Hydrogen Station Data Collection and Analysis

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This presentation does not contain any proprietary, confidential, or otherwise restricted information.
Overview

Timeline and Budget

- Project start date: 10/2011*
- Total DOE funds received to date: $785k
- FY14 DOE funding: $200k
- FY15 planned DOE funding: $300k

*project continuation and direction determined annually by DOE

Barriers

- Lack of current hydrogen refueling infrastructure performance and availability data

Partners

- California Air Resources Board (CARB)
- California Energy Commission (CEC)
- California State University, Los Angeles (CSULA)
- Gas Technology Institute (GTI)
- Hydrogen Frontier
- Linde
- Shell
- Proton OnSite
Relevance:
Project Objectives--Hydrogen Infrastructure Evaluation

FY15 Objectives
Analysis and reporting on infrastructure performance, cost, utilization, maintenance, and safety.

Overall Objectives
- Validate hydrogen infrastructure
- Identify status and technological improvements
- Provide feedback to hydrogen research
- Publish results for stakeholder use
Relevance: Metrics to Evaluate Infrastructure

Use metrics to clearly evaluate progress toward challenges

- **Location/Capacity/Utilization**
  - **Challenge:** Station coverage, hydrogen availability, minimal wait time.
  - **Metrics:** Station usage patterns and geographic locations

- **Fueling**
  - **Challenge:** Vehicles fueled in an acceptable amount of time
  - **Metrics:** Fueling rates, times, amounts, back-to-back fills, communication

- **Maintenance/Availability**
  - **Challenge:** Maintenance and downtime increase cost and impact customers
  - **Metrics:** Maintenance patterns, reliability and availability of stations

- **Cost**
  - **Challenge:** Hydrogen cost is dependent on several factors including where produced, how delivered, efficiencies, and maintenance requirements
  - **Metrics:** Energy cost, maintenance cost, station cost

- **Station Timing**
  - **Challenge:** Lead time to build out infrastructure to meet vehicle demand
  - **Metrics:** Permitting time, building time, commissioning time
Approach: Station Locations

- Maintain database of hydrogen stations in the U.S.
- Sync location data with:
  - Alternative Fuels Data Center (AFDC)
  - Pacific Northwest National Laboratory (PNNL)
  - FCHEA
Approach: National Fuel Cell Technology Evaluation Center (NFCTEC)

Bundled data (operation and maintenance/safety) delivered to NREL quarterly

Detailed Data Products (DDPs)
• Individual data analyses
• Identify individual contribution to CDPs
• Only shared with partner who supplied data every 6 months¹

Composite Data Products (CDPs)
• Aggregated data across multiple systems, sites, and teams
• Publish analysis results without revealing proprietary data every 6 months²

¹) Data exchange may happen more frequently based on data, analysis, and collaboration
²) Results published via NREL Tech Val website, conferences, and reports
Approach: Data and Templates

Data templates developed to collect similar data from multiple projects

- **Updated as new topics develop**
  - Future updates needed for items such as station downtime and validating J2601 fills.

- **Shared with others**
  - California Air Resources Board projects
  - California Energy Commission for inclusion in Program Opportunity Notices (PONs) and awards
  - Safety and Maintenance templates/data discussed with International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) to coordinate international data sharing

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**Safety**

Template last updated on April 5, 2012 (NREL)

Data should be from reporting quarter
Include all H2 leaks, incidents, and near miss events

**INSTRUCTIONS:**
1) Scroll over headings for definitions of each category

**SAFETY CATEGORIES:** (Choose from dropdown ‘pick lists’)
- **WARNING**
  - Adverse health condition, injury, or equipment damage
- **INCIDENT**
  - Near Miss
- **MINOR EVENT**
  - Near Miss
- **EVENT**
  - Near Miss

**Event Details**

- **Date of Event:**
  - 8/4/2001

- **Detailed Event Description:**

- **Lessons Learned:**
  - EXAMPLE DESCRIPTION: The failures on the desaturizer require more frequent inspection. This inspection will be added to routine maintenance and will be performed weekly rather than bi-weekly. We feel more frequent inspection of this device is important and should be shared with other teams.

- **Severity:**
  - Near Miss

- **Event Description:**
  - H2 Release - No accumulation

- **Equipment/Subsystem Involved:**
  - Reformer

- **Primary Factor:**
  - Inadequate/Non-Working Equipment

- **Damages and Injuries:**
  - No injury or property damage

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**Pick List for Each Safety Category**

<table>
<thead>
<tr>
<th>SEVERITY</th>
<th>EVENT TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident</td>
<td>H2 Release - Ignition</td>
</tr>
<tr>
<td>Near Miss</td>
<td>H2 Release - Accumulation</td>
</tr>
<tr>
<td>Minor H2 Leak</td>
<td>H2 Release - No accumulation</td>
</tr>
<tr>
<td>Non-Event</td>
<td>Non-H2 Release</td>
</tr>
<tr>
<td>Non-H2 Fire</td>
<td>Non-H2 Fire</td>
</tr>
</tbody>
</table>
Accomplishment: 43 Infrastructure CDPs – 9 Categories

Deployment and Overview (1,10,11,27)

Refueling (2,3,4,5,8,9,12,13,14,15,16,17,18,19,20)

Utilization (6,7)

Efficiency (35,36)

Maintenance, Reliability, Availability (21,22,23,24,26,28,30,37,38)

H2 Quality (25)

Operation Cost (39)

Station Cost (40,41,42,43)

Safety (31,32,33,34)

CDPs created from infrastructure data through 12/2014
A subset of the infrastructure CDPs presented here. All CDPs, including other projects, available at www.nrel.gov/hydrogen/proj_tech_validation
Accomplishments and Progress: Hydrogen Stations by Type

- Performance/operational data received for current stations (except those recently operational)
- Award data received for future stations
Accomplishments and Progress:
Hydrogen Dispensed by Quarter

Cumulative Hydrogen Dispensed = 62,784 kg
Accomplishments and Progress:
Histogram of Fueling Rates, Times, Amounts

19,414 Events
Average = 0.60 kg/min
16% >1 kg/min
5% >1.67 kg/min

Average Amount = 2.63 kg
Average time = 5.62 min
49% of fills less than 5 min
20% of fills less than 3 min
Accomplishments and Progress:
Monthly Averages for 700bar Fills >1kg with Pre-Cool of -20C

Averages for this subset:
Rate = 0.65 kg/min, Time = 6.1 min, Amount = 3 kg
Accomplishments and Progress:
Fueling Final Pressures

Average pressure at end of fill:
Low pressure fills: 346 bar
High pressure fills: 721 bar
Future Topic: Are customers getting full fills?

*The line at 450 bar separates 350 bar fills from 700 bar fills. It is slightly over the allowable 125% of nominal pressure (437.5 bar) from SAE J2601.
Accomplishments and Progress:
Dispensed Hydrogen per Day of Week

Most hydrogen is dispensed Monday through Friday

31 kg/day avg
Accomplishments and Progress: Station Capacity Utilization

Station Capacity Utilization

- **Maximum Daily Utilization**
- **Maximum Quarterly Utilization**
- **Average Daily Utilization**

Note: The focus for early stations is geographic coverage

Stations are dispensing well below their stated capacity

1. Station nameplate capacity reflects a variety of system design considerations including system capacity, throughput, system reliability and durability, and maintenance. Actual daily usage may exceed nameplate capacity.
2. Maximum quarterly utilization considers all days; average daily utilization considers only days when at least one filling occurred.
Accomplishments and Progress: Station Usage

On average, stations are dispensing less than 10 fills/day

Note: The focus for early stations is geographic coverage

1 Excludes hydrogen fills of < 0.5 kg
2 Average daily fills considers only days when at least one fill occurred
Accomplishments and Progress: Maintenance by Equipment Type

Most maintenance related to compressors and dispensers

Maintenance by Equipment Type

Total Events = 2,956
38% unscheduled

Total Hours = 22,440
18% unscheduled

- hydrogen compressor: 22%
- dispenser: 16%
- safety: 16%
- thermal management: 8%
- reformer: 9%
- sensors: 5%
- electrolyzer: 6%
- control electronics: 5%
- feedwater system: 4%
- storage: 8%
- electrical: 7%
- fittings&piping: 18%

MISC includes the following failure modes: seal, nitrogen system, hydrogen chiller, fuel system, software, air system, purifier, valves, other

Event Count:
- classified events: 2,111
- misc: 561
- multiple systems: 238
- entire system: 46

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Accomplishments and Progress: Maintenance MTBF

Best median MTBF is for electrolyzer at ~120 days, worst is for compressor at ~10 days
Accomplishments and Progress: Compressor Monthly Maintenance

For compressors, the average per station is 3 maintenance events and 12 labor hours per month with 158 kg dispensed per maintenance event. For all maintenance items, the station average is 38 labor hours per month.
Overall Average: $22,852 per station per quarter.
Accomplishments and Progress: H2 Quality

45 of 58 samples (78%) met the SAE J2719 guidelines. Consecutive samples may be for a single issue.

Values are in micromole/mole, except for particulate size (Psize) in micrometer. Only values that exceed SAE J2719 guideline are shown in text. Left edge of text box aligns with date.
Accomplishments and Progress: Safety Reports by Quarter

Most reports are minor hydrogen leaks

An Incident is an event that results in:
- a lost time accident and/or injury to personnel
- damage/unplanned downtime for project equipment, facilities or property
- impact to the public or environment
- any hydrogen release that unintentionally ignites
- release of any volatile, hydrogen containing compound (including the hydrocarbons used as common fuels)

A Near Miss is:
- an event that under slightly different circumstances could have become an incident
- any hydrogen release sufficient to sustain a flame if ignited

A Minor H2 Leak is:
- an unplanned hydrogen release insufficient to sustain a flame, and does not accumulate in sufficient quantity to ignite
Accomplishments and Progress:
Safety Reports by Equipment Involved

Most reported minor leaks associated with H2 Compressor, Dispenser and Pipes/Fittings/Valves

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Accomplishments and Progress:
Energy and Cost per kg of Hydrogen

Average Compressor Energy:
13.7 MJ/kg

Average Electrolyzer Energy:
235 MJ/kg

Average Compressor Energy Cost:
$0.628/kg
Accomplishments and Progress:
Station Costs

Based on award data, the stations that are near operational are expected to cost $2.14M on average (including cost share). This includes different station types and will be updated by type as more stations come online.

*Based on data that includes costs reported through 2014Q4 for projects at or near completion.

**Station includes: Hydrogen Equipment and Station Engineering, Design, Fabrication, Procurement, Site Preparation, Installation, and Construction
Accomplishments and Progress: Station Cost by Type

Station Cost by Type*

<table>
<thead>
<tr>
<th>Type</th>
<th>Total Budgeted Cost Share</th>
<th>Documented Cost Share</th>
<th>CEC Award Range per Project</th>
<th>Cost Share Range per Project</th>
<th>Number of Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivered Liquid By-Product</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Delivered Liquid SMR</td>
<td>9</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Delivered Compressed SMR</td>
<td>28</td>
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<td>1</td>
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<tr>
<td>On-Site Electrolysis-Delivered Liquid By-Product</td>
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<tr>
<td>On-Site Electrolysis-Delivered Liquid SMR</td>
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<tr>
<td>On-Site Electrolysis-Delivered Compressed SMR</td>
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<td>Mobile Fueler</td>
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<tr>
<td>Trailers</td>
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<td>1</td>
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</tbody>
</table>

Tracking budgeted vs documented cost share as projects are built along with range of awards from CEC.

*Based on California Energy Commission data that includes costs reported through 2014Q4.
Accomplishments and Progress:
Responses to Previous Year Reviewers’ Comments

• This project was not reviewed last year.
Collaborations

Data, feedback, and interactions with infrastructure partners makes this project work

• Memorandum of Understanding between CEC/NREL
  o Data templates included in Program Opportunity Notices/Awards
  o Will provide cost data as well as performance/operation data on latest infrastructure projects

• Partners providing data through DOE funding or voluntarily:
  o California Air Resources Board, California State University Los Angeles, Gas Technologies Institute, Hydrogen Frontier, Linde, Shell, Proton OnSite

• Organizations
  o California Fuel Cell Partnership Working Group
  o H2USA Hydrogen Fueling Station Working Group
  o IPHE for international data sharing
Proposed Future Work

• **Fall 2015**
  - Complete quarterly analysis of CY15 Q1 and Q2 data
  - Publish analysis results (10/2015)

• **Spring 2016**
  - Complete quarterly analysis of CY15 Q3 and Q4 data
  - Publish analysis results (4/2016)

• **Update data collection and analysis to address:**
  - Availability of stations
  - Performance compared to fueling standards
  - Usage of data results by others (cost analysis, safety, network health, customer satisfaction)
  - How metrics are changing over time
Summary

- **Relevance**
  - Independent validation of hydrogen infrastructure

- **Approach**
  - Collaborate with industry partners
  - Continue to develop core NFCTEC and analysis capability and tools
  - Leverage 7+ years of analysis and experience from the Learning Demonstration

- **Technical Accomplishments and Progress**
  - Analyzed performance data from 8 stations and cost data from planned stations
  - Performed detailed reviews of individual data results
  - Published results via CDPs that cover topics of station daily utilization compared to maximum demonstrated capacity, maintenance, fueling performance, operation costs, and efficiencies

- **Collaborations**
  - Working closely with industry and government partners to validate methodology and with key stakeholders to ensure relevance and accuracy of results

- **Future Work**
  - Complete analysis of hydrogen infrastructure and update results in Fall 2015; add new analysis topics
  - Identify new opportunities to document hydrogen infrastructure progress
Technical Back-Up Slides
Approach: Relationship to Other Tech Val Projects

Controlled Hydrogen Fleet and Infrastructure Analysis (FY03 – FY12)

- Fuel Cell Electric Vehicle Evaluation (FY13 – )
- Next Generation Hydrogen Infrastructure Evaluation (FY13 – )
Accomplishments and Progress: Maintenance Labor Hours by Month

Overall Average: 38 hours per station per month.

Stars represent individual station maintenance hours in a given month.