Technology Validation
-Session Introduction -

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2013 Annual Merit Review and Peer Evaluation Meeting
May 16, 2013
Technology Validation Activities

Technology Validation assesses the performance and durability of new technologies to provide feedback to the R&D sub-programs and confirm readiness for commercialization.

DOE Program Structure

- Basic & Applied Research and Technology Development
  - Hydrogen Fuel R&D
    - Production
    - Delivery
    - Storage
  - Fuel Cell R&D

- Systems Integration & Analysis
  - Manufacturing R&D
  - Safety Codes & Standards
  - Education

- Technology Validation

- Market Transformation
  - WIDESPREAD COMMERCIALIZATION ACROSS ALL SECTORS
    - Transportation
    - Stationary Power
    - Auxiliary Power
    - Backup Power
    - Portable Power
GOAL: Validate the state-of-the-art of fuel cell systems in transportation and stationary applications as well as hydrogen production, delivery and storage systems. Assess technology status and progress to determine when technologies should be moved to the market transformation phase.

By 2017:
• Validate commercial stationary fuel cells (100 kW to 3 MW) against 2015 system targets (50,000 h, 45% electrical efficiency).
• Validate durability of auxiliary power units (APUs) against 2015 fuel cell system target (15,000 h, 35% electrical efficiency).

By 2019:
• Validate hydrogen fuel cell electric vehicles with greater than 300-mile range and 5,000 hours fuel cell durability.
• Validate a hydrogen fueling station capable of producing and dispensing 200 kg H₂/day (at 5kg/3 min; 700 bar) to cars and/or buses.
Many challenges continue to be met through data collection efforts.

Technology Validation efforts cover a wide range of applications and components:

- Applications: Cars, buses, trucks, refueling stations, stationary systems, demand response, back-up power, material handling equipment.
- Critical Components: H₂ compressors and storage, fuel cell stacks, and electrolyzers.

Several challenges exist:

- Proprietary designs and data with competitive value are sensitive and need to be protected.
- Durability measurements need to be taken over significant amounts of time.
- Failure modes and degradation mechanisms need to be identified and communicated with DOE R&D programs.
- Results need to be compiled in a credible, meaningful and up-to-date manner for use by a variety of audiences, including end-users, investors and other decision-makers.
Technology Validation Budget

FY 2014 Request = $7.0M
FY 2013 = $8.5M

EMPHASIS

- Data collection, analysis and evaluation. (leverages equipment funded outside of Technology Validation).
  - Light-duty vehicles, buses and hydrogen refueling stations. (Collaboration on buses with DOT.)
  - Hydrogen compressors and advanced refueling components.
  - Forklifts and Stationary Fuel Cells.

- Real-world demonstration/evaluations (small number of units for validation purposes).
  - High-Pressure Electrolyzers.
  - Electrochemical Hydrogen Pumps.

* Subject to appropriations, project go/no go decisions and competitive selections. Exact amounts will be determined based on R&D progress in each area and the relative merit and applicability of projects competitively selected through planned funding opportunity announcements (FOAs).
Several major OEMs to demonstrate advanced light-duty FCEVs.

- 3 awards were made to date:
  - $5 million DOE funding.
  - Data to be collected from up to ~70 vehicles.
  - Planned mileage:
    - Phase 1 = ~190,000 mi
    - Phase 2 (anticipated) = ~204,000 mi

Validation of data via NREL:
- Validate light-duty FCEV performance and durability through analysis of dynamometer and real-world vehicle performance data.
- Completed data templates (operation, maintenance, safety, and specification) and HSDC security procedures.
- Prioritized key analysis topics.

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<tr>
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<th>Learning Demo</th>
<th>Current Projects</th>
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<tr>
<td>Range (mi)</td>
<td>196-254*</td>
<td>TBD</td>
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<tr>
<td>Efficiency (%)</td>
<td>53-59</td>
<td>TBD</td>
</tr>
<tr>
<td>Durability (hrs)</td>
<td>2,521</td>
<td>TBD</td>
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* Separately validated 430 mile range.
Progress: H₂ Station Data Collection

**DOE Awards $2.4M for Hydrogen Station Evaluations and Advanced Refueling Components**

350 bar and 700 bar fast-fill capability at all stations.

**California State University—Los Angeles (CSULA)**
- **Station Location**: Los Angeles, CA (on CSULA campus).
- **Station Characteristics**: Electrolyzer; 30-60 kg H₂/day.

**Proton Energy (Proton OnSite)**
- **Station Locations**: Wallingford, CT (SunHydro #1) and Braintree, MA (SunHydro #2).
- **Station Characteristics**: 65 kg H₂/day, advanced 57 bar PEM electrolyzer (at SunHydro #1 station); co-located PV array.

**California Air Resources Board (CARB)**
- **Station Location**: Newport Beach, CA.
- **Station Characteristics**: 100 kg H₂/day; natural gas reforming.

**Gas Technology Institute (GTI)**
- **Station Locations**: California (North: San Mateo, Cupertino, Mountainview, West Sacramento) & (South: Laguna Niguel, San Juan Capistrano).
- **Station Characteristics**: new 900 bar ionic compression; gaseous or liquid delivered hydrogen.

**KEY METRICS**

- **Location/Capacity/Utilization**: Station usage patterns and geographic locations.
- **Fueling**: Fueling rates, times, amounts, back-to-back fills, communication.
- **Maintenance/Availability**: Maintenance patterns, reliability and availability of stations.
- **Cost**: Energy cost, maintenance cost.
- **Station Timing**: Permitting time, building time, commissioning time.
Progress: Second Generation Fuel Cell Buses

New FC bus designs have ~1.9x the fuel economy of diesel buses, and ~2.3x the fuel economy of CNG buses.

**Top Fuel Cell Powerplant Exceeds 12,000 hours**

- **Top Fuel Cell Powerplant Exceeds 12,000 hours**
- **Data Summary for 2012:**
  - **AC Transit, Oakland, CA**
    - 40-foot Van Hool buses with ClearEdge Power FC (Zeba)
  - **CTTRANSIT, Hartford, CT**
    - 40-foot Van Hool buses with ClearEdge Power FC (Nutmeg)
  - **SunLine, Thousand Palms, CA**
    - 40-foot New Flyer bus with Ballard FC and Bluways hybrid system (AT)
    - 40-foot ElDorado bus with Ballard FC and BAE Systems Hybrid drive (AFCB)

**Miles per DGE**

- **Target: 8.0 mpg (diesel equivalent)**
- **1.89x 1.89x 1.39x 1.87x 2.26x**

**Number of Buses in Service**

- **21 active FCEBs at the end of 2012;**
- **Estimated 28 by the end of 2013**
Progress: Fuel Cell Material Handling Equipment

Operating with average availability of ~98% at eight end-user facilities. Most systems operate at least 6 hours a day.

- **Cost of ownership—fuel cell vs. battery MHE:** Significant cost savings for refueling labor and infrastructure space, but much greater cost for hydrogen infrastructure and fuel.

<table>
<thead>
<tr>
<th>Units in operation*</th>
<th>Hydrogen fills</th>
<th>Average fill time</th>
<th>Average fill amount</th>
<th>Hydrogen dispensed</th>
<th>Operation time</th>
<th>Average operation time between fills</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>246,997</td>
<td>2.3 min</td>
<td>0.6 kg</td>
<td>187,426 kg</td>
<td>1,445,558 hrs</td>
<td>4.6 hrs</td>
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*One project has completed.

**INFRASTRUCTURE RELIABILITY**

There are many different failure modes for the top four categories and these modes provide insight for RD&D needs.

<table>
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<tr>
<th>Category</th>
<th>Event Count</th>
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<tr>
<td>AIR SYSTEM</td>
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<tr>
<td>DISPENSER</td>
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<tr>
<td>CONTROL ELECTRONICS</td>
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<tr>
<td>HYDROGEN COMPRESSOR</td>
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Progress: Fuel Cell Back-up Power

Systems are operating reliably in 19 states.

1.86 MW
Installed capacity

99.6%
Successful starts

806
Systems in operation*

4-6 kW
Average site capacity

1,796
Start attempts

65 hrs
Continuous run
time demonstrated

1,153 hrs
Operation time

Reasons for unsuccessful starts include an e-stop signal, no fuel, and other system failures.

*Not all systems have detailed data reporting to NREL.
Progress: Technology Validation Projects

Technology Validation Projects Follow R&D Portfolio and Leverage ARRA Activities

Hydrogen Components (NREL)

Compressor Testing:
- Diaphragm compressor in low utilization service, includes analysis of “MBS.”
- Air driven piston running at high speed for failure analysis.
- Hydraulic piston 4x 16 week runs simulating station demand.

PEM Electrolyzer Stack Test:
- Completed 10,000 hours of testing on each of 3 stacks.
- Variable wind vs. steady-state load profiles.

Electrochemical Hydrogen Recycling (H2Pump)
- 8 systems in industrial heat treating, LED fabs., and semiconductor applications.
- Q1, 2013- Four installs completed.
- Q2, 2013- Remaining installs to be completed.
- Thru 2014- Operation and maintenance.
- Data collection on efficiency, stack degradation vs. potential contaminants, maintenance and repair.

Stationary Fuel Cell Evaluation (NREL)
- Installation data from California’s Self Generation Incentive Program (SGIP):
  - 5 companies.
  - From 2001 to 2012.
  - 249 units, 97 MW.
- Natural gas is most popular fuel choice, but renewable fuels (digester, landfill, biomass gas) account for 43% of capacity.
- Average installed cost was $10,223/kW. (Costs range from $3,000/kW to $21,000/kW.)
Potential Funding Opportunity

RFI Issued: “Fuel cell technology validation, commercial acceleration and potential deployment strategies in early market applications”

Closed April 10, 2013.

Notice of Intent to Issue Early Market Hydrogen and Fuel Cell FOA**

The Office of Energy Efficiency and Renewable Energy (EERE) intends to issue, on behalf of its Fuel Cell Technologies Office, a Funding Opportunity Announcement (FOA) entitled “Fuel Cell Hybrid Electric Medium Duty Trucks, Roof-top Backup Power, and Advanced Hydrogen Refueling Components.”

It is anticipated that the FOA will include the following topics:
• Demonstration and Deployment of Fuel Cell Hybrid-Electric Medium-Duty Trucks
• Validation of Advanced Hydrogen Refueling Components* (compressors, tube trailers, advanced on-site hydrogen production, alternative refueling protocols, nozzles).
• Demonstration and Case Study for Roof-top Installations of Hydrogen Fuel Cell Backup Power Systems
• Hydrogen Meter R&D

* Potential opportunities for leveraging state activities (e.g. CA state funding for fueling stations).
FCT will not be funding infrastructure but can fund technology innovation that could be applicable to/enable infrastructure (e.g. innovative refueling/compression technologies).

**Notice of Intent (NOI) only. DOE may issue a FOA as described herein, may issue a FOA that is significantly different than the FOA described herein, or may not issue a FOA at all.
**RFI Topic: Fuel cell technology validation, commercial acceleration and potential deployment strategies in early market applications.**

*Subject to appropriations.*

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### FY 2013
- **Issue Technology Validation RFI**
- Solicitation Closes
- **RFI Closed**
- Awards Made
- **Held Station Kick-off Meeting & Site Visits**
- Input from Delivery sub-program on candidate station compression technologies for potential technology validation.

### FY 2014
- Solicitation Closes
- **Awards Made**
- Report safety event data from ARRA projects.
- Potential Workshop on “Building-Integrated FC CHP Systems”
- Validate compression techs. capable of >200 kg/day for scalable (up to 500 kg/day) stations for motive applications.

### FY 2015
- Validate large scale (>100 kg/day) integrated wind-to-hydrogen production system.
- Complete validation of residential fuel cell micro-CHP systems (40% efficiency and 25,000 hr durability).
- Validate stationary fuel cell system that co-produces hydrogen and electricity (40,000-hour durability, 40% efficiency).
- Input from FC sub-program on micro-CHP and APU test data & from Production sub-program on H₂ production systems (central biomass and distributed electrolysis).
Participating Organizations

Technology Validation

AC Transit
Air Products & Chemicals, Inc.
BAE Systems
Ballard Power Systems, Inc.
CA Fuel Cell Partnership
CA Stationary Fuel Cell Collaborative
California Air Resources Board (CARB)
City of Burbank
ClearEdge Power
CA State University Los Angeles (CSULA)
CTTRANSIT
El Dorado National
FedEx Freight East
General Electric
GENCO
Gas Technology Institute (GTI)
H2Pump LLC
Hydrogen Frontier, Inc.
Hydrogenics Corporation
Linde
National Fuel Cell Research Center, U.C. Irvine
National Renewable Energy Laboratory
Nuvera
PDC Machines
Plug Power
Proterra
Proton
ReliOn Inc.
Several Auto Manufacturers
Shell Hydrogen
Sprint Communications
SunLine Transit Agency
Sysco of Houston
U.S. Department of Transportation
Xcel Energy
The Technology Validation Team

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Session Instructions

• This is a review, not a conference.
• Presentations will begin precisely at scheduled times.
• Talks will be 20 minutes and Q&A 10 minutes.
• Reviewers have priority for questions over the general audience.
• Reviewers should be seated in front of the room for convenient access by the microphone attendants during the Q&A.
• Please mute all cell phones and other portable devices.
• Photography and audio and video recording are not permitted.
Reviewer Reminders

• Deadline to submit your reviews is Friday, May 24th at 5:00 pm EDT.

• ORISE personnel are available on-site for assistance.
  • Reviewer Lab Hours:
    • Monday, 5:00 pm – 8:00 pm (Gateway ONLY)
    • Tuesday – Wednesday, 7:00 am – 8:00 pm (Gateway)
    • Thursday, 7:00 am – 6:00 pm (Gateway)
    • Tuesday – Thursday, 7:00 am – 6:00 pm (City)
  • Reviewer Lab Locations:
    • Crystal Gateway Hotel—Rosslyn Room (downstairs, on Lobby level)
    • Crystal City Hotel—Roosevelt Boardroom (next to Salon A)