



Hydrogen Production R&D

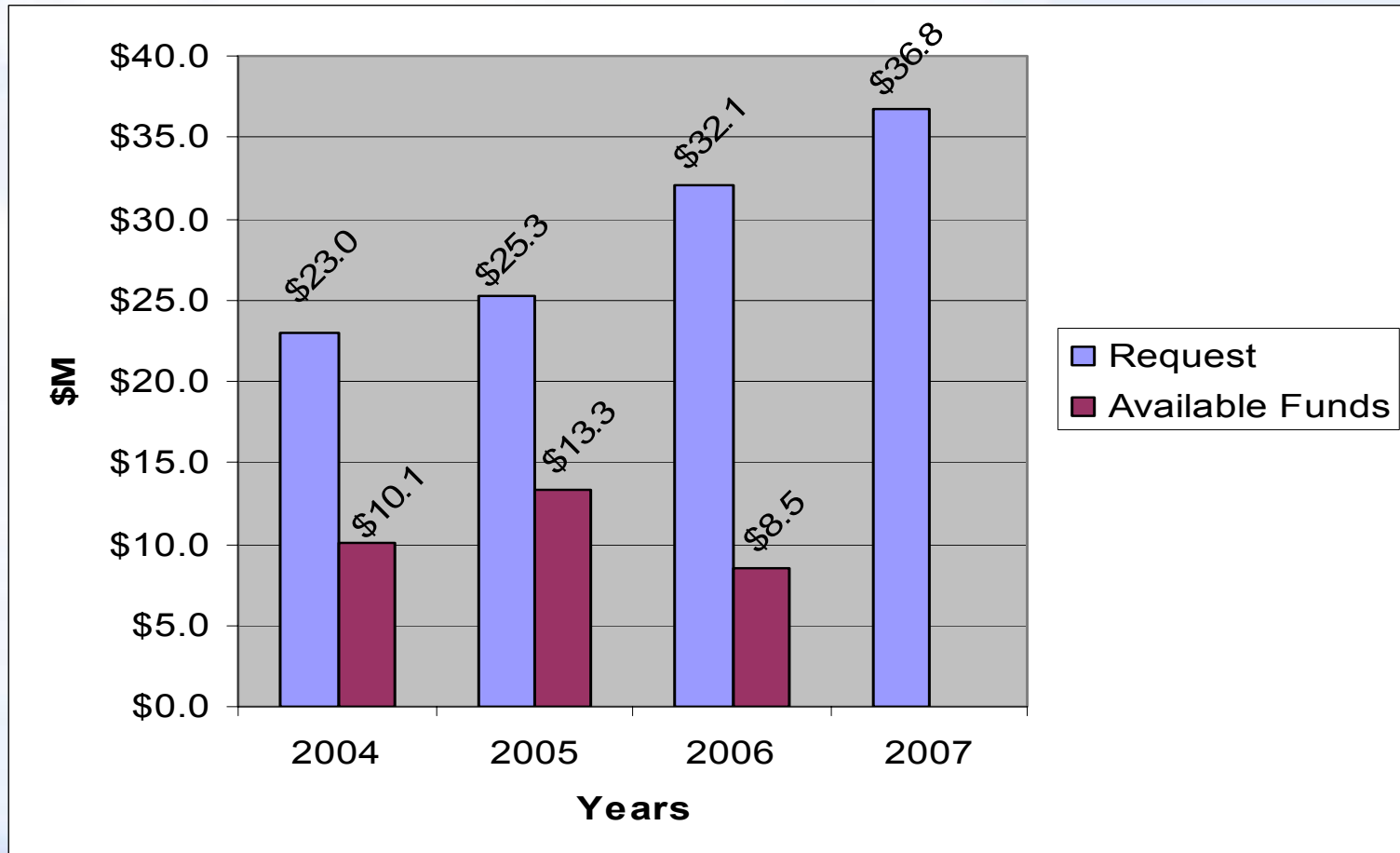


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EERE Hydrogen Production and Delivery R&D Budget



- Difference between the total 04-07 request and available funds is \$48.5M

Hydrogen Production Strategy

- Focus on near-term distributed production to support the 2015 Technology Readiness Milestone – *Distributed production pathways delay the need to build a hydrogen distribution infrastructure*
 - Natural gas distributed reforming
 - Renewable liquid reforming (alcohols, sugars)
 - Distributed electrolysis
- Longer-term renewable technologies
 - Central electrolysis
 - Central biomass gasification
 - Photoelectrochemical
 - Solar high-temperature thermochemical
 - Biological

Distributed Reforming Independent Cost Review

- Technical objective: Reduce the cost of distributed production of hydrogen from natural gas (delivered, untaxed) at the pump to:
 - \$3.00/gge by 2006 (best laboratory technology), \$3.00/gge to be demonstrated by Technology Validation in 2009
- Review strategy to verify cost status
 - Hydrogen Production Tech Team reviewed projects in conjunction with normal project reviews/visits. These reviews helped gather data for the independent assessment.
 - Experts conducting independent technology assessment
 - Managed by the Systems Integration Group
- DOE projects reviewed

The logo for Praxair, featuring the word "PRAXAIR" in green capital letters with a green grid pattern to the left.The logo for GTI, with "gti" in lowercase black letters and a small blue square above the "i".The logo for H2Gen, with "H2Gen" in white text on a blue rectangular background.The logo for Air Products, with "AIR PRODUCTS" in green capital letters and a green graphic element to the right.The logo for BOC, with "BOC" in red capital letters and a red graphic element to the left.

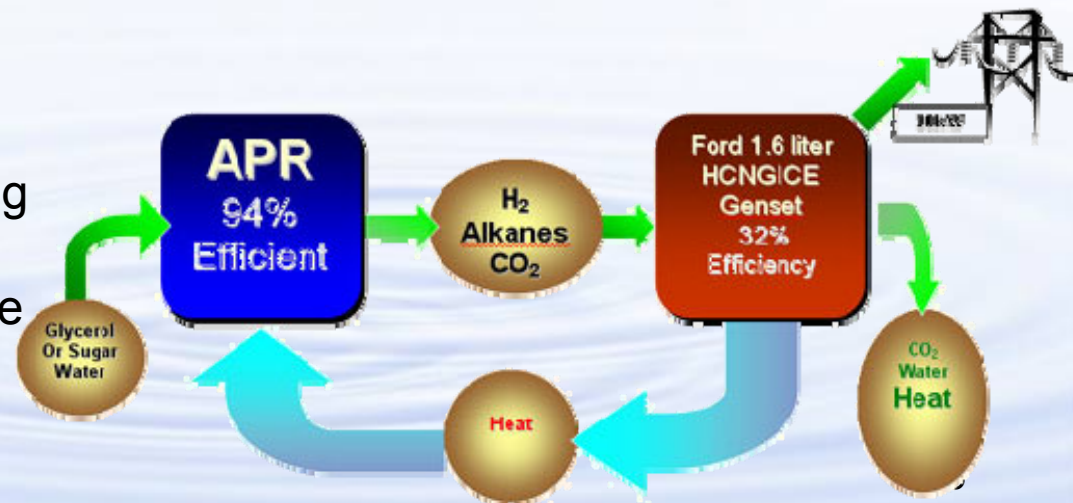
- Independent panel review results will be available this summer and published in our 2006 annual report

Distributed Reforming Accomplishments

● **Natural Gas – Air Products and Chemicals Inc.** Integrated energy efficient components into a refueling system that produces, dispenses and stores high purity hydrogen at a cost approaching our 2006 target. Gains achieved through improvements to the purification system, reactor design (materials and catalysts) and systems integration.

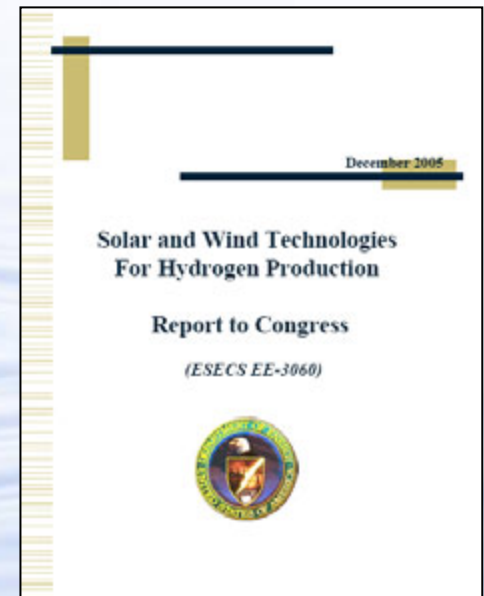


● **Renewable Liquids – Virent Energy Systems Inc.** Identified a new reactor system that allows the Aqueous Phase Reforming of bio-sugars. Improvements in hydrogen generation with appropriate catalyst, reactor configuration, and reaction conditions are underway.



Electrolysis Highlights

- Hydrogen Utility Group (HUG) - Involves utility participation (eight founding utilities) in hydrogen production technologies through the efforts of its members, in collaboration with key stakeholders.
- Analysis efforts - Economics of wind electrolysis completed and H2A analysis underway to refine technical targets for distributed and central applications
- Established NREL/XCEL cooperative research agreement - collaborative R,D&D project to characterize integration issues between wind and hydrogen production systems – test system to be assembled at NREL
- Giner lowered stack cost by achieving >50% reduction in part count – example: anode support structure reduced part count from 9 to 4
- Solar and Wind Technologies Report to Congress as required by Epact. The report details multiple solar/wind hydrogen production pathways



Long-term Technologies

High Temperature Solar

- Cycles evaluated and down selected
 - 353 cycles examined and down-selected to 14 based on literature work and initial thermodynamic and analyses
 - 3 cycles eliminated based on laboratory R&D
 - 7 cycles now under active R&D efforts (2 sulfur based cycles [NE], 2 volatile metal oxide cycles, 2 nonvolatile metal oxide cycles, hybrid Cu cycle).
- Initial systems designed and costs estimated for hybrid sulfur and a volatile metal oxide using H₂A. Preliminary H₂A results indicate this technology may be able to achieve a competitive cost.

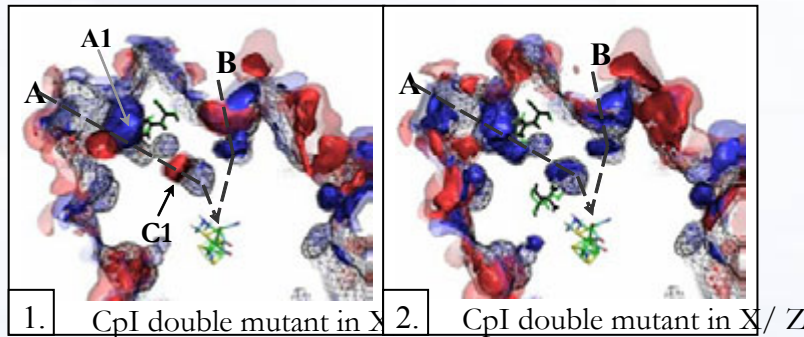


***Solar Two Power Tower,
near Barstow, California***

Long-Term Technologies

Biological – Budget constraints have restricted activity resulting in incremental progress:

- Completed the biochemical characterization of the *tla1* mutant and the molecular analysis of the *Tla1* gene.
- Identified additional pathways for mutagenesis, single and double mutants were constructed to improve oxygen tolerance.



Manipulating oxygen tolerance in FeFe Hydrogenase

Photoelectrochemical

- Developed new corrosion resistant, high efficiency tandem cell design for PEC water splitting based on GaPN
- Achieved 3.1% solar-to-hydrogen efficiency in a WO_3 hybrid photoelectrode device (2003 efficiency was 0.7%).
- We are working with Basic Energy Sciences to leverage activities and accelerate progress.

model of a basic cluster tool system

