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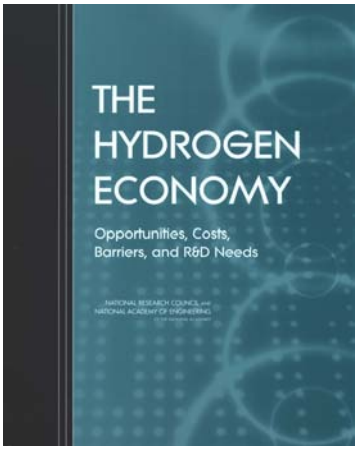
The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs--*Summary*

BOARD ON ENERGY AND ENVIRONMENTAL SYSTEMS

Background



In the summer of 2002, the Department of Energy (DOE) asked the National Research Council (NRC) to examine the technical and policy issues about the hydrogen economy. The NRC was asked to look at, among other things, the current state of technology, future cost estimates, CO_2 emissions, problems about hydrogen distribution, storage, and end use, and the DOE hydrogen RD&D program. The NRC was also asked to make recommendations on RD&D directions, priorities, and strategies. To carry out this study, the NRC appointed an ad hoc Committee on Alternatives and Strategies for Hydrogen Production and Use.

Major Findings

The hydrogen economy vision is based on the expectation that it can be produced from domestic resources in an economic and environmentally acceptable manner and that hydrogen end-use technologies can gain significant market share. To the extent these expectations can be met, a hydrogen economy will benefit the world by providing both greater energy security and environmental quality. Reaching this goal, however, will require overcoming many technical, social, and policy challenges.

Implications for National Goals. A transition to hydrogen as a major fuel over the next 50 years could fundamentally transform the U.S. energy system. Hydrogen has the potential for replacing essentially all gasoline and eliminating almost all CO_2 from vehicular emissions over the next 50 years. Conducting RD&D to determine whether a "hydrogen economy" might be realized is important to the nation.

RD&D Priorities. To reach that goal, a hydrogen system must be economic, safe and appealing, and offer energy security and environmental advantages. For the transportation sector, dramatic progress in fuel cell development, storage, and distribution systems is essential. Success is not certain. The four fundamental technological and technical challenges are: to develop and introduce economic, durable, safe, and

environmentally acceptable fuel cells and hydrogen storage systems; to develop the infrastructure to provide hydrogen for the light duty vehicle user; to reduce sharply the costs of hydrogen production from renewables over the next few decades; and, if policies for CO_2 reduction are implemented, to capture and store (sequester) the CO_2 byproduct of hydrogen production from coal.

The Challenge of Transition. The transition period to a hydrogen fuel system is likely to be lengthy. It will probably best be accomplished at first by distributed production of hydrogen using small natural gas reforming and electrolysis units, possibly using distributed renewable energy (e.g., wind or direct solar). A distributed system can allow time for development of the new technologies and concepts needed to permit widespread use of hydrogen. Such an approach, however, cannot yet be fully defined.

Impacts of Hydrogen-Fueled Light-Duty Vehicles. Successful penetration of hydrogen fuel-cell vehicles would have the following impacts: to the extent coal or other domestic energy sources are used for hydrogen production, energy imports would be reduced by the amount of gasoline displaced; and to the extent renewable or nuclear energy is used to produce hydrogen or carbon sequestration is coupled with fossil fuel production, CO_2 emissions from vehicles can be cut significantly. These impacts are likely to be minor for the next 25 years until significant numbers of fuel cell vehicles enter the fleet. Successful RD&D and large hydrogen and fuel cell investments, however, could result in major impacts after that.

Major Recommendations

Systems Analysis of U.S. Energy Options. Systems analysis is needed to coordinate the different paths within the hydrogen program and integrate them with other DOE energy efforts. DOE should continue the hydrogen initiative and develop a systems analysis approach to assess costs, options, research results, and provide a means to balance the short-, mid-, and long-term R&D directions and objectives.

Fuel Cell Vehicle Technology. Current fuel cell technology is far from meeting the cost, durability, and efficiency targets for widespread light duty vehicle applications. In particular, costs will have to be less than $100 per kilowatt, a goal that will require at least a decade to achieve. Increased R&D funding is needed to seek breakthroughs in on-board hydrogen storage, fuel cell costs, and materials for increased durability.

Infrastructure. Hydrogen as a fuel will not be widely used until a nation-wide safe and efficient infrastructure is in place. There are significant opportunities for large improvements in infrastructure and delivery, and DOE should put greater emphasis on these areas. Such areas as storage requirements, hydrogen purity, pipeline materials, compressors, leak detection, and permitting need attention. In addition, exploratory research on new hydrogen deliver concepts needs additional funding. Also, DOE should accelerate work on codes, standards, and permitting.

Transition. RD&D alone cannot facilitate the transition to a hydrogen economy. Other issues, such as safety and policy will play an important role. DOE's capability to analyze such issues needs to be strengthened in order to facilitate the government's role in aiding

this transition. The hydrogen economy will not result from a direct replacement of the current fossil-fuel-based economy. In particular, in the next 10 to 30 years distributed production of hydrogen will be the dominant source of the fuel, and such systems need more R&D funding. Also, DOE should undertake efforts to develop new distributed hydrogen production system concepts.

Safety. Safety will be a major issue for commercialization of hydrogen-powered vehicles. DOE's current safety program is well planned and should be a priority. DOE, however, needs to emphasize early discussion of safety policy goals with stakeholder groups, continuing work with standards development organizations, the inclusion of safety in systems analysis, a physical testing program to resolve safety issues, and public education focusing on hydrogen safety.

CO_2–Free Hydrogen. Hydrogen production by electrolysis (water splitting), if economic, can lead to major reduction in CO_2. A substantial reduction in the cost of fuel cells by focused research could also result in a corresponding drop in electrolytic cells to the point where the cost of electricity would be the major determinant in electrolytic production of hydrogen. DOE should increase emphasis on electrolyzer development and set more aggressive cost targets for unsubsidized nuclear and renewable generated electricity.

Carbon Capture and Storage. DOE's efforts on hydrogen and fuel cell technology will benefit from tighter coupling with the carbon capture and storage (sequestration) program. The hydrogen program should participate in all of the early carbon sequestration projects that address difficult institutional and public acceptance issues.

DOE's Hydrogen RD&D Plan. DOE's hydrogen program has progressed well. Two concerns, however, need to be raised. First, the plan needs better integration across all DOE programs. Second the program's priorities are unclear. Funding for the production, distribution, and dispensing portions of the program is probably inadequate. The program also has tried to establish RD&D activities in too many areas, resulting in a somewhat unfocused program. As a result, prioritizing efforts within and across program areas is extremely important. Furthermore, the program should establish partnerships with a broader range of academic and industrial organizations and an independent review process.

The program also should shift some development toward exploratory research, particularly in on-board hydrogen storage, photo-electrochemical production, delivery systems, pipeline materials, electrolysis, and material science. The DOE sponsorship of academic research centers that should focus on interdisciplinary areas of science and engineering would facilitate this research.

The following areas should receive increased R&D emphasis by DOE: fuel cell vehicle development, distributed hydrogen generation, infrastructure analysis, carbon sequestration and the FutureGen project, and CO_2–free energy technologies.

For further information;

Copies of *The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs* are available from the National Academy Press; call (800) 624-6242 or (202) 334-3314 (in the Washington metropolitan area), or visit the NAP Web site at < http://www.nap.edu/catalog/10922.html, >.

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