Hydrogen By Wire – Home Fueling System

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Organization: Proton Energy Systems
Date: June 7, 2010
Overview

Timeline

• Project Start: 21 Sep 2009
• Project End: 21 May 2010
• Percent complete: 100%

Budget

• Total project funding
  – DOE share: $99,990
• Funding for FY10
  – DOE share: $99,990

Barriers

• Barriers addressed
  G: Capital Cost
  H: System Efficiency

Technical Sources

• Hydro-Pac
• W.E.H.
• GTI

Table 3.1.4. Technical Targets: Distributed Water Electrolysis Hydrogen Production

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Units</th>
<th>2003 Status</th>
<th>2006 Status</th>
<th>2012 Target</th>
<th>2017 Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Cost</td>
<td>$/gge</td>
<td>5.15</td>
<td>4.80</td>
<td>3.70</td>
<td>&lt;3.00</td>
</tr>
<tr>
<td>Electrolyzer Capital Cost</td>
<td>$$/kW</td>
<td>NA</td>
<td>1.20</td>
<td>0.70</td>
<td>0.30</td>
</tr>
<tr>
<td>Electrolyzer Energy Efficiency</td>
<td>% (LHV)</td>
<td>NA</td>
<td>82</td>
<td>69</td>
<td>74</td>
</tr>
</tbody>
</table>
Relevance
Hydrogen Fueling Pathways

• Continuum of options
  – Large, centralized plants
    • Requires transportation or distribution of fuel
  – Neighborhood fueling stations
    • Compatible with medium-to-large scale PEM Electrolysis
    • Generates fuel closer to end-user
    • Can be renewable
  – Home-based fueling
    • Compatible with small scale PEM Electrolysis
    • Generates fuel in the end-user’s garage
    • Can be renewable

• Each generation scale will have its place
Relevance
Fueling Infrastructure Challenges

- Ramp-up
  - Fuel production
  - Storage
  - Transportation and/or distribution
  - End-customer delivery

- Pace with parallel ramp-up of related vehicles

Existing:
- Electricity
- Water
Relevance
Advantages of Hydrogen Home Fueling

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Range (Miles)</th>
<th>Empty to Full Refueling / Charging Time (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plug-in Hybrid Electric (PHEV)</td>
<td>40</td>
<td>4 to 6 (@110V)</td>
</tr>
<tr>
<td>Battery Electric Vehicle (BEV)</td>
<td>100</td>
<td>8 to 16 (@110V)</td>
</tr>
<tr>
<td>Compressed Natural Gas (CNG)</td>
<td>200-300</td>
<td>* 8 to 16 (potential &lt;6h)</td>
</tr>
<tr>
<td>Fuel Cell Hybrid Electric Vehicle (FCV)</td>
<td>300</td>
<td>* 1 to 6 (Targets of study)</td>
</tr>
</tbody>
</table>

Comparison of Residential Fueling Charge Time and Vehicle Range (J. Schneider et. al, NHA 2009)
Relevance
Project Objectives

• Define critical requirements for PEM Electrolysis Home Fueling System
  – Technical
    • Define hydrogen production capacity for a recharge time relevant to end-user
    • Estimate electrical service and physical size
  – Capital and operating cost
  – Codes and standards
  – Product safety
  – Operation and maintenance
Approach
Task Breakdown

• Task 1.0: Technical Requirements Analysis
  – 1.1 Capacity:
  – 1.2 Efficiency and power usage
  – 1.3 Physical size
  – 1.4 Preliminary design requirements

• Task 2.0: Cost Analysis
  – 2.1 Cost of hydrogen for different vehicle scenarios
  – 2.2 Effect of technology improvements and production volume increases

• Task 3.0: Installation Analysis
  – 3.1 Cost impact of current code compliance environment, and direction of national and international standards
  – 3.2 O&M and energy comparison to other residential appliances
## Technical Accomplishments

<table>
<thead>
<tr>
<th>Task</th>
<th>Task Description</th>
<th>Progress Notes</th>
<th>Completion</th>
</tr>
</thead>
</table>
| 1.0  | Technical Requirements Analysis   | • Estimated required capacity for a range of vehicle fuel efficiency values and vehicle usage profiles.  
• Estimated physical size, electricity usage.  
• Tabulated product requirements.               | 100%       |
| 2.0  | Cost Analysis                     | • Estimated required bill-of-materials.  
• Estimated $/kg cost for a range of fuel efficiency and vehicle usage profiles using H2A model. | 100%       |
| 3.0  | Installation Analysis             | • Tabulated list of relevant codes and standards.  
• Estimated cost impact of municipality specific codes and standards environment.  
• Defined maintenance strategy.                | 100%       |
Approach

Task 1.0: Technical Requirements

- Estimate high, medium, and low users based on:
  - Commute distances
  - Driving profiles
  - Day-to-day variation

- Estimate available recharge hours (assuming no storage off-board vehicle)

- Data:
  - Average One-Way Commute Miles: 14.5 [1]
  - Average Daily Driver Miles: 32.89 [2]
  - FCV MPGGE (Light Truck): 56.1 [3]

Technical Accomplishments
Task 1.0: Technical Requirements

• Task 1.1: Capacity - Scenarios

Scenarios: Average Daily Driving Distance & Available Recharge Time

- Single Vehicle
- Multi-Vehicle

Scenarios: Average Daily Driving Distance & Available Recharge Time

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Driving Distance (mi)</th>
<th>Recharge Time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>40</td>
<td>12</td>
</tr>
<tr>
<td>F</td>
<td>30</td>
<td>8</td>
</tr>
<tr>
<td>G</td>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>H</td>
<td>80</td>
<td>12</td>
</tr>
<tr>
<td>I</td>
<td>100</td>
<td>16</td>
</tr>
<tr>
<td>J</td>
<td>120</td>
<td>18</td>
</tr>
</tbody>
</table>
Technical Accomplishments

Task 1.0: Technical Requirements

• Task 1.1: Capacity

Electrolysis-Based Home Fueler
Hydrogen Generation Rate
(Average Daily)
Technical Accomplishments
Task 1.0: Technical Requirements
• Task 1.1: Capacity – Effect of Ground Storage

Scenarios: Addition of Ground Storage - Effect on Electrolyzer Production Capacity

- Single Vehicle
- Multi-Vehicle

Scenarios: E, F, G, H, I, J

Ground Storage (kg) vs. Percent of Non-Storage Electrolyzer Capacity
Technical Accomplishments

Task 1.0: Technical Requirements

• Task 1.2: Electrical Service
Technical Accomplishments

Task 1.0: Technical Requirements

- Task 1.3: Physical Size – 2’ x 3’ x 5’
Technical Accomplishments
Task 1.0: Technical Requirements

• Task 1.3: Physical Size – 2’ x 3’ x 5’
Technical Accomplishments

Task 1.0: Technical Requirements

• Task 1.3: Physical Size
  – With mechanical compression and ground storage footprint and complexity increase greatly
Technical Accomplishments

Task 1.0: Technical Requirements

- Task 1.4: Product Requirements Definition

![Image of technical requirements table]
Technical Accomplishments

Task 2.0: Cost Analysis

• Task 2.1: Effect of driving scenarios

Baseline Prototypes

- Proton S-series baseline
- 1 car, 55 mpg
- 1 car, 90 mpg
- 3 cars, 55 mpg

H2A

Simplified
Technical Accomplishments
Task 2.0: Cost Analysis

• Task 2.1: Effect of ground storage and mechanical compression
Technical Accomplishments

Task 2.0: Cost Analysis

• Task 2.2: Effect of Cost Reductions

![Long Term Cost Reduction Projections](chart.png)
Technical Accomplishments
Task 3.0: Installation Analysis

• Task 3.1: Current Codes and Standards
  Environment
  – NFPA 70 National Electric Code
  – NFPA 79 Electrical Standard for Industrial Machinery
  – NFPA 69 Standard on Explosion Prevention Systems
  – IEC/UL 61010-1 Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use
  – Municipality specific codes vary by location
Technical Accomplishments
Task 3.0: Installation Analysis

• Task 3.1: Desirable Codes and Standards Environment
  – ISO/IS 22734-1 (Commercial/Industrial)
  – ISO/DIS 22734-2 (Residential)

  – Education campaign to make local AHJ’s familiar with the ISO standards and hydrogen equipment
Technical Accomplishments
Task 3.0: Installation Analysis

• Task 3.2: Operation and Maintenance
  – Service plan:
    • Home-owner access to:
      – Air Inlet Filter
      – Water De-Ionizing Cartridges
    • Annual maintenance required for additional items
      – Locked cabinet accessible only to qualified service technicians
      – Service centers to stock replacement parts and dispatch technicians
Collaboration

• Technical sources
  – Hydro-Pac
  – W.E.H.
  – GTI
Future Work

• Fabricate prototype based on existing commercial components
• Develop key electrolysis system components to achieve cost, manufacturability, and serviceability requirements
• Extend electrolysis pressure range
• Transition full pressure, cost-reduced, residential fueling product to commercial readiness
Future Work: Home Fueler Roadmap

- **Proton Internal R&D funding**
  - HP Stack Development
    - HP Stack Improvements
      - Cost Reduction of HP Stack
        - 2400 psi demo, outdoor capable
  - EMTEC
    - 2200 psi system demo
  - CERL Phase 1
    - Manufacturing Improvements
  - NYSERDA
    - Home Fueler concept design
  - CERL Phase 2
    - DOE home fueler trade study
    - Prototype Home Fueler (2400 psi stack pressure)
  - DOE UNLV Subcontract
    - 1100 psi system demo
  - Proton Internal R&D funding
    - 5000 psi stack development
    - 5000 psi home fueler
Summary

• **Relevance:**
  - Home fueling is a viable pathway on the continuum of options. Home fueling grows organically with vehicle introduction. PEM electrolysis is ideal technology for small footprint, easy maintenance.

• **Approach:**
  - Examine key technical, cost, and installation requirements through a sound analytical approach. Draw upon Proton’s experience with commercial products to inform the design, cost estimates, and technical service plans.

• **Technical Accomplishments:**
  - Developed model for electrolysis capacity based on real-world driving data. Examined effects of different driving scenarios on capacity, size, service rating and cost. Described the codes and standards environment.

• **Collaborations:**
  - Drew upon relevant data from prior work and key component suppliers.

• **Proposed Future Work:**
  - Prototyping, component development, product development.