IV Production

IV.1 Hydrogen Production Overview

Introduction

The Hydrogen Production activity is focused on developing hydrogen fuel production technologies that enable the introduction and long-term viability of hydrogen as an energy carrier for transportation and stationary power. A variety of feedstocks, processes, and pathways are being pursued to meet the objective of producing hydrogen that is pure enough for use in fuel cells and cost-competitive with gasoline.

Four DOE offices are engaged in R&D relevant to hydrogen production. The Office of Energy Efficiency and Renewable Energy (EERE) is developing technologies for producing hydrogen in a distributed manner from natural gas, liquid renewable fuels, and by electrolysis of water, and is developing centralized renewable production options that include water electrolysis using renewable power (e.g., wind, solar, hydroelectric, geothermal), biomass gasification, photoelectrochemical and biological processes, and high-temperature solar thermochemical cycles. The Office of Fossil Energy (FE) is focused on advancing the technologies needed to produce hydrogen from coal-derived synthesis gas, including co-production of hydrogen and electricity as well as carbon sequestration. The Office of Nuclear Energy, Science and Technology (NE) is developing commercial-scale production of hydrogen using heat from a nuclear energy source. The Office of Science's basic research program is emphasizing fundamental understandings of bio-inspired materials and processes, photoinduced water splitting, catalysis, membranes, and gas separation.

In FY 2005, 24 EERE cooperative agreements were started to conduct research on hydrogen from biomass, photolytic processes, distributed production technologies, separation and purification technologies, advanced electrolysis systems, hydrogen production using high-temperature thermochemical water splitting cycles, hydrogen production infrastructure analysis, crosscutting projects, and university projects. Six awards were postponed until FY 2006 because of funding constraints.

On May 25, 2005, Secretary of Energy Samuel W. Bodman announced the award of 70 new projects in support of the President's Hydrogen Fuel Initiative (HFI). The projects will conduct fundamental research within the Basic Energy Science (BES) program within the HFI to help overcome key hurdles in hydrogen production, storage, and conversion. Participants in the projects include more than 50 research organizations in 25 states. The awards include 16 projects ($12.3 million) to develop membranes for separation, purification, and ion transport; 13 projects ($10 million) for solar hydrogen production; and 6 projects ($7 million) to research bio-inspired materials and processes.

In 2005, the hydrogen cost target was revised to a range of $2.00 to $3.00 per gge of H_2 at the pump in 2015. This target is independent of the pathway used to produce hydrogen and accounts for the energy efficiency of the gasoline hybrid vehicle and the fuel cell vehicle on a cost-per-mile basis. The target provides a yardstick against which the commercialization potential of different hydrogen production technologies can be measured.

Goal

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

Objectives

- By 2010, reduce the cost of distributed production of hydrogen from natural gas to \$2.50/gge (delivered, untaxed) at the pump.
- By 2015, reduce the cost of distributed hydrogen production from biomass-derived renewable liquids to \$2.50/gge (delivered, untaxed) at the pump.
- By 2010, verify distributed grid-connected water electrolysis at a projected delivered hydrogen cost of \$2.85/gge. By 2015, verify renewable central hydrogen production at a projected cost of \$2.75/gge delivered.
- By 2015, reduce the cost of hydrogen produced from biomass to \$1.60/gge at the plant gate (\$2.60/gge delivered) by developing reforming technologies for gasification processes.
- Develop advanced renewable photoelectrochemical and biological hydrogen generation technologies. By 2015, verify the feasibility of these technologies to be competitive in the long term.
- By 2015, develop high-temperature thermochemical cycles driven by concentrated solar power processes to produce hydrogen with a projected cost of \$3/gge at the plant gate (\$4.00/gge delivered).
- By 2015, have ready to operate a zero emissions, high-efficiency co-production power plant that will produce hydrogen from coal along with electricity.
- Demonstrate the commercial-scale, economically feasible production of hydrogen using nuclear energy by 2017.

FY 2005 Technology Status

The hydrogen production activity is approaching its distributed hydrogen production target of \$3.00 per gge H_2 at the pump (5000 psi) using reforming of natural gas. Other production and delivery technologies are in various stages of development. For each production technology area, the ultimate target is for the hydrogen fuel to be competitive with gasoline. However, because some technologies are more mature than others, the timeline for meeting the ultimate target varies by feedstock and process option.

Several changes were made to EERE's Multi-Year Research, Development and Demonstration Plan in 2005. New targets were established for distributed natural gas and renewable liquid reforming, water electrolysis from central renewables, dense metallic and microporous membrane separation technologies, biomass reforming, and photosynthetic bacteria and dark fermentation. A common set of economic parameters was applied in the development of R&D targets. Capital equipment targets were separated from operations and maintenance targets, total system energy efficiency targets were developed, and capacity utilization factors were specified for the technical targets.

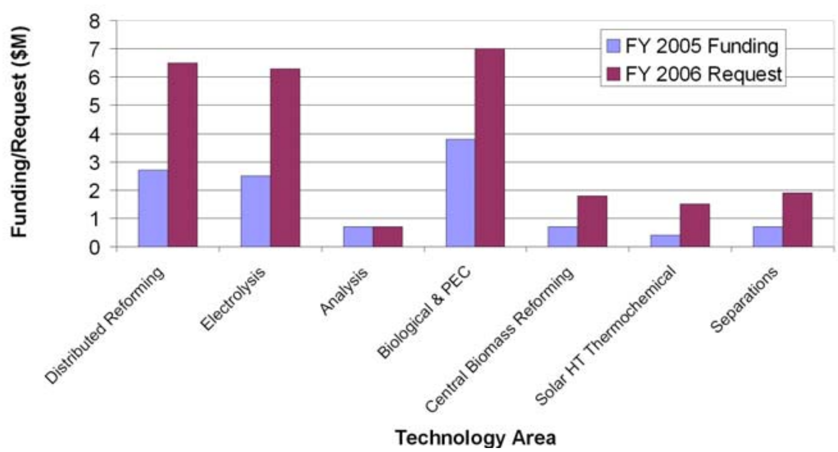
FY 2005 Accomplishments

- The Hydrogen Technology Program completed the research for two distributed natural gas-to-hydrogen production and dispensing systems that are expected to produce 5,000 psi hydrogen at a cost of \$3.00/gge. Three research projects contributed to meeting this target, and advances included a 4X reduction in pressure swing adsorber cost, improved fuel processing via steam methane reforming, and development of an efficient and compact autothermal cyclic reformer.
- Achieved 2000 psi H_2 production in a planar electrolysis stack.
- Developed new electrolysis system designs with 40-50% part count reduction.
- Developed a new design for electrolysis systems with potential for achieving a hydrogen production cost of \$2.85/gge by 2010.
- Evaluated alkaline and proton exchange membrane electrolysis technologies for high-pressure operation.

- Completed the criteria-based screening of over 200 potential solar-driven high-temperature thermochemical cycles, down-selected to four groups of cycles (volatile metal, metal oxide, sulfate, and sulfuric acid), and initiated research on these cycles. The zinc oxide cycle high-temperature (~1800°C) reduction step to zinc metal was demonstrated in the laboratory.
- Conceptual design documents were completed for pilot-scale thermochemical cycle experiments (200 kilowatt high-temperature electrolyzer experiment and 500 kilowatt sulfur-iodine thermochemical process experiment).
- An International Partnership for the Hydrogen Economy global project on solar-driven high-temperature thermochemical cycles for hydrogen production was initiated. This project includes the key solar energy research groups from Switzerland, Germany, France, Israel, Spain and the U.S.
- Durability of 760 hours (100 hours in 2003) was demonstrated with a new gallium phosphide nitride material producing hydrogen via photoelectrochemical technology.
- Oxygen tolerance in photolytic biological hydrogen production from water was increased by 40-50%.

Budget

The President's FY 2006 budget request (subject to Congressional appropriation) includes increased funding for R&D on distributed natural gas and renewable liquid reforming, distributed electrolysis, biological and photoelectrochemical (PEC) processes, central biomass reforming, solar high-temperature thermochemical cycles, and hydrogen separation technologies. The request reflects the recommendations of the National Research Council and supports the achievement of the goals and objectives named above.



2006 Plans

- An independent technical target verification process will be implemented in FY 2006 to verify achievement of the target of \$3.00/gge H_2 from natural gas reforming. The process will utilize the knowledge and experience of DOE's industrial partners; three primary projects will be examined to determine if the target has been met.
- The Hydrogen Production Sub-Program will narrow the scope of distributed reforming research to continue developing only the most viable technology options.
- Establish a hydrogen utility working group to increase collaboration with electric utilities on electrolysis technology development.
- Continue development of high-efficiency, low-cost alkaline and proton exchange membrane electrolysis systems.
- Increase focus on the integration of electrolysis technologies with renewable electricity sources.
- Evaluate high-temperature electrolysis systems for higher-efficiency operation.
- Model the two biomass reforming technology development project approaches being funded to confirm the potential to achieve the 2010 target of \$1.75/gge at the plant gate.

- Complete long-duration and transient testing of high-temperature electrolysis cell stacks that incorporate various cell materials and configuration options.
- Operate the sulfur-iodine cycle chemical component reaction sections individually and initiate assembly in preparation for integrated laboratory-scale system operation in FY 2008.
- Complete initial research on the solar-driven high temperature thermochemical cycles under consideration and down-select to four or fewer cycles for development.
- Complete the structure and initial data population of the photoelectrochemical materials database to allow material data sharing among researchers.
- Establish standard testing protocols for photoelectrochemical materials for validating efficiencies to allow functional comparisons between materials.

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