

U.S DEPARTMENT OF ENERGY HYDROGEN PROGRAM INFRASTRUCTURE ACTIVITIES

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Abstract

In fiscal year 2000, the National Renewable Energy Laboratory (NREL) undertook two primary activities to support the assessment and development of infrastructure for the use of hydrogen in buildings and transportation applications. Those activities include: (1) the Blueprint; a government-industry effort to facilitate the development of adequate infrastructure in the next five years for hydrogen technologies; and (2) codes and standards activities, designed to incorporate hydrogen safety issues into existing and proposed national and international codes.

This paper will review both activities with respect to: (1) background issues; (2) goals and objectives; (3) status of progress; (4) milestones; (5) proposed future work; (6) leadership and cooperative efforts; and (7) methodology.

Background

Hydrogen is already being used as an energy resource in modest amounts in the United States and other industrialized countries. But more importantly, hydrogen is one of our “fuels of the future” for buildings, transportation, and portable applications.

The United States Department of Energy (DOE) has established a goal for hydrogen to supply 10 percent of the nation’s demand for energy by 2025. It is anticipated that hydrogen technologies in the transportation sector will be coming online in the next five to ten years. To assess the key issues associated with developing supporting infrastructure, the Blueprint government-industry

effort is focusing on four main technical areas: (1) refueling stations; (2) hydrogen storage systems; (3) hydrogen safety issues; and (4) codes and standards. The Blueprint is also geared at developing government-industry action plans for each of these technical areas.

With respect to codes and standards, existing safety rules, regulations, and consensus standards relating to the transporting and utilization of hydrogen are adequate for today's small markets. However, in the case of widespread usage of hydrogen for future emerging applications, today's safety rules, consensus standards and codes will not be adequate. Systematic efforts are required at the local, state, and federal government levels, as well as by producers and users of hydrogen products, (e.g., automotive industry) to: (1) identify safety-related issues; and (2) develop, update and validate regulations and codes and standards relating to the safe production, transportation, use, and servicing of hydrogen-fueled systems.

Goals and Objectives

Blueprint

The goal of the Blueprint effort is to outline a five-year action plan to develop a hydrogen fuel infrastructure for both heavy-duty and light-duty vehicles. The Blueprint is based on the assumption that hydrogen-fueled vehicles, in both fuel cell and hydrogen internal combustion engine (ICE) applications, will fulfill a portion of the zero emission vehicle (ZEV) requirement in California and other states that have adopted the ZEV program. The Blueprint's goal is to work closely with facilities instituting hydrogen systems, and to facilitate the assessment of additional infrastructure requirements and deployment activities.

The primary objective of the Blueprint is to propose a strategy to develop a fuel infrastructure to meet near-term needs for hydrogen systems. This strategy will closely reflect on-going activities, and reference key engineering and institutional issues. A cooperative government-industry process will be outlined, utilizing current experience to craft future activities.

Codes and Standards

The goal of the codes and standards effort is to incorporate hydrogen safety issues into existing and proposed national and international codes in order to facilitate market acceptance and deployment. The objective is the development of codes and standards for the following applications:

- transportation (fuel cells and internal combustion engines)
- buildings (fuel cells)
- portable appliances (fuel cells).

For these three applications, codes and standards are being developed relating to producing, transporting, storing, dispensing and using hydrogen.

Status of Progress

Blueprint

The Blueprint Roadmap Meeting, held in September 2000 produced consensus on the most important and pressing issues to be considered in hydrogen infrastructure development and deployment. The issues are organized according to four technical areas, listed below.

Refueling Stations

- A master rollout plan is critical, focusing on commercialization requirements as well as technical issues. The rollout plan will include a deployment plan, and will identify markets.
- An economic assessment is needed that will examine subsidies, incentive programs, and cost targets.
- Accurate and affordable metering is a top priority. Equipment R&D, and customer interface are two key areas.
- Gas purity/composition standards are also central. Technology improvement is needed in the hydrogen gas cleanup system.
- Design optimization for refueling stations can be realized through expandable and upgradeable station designs.
- Training and education is key, particularly emergency response training.

Hydrogen Storage

- 5000 psi technology, including a focus on components, leakage and permeation, and standards.
- 10,000 psi technology, placing an emphasis on container optimization, components, and in and out efficiency.
- Liquid technology, focusing on container optimization, components, and infrastructure.
- Low-pressure adsorption was considered in the discussions but the issues were not prioritized because of the long-term implications of the storage medium.

Codes and Standards

- Coordination and synchronization of codes and standards on the national and international level is critical.
- Currently, a lack of suitable installation, product, and storage standards exists, therefore complicating, if not precluding, commercial project development.
- A technical basis is needed for codes and standards development.
- Education of codes and standards officials is vital.

Hydrogen Safety

- A great need exists for a comprehensive database that will serve as a knowledge center, and as a living web site technical tool.

- Increased detection and verification facilities are needed to accommodate a variety of hydrogen development and demonstration activities.
- A verification facility is needed to execute integrated system design. The verification facility would provide the opportunity to design, build, and verify integrated systems.
- Operations, maintenance, and training are key. A verification facility could be used to determine procedures and to train personnel.
- Education of John and Jane Q. Public is critical. An everyday device or “toy” is needed to familiarize the public with the use of hydrogen.

As a result of the Blueprint meeting, the DOE Hydrogen Program expanded its 2001 work effort to include safety database development, increased solicitations for onboard and off-board refueling and storage, and field verification activities.

The Blueprint effort is receiving support from the National Hydrogen Association, industry, the South Coast Air Quality Management District, and other agencies. In addition, efforts are ongoing to ensure active participation from the natural gas industry, and to integrate applicable “lessons learned” into the development of hydrogen infrastructure.

Codes and Standards

International Code Council (ICC) Hydrogen Ad Hoc Committee

Between regularly scheduled meetings, the International Code Council (ICC) Hydrogen Ad Hoc Committee is continuing its efforts through six working groups:

- Working Group 1: Residential Garages
- Working Group 2: Commercial Garages (open and enclosed)
- Working Group 3: Fuel Dispensing/Refueling Stations
- Working Group 4: Portable Fuel Cell Appliances
- Working Group 5: Hydrogen Gas Generation Appliances
- Working group 6: Identification of Standards Deficiencies and Needs

The Ad Hoc Committee has completed initial rough drafts of code changes proposed for incorporation into the International Fire Code and the International Fuel Gas Code. The goal is to complete recommended changes so that they can be presented for approval at the ICC 2002 code development/hearing cycle. The next meetings of the full Ad Hoc Committee meeting will be held on June 4-5, 2001 at NREL.

The National Fire Protection Association (NFPA)

The National Fire Protection Association (NFPA) has made the decision to develop its own new building code called *NFPA 5000* independently of the ICC. The NFPA 5000 will address hydrogen in the code.

NREL initiated working with NFPA to coordinate efforts. In addition, NREL is working towards becoming a representative on one of the *NFPA 5000* code development committees.

NFPA recently made the decision to participate in the NREL technology transfer/marketing research targeted at building code and fire safety official officials. This includes participating in the focus group program to (1) generate feedback regarding the usefulness of the hydrogen safety handbook; (2) generate feedback regarding the usefulness of the hydrogen safety video; (3) generate input regarding hydrogen safety-related information needs not being addressed in the handbook and/or video; and (4) generate input regarding the best ways and mechanisms for providing needed information.

Fire and Flame Impingement Tests

NREL is monitoring the work and results from the hydrogen fire and flame impingement tests being conducted for the Hydrogen Program by Dr. Michael Swain (Associate Professor of Mechanical Engineering at the University of Miami). The objective of these tests is to assist the ICC Hydrogen Ad Hoc Committee and others in determining what level of fire protection is needed for hydrogen-powered or hydrogen-fuel-cell powered vehicles housed in residential garages. Concerning his results, NREL funded Dr. Swain to present a paper at the NFPA World Fire Safety Congress held in Anaheim, CA in May 2001.

International Standards Organization

NREL is supporting the International Standards Organization's Technical Committee 197 (ISO/TC197) hydrogen standards development efforts. NREL has awarded a subcontract to TISEC, Inc., to address the issue of identifying internationally acceptable criteria for confining hydrogen under pressure. Dr. Robert Hay will be the TISEC principal investigator in this activity.

The subcontract was awarded on April 24, 2001. It will involve conducting a quantitative study of requirements and existing pressure vessel codes and standards to formulate recommendations to ISO/TC-197 that will resolve the current national differences existing among committee members and that are compatible with other existing international codes and regulations

International Electrotechnical Commission

Mr. Algis Vasys (consultant to NREL on hydrogen codes and standards) has been appointed to serve as the DOE/NREL Hydrogen Program's representative on Technical Committee 105 (TC/105) of the International Electrotechnical Commission (IEC). Within TC/105, Mr. Vasys will be serving on WG5, that addresses stationary fuel cell power plant installation standards.

The mission of IEC is to promote, through its members, international cooperation on all questions of electrotechnical standardization and related matters, such as the assessment of the conformity to standards. The technologies coming under the purview of IEC includes: electricity, telecommunications, energy production and distribution, and electronics.

Milestones

Blueprint

Conduct Core Group Meeting. (May 2000)

The Blueprint's Core Group, comprised of Shell Hydrogen, Praxair, Air Products, Ford Th!nk Group, Stuart Energy, and the California Energy Commission met on May 8, 2000. The purpose of the meeting was to develop better coordination and collaboration with the Gas Research Institute's Natural Gas Vehicle Infrastructure Industry Working Group, with the DOE Office of Transportation Technologies' "Fuels for Fuel Cells Plan," and with the California Fuel Cell Partnership. In addition, potential brainstorming exercises were conducted with respect to developing a roadmap for the Blueprint.

Conduct Roadmap Meeting. (September 2000)

A Blueprint roadmap meeting was held on September 21 – 22, 2000 to prioritize critical issues and develop initial action plans. The group divided into focus groups concentrating on four key technical areas: safety, storage, refueling stations, and codes and standards. Focus group findings are reviewed in the previous section.

Conduct Working Group Meeting. (September 2001)

A hands-on meeting is scheduled to include all of the facilities that are currently installing hydrogen infrastructure for transportation application. An inventory of key institutional and technical issues will be developed, highlighting "lessons learned." Technical teams will be formulated to follow up with next steps, including station design, and tank certification. A key element to the working group meeting scheduled for September 2001 will be to identify markets to focus infrastructure efforts. These will focus on a small number of "early adopters" in California, Nevada, Arizona, New York, and Massachusetts. Regional market for penetration profiles will be developed. Retailing stations will be geographically concentrated to fully utilize the infrastructure. The purchase of government fleet vehicles will be carefully coordinated with infrastructure installation. Finally, coordination will be developed between our manufacturers and fuel providers to optimize timing of supply and demand.

Codes and Standards

Draft a professional quality document on codes and standards issues. (July 2001)

NREL initiated a marketing research and technology transfer activity targeted at the nation's building code and fire safety officials. This included disseminating copies of the draft report "*The Hydrogen Handbook for Building Code and Fire Safety Officials*" and the video "*Hydrogen: The Matter of Safety*." The objectives are to: (1) get feedback regarding the usefulness of the handbook; (2) get feedback regarding the usefulness of the video; (3) get input regarding hydrogen safety-related information needs not being addressed in the handbook and/or

video; and (4) get input regarding the best ways and mechanisms for providing needed information. NREL planned and began conducting a series of focus group sessions around the country targeted at building code and fire safety officials to determine information needs and mechanisms. The results from the focus group sessions will be used as the basis for designing the new document and its contents. Sessions are planned with: (1) International Conference of Building Officials; (2) Underwriter Laboratories; (3) Fairfax County, VA building code officials; (4) Southern Building Code Congress; (5) Marietta, GA Fire Department fire safety officials; and (6) National Fire Protection Association.

Participate in ICC meetings and report as necessary. (September 2001)

NREL is participating in the work of the International Code Council (ICC) Hydrogen Ad Hoc Committee. The objectives of the Ad Hoc Committee are to: (1) review current codes and standards relating to hydrogen; (2) identify proposed changes to international codes and work to get them incorporated into the International Residential Mechanical/Plumbing Code (IRM/PC), the International Fire Code (IFC) and the International Fuel Gas Code (IFGC); and (3) identify other standards needs and deficiencies and generate standards for incorporation into model codes.

The Ad Hoc Committee was successful in getting its initial recommended changes into the ICC's IRM/PC, IFC and IFGC at the ICC 2001 Code Development/Public Hearing Cycle on 19 March 2001 held in Portland, OR. In addition, the Committee completed initial rough drafts of standards proposed for incorporation into the IFC and IFGC as part of the ICC 2002 code development cycle.

Proposed Future Work and Milestones

Blueprint

Work for the remainder of fiscal year 2001 will focus on organizing and designing the Blueprint working group meeting, tentatively scheduled for September 2001. In the planning process, coordination will take place with other groups who have initiated hydrogen infrastructure development, such as the California Fuel Cell Partnership in the Sacramento, CA area, and Sunline Transit Agency in Thousand Palms, CA. In addition, technical teams addressing tank certification, refueling station design, and other technical issues will be formulated.

It is anticipated that the Blueprint technical teams will refine action plans as necessary, continuing to meet in fiscal year 2002.

Codes and Standards

The work of the ICC Hydrogen Ad Hoc Committee will continue to develop consensus standards and to incorporate hydrogen-related standards into the IFC, IRM/PC and the IFGC. The focus of these efforts will be: (a) hydrogen flexible connector standard; (b) portable fuel cell appliance standard; (c) need for harmonizing standards regarding the definitions of "stationary," "portable" and "residential" fuel cell power plants; and (d) need for resolving differences between standards

regarding stationary fuel cells available today and anticipated concepts involving new technologies.

The marketing research and technology transfer activities targeted at building code and fire safety officials will continue. The focus will be on continuing to identify their issues and concerns regarding the installation and safe use of hydrogen-powered appliances and addressing these issues and concerns in a credible, professional-quality manner. The emphasis will be on using results of “code and standards validation work” (e.g., testing and evaluation work being conducted by Dr. Michael Swain of the University of Miami).

Since a major promising potential application of hydrogen fuel cells is motor vehicles, the Program will seek to establish a collaborative working relationship with the Society of Automotive Engineers with respect to codes and standards work.

The Program is developing hydrogen technologies for three applications: transportation, buildings and portable applications. For each of those applications, safety issues must be addressed with respect to the production, transportation, storage, dispensing and use of hydrogen. Furthermore, many organizations are involved in developing standards (e.g., NFPA, SAE, ICC, etc.). Consequently, major thrusts in the Program’s codes and standards activity must be to: (a) keep abreast of hydrogen-related codes and standards ongoing in various organizations; (b) work to coordinate efforts and prevent needless duplications of efforts; (c) identify deficiencies and gaps in the work in progress throughout the country; and (d) work to identify the appropriate forums for addressing any critical deficiencies and gaps. These coordination and “codes and standards development management” activities will continue.

Proposed Milestones

- Development of three new proposed draft standards by the ICC Ad Hoc Committee to address deficiencies in the ICC model codes (September 2002)
- Blueprint Technical Team refined action plans (September 2002)

Leadership – Cooperative Efforts with Other Organizations

NREL is an invited member of the Society of Automotive Engineers (SAE) Fuel Cell Recycling Subcommittee. In addition, NREL has been and will continue to work collaboratively with SAE, the International Code Council, the National Hydrogen Association and the International Standards Organization.

Methodology

The methodology for both infrastructure tasks is to optimize the Blueprint and codes and standards activities through coordination and joint work projects with ongoing hydrogen infrastructure efforts. In particular, coordination will take place with the National Fire Protection Association, Natural Gas Institute, International Standards Organization, International Electric Technical Commission, Society of Automotive Engineers, and numerous hydrogen fueling facilities in California, Nevada, and Michigan.