EXECUTIVE SUMMARY

The 1999 Implementation Plan (IP) provides a path to achieve the near-term goals of the NHA's Hydrogen Commercialization Plan (HCP).

The HCP, as first drafted in 1996, challenged industry and others to show their commitment to making hydrogen a major "energy carrier" in three major markets — autos, buses, and power generation. Industry, government, and other sectors are responding to this challenge through the development of hydrogen products with aggressive milestones and field tests. The Implementation Plan lays out a strategy which, if followed, would achieve the near-term goals of the HCP. Achievement of these goals will also establish niche markets or a market presence important for hydrogen energy systems.

Given the constraints of trained personnel and infrastructure, hydrogen vehicle niche markets are fleets and airport vehicles. Mass vehicle purchases by industry and government will help to drive vehicle costs down as experience is gained in operating vehicles. This approach also requires modest initial infrastructure support. The IP assumes that the advantages of on-board hydrogen fuel are recognized and that hydrogen-refueling systems are developed and used. The Plan proposes immediate emphasis on this requirement, including establishment of at least three new fueling demonstration projects during October 1999 to October 2000 (the federal government's fiscal year). Commercial offerings of fuel cell vehicles by auto manufacturers in 2004 should move this process forward. Outstanding issues include fuel choice for on-board systems and the timeliness of hydrogen infrastructure development. There has been movement toward the use of on-board hydrogen storage.

The 2005 commercialization goal of 100 hydrogen buses in revenue service appears attainable, given the progress in developing these vehicles and the demonstrated market interest on the part of transit authorities and others. Support of continued innovative development of hydrogen-fueled buses by commercial sources accompanied with progressive reliability improvements are required for the maturation of the technology in a time frame consistent with HCP goal.

To focus and coordinate federal hydrogen efforts, creation of an Interagency Hydrogen Task Force is urged, with participation by the U.S. Departments of Energy, Transportation, Defense, and Commerce; the U.S. Environmental Protection Agency; the National Aeronautics and Space Administration; and the National Park Service. The IP encourages an Administration mandate to promote the use of hydrogen within agencies in order to assist in the development of hydrogen-related business.

As customer choice for retail power emerges, some consumers may opt for a power generation appliance for home or business. Fuel cells operating on hydrogen could be the ultra-clean, quiet appliance for those electric customers. In the interim, remote power and distributed generation offer favorable opportunities for limited-scale implementation of power systems using renewable resources. Technology development and cost reduction

needed for widespread commercial application can be promoted by demonstrations and through joint programs with the U.S. Department of Defense and other agencies.

The need for safety-related activities is urgent, which is why the NHA is leading the timely development of codes and standards. Participation by permitting agencies and the insurance industry is urged, along with equipment testing programs.

The roles of industry, government, and academia are discussed in some detail with recommendations for NHA/industry leadership in moving forward.

INTRODUCTION

The National Hydrogen Association (NHA) continues its work on developing an industry and government consensus on the progress needed to move hydrogen technology more rapidly into the marketplace. This plan picks up from *The Hydrogen Commercialization Plan* (HCP), which has been adopted by the NHA membership and the U.S. Department of Energy's (DOE) Hydrogen Program.

The primary objective of the plan is to obtain commitments from both industry and government to begin implementing hydrogen energy. Such joint commitment will require an economical and technically feasible road map that describes how to achieve this end. Industry must be convinced that it can eventually make a return on investments in hydrogen technology. Government must be convinced that its investments will leverage larger societal benefits in the form of reduced health costs, reduced oil imports, and improved international competitiveness over time. In short, the hydrogen Implementation Plan must provide a clear pathway for achieving the near-term goals of the HCP adopted by industry and government. The HCP, in turn, must point to a credible benefit/cost ratio for all participants, although the initial steps described in this Implementation Plan may not.

The NHA recognizes there are other activities not contained in the plan which will also promote the use of hydrogen. These activities are not discouraged, but are not within the scope of this document.

It is our intention that this plan will be used to:

1. Identify near-term opportunities for unique niche markets where hydrogen is economical now, or nearly so, with growth potential toward longer-term goals.
2. Identify appropriate companies, both members and nonmembers of the NHA, to make near-term investments in hydrogen development, demonstration, and commercialization projects, with a likelihood of success for reaching a goal.
3. Convince government decision makers to provide steadily increasing support for hydrogen and fuel cell development programs in the near-term, with the

realization that these technologies will eventually become economically viable on a broad scale without any government support.
4. Help guide hydrogen energy investment choices by government agencies in the industrialized world, including choices by the DOE.
5. Help convince other key players — such as state and local officials, building inspectors, the insurance industry, the investment industry, and the public at large — that the hydrogen energy industry is safe, economical, and sustainable.
6. Encourage other companies and organizations to join the NHA.
7. Suggest a role in which academia and outreach organizations promote public awareness and acceptance.
8. Increase use of hydrogen energy, thereby reducing pollution at the source. Environmental regulations are focusing on a cradle-to-grave approach to pollution prevention. Source reduction or elimination has been shown to be a cost-effective strategy over the life cycle of a system, as this eliminates the need to mitigate the pollution after release.

Opportunities for early market entry exist near hydrogen plants and by-product hydrogen sources. Infrastructure growth potential is most favorable where natural gas or off-peak electricity prices are low. The locations of existing renewable energy facilities point the way toward the future.

The plan identifies specific action items to implement the near-term goals of the HCP with the understanding that the transition from fossil-based fuels to sustainable, renewable hydrogen is the most difficult task. Taken together, these actions will provide a realistic transition path toward the hydrogen energy industry.

The NHA hosted a workshop to review the institutional recommendations in the *Commercialization Plan* and determine its relevance to near-term goals that are common to the NHA's *Hydrogen Commercialization Plan* and DOE's Hydrogen Program. The results from these activities will be provided to DOE and the Hydrogen Technical Advisory Panel (HTAP) in the form of the Implementation Plan.

The workshop participants developed commercialization scenarios and strategies to introduce hydrogen in near-term[1] transportation and power markets. The first step in this effort was the industry's acceptance of *The Hydrogen Commercialization Plan* that identified market barriers and set goals for hydrogen use.

The next step was the first Implementation Plan Workshop that served as a brainstorming session on Infrastructure and Transitioning from Demonstration to Commercialization.

There are several hydrogen applications that might offer cluster opportunities:

1. Power generation from hydrogen produced from municipal solid waste (MSW) and other sources
2. Airport fleets that could be operated on hydrogen (vans, buses, etc.)
3. Industries that already use hydrogen for their industrial processes

4. Remote power applications for remote villages and Native American reservations

These were addressed in this workshop in three market areas:

1. Buses/Corridors
2. Cars/Fleets
3. Power Applications/Remote Villages

In general, any corridor development will hinge on hydrogen-fueled bus development that puts into place the needed infrastructure for hydrogen-powered cars and fleets. The scenarios for all three market areas describe a market environment that solves air quality issues in nonattainment areas and connects with areas of current or potential renewable energy activity.

Three papers were drafted for each market session to provide a framework for discussion. At the workshop, we collected member reactions and input to modify and finalize these scenario market development strategies. Results of this workshop, along with input from the members of the Implementation Plan Committee and other invited experts, were incorporated into this draft Implementation Plan which aims to create a vision for commercialization of hydrogen and initiate proactive partnerships to make hydrogen use a reality.

IMPLEMENTATION PLAN ROLES

Federal, state and local government, industry, and academia each have a role in the development of the markets identified in the Commercialization Plan, which is further defined in this document. The specifics of their respective roles are contained in the various market sections to provide a complete and self-contained scenario for that market segment. In general the roles of the various entities can be described by the following:

1. The **federal government**'s role is to remove financial and nonfinancial barriers to the implementation of commercial technologies.
2. The **state and local government**'s critical role is to address code, siting and other zoning issues and, if appropriate, augment the federal role.
3. The role of **academia** — which includes universities, academic institutions, and outreach organizations — is to increase public awareness about hydrogen through education on hydrogen energy systems and the true cost of fossil fuels.
4. The role of **industry** is to define the energy needs of the marketplace and create combinations that tailor hydrogen products and systems which meet those needs in a sustainable and economic manner.

The specific actions required by each of these groups in achieving the near-term goals in the *Commercialization Plan* are presented in the respective market sections of this report.

CARS & FLEETS

Background:

The problem with the introduction of hydrogen in the fleet and passenger vehicle market is primarily due to the "chicken or the egg" dilemma. For example, automakers will not build hydrogen vehicles unless there is easy access to the hydrogen that they require. On the other hand, energy companies will not make hydrogen without a vehicle that uses it. The questions are: which comes first and then, how does it come about?

The establishment of a network of refueling stations and buses leads naturally to consideration of fleets of hydrogen vehicles. This could then be followed by both public refueling at selected fleet centers and the addition of hydrogen dispensing at existing service stations.

There have been demonstrations of converted internal-combustion engine (ICE) vehicles in operation for several years. These are proving the concept of hydrogen-powered fleet vehicles. The planned upcoming move of the Clean Air Now! trucks to a new site may reinvigorate public interest in the vehicles. In addition, demonstrations in Nevada and Los Angeles [California] are near-term targets. Sacramento [California] Municipal Utility District (SMUD) could operate a fleet of hydrogen cars using renewable energy to produce electrolytic hydrogen. Airports are also prime candidates for fleets of cars or vans, the Palm Springs [California] airport had a successful demonstration in 1998.

Safety must be a consideration across the board. Long-term testing is essential to prove new safety technologies and other hydrogen hardware. Fire departments and the insurance industry must be involved early to reduce the barriers to commercialization. The key to deploying a hydrogen infrastructure is safety codes and standards for hydrogen systems.

The United States, with the participation of other member countries of the International Standards Organization Technical Committee on Hydrogen Technologies (ISO TC/197), is in a position to set the terms for the performance standards for these systems for purposes of international trade. The NHA, with DOE support, is working with ISO TC/197 on hydrogen vehicle fuel systems and onboard hydrogen storage. The expertise and experience of near-term demonstrations will help us better define the terms of the dispensing facility and for an automobile onboard fuel system. In this capacity, it is important too for industry to work together in the NHA to develop the corridor concept and apply that experience to the anticipated four year development period for these standards.

Hydrogen Commercialization Goals[2]:

Hydrogen Vehicle Demonstration Goal

1. By 2000, establish at least three new hydrogen vehicle demonstration projects, including local hydrogen production by small-scale stream methane reforming or small-scale steam methane reforming or small-scale electrolysis, and dispensing to service at least 10 hydrogen-powered vehicles each. Vehicles may store gaseous or liquid hydrogen, and the fuel might include mixtures of hydrogen and natural gas. At least one demonstration project will produce hydrogen from a renewable resource (solar, wind, or biomass) or from municipal solid waste.

Hydrogen-Fueled Passenger Vehicle Goals

1. By 2010, produce enough hydrogen to supply 50% of all new vehicles sold under the California Zero-Emission Vehicle (ZEV) program (including other opt-in states), on the assumption that half of these vehicles will be hydrogen-fueled.
2. By 2015, produce enough hydrogen to supply 25% of all new passenger vehicles. Cost goals incorporate hydrogen-fueled ICE hybrid power train or vehicle fuel cell systems at less than US$35/kW and delivered hydrogen at less than US$2.50/kg (US$5.91/1,000 SCF) from natural gas at US$4/GJ (US$4.05/1,000 SCF).

Commercialization Strategy:

By 2002, two thousand hydrogen vehicles may be on the road via custom production demonstrations and four major fleet markets:

1. airport vehicles
2. state and local government vehicles
3. utility fleets
4. federal government fleets

By this time, there should be small-scale production of hydrogen-powered passenger cars and vehicle emission requirements going into effect to prompt demand for ultra-low (ULEVs), or zero-emission vehicles.

The sum of these efforts coupled with the extension of fleet to passenger vehicles could lead to 50% of all new ZEV vehicles on the road in Southern California fueled by hydrogen.

<u>Airport Fleets</u>

The first demonstration of hydrogen-fleet vehicles in the airport fleet mix should be initiated as soon as possible, beginning with five hydrogen vehicles. In 2000, this could be quickly applied to three additional airports with 10 hydrogen vehicles each. And in 2002, this could be increased to five airports with 50 vehicles each. By this time, a provision or incentive program should be initiated to introduce hydrogen-powered vehicles at this rate to all airports located in nonattainment areas.

<u>State and Local Government Fleets</u>

State and local government fleets in nonattainment areas could be counted as several alternative vehicles for the purposes of ULEV and ZEV. Demonstrations could start with ten vehicles at three sites by year 2000 and rapidly expand to all jurisdictions in nonattainment areas by year 2002 and beyond.

<u>Utility Fleets</u>

A parallel utility fleet vehicle program could also be undertaken in service territories located in nonattainment areas. An example program may look something like 2% of their fleet mix include hydrogen-powered vehicles by year 2002, rising to 20% of fleet vehicles by 2006.

<u>Federal Government</u>

The federal government could require that every federal facility and military base with hydrogen bus refueling stations or hydrogen storage capacity operate ten hydrogen vehicles by 2002.

Roles:

<u>Federal Government</u>

The main role of the federal government is to reduce barriers to implementation. This can be accomplished through training and information dissemination at the state and local level, and cooperation between federal programs and other organizations that can assist commercialization. This includes working with industry and others through an organization such as the National Hydrogen Association to assure that the hydrogen community is moving toward the same goals, and that duplication of effort is minimized. The federal government also must work with industry to set the policy for hydrogen in the future. It is imperative that a long-term Hydrogen Policy is established that allows the future goals and opportunities to provide the framework for the intermediate and near-term. Only in this way are we assured that the short-term goals will indeed yield our long-term vision.

The federal government must provide implementation training and barrier reduction downward to local/regional government. The NHA will work with the federal government to develop mutually agreeable programs for training and barrier reduction.

The Sourcebook for Hydrogen Applications has been developed through DOE, National Renewable Energy Lab (NREL), and others to assist in barrier reduction. Along with training, the *Sourcebook* can be used to assist local and state government with information, understanding and guidelines for safe hydrogen projects.

The federal government is also a market for fleet vehicles at hundreds of sites around the country. The government could place public dispensing stations at these sites for federal and other vehicles. Hydrogen vehicles could be put in General Services Administration (GSA) catalogues for purchase or lease by federal agencies. NHA members could develop consortia of industrial, academia, laboratory, and governmental agencies to develop suitable hydrogen cluster activities that are beneficial to the hydrogen industrial community.

State Government

State government must take the role to assist in siting and permitting issues, including those required for refueling stations, parking garages, bridges, and tunnels which may accommodate hydrogen-fueled vehicles. In addition, the state can take an active role in encouraging insurance companies to cover hydrogen-fuel projects. Finally, the state can help reduce the cost barrier by providing state tax incentives for clean fuel vehicles. In addition, states could provide incentives for fleets to use hydrogen vehicles by counting hydrogen vehicles as the equivalent of several alternative fuel vehicles.

Local Government

Local government can play a key role in permitting, siting, and other zoning issues by working with state and federal governments using tools such as the *Sourcebook for Hydrogen Applications* and adopting standards being developed with industry through the NHA.

Industry

To foster the commercialization of hydrogen technology at all levels of the value chain, industry must take a multifaceted approach and work within a short, mid-, and long-term horizon. From production to storage, safety and transportation to enabling end-use applications, the perspective of hydrogen as an integral part of the emerging energy infrastructure should be akin to that currently in place for hydrocarbons.

In defining a market for hydrogen, industry must assess the status quo, determine areas of growth from its unique perspective (production, safety, storage, end-use application, etc.), and develop a mid- to long-term plan which incorporates realistic big picture assumptions on the development of new and existing markets, including the introduction and continued development of systems and components which advance the commercialization of hydrogen.

Academia

The key role of academia is to increase public awareness and acceptance through education of high school and college students about hydrogen systems, and informing the public of the true cost of fossil fuels, far more than simply the price at the pumps.

In addition, academia can solve long-term technical issues for future generations through research and development. This may be accomplished through government and industry support.

Barriers:

The main barriers to wide-scale use of hydrogen-fueled cars and fleets include lack of: an infrastructure; public acceptance; coordination or collaboration among potential fleet operators; and applicable codes, standards, and other safety information which can enable siting and insurance of the required infrastructure. Removal of these barriers requires that government organizations work together and include industry and academia where appropriate to educate the public and prove that fleets of hydrogen-powered vehicles can be operated safely and cost-competitively. Addressing these issues necessitates funding. Cost-shared programs, industry consortia, and tax incentives all combine to help overcome these barriers.

Recommendations:

Federal Government

The federal government must lead by example. The most effective way to implement hydrogen systems — thereby reducing costs and risks for future systems, as well as increasing public acceptance of hydrogen technologies — is to require the government to promote hydrogen through use at the DOE, the U.S. Department of Transportation (DOT), the U.S. Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), the National Park Service (NPS), and the U.S. Environmental Protection Agency (EPA). All of these organizations run fleet vehicles of some type. Mandated phasing-in of hydrogen cars and fleets at these sites will help realize the commercialization plan goals.

The federal government, in cooperation with industry (through the NHA), should take a lead in the following activities:

1. Identify existing organizations that can assist with hydrogen commercialization.
2. Begin work on legislation which helps press hydrogen past the Hydrogen Future Act of 1996.
3. Recommend roles for the following agencies: DOE, DOT, DOD, NPS, EPA, others.

4. Team with industry to site and permit hydrogen activities. NHA needs to promote the development of industrial consortia to help site and permit hydrogen cluster activities.
5. Create an interagency hydrogen task force to coordinate hydrogen technology development and commercialization, share ideas and lessons learned, and leverage funding.
    a. Form and fund interagency/interoffice task force. Members of the task force should include: DOE, DOT, DOD, EPA, etc.
    b. Define roles and responsibilities of task force.
    c. Develop process that task force could use to further hydrogen technology commercialization within federal agencies.
6. Facilitate growth from research and development to commercialization.
7. Provide subsidies and tax incentives for clean fuel projects

State Government

State government should work with the hydrogen community to take an active role in the following near-term activities:

1. Provide incentives for hydrogen (tax and pollutant credits, etc.).
2. Define the motor vehicle registration process, as it might relate to hydrogen-fueled vehicles.
3. Define emissions, siting, and permitting requirements.
4. Provide insurance coverage through state insurance regulators.
5. Provide state subsidies.

Local Government

Local government can play a key role in permitting, siting, and other zoning issues. Activities include:

1. Put zoning ordinances in place.
2. Define siting and permitting.
3. Maintenance, operations, and safety (in particular, emergency response) agreed to by fire, police, city, and county.
4. Access to local government resources, as a user or partner to ensure infrastructure support.
5. Hydrogen promotion and local support.

Industry

Industry is taking a leading role in hydrogen transportation systems by producing cars, fleet vehicles, fuel, and fueling stations. Industry intends to pursue demonstration projects in the year 2000 and 2001. Industry is also developing hydrogen-powered automobiles that are expected to be commercially available around 2002, as well as efficient hydrogen refueling stations. There is an ample supply of hydrogen available; however, the ability to supply it in a cost-competitive nature with conventional fuels must be addressed. All industries can play a role in developing a hydrogen future by using hydrogen-powered cars for their company fleets.

Academia

The Hydrogen Program Education Outreach portfolio includes many of the necessary elements to assure future public acceptance and training in hydrogen energy systems. These efforts should continue and grow. There is a role for government and industry to participate in and help fund the efforts which academia must undertake. Existing or planned efforts include:

1. Field-testing and evaluation of high school curricula, leading to broad curriculum dissemination and widespread teacher training. The high school curriculum should be modified for a middle school curriculum. The curricula will be available on the Internet. This activity could be carried out by education outreach consultants to the DOE with the cooperation of industry.
2. Dissemination of hydrogen curricula that provides classroom materials for teachers and students by making available teacher kits. The kits will feature a remote control demonstration car and other devices that illustrate the characteristics and value of hydrogen as a fuel and energy carrier. The kit will also contain Hydrogen Program films and videos that supplement other education materials. It is expected that the national laboratories and industry will contribute to the teacher kits.
3. CD ROM development, such as *Mission H_2* and others should be funded and completed, to allow students worldwide the opportunity to begin to incorporate hydrogen system learning in their curricula.
4. Financial incentives, such as the proposed Hydrogen Fellows Program, should be instituted at graduate school Centers of Excellence to promote study and research. Cooperation with institutions of higher learning and national laboratories will be key to development of the Fellows Program. Other similar programs, sponsored through industry and government are encouraged.
5. Promotional efforts such as *The Dr. Bob Show* will continue. *The Dr. Bob Show* may generate cable and film production opportunities that would be explored and pursued, resources permitting.
6. The Fuel Cell Propulsion Institute will lead a collaboration of the hydrogen and mining industries, the DOE Hydrogen Program, national laboratories, and academia in planning, analysis, research, and development activities aimed at fostering the demonstration of fuel cell vehicles for mining as well as related enabling technologies. Other federal agency involvement is intended. The focus of the efforts is expected to be sub-surface mining applications. It is anticipated that these activities will result in market introduction of one or more mining vehicles over the five-year life of the plan.

BUSES & CORRIDORS

Background:

The development and operation of hydrogen-powered bus fleets is a major part of the NHA's *Hydrogen Commercialization Plan,* which identified market barriers and set goals for hydrogen use. Buses are considered highly visible, utilitarian applications which make a strong statement regarding public acceptance of hydrogen energy. Both the buses and the fueling infrastructure must evolve in concert and centralized fleet operations require less infrastructure than personal transportation. DOE and several members of academia and industry believe that a clusters/corridors growth mechanism will assist development of this scenario.

Codes and standards (e.g., environmental regulations), policy drivers (e.g., government initiatives), and economic pressures (e.g., locally high transportation costs) will open the opportunity to establish hydrogen "nodes" or clusters which may be located in several candidate applications: dense urban areas, environmentally sensitive parks and areas, politically independent areas, (e.g., Native American reservations), and many others. These nodes or clusters of opportunity begin the development of a hydrogen infrastructure. Clusters that are within the effective range of each other define a hydrogen corridor. The evolution of a corridor begins with hydrogen refueling requirements or overcapacitized industrial hydrogen production. Bus operation and fleet support may arise from other hydrogen applications which can adapt to provide quick refueling to ground transportation.

In general, any corridor development will hinge on hydrogen-fueled bus development that puts into place the needed infrastructure for hydrogen-powered cars and fleets. The scenarios for most hydrogen market areas describe a market environment that solves air quality issues in nonattainment areas and connects with areas of current or potential renewable energy activity.

Current Hydrogen Commercialization Goals:

In 1996 the NHA adapted the following initial goals:

1. By 2005, operate at least one hundred hydrogen-powered buses on regularly scheduled routes. Cost goals include hydrogen-fueled ICE hybrid or fuel cell powertrain systems at less than US$500/kW and dispensed hydrogen costing less than US$4/kg (US$9.45/1,000 SCF) for bus refueling.
2. By 2010, 50% of all new buses shall be powered by hydrogen. Cost goals shall include hydrogen-fueled ICE hybrid power train or fuel cell production costs less than US$80/kW and delivered hydrogen costs of less than US$3/kg (US$7.09/1,000 SCF), made from natural gas at US$4/MBtu (US$4.05/1,000 SCF) or from renewable resources, including municipal solid waste.

Implied in these goals is the creation of an infrastructure that can provide buses and fueling stations:

1. Dispensing Stations

   One or two dispensing facilities can refuel a large number of buses at a central facility. Refueling stations may be installed at each cluster node, about four hundred miles apart. Several different hydrogen production technologies may be used at the refueling stations as demonstrations of these individual technologies and to promote the industrial base in hydrogen production, including small-scale steam reforming, electrolysis using power from the grid or renewables, and plasma hydrogen production.

2. Conversion of Buses

   In the near-term, hybrid engine vehicles will be converted to operate on hydrogen. This will open the market for future use of mobile fuel cells.

   The goal to operate one hundred hydrogen-fueled or hydrogen blends-fueled buses can be met by a series of field tests shown in the table below:

No. of Buses	Location/Corridor	Time Frame
5	Chicago (Illinois, U.S.A.)	2002
5	Vancouver (B.C., Canada)	2002
10	Lower West Corridor	2002
10	Upper West Corridor	2002
10	Southeast Corridor	2003
30	Government Facilities	2004
15	Northeast Corridor	2003
5	Other Urban Corridors (i.e., Atlanta, Georgia, U.S.A.)	2004
10	New York City (New York, U.S.A.)	2004
100 = TOTAL BUSES		

Roles:

Industry will lead the way by developing the ability to build, integrate, and operate the hardware necessary for both buses and fueling stations. Industry will probably request sponsorship from the government via demonstration programs to mitigate the business risk in applying resources to an untested market. Several large firms have initiated bus demonstration programs, but with limited success due to reliability and field support issues. Mainstream bus fleet operators must become involved early in the effort to ensure operational feasibility and cost verification. Government can assist industry through funding at the appropriate levels to ensure ease of permitting, zoning, licenses, and regulatory oversight. There is a need to educate government officials in order to responsibly modify local regulations. There is a role for academia and public interest groups to ensure public acceptance and the long-term availability of the expertise required for the new technology.

Barriers:

Every step in the commercialization process encounters barriers that must be defined and overcome. The critical issues that face decision makers about hydrogen fuel cell buses are:

1. **Does the public want them?** The public must see hydrogen as a positive in terms or air quality and energy security.
2. **Do they perform as well as diesel buses?** In the long run, fuel cell hydrogen buses must perform better than conventional diesel buses or less clean alternate vehicles that do will be used.
3. **Can my transit authority afford them?** Transit authorities rely on the federal government for much of the funding of urban transit buses. If the federal government can be convinced about the value of hydrogen-fueled buses, then they can provide much of the cost share money with which transit authorities buy buses.
4. **What do we do about infrastructure?** Industry and government must work together to fund infrastructure for producing, storing, and dispensing hydrogen at one central location. Initially, this may be from natural gas reforming or electrolysis of water.
5. **Where is the training for operators and maintenance personnel?** Industry must set up the training facilities where personnel may be trained in the operation and maintenance of these systems.
6. **What codes and standards should be followed?** The government and industry must work together to develop standards that provide for safe operation of hydrogen systems and are adopted by the appropriate standards organizations.
7. **How safe are the buses, storage, and dispensing stations?** The government should undertake risk assessment of all early dispensing stations and bus fleets to assure that the unique risk of accident in each facility is quantified and minimized. The transit authority may still require insurance, so the hydrogen industry and government must work together to provide that layer of security before hydrogen buses are accepted.

Recommendations:

In order to realize the near-term goals of the hydrogen commercialization plan, there are several actions that federal, state and local government, and industry must take.

Federal Government

1. Provide implementation training and barrier reduction downward to local and regional government.
2. No cost/low-cost resources they can use (e.g., *The Sourcebook for Hydrogen Applications*)
3. Require the government to promote hydrogen through use at the DOE-, DOT-, DOD-, NASA-, NPS-, and EPA-controlled sites which have controlled access.
4. Create an interagency hydrogen task force to coordinate hydrogen technology development and commercialization, share ideas and lessons learned, and leverage funding. Members of the task force should include: DOE, DOT, DOD, EPA, etc.
5. Reauthorize, extend, and expand the Hydrogen Future Act of 1996, scheduled to expire in 2001.
6. Possible tax incentives for hydrogen and related equipment.
7. Use success to invigorate new programs. The knowledge, equipment, and systems developed in one project should be leveraged or utilized in a subsequent project whenever practical.
8. Obtain policy changes and funding to implement purchase by federal agencies.
9. Request for Proposals from the Federal Transit Administration (FTA) to run a fleet of hydrogen buses with DOT/DOE technical support.
10. Obtain federal authorization to purchase hydrogen fuel cell buses for federal fleets. Obtain funding for that purpose.
11. Require use of fuel cell hydrogen buses in national parks and make all their NPS vehicles the same.
12. The DOT and DOE should support a number of ten bus hydrogen demonstrations like the Las Vegas [Nevada] bus project.
13. The DOE must continue to fund the research and development for hydrogen storage, balance of propulsion system, and fuel cells for buses.
14. DOE and DOT must work with industry to develop codes and standards for buses and have them adopted at the local level and by each state's Department of Motor Vehicles (DMV).
15. The GSA must include hydrogen buses and refueling stations among the items federal agencies can purchase.
16. The DOT's Federal Transit Administration must be willing to fund the purchase of fuel cell buses by transit authorities.
17. DOE and DOT must work with industry to improve the performance and reduce the cost of fuel cells and fuel cell buses.
18. An executive order should be issued that instructs the government agencies to have a percentage of their bus fleets operate on hydrogen.
19. Educate transit authorities about the benefits of hydrogen buses.

State Government

1. State energy and environmental agencies should evaluate hydrogen options to solve environmental or energy problems.

    a. air resources board
    b. waste management board

2. Provide incentives for hydrogen (tax, pollutant credit, etc.).
3. Define a certification, inspection, and reinspection process for DMV registration of hydrogen buses.
4. Define the process steps required to obtain siting approvals and operating permits for dispensing stations and other hydrogen-related facilities associated with refueling hydrogen buses.
5. State insurance regulators should ensure the availability of insurance coverage for hydrogen buses.
6. Encourage state insurance regulators to make providing insurance for hydrogen buses a condition for an insurance company doing business in the state. Initially a risk pool might be created for hydrogen vehicles and facilities so that the risk is not borne by one entity.

Local Government

1. Put zoning ordinances in place for hydrogen applications.
2. Define siting and permitting for hydrogen projects.
3. Require procedures for maintenance, operations, and safety (in particular, emergency response).
4. Use economic development incentives to encourage hydrogen industries.
5. Promote hydrogen activities in local communities.

Industry

Industry must develop and test hardware and methodologies to deploy buses, fleets, and refueling stations. Industry must be able to do this in a manner that can compete with existing technologies on cost, convenience, and improved quality of life. This requires a multifaceted approach to marketing and development. Some activities must be performed by the specific industry, but many others can be accomplished through an industry consortium of NHA members. Challenges for industry in the next three to five years include:

1. **Educate the market** (define players in the market including general public)
2. **Create turnkey product.** Industry wants to deliver turnkey systems, meaning: buses, refueling systems, maintenance and operating procedures, insurance, and maintenance expertise. It must be packaged in one entity as the operator does not want to perform the integration of the new processes and products. This should be

offered from 2002 on for hydrogen blends and for 100% hydrogen-powered buses.

3. **Commercialize through a consortium.** The delivery of a turnkey product from the year 2002 forward necessitates the creation of consortia for hydrogen blends and for 100% hydrogen-powered buses, as well as for stationary systems to be able to take global responsibility of products.
4. **Guarantee the technology** so that it may be insured; work with end user to assure insurance.
5. **Incorporate goals, as appropriate, from the *Commercialization Plan*** into company's business plan.
6. **Develop and agree to use ISO/TC-197 standards.** Industry commits itself to use the ISO/TC-197 standards from the year 2000 to ensure the standardization and acceptance by the users of the hydrogen-related products and processes. The list of ISO/TC-197 standards is hereby attached (Appendix A).
7. **Utilize safety equipment that has been certified and tested.** Industry will commit itself to use only certified equipment.
8. **Use standard risk assessment and liability protection** to improve the economy of insurance available to the hydrogen community. Until codes and standards are in place, and there is sufficient operating experience, all products and systems should undergo a HAZOP analysis by a qualified organization to assess risk levels and their compliance with internationally accepted standards.

Corridor Development:

1. Create a Lower-West Corridor [Los Angeles (California)-Las Vegas (Nevada)-Phoenix (Arizona)-Albuquerque (New Mexico)]: Connect clusters of hydrogen applications in Los Angeles, install dispensing stations to allow hydrogen-fueled transportation along this route.
2. Create Upper-West Corridor by extending Lower-West Corridor [Los Angeles (California)-Sacramento (California)-Reno (Nevada)-Salt Lake City (Utah)-Denver (Colorado)].
3. Conduct feasibility study of the corridor concept and explore the interest in and viability of creating three additional hydrogen corridors in the Gulf States, the Northeast, and Southeast [Miami (Florida)-Augusta (Georgia)-Aiken (South Carolina)].

Several other clusters or corridor sites may arise from existing government hydrogen facilities such as NASA, national laboratories (National Renewable Energy Laboratory, Sandia National Laboratories, Lawrence Livermore Laboratory), and military installations.

Other Recommendations:

There are transportation implementation opportunities, such as maritime, which may be implemented concurrently with buses. Maritime scenarios are not in the current version of the NHA Commercialization Plan and it is recommended they be considered for the next revision.

GRID-CONNECTED & REMOTE POWER

Background:

Hydrogen is an energy carrier with use as an energy storage medium. It is a potential fuel for pollution-free, sustainable, and remote electricity production in existing niche markets that may or may not have an existing electrical infrastructure. Candidates for early applications include:

1. *Remote sites with renewably produced hydrogen from solar, wind, biomass, or small hydroelectric sites.* Areas that lack a fuel or electric infrastructure are ideal for demonstrating the production of hydrogen with small renewable energy systems for power and dispensing stations for buses and fleets. Such areas may include sites along the corridor, remote villages and other isolated areas in developing and island countries, sparsely populated areas in the U.S., and regions with intermittent or unreliable power. Additional market niches are defined by logistical, political, and unique geo-economical considerations.
2. *Gasified municipal solid waste, landfill gas, and other biomass waste streams that can be used to produce hydrogen for power generation, fleet vehicles or chemical processes.* Such biomass projects, coupled with recycling, offer many opportunities and could help stabilize landfills in urban areas.
3. *Urban or sprawling communities with air quality problems.* Nonattainment areas requiring generation near the load due in part to the high cost of transmission lines may require hydrogen coupled with fuel cells to provide clean generation to areas with load growth. Nonattainment areas would be prime candidates for siting hydrogen-powered fuel cells near customer loads. The difficulty and costs associated with obtaining new or expanding existing transmission right-of-ways in urban nonattainment areas, such as Los Angeles (California), make renewable hydrogen powered fuel cells an attractive option as load leveling and end-of-line support.
4. *Premium Power-Uninterruptable Power Supply (UPS)* for critical electrical loads, such as computer centers and airport control towers.

Hydrogen Commercialization Goals[3]:

<u>Grid-Connected</u>

1. By 2002, install at least fifty megawatts (cumulative) of hydrogen-powered fuel cell electricity for widely distributed, grid-connected power at multiple sites in the world.

2. By 2015, 10% of all new electrical generation capacity shall be from hydrogen-powered fuel cell [cogeneration] systems. [Alternative: By 2005, hydrogen-powered fuel cells will supply 50% of new market “High Quality Power” applications, replacing the need for onsite “emergency” generators and UPS systems.]

Remote Power

1. By 2001, establish at least two remote village power demonstration projects using intermittent renewable energy sources and hydrogen to store energy. The cost goal for this integrated energy system is 12 cents per kilowatt-hour.
2. By 2015, install at least 10 megawatts (MW) of remote renewable power systems with hydrogen storage. Particularly choice market opportunities exist for sites requiring more than four days of energy storage.

Commercialization Strategy:

Installing 50 MW of power by year 2002 can be accomplished by taking advantage of the above niche markets through government-industry partnerships and independent industry initiatives.

Two renewable remote energy systems could be operating by 2002. This is foreseeable with the interest in remote power generation as exhibited by the DOE solicitation for a remote power hydrogen demonstration system, the Remote Area Power Program project, and the qualification of ONSI’s phosphoric acid fuel cell to operate on hydrogen. Also, with introduction of Proton Exchange Membrane (PEM) fuel cells, manufacturers are driven to develop early markets and generate interest in their technologies through user groups.

Installing 50 MW of remote power could begin with the operation of two renewable hydrogen energy systems at remote villages by year 2000 (400 kW total). The combination of Native American reservations and Alaskan villages using hydrogen power could generate interest in perhaps 10 MW of power orders by 2002, with 2 MW of power orders in 2000 and 4 MW per year in 2001 and 2002.

The military could use fuel cells with renewably produced hydrogen to replace diesel at remote stationary facilities and communication sites. These opportunities have begun to be identified and developed beginning in 1999. There could be up to 5 MW per opportunity each year for these applications beginning in 2000.

The combination of these activities could lead to the achievement of the near-term goals for hydrogen power generation, assuming that sufficient production capacity is available to produce and install 50 MW of PEM, phosphoric acid, and molten carbonate fuel cells. Nonattainment areas would be prime candidates for siting hydrogen-powered fuel cells near customer loads. The difficulty and costs associated with obtaining new or expanding existing transmission right-of-ways in urban nonattainment areas, such as Los Angeles

(California), make renewable hydrogen-powered fuel cells an attractive option that by itself could satisfy the goal of 50 MW of hydrogen fuel cell generation by 2002. In addition, discussions about sequestering carbon may result in wellhead or minemouth hydrogen production which would enhance achievement of that goal. Finally, MSW conversion to a hydrogen-rich gas, perhaps with CO_2 separation using a molten carbonate fuel cell, is being considered for demonstrations in roughly 2.5- to 5-MW sizes at four locations: Los Angeles (California), New York State, Burlington (Vermont), and Chariton Valley (Iowa).

Roles:

Government

There are a number of actions that government might take to assure that 50 MW of fuel cells, operating on hydrogen, are installed by 2002.

1. The government should increase its funding of fuel cell research, development, and demonstrations to show increased performance and reliability.
2. The DOE should continue to organize project teams and financially support projects that demonstrate renewably produced hydrogen coupled with hydrogen storage and power produced from fuel cells.
3. In environmentally sensitive areas with high power costs, the government should provide a combination of subsidies, low-interest loans, and loan guarantees to encourage these remote power systems in Alaska, Native American Reservations, and other remote sites without a fuel infrastructure.
4. In addition to fuel cells, a program should be created to provide for microturbines operating on hydrogen in remote areas as an interim measure.
5. DOE should cost-share the qualification of microturbines operating on hydrogen.
6. DOE should provide technical assistance to project teams and state and local governments on implementing renewable projects using hydrogen and fuel cells.
7. DOE should have a program for large size hydrogen fuel cells for the purpose of applying advanced materials and fabrication techniques to the manufacture of fuel cell stacks and components.

Industry

1. Work with government to apply technology that develops improved and less costly projects.
2. Develop and apply new manufacturing techniques, thereby lowering costs.
3. Develop codes and standards that assure the safe use of the remote power systems, including ISO standards to enable trading of hydrogen power and hydrogen fuel across borders.
4. Define the market and educate customers on the benefits of remote power and other hydrogen technologies.

5. Solicit interest of cooperatives and municipal utilities in Alaska and throughout the west to install remote hydrogen systems in areas with high price electricity, no fuel infrastructure, and environmental problems.
6. Convey to government the needs of industry and the requirements to commercialize products derived from hydrogen technologies.
7. Act collectively to address insurance, government funding, and financial sector issues.

Barriers:

The primary constraint on remote hydrogen generation from fuel cells is economical. Power is inexpensive in the United States. For a fuel cell to compete with other generation sources, its price must be reduced dramatically. Remote power applications offer the best opportunities for fuel cells to compete economically. Generally speaking, the cost of the hydrogen should be under US$10/MMBtu to be competitive with other energy sources. Fuel cells at customer sites with a use for the waste heat must be acquired and installed at a cost under US$2,000/kW.

Research and development is required to improve the performance and lower the cost of all renewable, storage, and fuel cell technologies. Funds must be available to provide technologies that can produce hydrogen renewably for the price of gasoline. Storage technologies must be developed to allow cheap, safe hydrogen storage. Finally, fuel cell technology must advance to improve efficiency and reduce resource depletion.

Safety is a prime consideration for stationary fuel cells. As fuel cells come closer to the customer, codes must be written and building inspectors educated to allow the introduction of renewable fuel cell power systems. Standards are being developed for on-board hydrogen, but these efforts must be expanded to include standards in building codes and for on-site hydrogen production, storage, and use at industrial sites. Codes and standards activities along these lines are underway.

Difficulty in obtaining insurance is of prime concern for siting hydrogen projects. Efforts must be undertaken for the government to provide a layer of insurance coverage. In addition, insurance companies must be educated as to the proper handling of hydrogen and the associated risks. This would allow for property, liability, and efficacy insurance to be offered at reasonable rates.

Public outreach is necessary for the development of hydrogen technologies. The public perception is that hydrogen is dangerous. EPA lists hydrogen as a hazardous chemical. The public requires positive experiences in using hydrogen at work or in transportation to overcome negative perceptions. Children can be educated at school with a curriculum that includes studying hydrogen as a renewable, nonpolluting energy source.

Recommendations:

The following recommendations are made to allow us to achieve the goals expressed in the NHA's *Hydrogen Commercialization Plan.*

1. The Department of Energy (DOE) should fund several remote power demonstrations in locations that are likely to be fertile markets for those systems in the near-term.
2. DOE should follow up those efforts with a project office for each market for the purpose of fostering the development of teams to pursue addition projects. These project offices would consist of small teams funded by DOE and lead by industry, that could guide new projects through the technical, institutional, and financial issues associated with remote power generation with hydrogen.
3. DOE should set up an Renewable Finance Corporation for the purpose of providing and administering subsidies, low-cost loans, and loan guarantees for renewable hydrogen projects. Such an office would develop with industry financial and safety standards that all projects must meet to qualify for project funding.
4. Demonstration projects that are of high visibility must be performed to expose the general public to hydrogen technologies, and information on these demonstrations must be widely disseminated. For example, renewable demonstrations at high visibility sites like Disney World or university campuses would be ideal.
5. Organizations serving rural areas, like the National Rural Electric Cooperative Association, must be stakeholders in cost-effective renewable demonstrations which lower their customers' cost of power with federal support.
6. Qualifying microturbines might be one way of qualifying cost-effective power generation on hydrogen in the near-term.

<u>Industry</u>

1. HTAP should increase its scope to include fuel cells in its review and encourage the measures that materially reduce the cost of fuel cells and increase their reliability.
2. Industry should put a greater emphasis on hydrogen in policy efforts to assure continuation of the Hydrogen Future Act and full funding of the hydrogen authorization under that act.
3. Industry should develop a unified position on the financial aspects of commercializing hydrogen power generation that includes subsidies, tax credits, low-interest loans, and insurance.
4. Industry should develop a plan to regularly meet with DOE officials to present these views in a united manner.
5. Industry must take the lead in developing codes and standards that assure safety of life and property in the use of hydrogen.
6. Industry should study restructuring and determine its likely effect on remote power, renewable systems, and fuel cells, and develop policy positions that encourage the development of hydrogen power generation.
7. Industry should identify the conditions that make renewably produced hydrogen power increasingly more attractive and test markets with those conditions.

8. Qualification for home and business use of fuel cells and hydrogen storage should be systematic and government should have a simple set of permitting, zoning, and licensing rules that does not encumber the deployment, installation, and servicing of hardware.

Academia

The academic community can support stationary fuel cell deployment by conducting research on new materials and fabricating techniques, improving efficiency and advances in balance of power plants. NREL, national labs, and universities should be adequately funded to perform these activities.

In addition, colleges and universities have the responsibility to develop the technical personnel to build, design, operate, and maintain fuel cells.

SUMMARY

Progress is being made to achieve the core near-term goals of the National Hydrogen Association's *Hydrogen Commercialization Plan*. These goals are achievable on schedule if the authorizations under the Hydrogen Future Act of 1996 are fully funded and the act extended for five years beyond 2001. It is industry interest that will raise this to a priority both at DOE and in Congress. In addition, a number of government agencies have a role in making these goals achievable. The federal government has a wide range of means to enable, promulgate, and purchase hydrogen and related technologies. These methods must be mobilized to require use of hydrogen technologies in areas under its control and to move from first applications to general use by the federal government. The new industries created by such activity will then seek out opportunities in the commercial sector. Here, again, government can help by encouraging the use of new techniques and materials, by providing incentives to the customer, by facilitating the formation of teams, and by helping to identify and create markets abroad.

Many of the recommendations in this Plan relate to what government at both a federal and local level can do. There is also much that industry can do. It needs to develop a clear vision of how to work with government and other commercial partners to develop sustainable and profitable ventures. In some instances, where the goals are common, it is desirable to act collectively through organizations like the NHA. Policy activities, codes and standards, and information exchange with DOE are probably best handled collectively. Project-specific activities are probably best handled by individual teams directly with the appropriate government agency. Organizations like the NHA remain a method of disseminating information about an activity in order to stimulate others to think along similar lines.

Education is one of the most important aspects of enabling widespread use of hydrogen technologies. The hydrogen industry is moving into demonstrations and field tests that must be carefully selected to assure high performance and visibility. To assure favorable public reaction, the technology must be displayed in a manner which highlights its advantages. This means that demonstrations that test technology that is not commercially ready should not take place in high visibility environments such as Disney World.

Finally, hydrogen is the fuel of the future. The question is whether the future is now or two generations from now. The near-term goals of the *Hydrogen Commercialization Plan* put us in the position to commercialize hydrogen-related technologies in the next 15 years. If the hydrogen community achieves these goals, then it is in the position to systematically begin commercializing buses, cars, and stationary power — along with their infrastructure — in about 2004. The next planned implementation plan in about 2003 or 2004 will be a commercialization plan for large-scale deployment of technology for the general public. This success will allow us to skip a 60-year period of slow and steady progress in hydrogen development.

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[1] Near-term in this activity is defined as the first goals in each of the market areas that may be realized in the 2000-2005 time period. BACK
[2] Taken from *The Hydrogen Commercialization Plan,* adopted in November 1996. BACK
[3] Taken from *The Hydrogen Commercialization Plan,* adopted in November 1996. BACK

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Appendix A
List of ISO/TC-197 Standards

International standards already published are:
ISO 13984: Liquid Hydrogen – Land Vehicle Fueling System Interface
ISO 14687: Hydrogen Fuel – Product Specification

Standards under development are:
ISO/CD 13985: Liquid Hydrogen – Land Vehicle Fuel Tanks
ISO/WD 13986: Tank Containers for Multimodal Transportation of Liquid Hydrogen
ISO/WD 15594: Airport Hydrogen Fueling Facility
ISO/WD 15866: Gaseous Hydrogen Blends and Hydrogen Fuel – Service Stations
ISO/WD 15869: Gaseous Hydrogen and Hydrogen Blends – Land Vehicle Fuel Tanks
ISO/WD 15916: Basic Requirements for the Safety of Hydrogen Systems
ISO/AWI 17268: Gaseous Hydrogen – Land Vehicle Fueling Connectors