Industry Report on the DOT Gap Analysis

Prepared by the *National Hydrogen Association*
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Acknowledgements

The National Hydrogen Association (NHA) staff and Codes & Standards Steering Committee prepared this Industry Report on the DOT Gap Analysis, with support from the US Fuel Cell Council, the National Renewable Energy Laboratory, and the National Hydrogen & Fuel Cell Codes & Standards Coordinating Committee (NHFCCSCC). The NHA would like to thank a number of contributors and reviewers for graciously donating their time; their input and constructive criticism has been very helpful. In addition, this industry report would not have been possible without the support of the hydrogen industry and their willingness to share information and experiences. Any errors or omissions are the sole responsibility of the NHA.

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Introduction

Codes and standards have repeatedly been identified as a major institutional barrier to deploying hydrogen technologies and developing a hydrogen economy. Industry has come a long way in the past 10 years identifying needed standards for commercialization of hydrogen energy systems, and participating with Standards Development Organizations to develop these standards. In the past 5 years, industry has again come forward to support changes to the US model codes to allow the installation of hydrogen energy systems, including stationary applications and hydrogen refueling stations. These efforts, of course, must continue to meet commercialization timeframes.

Some hydrogen requirements are based on other fuels, such as natural gas, or based on industrial quantities and uses for hydrogen. Research is needed to complete some of the developing codes and standards, and to validate requirements for the intended quantities and uses.

Concurrent with continued development of appropriate codes and standards to ensure high levels of safety and environmental protection, industry must now review the current state of regulations that pertain to the transport of hazardous materials and determine whether they are adequate for the envisioned hydrogen economy.

In its report entitled *Hydrogen Infrastructure Safety Technical Assessment and Research Results Gap Analysis*, DOT-T-06-01, April 2006, (DOT Report) the U.S. Department of Transportation (DOT) has recently provided a starting point for assessing existing regulations, and determining where research is needed to revise existing regulations or develop new regulations, and where amendments may be necessary to enable the hydrogen infrastructure. DOT has identified the status of applicable regulations for hydrogen infrastructure. DOT is actively encouraging stakeholder feedback on its report to assist in prioritizing future efforts.

Industry is very sensitive to the potential for enforceable standards or regulations to be implemented prematurely, which have the potential to hinder, rather than help, the advancing hydrogen economy. There are areas in the country now where local regulatory agencies are moving forward with regulations before the data necessary to support these regulations are available. This rush to regulation has the potential to stifle technology innovation or worse – simply make it impossible to commercialize the very technologies the regulations are meant to encourage.

Industry has been consistent with the message that until enough is known to allow commercialization decisions, guidelines and technical reports should be developed in lieu of standards and regulations. The information in these documents can be applied, at the appropriate time, to the development of standards and regulations. Therefore, the final report may address areas where additional information is required before standards and regulations can be put in place. In addition, a number of activities that are developing recommended practices, technical reports, national and international standards, and model codes, while not directly applicable to DOT's focus, may contain data and rationale that may be useful in establishing regulations appropriate for hydrogen infrastructure. It is important to note that these development activities are still in process, and industry is using information from these activities to generate the "best practices" that are necessary in advance of regulations in these areas.

Procedure

An important aspect of the *Industry Report on the DOT Gap Analysis* is the view of various industry sectors that are involved in the development of the hydrogen infrastructure. Research began by making the DOT report available to all interested stakeholders and inviting them to provide feedback. This began with the NHA's Codes & Standards Steering Committee, and was expanded to include the US Fuel Cell Council and National Renewable Energy Laboratory. Two articles describing the report and inviting stakeholder input were published in the NHA's *Hydrogen and Fuel Cell Safety Report*, an electronic publication that is freely available to all interested parties at www.hydrogenandfuelcellsafety.info.

Another critical component of the *Industry Report on the DOT Gap Analysis* is the Hydrogen Codes and Standards Matrix. The National Renewable Energy Laboratory (NREL) developed a draft matrix containing the U.S. codes and standards pertaining to hydrogen. The format of NREL's matrix was modified to be user-friendly by Kelvin Hecht and posted online at www.fulcellstandards.com. Mr. Hecht works with industry as well as codes and standards development organizations to keep the information updated. The DOT report provides an opportunity to utilize the matrix to fill in some gaps, as well as to confirm the existence of gaps that had not been identified previously.

PDF files of the Matrix for Stationary, Transportation, Portable, and Infrastructure applications are available from Mr. Hecht's website, www.fuelcellstandards.com. The PDF file for Infrastructure applications is included in the Appendices to aid review of this industry report. It is important to note that the codes and standards shown in the Matrix are developing rapidly. Therefore it is advisable to review the Matrix online at www.fuelcellstandards.com periodically for the most up-to-date information regarding the status of the developing codes and standards. The NHA would like to work with DOT to cross-reference the matrix with the DOT report to fill in any available information on codes and standards that may be in development to address the areas of the DOT report.

The NHA provided a copy of the draft report to the US Fuel Cell Council and the National Hydrogen & Fuel Cell Codes & Standards Coordinating Committee for comments and review. These comments, as well as those received on September 15, were then incorporated into this final report.

Issues Raised by the Industry Sector

This section of the report provides feedback received by industry on the DOT report, including concerns that are currently not addressed in the DOT report. In some cases, these may not relate directly to activities in DOT's purview. They are included here to be inclusive and to assist DOT in understanding industry's priorities. Additional work may be needed in advance of some of the regulatory work described in the DOT report. In many cases, industry feels there is a role for DOT in resolving the issues. These are explained below in the context of the issues raised.

Issues from Original Equipment Manufacturers (OEMs)

The following is a brief summary of Original Equipment Manufacturers input to the report.

<u>After Market Enforcement:</u>

It was noted by the OEM sector that DOT should also look at how regulations will be enforced on after-market repairs and end-of-vehicle life. For example, DOT will have requirements that

storage tanks not be returned to service without requalification following a crash or at the end of the tank service life. Some consideration regarding how this will be enforced is requested. During an in-person meeting of the National Hydrogen and Fuel Cells Codes and Standards Coordinating Committee (NHFCCSCC) on September 15, participants discussed possibilities in this regard. SAE is including statement in its tank document to say tanks should not be moved between vehicles, although it cannot really be prevented. State periodic vehicle inspection is one option, although not all states require this.

Tanks may have a certain number of fills before they "expire". This is also a concern for stationary tanks. Tanks may be requalified. Some vehicle repair facility issues are best handled by the states, although the Federal government may have a role in some cases. It was agreed that industry and regulators need to think about how much of this issue pertains to repair facilities, repair personnel, and enforcement, and develop appropriate safeguards and education.

OEMs are less concerned about fueling stations since local Codes (ICC or NFPA codes and CSA dispenser standards) should be operative by the time vehicles are truly commercially available in the marketplace. However, OEMs would be concerned if onerous premature requirements prevented infrastructure deployment, and thereby, prevented access to drivers for refueling.

There are numerous recommended practices and technical reports being developed by the SAE Fuel Cell Standards Committee, which utilize input from OEMs, fuel cell developers, and on-board storage system manufacturers. The safety and technical justification for much of this material may be of use to DOT as regulations are developed.

Hydrogen Infrastructure

Bulk hydrogen suppliers raised the following issues. They are considered potentially serious roadblocks to the development of an infrastructure to support hydrogen vehicle fueling in the United States.

Shipping small quantities:

The first issue is the challenge of shipping the small sample quantities necessary for verifying hydrogen quality at fueling stations. Samples would be shipped back to analytical laboratories.

Existing shipping procedures are recognized as difficult to implement. An ASTM team that is developing hydrogen sampling standards is making progress using standard analytical methods, but getting small quantities shipped through common carriers is very difficult. The quantities allowed to be shipped are small (typically 1 liter, 10g/l at 1500 psig) with a maximum pressure during shipment of 500 –1500 PSIG.

Hydrogen suppliers believe that industry should be able to put a sample cylinder in a car and carry it to a sampling site. Industry should be able to ship the samples via common carrier. If DOT exemptions or CFR rules allow either of these forms of transport, they are not well understood and NHA would be interested in helping DOT to disseminate that information. Otherwise, DOT may need to establish new exemptions - special permits and CFR rules to make

it easier to ship small quantities of hydrogen to support fuel quality testing.

Composite storage:
At present, composite tanks in passenger cars are not approved for ground storage or for commercial transport of gases. Therefore it is not possible to use 350bar and 700 bar composite storage vessels to take samples for hydrogen fuel quality testing at stations without using pressure reducing valves because DOT exemptions for their transport are lacking. There is a need to gain industry consensus on the suitability of composite storage cylinders for ground storage and commercial transport.

During the NHFCCSCC meeting on September 15, DOT indicated that there are approved cylinders, and other cylinders can be used with special exemptions. It is also possible to petition the HazMat office for a rule change, if necessary. It was also noted that an exemption is possible as a 'material of trade.' Cylinders are covered by 49 CFR 173.6 B5. Approved packaging is required. Clarification is needed as to whether a sample can be considered a material of trade. Industry has indicated that composite cylinders have not been approved under this process in the past. There is a continued need for a small 700 bar composite cylinder that can be shipped. Industry requests DOT assistance in helping to achieve this.

ASME has a task force working on use of composite storage systems for hydrogen. CGA has recently developed and approved PS-26, which gives guidelines for use of composite tanks in ground storage in the interim period. This is expected to be published in the spring of 2007.

DOT will require a special permit for high-pressure transport. DOT recently updated their rule making based on ISO 11119 for composite tanks.

It is not clear that the samples need to be transported, or tested, at the working pressure. There is a need to gain industry consensus on the suitability of composite storage cylinders for ground storage and commercial transport, as well as clearer requirements on the pressures for samples, as required in the hydrogen fuel quality specifications (and future California regulations).

Odorization of Hydrogen:
The second issue is cited in DOT's gap analysis as area 16.11, *Odorization of Gas*, which has a DOT criticality rating of high, and is considered in the DOT report to not be addressed. Subpart L of 49 CFR 192 states that "a combustible gas in a distribution line must contain a natural odorant or be odorized so that at a concentration in air of one-fifth of the lower explosive limit, the gas is readily detectable by a person with a normal sense of smell."

A natural odorant compatible with hydrogen use in fuel cells has not been identified and validated, and equipment and processes to remove odorants at each point of use are not practical. In addition, the issue of detection must apply to both gaseous and liquid hydrogen. Industry must either find a workable odorant or come forward with alternatives to current odorant requirements that preserve the level of safety intended by the regulation. For example, the regulation might be amended to include other methods of leak detection. The NHA would like to work with DOT to address this topic.

During the NHFCCSCC meeting on September 15, it was noted that odorization may not be required until 2010-2012. It was also noted that the CFR statement is based on the Lower Explosive Limit, rather than the Lower Flammability Limit, which may be more appropriate for hydrogen. Industry noted that consideration must be given to the amount of odorant that would be required to meet the eventual requirement, assuming a suitable odorant could be identified. The discussion generated on this topic reaffirmed that this issue is multi-faceted. Consideration should be given to research to identify a suitable odorant, as well as mechanisms to revise the regulation in order to meet the true intent – safety by detection.

Industry requested further clarification on what is done currently with hydrogen pipelines and other forms of transport, as well as transport of other fuels. For example, is hydrogen currently odorized for use in pipelines? Are all other fuels? Hydrogen is transported across state and country borders today. Industry is interested in understanding what triggers the need for additional regulations, and what is done for other fuels today. By fully understanding the triggers and how other fuels are treated with respect to regulations, industry can better address issues of timing for meeting a trigger point, as well as how the anticipated use of hydrogen might be similar to or different from other fuels at various trigger points.

DOT is working with the National Association of State Fire Marshals on LNG work that will carry over to hydrogen. There are currently regulations at DOT for validating hydrogen pipelines. It is important to note which requirements apply to transmission pipelines versus distribution pipelines. CFR 49 applies to piping into homes (distribution). Transport by truck or other methods do not require odorization. Descriptions of transmission and distribution lines are shown below, and are available on the DOT website at http://www.phmsa.dot.gov/media/pipeline_qa.html.

Pipeline systems consist of a few major components:

- *Pipelines that collect products from sources, such as wells on land (**gathering lines**) or offshore, or from shipping, such as tankers for oil or liquefied natural gas (LNG). These systems move the product to storage, processing (such as treatment for gas or refining of petroleum)*
- ***Transmission pipelines** that transport large quantities of hazardous liquids or natural gas over longer distances; transmission lines deliver natural gas to distant power plants, large industrial customers and to municipalities for further distribution; petroleum transmission lines deliver crude oil to distant refineries or refined products to distant markets, such as airports or to depots where fuel oils and gasoline are loaded into trucks for local delivery;*
- ***Distribution lines** are a part of natural gas systems, and consist of main lines that move gas to industrial customers, down to the smaller service lines that connect to businesses and homes throughout a municipality.*

Training:
The third issue is training. Area 20 of the DOT report describes 49 CFR 172.700-172.704 regulations pertaining to training requirements. Industrial gas suppliers provide training to employees, and offer training to customers. Hydrogen suppliers agree that safety training for

refueling station resupply and maintenance personnel is needed. There are a number of training opportunities, including those offered by industrial gas providers. The US Department of Energy has developed a basic hydrogen training module and plans to expand it for specific target audiences. The National Hydrogen Association also offers workshops in properties of hydrogen, often calling upon the expertise of industrial gas suppliers as presenters. Industry continues to be supportive of efforts to provide safety training.

Training certification in hydrogen safety is required in areas where training certification is required for other fuels; for example, pipeline maintenance. In other areas, such as vehicle refueling, NHA will enthusiastically work with industry, DOT and other regulators to ensure education in safe hydrogen practices is available and disseminated broadly. In some areas, training is required for natural gas fueling. This training is sometimes implemented via video displays incorporated into natural gas dispensers. The first time a customer uses a facility (or network of facilities), a short video covering basic safety and operational procedures is shown and fueling is disabled until the video finishes. This is due to the unfamiliarity of the user with the equipment, its operation, and basic safety practices. This type of training may be appropriate for hydrogen refueling in some areas as well.

There have been organizations that are attempting to create personnel certification programs for hydrogen where they are generally not required for other fuels. The hydrogen industry recognizes that perceptions can lead to false impressions, and are concerned that any program that requires "special training" and certification for hydrogen and not other fuels, such as gasoline and natural gas, may lead to a misperception that hydrogen is somehow less safe than other fuels. Therefore we would want to ensure that these misperceptions couldn't occur by discouraging efforts to require certification for hydrogen where it isn't required for other fuels. Industry does support training in the normal sense, where personnel who will be working with hydrogen can understand hydrogen's unique properties and are trained in handling hydrogen safely. Industry would like to work with regulators to ensure hydrogen safety training is available and adequate, yet does not constitute unusual requirements for hydrogen use.

Industry is therefore interested in working with DOT to understand the training requirements in 49 CFR, and determining how best to meet them.

Fuel Cell Manufacturers

Input from fuel cell manufacturers indicated the following issues, identified in the DOT report, which may adversely impact the hydrogen and fuel cell industry. Additional dialog between DOT and industry is requested so that efforts in these areas are scoped appropriately, and do not inadvertently create barriers for hydrogen.

Investigation of Failures (16.7) Generate a risk assessment tool with SNL and NREL. This tool is envisioned to be incorporated into the language of 49 CFR 192.

Compressor Stations Gas Detection (17.9) Adopt standards for gas detection and incorporated into the language of 49 CFR 192.

Odorization of Gas (16.11) Require an appropriate odorant at an appropriate concentration for hydrogen distribution pipelines. When this is decided upon, the requirement will be incorporated into the language of 49 CFR 192. The specialty gas companies have objected to odorizing transmission pipelines. Members of fuel cell industry are also on record against odorants at this point in time.

The following cross-cutting research topics identified in the DOT report support development activities for standards and may indirectly benefit the fuel cell industry:

- Effects of non-hydrogen constituents in a fuel grade hydrogen on the containment materials.
- Effects of pressure and temperature on hydrogen embrittlement and hydrogen attack on containment materials.
- Effects of pressure and temperature on composite reinforced pipe.
- Effects of a fuel grade hydrogen on plastic pipe materials.
- Fatigue crack growth in hydrogen.
- Test Methods for qualifying materials for piping, pipelines and storage containers.

Portable Power Suppliers

During the NHFCCSCC meeting on 15 September, one portable power supplier shared three specific points that generated some discussion:

1. The DOT reference to the progress of Portable Power devices is not up to date. The manufacturer has many units in many different applications.
2. While there are special permits to ship metal hydrides, there are limitations such as the ONLY major carrier in the U.S. that will take the Special Permit is DHL. FedEx and UPS will not. This really limits the business and as a whole does not promote an effective hydrogen economy.
3. While manufacturers are able to ship hydrogen canisters to customers, the customers are finding huge challenges with the local fire department officials. The interpretation of fire codes, as well as the adoption of numerous editions by local entities, creates great disparity and huge inconsistencies in what customers must do to utilize hydrogen for portable products.

While these issues may seem to be outside of the DOT purview, DOT is in a position to facilitate resolution through clarification of the permits for metal hydrides, and education and awareness campaigns aimed at code officials and shipping carriers.

Discussion of Gaps

One comment received from several industry sectors was that the tone of the Executive Summary and Introduction in the DOT report seemed unduly pessimistic. It was only after further investigation that the readers could appreciate the tone and intent of the document. Several commented that they had the initial impression that codes, standards, and regulations for hydrogen infrastructure will not be ready to support a timely deployment of hydrogen for transportation. In fact, much more has been done than is described in the report. For this reason the next section addresses the codes and standards that relate to activity that is not mentioned in the report. In addition, the relevant PDF file on hydrogen infrastructure from www.fuelcellstandards.com is attached to this industry report.

In reviewing the matrix of hydrogen rule-making activities, it is remarkable how many categories of issues are being addressed. Two areas that are not being addressed are:

1. The interface between the portable system and end-use (which includes standard connections for power and fuel for small portable devices, such as cell phones, laptops, games, etc.); and
2. Home refueling and storage. The use of portable refueling devices may have additional regulatory implications, as it may be used at home as well as on the road. It is also worth noting that the U.S. and Canada follow similar standards approaches and have a number of standards such as many from NFPA in common. A discussion of recent efforts to develop codes and standards for hydrogen energy systems, including fuel cells, is provided below.

Stationary Applications

The U.S. has several national efforts to develop national standards for fuel cells. ANSI, CSA, UL, IEEE, ASME, NFPA, and ICC are all involved in national efforts. International efforts that the US is supporting include IEC TC 105, which is developing international standards for fuel cells; and ISO/TC 58, which develops standards on hydrogen tanks and includes embrittlement tests.

The current Matrix for stationary applications can be found at www.fuelcellstandards.com.

Transportation Applications

U.S. efforts in onroad vehicles standards are led by SAE, which is developing industry best practices for fuel cell electric vehicles, including fuel systems, onboard fuel processors, safety, refueling interfaces, emissions, and recyclability. Complementary ISO standards are under development for vehicle safety, on-board storage and the vehicle and refueling interface. Similarly, SAE and ISO are developing complementary hydrogen fuel quality standards. There remains development needs on O&M issues, safety systems, and testing and evaluation. CSA CAS No. 33 is a published standard on component acceptance service for PEM fuel cell modules. CSA is developing standards for compressed hydrogen gas containers based on CNG

requirements. ANSI/CSA expect to develop and publish standards for fueling connection devices, pressure relief devices, dispensing systems, hoses, and breakaway connections for CHG vehicles.

The international community is dealing in a comprehensive way with hydrogen-fueled vehicles and hydrogen fuel quality for fuel cell powered vehicles. ISO has developed a standard for on-board liquid hydrogen storage. Japan has the largest government activity related to vehicle hydrogen regulations, and the EU is considering regulations. The U.S. has a number of standards activities related to O&M and Testing and Evaluation, which SAE is developing.

There are also efforts for off-road vehicles. For example, UL 2267 relates to fuel cell powered forklift trucks.

The current Matrix for transportation applications can be found at www.fuelcellstandards.com.

Portable and Micro Applications

Manufacturers of portable hydrogen systems have indicated that some current products and applications have been omitted from the DOT Gap Analysis. Off-grid power solutions for a variety of applications are currently available, including cameras, laptops, communications, and campers. In addition, portable hydrogen refuelers are available.

The definitions for "portable" and "micro" vary. It is advisable to review the scopes of the standards within the matrix to understand the actual size limitations on each standard. CSA CAS No. 33 contains specifications for providing CSA International component acceptance service for PEM fuel cell stacks. CSA is developing standards on portable fuel cell power generators and portable fuel cell appliances. UL is developing standards for gaseous hydrogen generating appliances, replacement fuel cell power units for appliances as well as an outline investigation for portable PEM fuel cells with or without uninterruptible power and for factory installation in OEM equipment for indoor use. ASME PTC 50 covers testing procedures for fuel cell power system performance. There is international standards development by IEC TC 105 on portable fuel cells and by ISO/TC 197 on hydride storage containers for hydrogen. A standard exists for fuels for fuel cells and should be evaluated by fuel cell manufacturers as to suitability for their product. Standards or guideline may need to be developed for Interfaces between portable system and end-use and safety systems.

The major international activities with respect to portable applications are IEC 62282-5 Portable Fuel Cell Power Generators and the work group established by ISO/TC 197 on hydride storage for portable applications. In the U.S. UL and CSA also have or are working fuel cell and electrolyzer standards.

The biggest issue identified for portable and micro applications is shipping. As there are many standards available covering portable and micro fuel cells, as well as other hydrogen energy equipment, it is worth considering how these standards might be used to resolve the issues identified with shipping.

The current Matrix for portable applications can be found at www.fuelcellstandards.com.

Hydrogen Infrastructure

There is an extensive set of standards for hydrogen infrastructure that has operated for decades. National standards on hydrogen production are included in general requirements such as the National Electrical Code, NFPA 30 and CGA guidelines. UL 2264 is being initiated and will cover gaseous hydrogen generating appliances. ASME has published standards for pipeline distribution. DOT 49 CFR covers transportation of hazardous materials. NFPA and CGA standards include stationary storage at commercial facilities. ANSI/CSA will develop hydrogen fueling station standards. NFPA is revising standards to include hydrogen refueling and service stations and repair garages. ICC has approved changes in the International Fire Code, International Fuel Gas Code, International Residential Code, International Building Code, and International Mechanical Code for hydrogen refueling stations, piping systems, fire safety, and garage ventilation.

In hydrogen infrastructure virtually every category of activity is being addressed. Hydrogen production and storage are being addressed nationally and internationally. Transport of bulk hydrogen is being addressed by the U.S., Canada and Japan, but not internationally. Specifically, there are no international standards being developed for hydrogen pipelines. Hydrogen refueling stations standards are only now being addressed internationally. There are no national standards for hydrogen refueling stations in place, although some activity at CSA has begun, and work at SAE ties into the needs for refueling vehicles. There are no international standards being developed in the areas of buildings and safety and emergency response. The NHA would like to work with DOT in addressing regulations where infrastructure crosses state lines or is otherwise under the purview of DOT.

Appendix A contains the current Matrix for hydrogen infrastructure.

Conclusions

Industry has come a long way in the past 10 years identifying needed standards for commercialization of hydrogen energy systems, and participating with Standards Development Organizations to develop these standards. In the past 5 years, industry has again come forward to support changes to the US model codes to allow the installation of hydrogen energy systems, including stationary applications and hydrogen refueling stations. These efforts, of course, must continue to meet commercialization timeframes.

Concurrent with continued development of appropriate codes and standards to ensure high levels of safety and environmental protection, industry must now review the current state of regulations that pertain to the transport of hazardous materials and determine whether they are adequate for the envisioned hydrogen economy.

The U.S. Department of Transportation (DOT) has provided a starting point for assessing existing regulations, and determining where research is needed to revise existing regulations or develop new ones, and where amendments may be necessary to enable the hydrogen

infrastructure. DOT has identified key areas for hydrogen infrastructure, and the status of applicable regulations in those areas.

Hydrogen Infrastructure Safety Technical Assessment and Research Results Gap Analysis, DOT-T-06-01, April 2006, highlights the current state of key areas, and the criticality of these areas. It also assesses the current state of codes, standards and regulations for these areas. In many cases, regulations have not yet been addressed. In some cases, specific industry input on key recommendations is required to ensure the regulations are developed at the appropriate time to facilitate commercialization. It is important to industry that binding requirements, such as codes, enforceable standards, and regulations are not developed prematurely, so as to prevent the unintended consequence of constraining use of technology advances needed to achieve commercial feasibility. Likewise, it is important that commercialization is not impeded by the lack of necessary regulations.

Coordination between industry, DOT, and DOE can facilitate smooth commercialization of hydrogen and fuel cell systems. By working together, we can identify timely priorities to promote the necessary markets and commercial deployment. The industry supports the continuation of dialog among these stakeholders, as well as applicable state agencies, to study the range of codes, standards, and regulatory activities that are needed to ensure a smooth transition to a hydrogen economy, as well as the research to support them. The industry welcomes further dialog through the National Hydrogen and Fuel Cell Codes & Standards Steering Committee and other forums as may be deemed appropriate. The NHA and its partners in this report further support Federal funding for both the DOE and DOT research priorities, developed in collaboration with industry. It may be necessary to clarify and strengthen DOT's authorization to review and facilitate the introduction of advanced vehicle technologies, the specific areas where interagency cooperation is needed between DOT, DOE and DOD, and request specific funding appropriations in the Federal Budget. The industry may want to pursue these efforts with the Congress. Through continued coordination, research funding can be targeted at areas with the greatest needs, consistent with commercialization timeframes, and consistent to support related research work timetables, reducing the need for duplication of effort.

Appendix 1: Hydrogen Infrastructure Matrix