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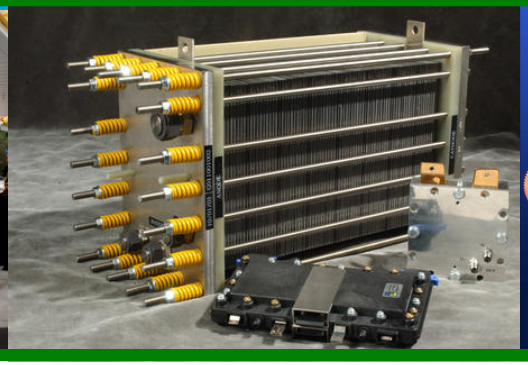
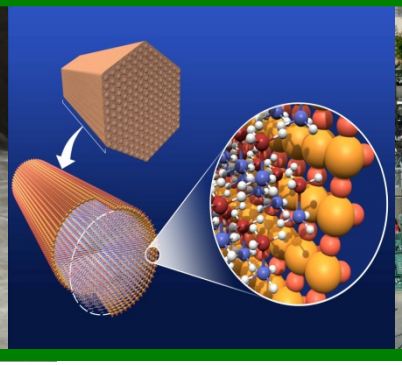

Technology Validation

-Session Introduction -

Jason Marcinkoski

2013 Annual Merit Review and Peer Evaluation Meeting

May 16, 2013

Technology Validation Activities

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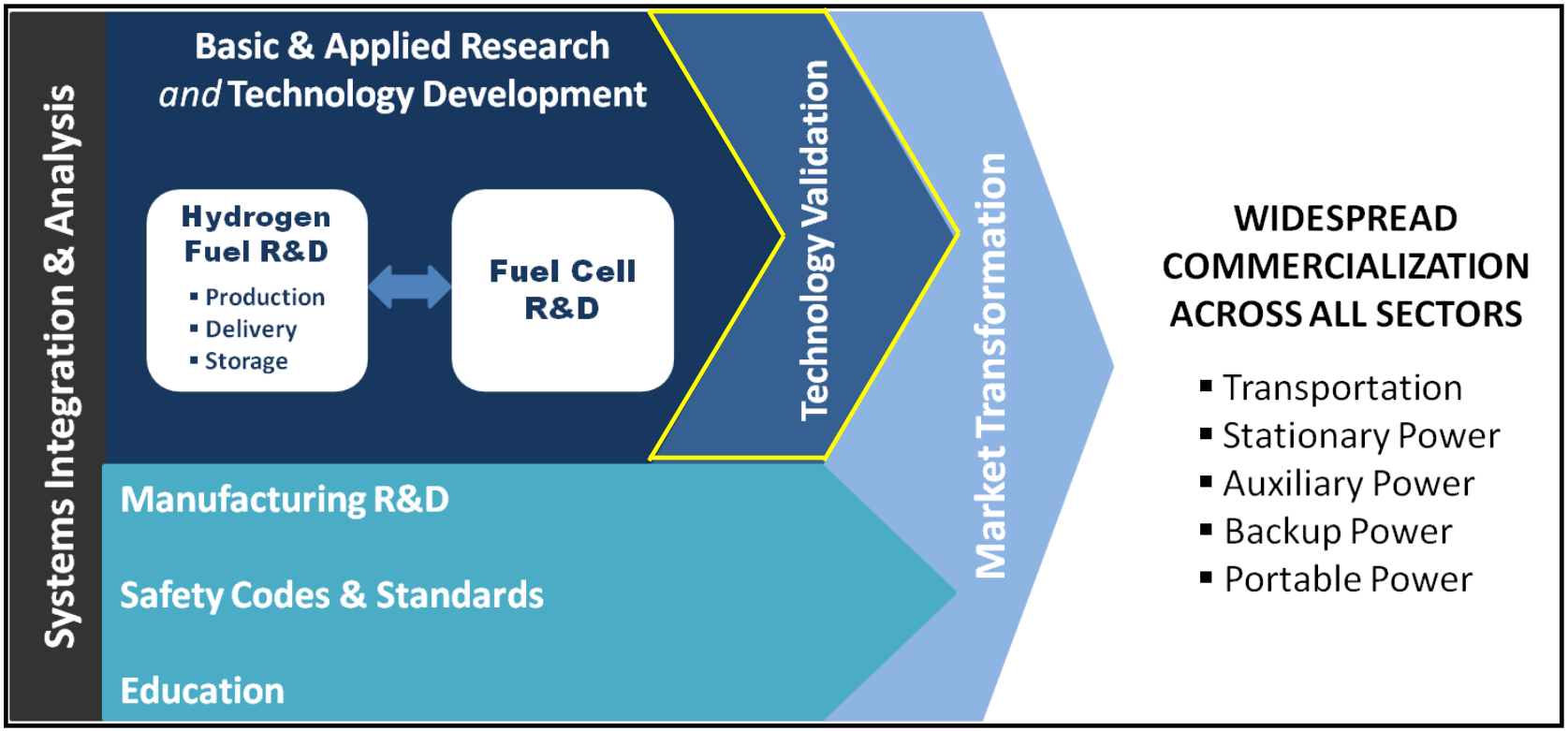
Technology Validation assesses the performance and durability of new technologies to provide feedback to the R&D sub-programs and confirm readiness for commercialization.

DOE Program Structure



Goal and Objectives

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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 H_2/day (at 5kg/3 min; 700 bar) to cars and/or buses.

Challenges

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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: H_2 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

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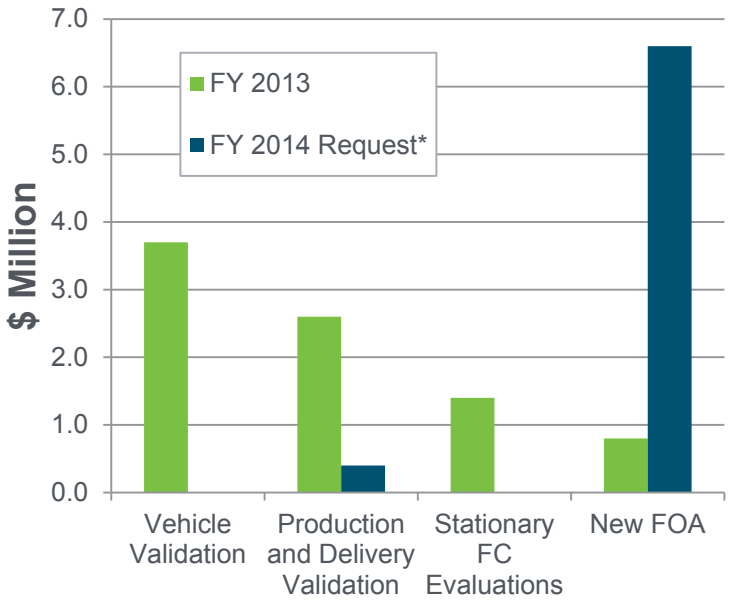
FY 2014 Request = $7.0M

FY 2013 = $8.5M



* 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).

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.

Progress: Vehicle Data Collection

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Several major OEMs to demonstrate advanced light-duty FCEVs.

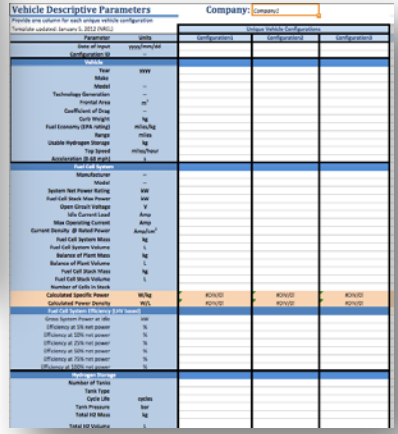
- 3 awards were made to date:
  - ❑ $5 million DOE funding.
  - ❑ Data to be collected from up to ~70 vehicles.
  - ❑ Planned mileage:
    - ✓ Phase 1 = ~190,000 mi
    - ✓ Phase 2 (anticipated) = ~204,000 mi

	Learning Demo	Current Projects
Range (mi)	196-254*	TBD
Efficiency (%)	53-59	TBD
Durability (hrs)	2,521	TBD

** Separately validated 430 mile range.*

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.



Progress: H_2 Station Data Collection

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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 H_2/day.

Proton Energy (Proton OnSite)

- **Station Locations:** Wallingford, CT (SunHydro #1) and Braintree, MA (SunHydro #2).
- **Station Characteristics:** 65 kg H_2/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 H_2/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

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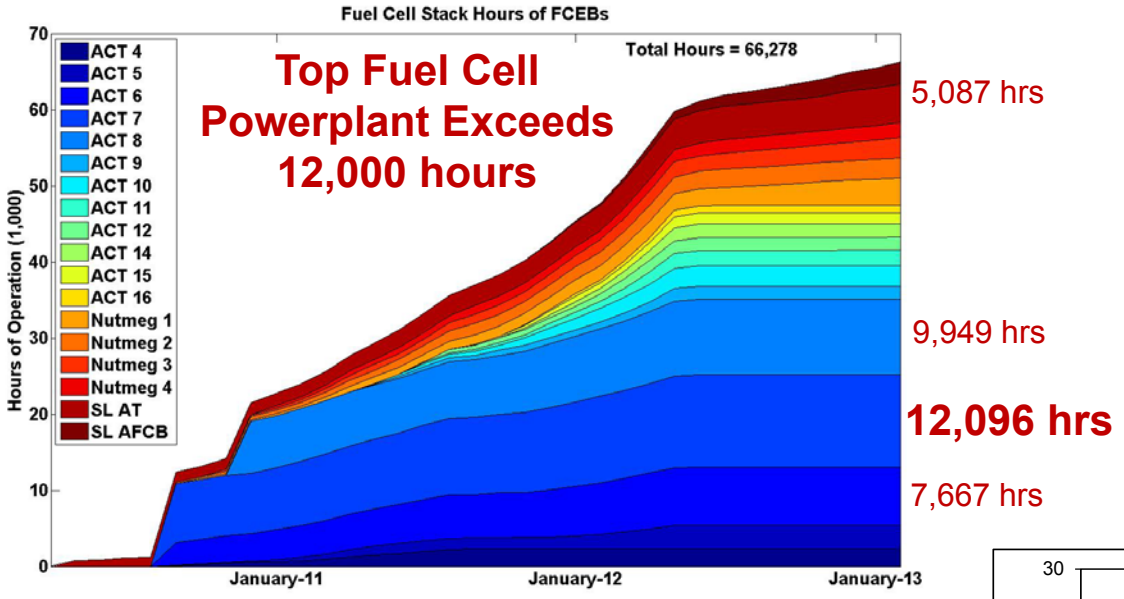
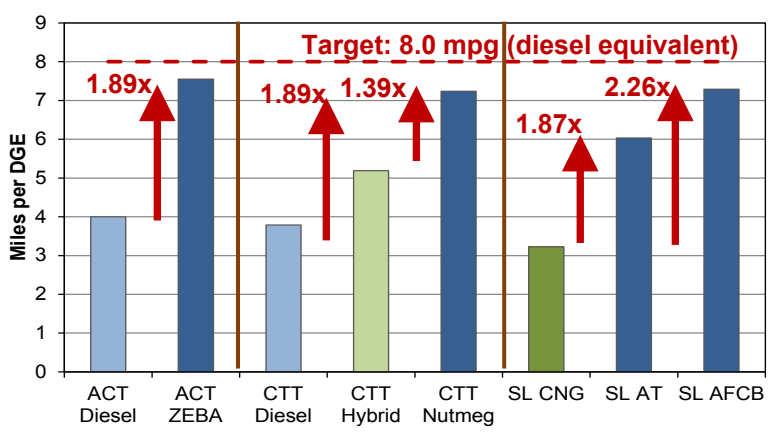
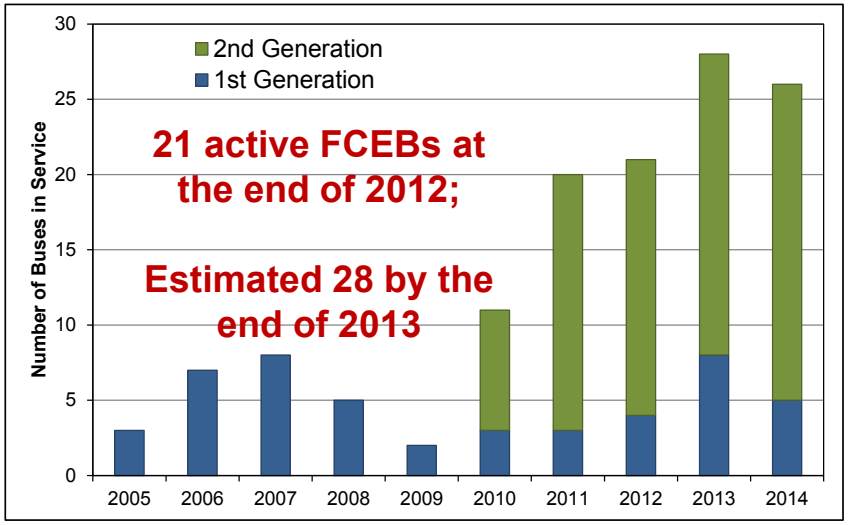
New FC bus designs have ~1.9x the fuel economy of diesel buses, and ~2.3x the fuel economy of CNG buses.





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)



Progress: Fuel Cell Material Handling Equipment

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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.

246,997
Hydrogen fills

2.3 min
Average fill time

0.6 kg
Average fill amount

187,426 kg
Hydrogen dispensed

1,445,558 hrs
Operation time

4.6 hrs
Average operation time between fills

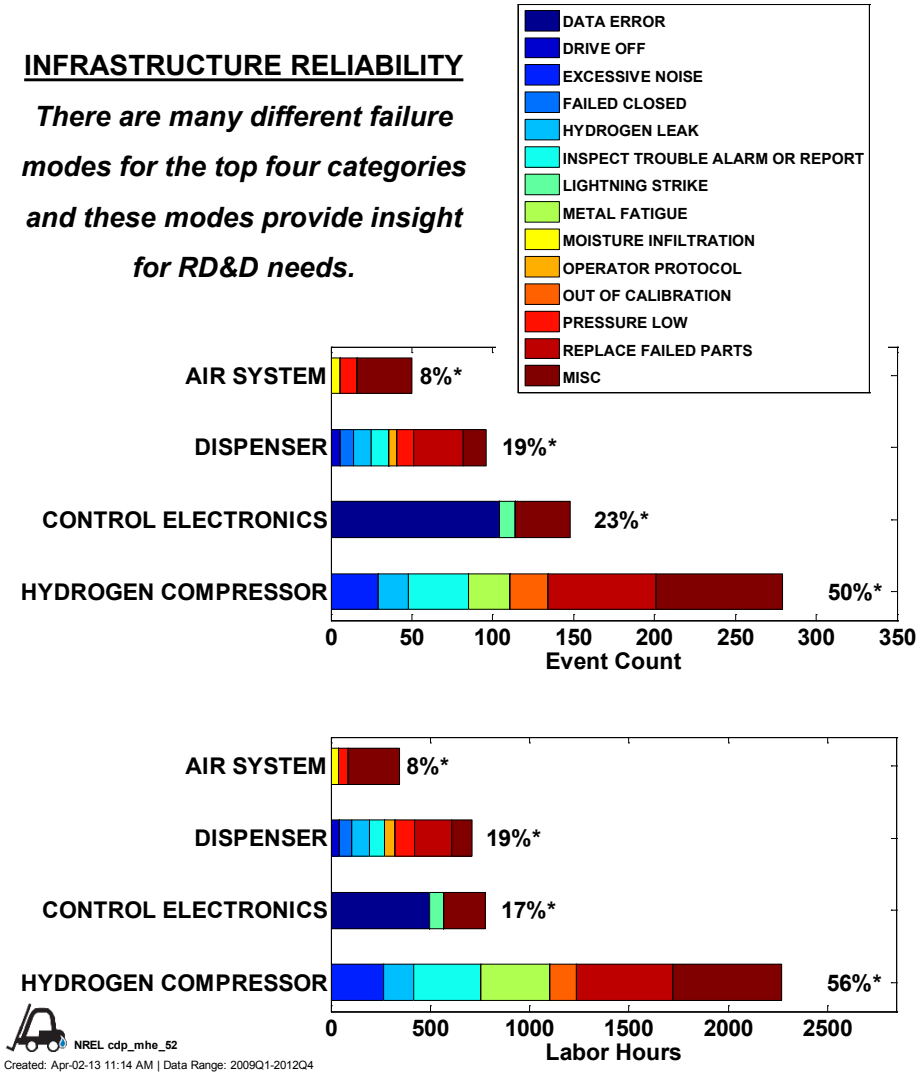
490
Units in operation*

*One project has completed.

An Evaluation of the Total Cost of Ownership of Fuel Cell Powered Material Handling Equipment, NREL report (NREL/TP-5600-56408), April 2013, http://www.nrel.gov/docs/fy13osti/56408.pdf

INFRASTRUCTURE RELIABILITY

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



Progress: Fuel Cell Back-up Power

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Systems are operating reliably in 19 states.

1.86 MW
Installed capacity

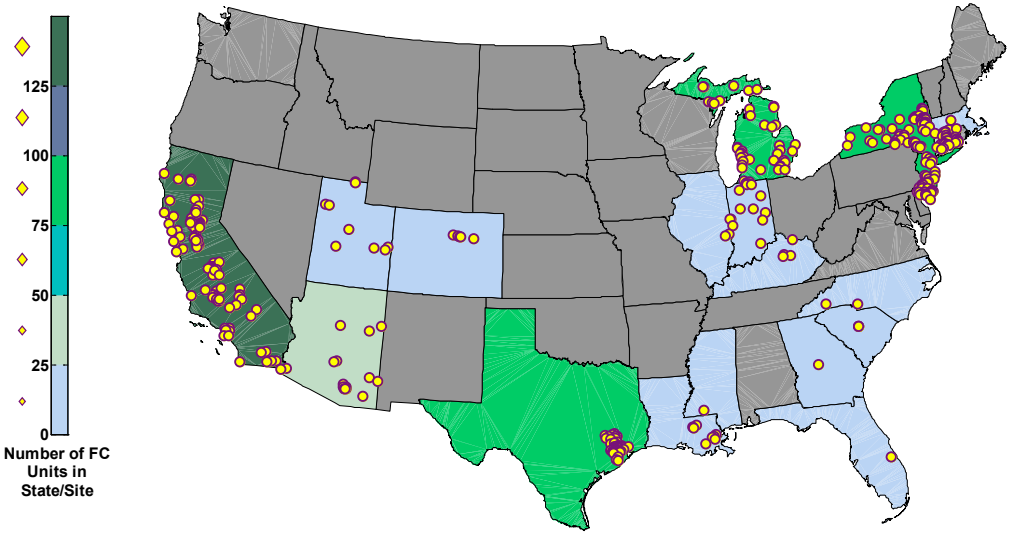
Reasons for unsuccessful starts include an e-stop signal, no fuel, and other system failures.

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

*Not all systems have detailed data reporting to NREL.

Progress: Technology Validation Projects

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

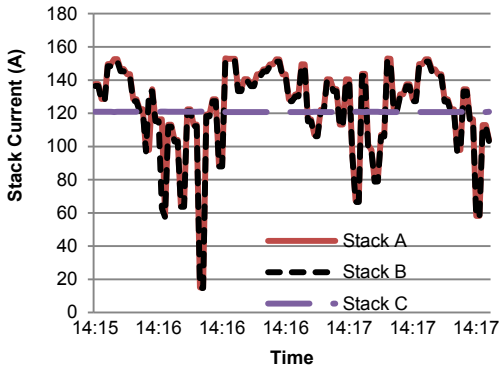
Hydrogen Components (NREL)

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.

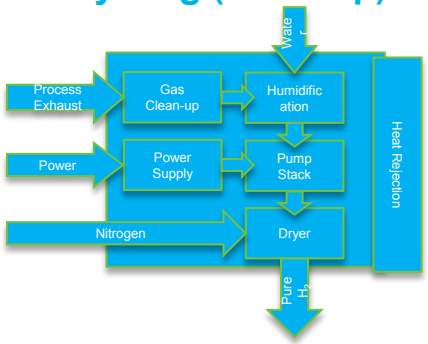
PEM Electrolyzer Stack Test:

- 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 semi-conductor 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

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

http://www1.eere.energy.gov/hydrogenandfuelcells/news_detail.html?news_id=19089.

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.**

Summary

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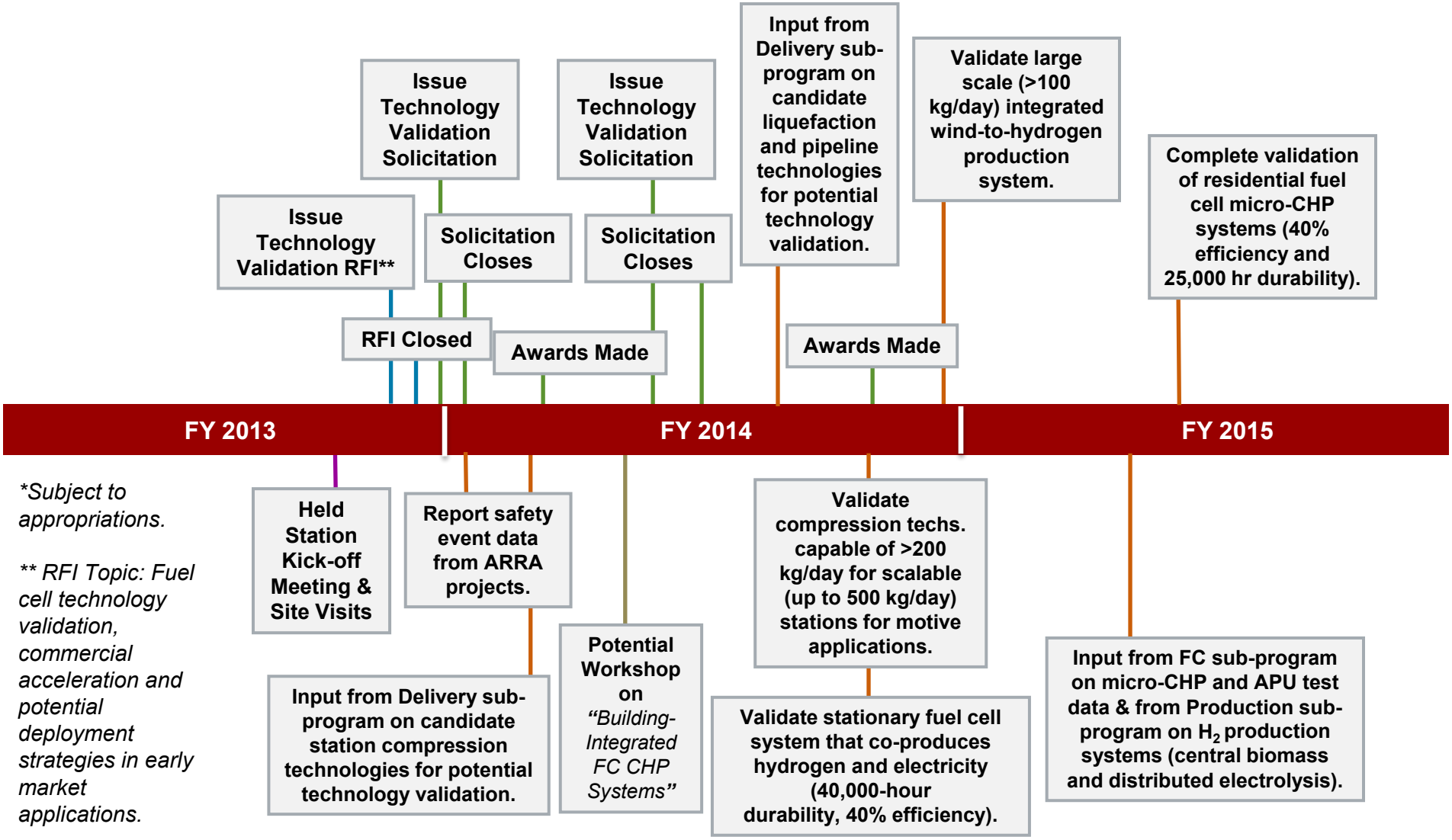
Key milestones and future plans



**Subject to appropriations.*

*** RFI Topic: Fuel cell technology validation, commercial acceleration and potential deployment strategies in early market applications.*

Participating Organizations

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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

U.S. DEPARTMENT OF ENERGY

For more information contact:

Jason Marcinkoski – Acting Team Lead **202-586-7466** **Jason.Marcinkoski@ee.doe.gov**	
Jim Alkire *Golden Office* 720-356-1426 James.Alkire@go.doe.gov	Elvin Yuzugullu *Contractor Support* 202-586-9583 Elvin.Yuzugullu@ee.doe.gov
Jennifer Kurtz *National Renewable Energy Lab* 303-275-4061 Jennifer.Kurtz@nrel.gov	Leslie Eudy *National Renewable Energy Lab* 303-275-4412 Leslie.Eudy@nrel.gov
Sam Sprik *National Renewable Energy Lab* 303-275-4431 Sam.Sprik@nrel.gov	Chris Ainscough *National Renewable Energy Lab* 303-275-3781 Chris.Ainscough@nrel.gov
Genevieve Saur *National Renewable Energy Lab* 303-275-3783 Genevieve.Saur@nrel.gov	

Session Instructions

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- 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

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- 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)