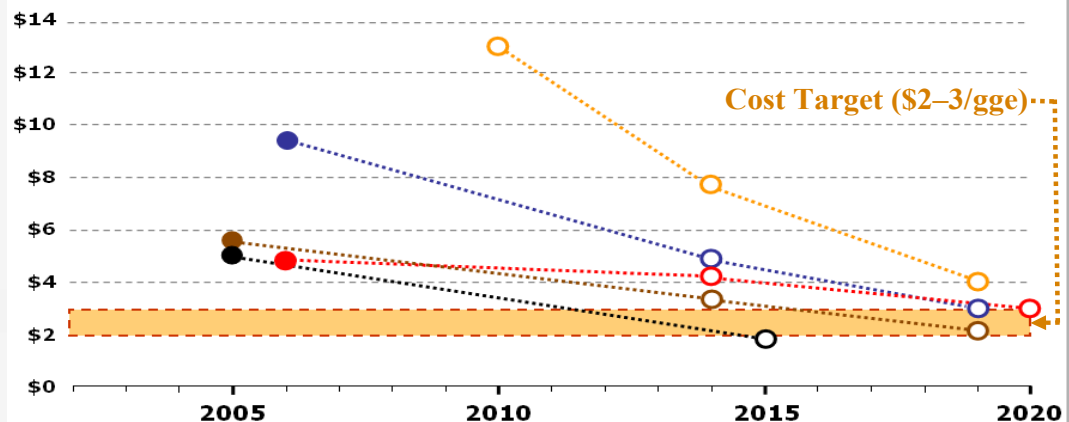
- ▲ Distributed Natural Gas
- ▲ Distributed Electrolysis
- ▲ Distributed Bio-Derived Renewable Liquids



LONGER TERM: Centralized Production

→ Large investment in delivery infrastructure needed

- Biomass Gasification
- Central Wind Electrolysis
- Coal Gasification with Sequestration
- Nuclear
- Solar High-Temperature Thermochemical Cycle





For More Information

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