March 10th, 2015

Webinar to report out on:

The 2nd International Workshop on Hydrogen Infrastructure and Transportation

Torrance, CA, USA - May 8th-9th 2014

European Commission

NEDO New Energy and Industrial Technology Development Organization

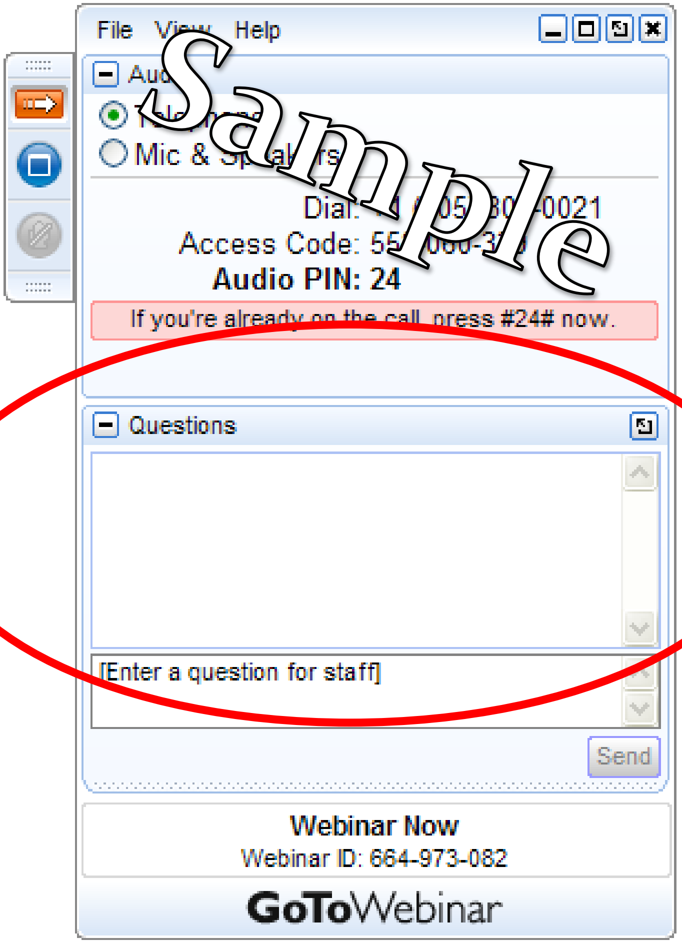
NOW National Organisation Hydrogen and Fuel Cell Technology

Scandinavian Hydrogen Highway Partnership

U.S. Department of Energy | Energy Efficiency & Renewable Energy | Fuel Cell Technologies Office

Questions and Answers

- Please type your question into the question box



Agenda

- Overview
- Hydrogen Infrastructure by Region
- Fueling
- Quality
- Metering
- Station Hardware
- Q&A

Overview

The 2nd International Workshop on Hydrogen Infrastructure & Transportation continued the work of the first workshop that was held in Berlin on June 24th-26th, 2013.

The workshop aimed to identify solutions, share experience, best practices and progress on four key issues facing hydrogen infrastructure fuel cell electric vehicles in the U.S. Europe, Germany, Scandinavia, and Japan.

- H_2 Fueling
- H_2 Quality
- H_2 metering
- H_2 Station hardware

Participants were asked to present on the current status in their regions and then participate in break out sessions to identify key priorities going forward

Europe Overview

Activities and Policies:

- The Directive for Alternative Fueling Infrastructure Deployment (AFI) requires common technical specifications for infrastructure across the European Union (EU)
- Article 5 of the AFI addresses hydrogen, requiring that member states that adopt hydrogen infrastructure must build an acceptable network, with cross-border links, by the end of 2025.

Standardization:

By 2017 European standards are expected for:

- Fueling stations
- Hydrogen purity
- Filling protocol
- Connectors

FCH2JU Funding:

By 2016 it will be achieved:

- ~150 FCEVs and ≥45 buses
- 6 vehicle fueling stations and 8 bus fueling stations

Germany Overview

Activities and Policies:

- H_2-Mobility partners (Air Liquide, Daimler, Linde, OMV, Shell and Total) developed a joint venture to install and operate HRS.
  - achieve a maximum of 90-km between each HRS on the highways
  - with 10 HRS in each metropolitan area
  - Total invest. of roughly 350 million €
  - to deploy 400 HRS by 2023 (100 HRS by 2017).
- The joint venture started operation by the beginning of this year.

Funding:

- The National Innovation Program for Hydrogen and Fuel Cell Technology (NIP) provides €700-million € (from 2006 through 2016)

By mid 2016 there will be 54 Hydrogen refueling stations (public and private funding is secured, applications are filed) within the Clean Energy Partnership

12 are currently in operation
6 will be operational by end of April 2015
16 locations are contractually fixed and in development
20 are in the final planning/negotiation phase

Scandinavia Overview

Activities and Policies:

- Scandinavian Hydrogen Highway Partnership (SHHP) includes member countries Norway, Denmark, and Sweden, as well as collaboration with Iceland.
- Target of 300 stations and 200,000 FCEVs by 2025
- ZEV vehicle purchases are exempt from the registration tax of ~100 - 180% in Norway and Denmark.

Funding:

- > 400M € have been spent on R&D for hydrogen fuel cell technologies to date

By 2016 there will be:
19 Hydrogen refueling stations
Norway – 7 HRS
Denmark – 11 HRS
Sweden – 1 HRS

Japan Overview

Activities and Policies:

- Strategic Energy Plan identifies hydrogen as a very important secondary energy source and its production, transportation, storage and utilization will be promoted by the Japanese government.

Funding:

- Funding of ¥7.2 billion ($70.4 million) from the ministry of Economy, Trade and Industry (METI) in 2014 for stations development.
- METI also supplies R&D funding of ¥3.25 billion ($31.8 million) to NEDO

Hydrogen Refueling Stations :

- By 2015, there will be 100.
- 41 are decided at present.
- As of end of February 2015, 9 are operating commercially.

USA overview

Activities and Policies:

- Multi-State Zero Emission Vehicle (ZEV) action Plan to put 3.3 million ZEVs on the road by 2025.
- California's ZEV program is intended to place 1.5 million ZEVs on the road by 2025
- H2USA – A public private partnership focused on advancing hydrogen infrastructure to enable fuel cell electric vehicle deployment.

Funding:

- ~$135M/yr funding for Fuel Cell Technologies R&D through the Department of Energy*
- ~$60M/yr funding for Fuel Cell Technologies through other agencies*
- $20M/yr from California Energy Commission to build 100 stations in California through 2020.

By 2016: 51 H_2 stations are planned in California

8 are open

43 are in development

Additional activities are underway in the Northeast.

*Based on FY14 and including stationary applications

Hydrogen Fueling

SAE J2601 (with SAE J2799) released in July of 2014 established a standard protocol for refueling of light duty fuel cell electric vehicles worldwide

- Protocol allows for a safe 3-5 minute fill for FCEVs with 2-10kg storage
- Standard Look-up table based approach with new features for robustness
- Validated with lab and field data (http://papers.sae.org/2014-01-1990/)
- Allowance for communication and non-communication fills
- The Alternative fueling methods, MC Method referenced in the appendix

Note: SAE J2601 (2014) cannot be directly referenced as a European standard; the AFI must refer to ISO/TS 20100 (revised as 19880-1) Gaseous Hydrogen Fuelling Station Standard

Fueling

Top 4 Fueling Challenges and Activities Identified	
Lack of a procedure and equipment to certify station performance relative to SAE J2601 -2014	a) Create a device to verify station performance for each market b) Develop/finish test procedures and goals to certify stations c) Identify 3rd party testers for certification d) Define frequency requirement for certification and work with ISO 19880-1 t
Lack of metering technologies which are accurate enough for the legal sale of hydrogen.	a) Focused industry-government project to enable more accurate and affordable mass flow meters (goal 1-2% FS accuracy).
Lack of standard station acceptance criteria	a) Lessons learned to assist in permitting stations needed b) Consolidate requirements (minimum criteria checklist) with input from OEMs, IGCs, and other stakeholders into ISO 19880-1 c) Training and Information for implementation for SAE J2601 standard d) Prepare requirements of how to implement the MC protocol SAE J2601.
High cost of fueling validation	a) Develop combined hydrogen "station test apparatus" for a one stop for station acceptance (e.g., metering, quality, fueling protocol, modified FCEV capable of performing the testing) b) Government issues RFQ to fund reasonably priced device to verify station performance c) Consider type testing at time of station manufacturing

Quality

⇒ The H2 quality requirements for FCEVs are defined in ISO 14687-2 (harmonized with SAE J2719)

- **Technical feasibility:**
  - Existing methods are still costly and time consuming
  - Reliability of the results is essential
  - Not all impurities defined are relevant to all fuel sources

- **Commercial feasibility:**
  - Analytical costs could be a show stopper for commercialization
  - New methodology for H2 quality assurance could be the cost reduction enabler short/mid-term
  - Sampling method, container and frequency are also key for cost-reduction

		ISO 14687-2 rev. 2012
Constituent	**Chemical Formula**	**Limits (µmol/mol)**
Hydrogen fuel index	H2	> 99.97%
Acceptable limit of each individual constituent		
Water	H20	5
Total hydrocarbons	(C1 basis)	2
Oxygen	O2	5
Helium	He	300
Nitrogen	N2	100
Argon	Ar	
Carbon dioxide	CO2	2
Carbon monoxide	CO	0,2
Total sulfur compounds		0,004
Formaldehyde	HCHO	0,01
Formic acid	HCOOH	0,2
Ammonia	NH3	0,1
Total halogenated		0,05
Particulate Concentration		1 mg/kg

Quality

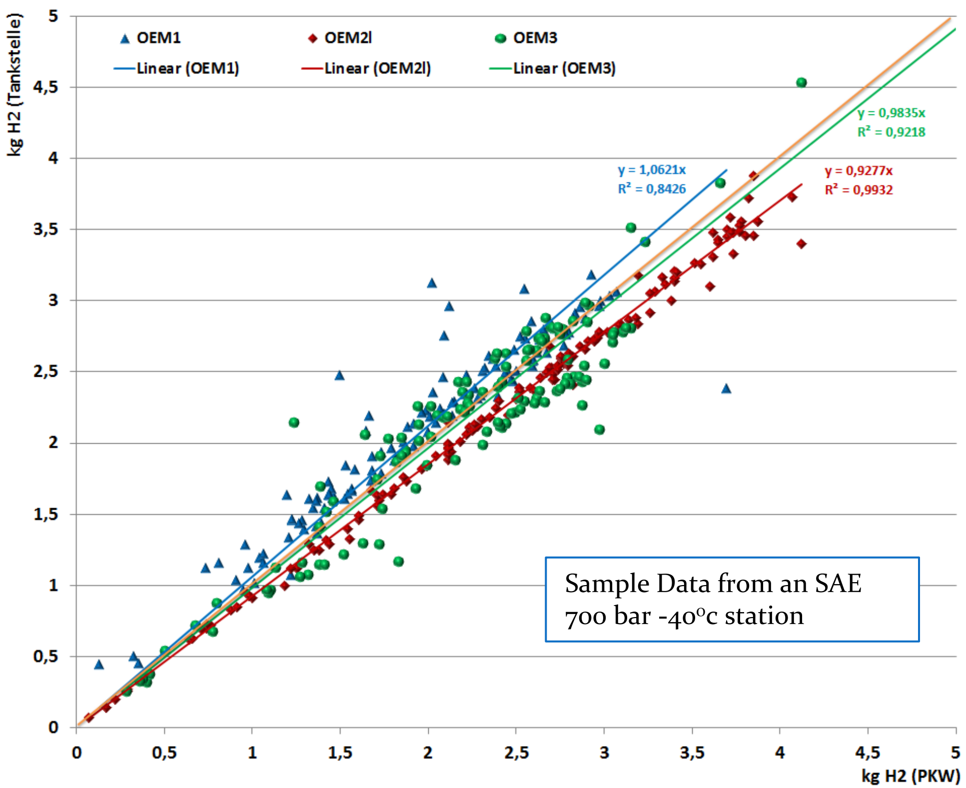
Top 4 Quality Challenges and Activities Identified	
Lack of in-line monitoring	a) Develop affordable continuous, in-situ monitoring device/system for use at the station
Cost reduction for analysis	a) Reduction of the number of chemical species which must be analyzed. b) Develop easy and affordable method for analysis and sampling
Standardization of sampling	a) Joint International Standards Organization (ISO/TC 197)/American Society for Testing and Materials (ASTM) sampling protocols, harmonization with ASTM D7606 b) International Partnership for Hydrogen and fuel Cells in the Economy (IPHE)/Regulation, Codes and Standards (RCS) working group round robin on fuel quality testing on stacks c) Adopt globally recognized (by ISO and national standards organizations) sampling for specific constituents per production method.
Station quality control (QC)	a) Identify critical parameters to monitor on-line b) Harmonize efforts to develop best practices and QC, e.g., ISO fuel quality working group

Metering

Metering accuracy requirements are variable depending on the region

- US – NIST standard is 1.5 %; California has made an exception of early stations
- CEP – no standard yet but weights and measure act allows 2% for CNG
- Japan – Requirement is not yet set

Comparison of Refuelling data Station (measured) - Car (calculated)



In Germany the analysis of more than 2,000 field data points in 2012/2013 reveals in average

- 11 % of all refuelings have a deviation below 2 %
- 44 % of all refuelings have a deviation below 5 %
- 20 % of all refuelings have a deviation above 10 %

Metering

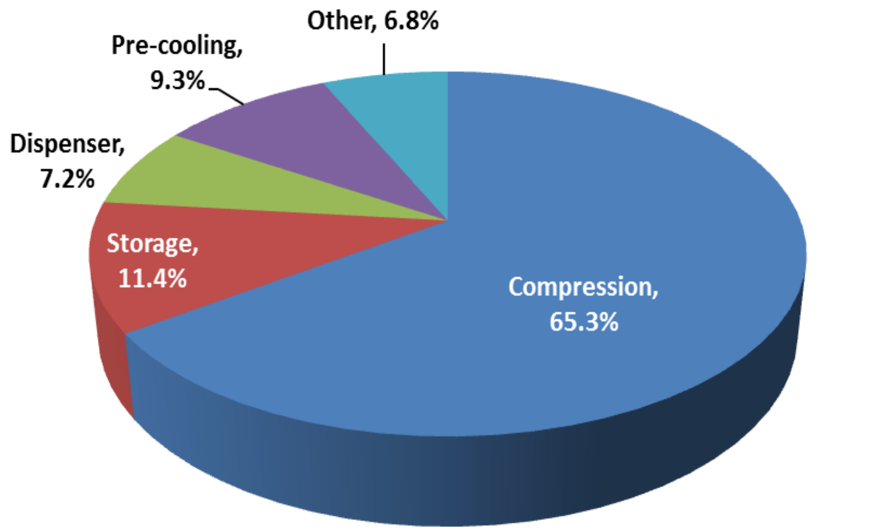
Top 3 Metering Challenges and Activities Identified	
Ambiguous definition of metering accuracy	a) Keep standardized refueling procedures for at least some years. b) Decrease hydrogen loss after filling through nozzle development c) Repeatability and accuracy should be improved d) Engage Weights and Measures community to establish the best guideline for each country e) OIML/MID adopted definition for accuracy f) Evaluation test for the dispenser system. Not for flow meter only. g) Exchange for meter test results, harmonize the test procedure h) Have common definition i) Define accuracy classes
R&D for Flow Measure	a) 100% public funded R&D contract/tender. 3-4 suppliers only to create high accuracy meters (competition) b) To reduce effect from temperature, season, country. Measure at same temperature/place, for example, after pre-cooling. c) R&D specific call within FCH2JU program coordinated with DOE d) Coordinate regional funding programs
International Cooperation	a) Standard requirements between NIST and International Organization of Legal Metrology (OIML) b) Arrange workshop for all "weight and measures" people c) International round robin to R&D flow meter d) Start with standardization nationally (US) adoption of accuracy classes, adopted from California, then propose these to OIML, EU/Measuring Instruments Directive (MID) e) Organize regional workshops with authorities f) IPHE RCS working group

Hardware

The cost and reliability of station hardware remains a key challenge to successful commercialization.

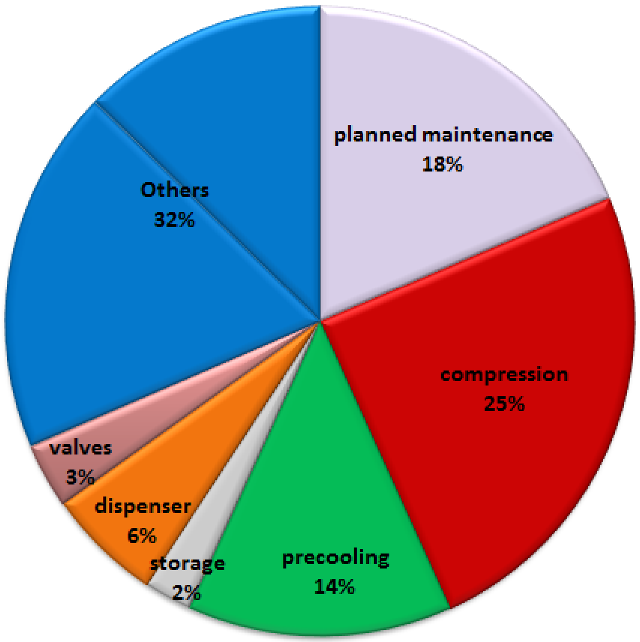
The top components to be addressed are:

- Compressors
- Dispensers
- Pre-cooling equipment



Station Equipment Cost Contributions

Maintenance by equipment type (Q4 2013)



Hardware

Top 4 Station Hardware Challenges and Activities Identified	
High cost of compressor hardware	a) Multiple type specs for compressor ability b) Standardization of compressor size c) Information exchange on technology and operation d) Continued R&D on compression technologies e) Targeted R&D to improve durability and reliability
High cost of gaseous storage	a) Develop low-cost underground storage b) H-Prize for achieving cost reduction c) Standard template for Authorities Having Jurisdiction (AHJ) approval. d) Improve understanding of storage cycling through R&D, definition of life parameters, cycle testing e) Develop inspection protocols and hardware f) Reduce the cost of storage materials.
Improvement of dispensing hardware	a) Develop improved customer look and feel (weight, flexibility, ease-of-use) b) Improve robustness of fueling hoses c) Design an integrated dispenser system
High energy consumption for pre-cooling	a) Optimizing pre-cooler and heat exchanger operation b) Perform study on costs, temperature, rates & utilization c) Review other fueling protocols d) Semi-continuous cooling to meet SAE J2601 (2014) e) Develop and on-demand hydrogen chiller

Wrap-up

- These top priorities and identified needs are documented in the workshop report which will be available through the IPHE website shortly. http://www.iphe.net/
- We, the participating regions are working both independently and in collaboration to address our common challenges
- We continue to collaborate on these priorities and are in the process of planning our next information exchange meeting to monitor the status, share lessons learned and identify key areas for further development

Questions?