The Hydrogen Program of the United States

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Abstract

The National Hydrogen Program of the United States is dedicated to encouraging and supporting the development of safe, practical, and economically competitive hydrogen technologies and systems to meet our energy needs. The future world energy industry will need to use hydrogen from renewable resources to satisfy energy demand and to reduce pollution.

The U.S. Department of Energy (DOE) manages the National Hydrogen Program. In this role, DOE provides national leadership and acts as a catalyst through partnerships with industry. These partnerships are needed to assist in the transition of sustainable hydrogen systems from government-supported research and development to commercial successes in the marketplace.

The challenges that the program is addressing include infrastructure issues, process efficiency, environmental impacts and advantages, safety issues, reliability, and cost competitiveness. We are addressing these obstacles through core research and development, technology validation, demonstrations, industry interaction, and systems analysis.

The U.S. Hydrogen Program is poised to overcome the technical and economic challenges that currently limit the impact of hydrogen on our energy picture. With cooperative research, development, and demonstrations, the hydrogen future will become a reality.

Introduction

Hydrogen will join electricity in the 21st century as a primary energy carrier in a sustainable energy future. Hydrogen and electricity will ultimately come from renewable energy sources, although fossil fuels will provide a long-term transitional resource. Future hydrogen suppliers will deliver a significant portion of our energy for transportation and other applications. For these applications, hydrogen offers a nonpolluting, inexhaustible, efficient, and potentially cost-effective energy system derived entirely from domestic energy sources. To encourage and support the development of safe, practical, and economically competitive hydrogen technologies and systems, the U. S. Department of Energy (DOE) conducts research in the production, storage, and use of hydrogen.

DOE provides national leadership and acts as a catalyst through partnerships with industry. These partnerships are needed to assist in the transition of sustainable hydrogen systems from government-supported research and development to commercial successes in the marketplace. The outcome of the program is expected to be the orderly phase-out of fossil fuels as a result of market-driven technology advances, with a least-cost, environmentally benign energy delivery system. The goals of the program include doubling, by the year 2005, current hydrogen use in the chemical and petroleum sectors as a feedstock for reformulated gasolines. In addition, the program has set a goal for 25% of all new vehicles sold in the United States in 2010 to be hydrogen powered, either as hybrids or as fuel cell vehicles. This will result in an important reduction in NO_x, CO, and CO_2 emissions. A significant portion of the hydrogen required for these vehicles will be produced from biomass and municipal solid waste gasification and pyrolysis. Finally, the program has set a goal of an 8%-10% hydrogen contribution to the total energy market by 2025.

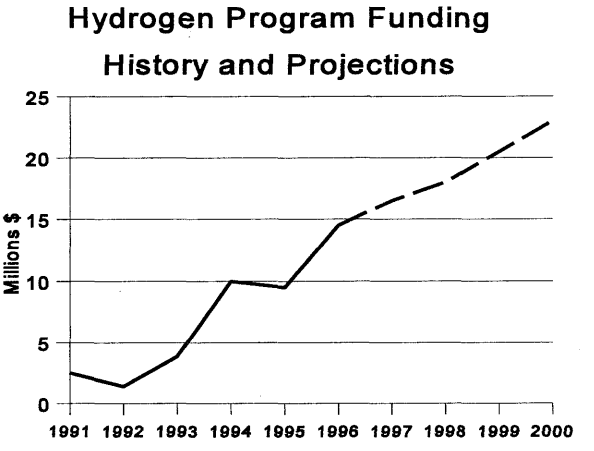
Legislative Actions

Legislative initiatives are in place to facilitate the incorporation of hydrogen into the United States' energy economy. The Hydrogen Research, Development, and Demonstration Program Act of 1990 (often referred to as the Matsunaga Act, after the late Senator Spark M. Matsunaga of Hawaii, who sponsored the legislation), established a number of requirements for the program. DOE prepared a comprehensive 5-year program management plan for hydrogen research and development, with renewable energy as the primary source for the production of hydrogen. An implementation plan for a technology assessment and transfer program among other federal agencies was also developed. The legislation shifted the focus of the program to emphasize production from renewable resources, with fossil fuels serving only in the transition to hydrogen production from renewable resources.

The Matsunaga Act also established the Hydrogen Technical Advisory Panel (HTAP), which advises the Secretary of Energy. The panel is appointed by the Secretary of Energy and consists of representatives from industry, universities, professional societies, government laboratories, financial, environmental, and other appropriate organizations. The panel makes recommendations to the Secretary of Energy on implementing and

conducting the program; economic, technical, and environmental consequences of hydrogen production and use; and improvements to the comprehensive 5-year plan.

The Energy Policy Act of 1992 supplemented the Matsunaga Act by requiring the assessment and development of hydrogen production from renewable resources; systems for hydrogen storage that may be suitable for electric vehicles powered by fuel cells; natural gas pipelines to carry hydrogen; and other research and development programs as deemed necessary by DOE.



Recent legislative action includes a bill that will extend and expand the Matsunaga Act. Current bills in the U.S. House of Representatives and the U.S. Senate call for a substantial increase in funding, and industry participation in research, development, and demonstration projects. The Hydrogen Future Act of 1995, which will extend many of the provisions of the Matsunaga Act, was passed by the House of Representatives and awaits action by the Senate.

Program Activities

The Hydrogen Program provides rapid and aggressive implementation of a well-balanced portfolio of research and development projects that minimize technology risks. The development and demonstration of processes and technologies to produce, store, transport, and use hydrogen form the basis of the effort. Through interactions with other federally funded programs, the Hydrogen Program is able to leverage significant federal research funds.

The Program funds research and development activities in hydrogen production, storage, and use to ensure that the technologies are available for industrial consideration. Production research is being conducted in three main areas: photolysis, electrolysis, and thermal processes. Photolytic processes include enzymatic production systems and photoelectrochemical systems. Enzymatic research is focused on isolating bacteria and algae with oxygen-tolerant hydrogenases and efficient photosynthetic systems. Engineering issues include designing systems that are easy to operate and control, and reactors that are efficient. Photoelectrochemical development issues include the separation of hydrogen and oxygen, system costs, and materials of construction. Research in electrolytic systems includes the development of solid electrolytes for water electrolysis at higher temperatures than current systems, and the production of hydrogen using an HBr system. Issues include materials of construction and system costs. Thermal research is being conducted in gasification and pyrolysis systems, with biomass and

municipal solid waste as the target feedstocks. Research needs include production cost reduction and improved system integration.

Hydrogen storage for stationary and mobile applications presents significant challenges. Recent industry cost-shared research efforts have resulted in potential demonstration projects, with integrated storage systems that are efficient and cost effective. Fundamental research continues in more advanced storage systems, including a number of projects using carbon-based systems and glass microspheres. The goal of the program is to develop storage systems that result in an added cost of 50% or less to the cost of delivered hydrogen. Opportunities exist for cost reductions through capacity and efficiency increases and weight reduction, while maintaining and enhancing system safety and reliability.

The use of hydrogen in internal combustion engines is being studied in a collaborative effort with other offices in DOE. The work is directed toward the development of a mechanical equivalent to the fuel cell. In a partnership among three national laboratories, industries, universities and DOE, the participants are providing fundamental combustion and engine data, information on hydrogen use in internal combustion engines, chemical kinetics calculations of hydrogen and hydrogen/methane combustion, design of hybrid vehicle, and materials for hydrogen storage systems. The selection of a particular engine by the industrial partner will be based on technical merit and the probability of market penetration.

The Hydrogen Program uses a number of techniques to evaluate and compare hydrogen technologies and integrated systems. Analytical models have been developed to provide comparisons of advanced and conventional hydrogen energy pathways on an equivalent basis. Studies have been conducted to identify infrastructure issues and to determine potential optimum delivery system designs. An analysis was conducted of hydrogen production via small- and large-scale natural gas steam reformers for vehicle refueling stations. The study focused on the use of zero emission vehicles in southern California, where legislation will likely result in the first use of hydrogen as a motor vehicle fuel. In the study, the large-scale system was centrally located, with hydrogen delivered to refueling stations as compressed or liquid hydrogen. The small-scale system was located at the refueling station, and produced fuel-cell quality hydrogen. Preliminary cost estimates were performed for a non-optimized design. The reformer capital cost was an important factor in the overall cost of hydrogen.

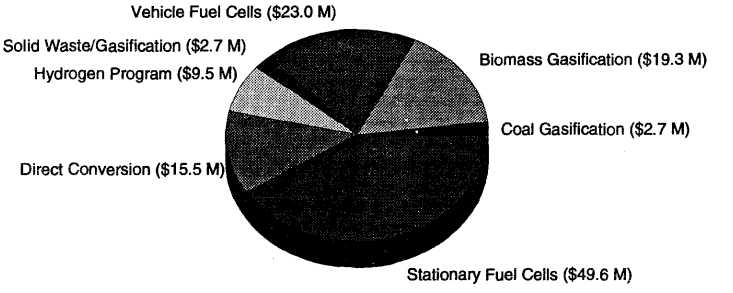
Economic analysis is also used to identify areas requiring further research and to track research progress. Different levels of analysis are used for fundamental, advanced, and near-commercial processes. The appropriate level depends on the availability of data and system design. Studies are under way to develop base-line economics for current hydrogen production and storage research projects.

Related Research Programs

In addition to the Hydrogen Program, DOE funds a number of programs that are directly related to developing a hydrogen energy economy. Overall funding for hydrogen research

in fiscal year 1995 was $122.3 million, more than ten times the Hydrogen Program budget of $9.5 million in fiscal year 1995. Funding for the Hydrogen Program in fiscal year 1996 is $14.5 million.

DOE Funding for Hydrogen-Related Technologies ($122.3 million in FY 1995)



Information sharing and communication between the programs are important in maximizing the benefits of these diverse research efforts. Biomass gasification and solid waste management research programs are working closely with the Hydrogen Program to develop systems that can be used to produce hydrogen from sustainable and renewable resources. Funding levels for stationary molten carbonate fuel cell research and vehicle fuel cell research programs are also significant.

Realizing the Hydrogen Future

Our team of researchers is a highly motivated, talented group of scientists and engineers dedicated to seeing hydrogen become an important contribution to the United States' energy future. DOE endeavors to provide technology exchange with industry to facilitate the transition to renewable energy. Increased funding, provided by progressive legislation, will help accelerate the fulfillment of our vision.