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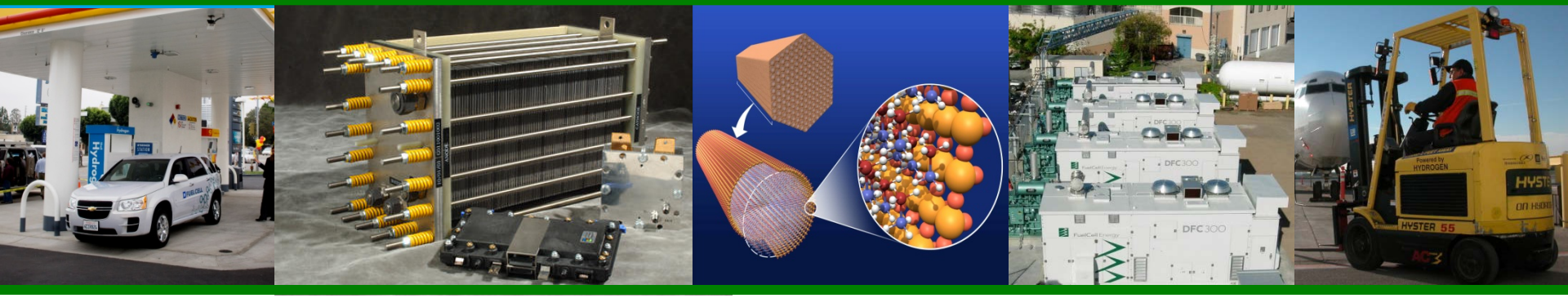


Market Transformation

- **Plenary Presentation** -

Pete Devlin

Fuel Cell Technologies Office

2014 Annual Merit Review and Peer Evaluation Meeting

June 16-20, 2014

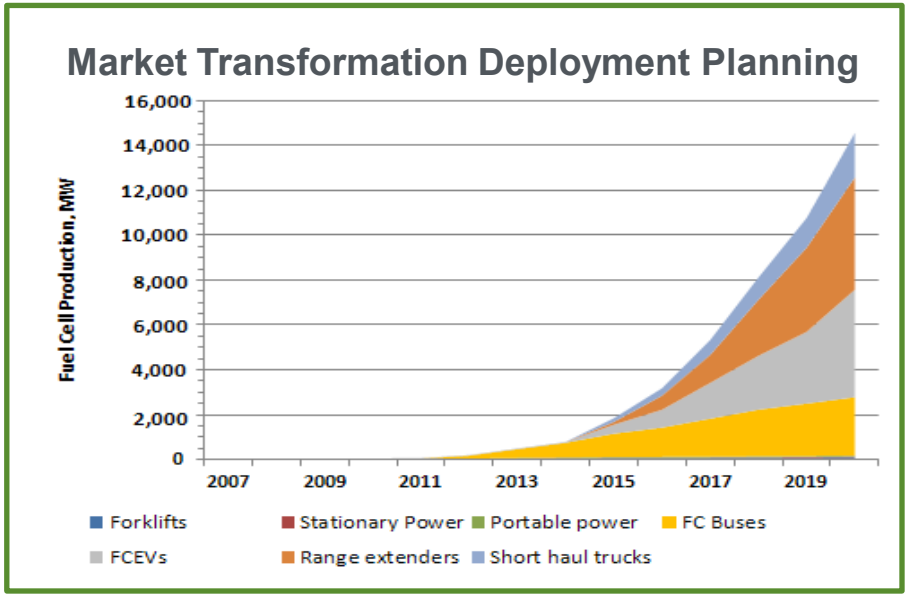
Goals and Objectives for Market Transformation

U.S. DEPARTMENT OF ENERGY

GOALS: Accelerate technology utilization growth for domestically produced hydrogen and fuel cell systems. Lower fuel cell life cycle costs by reducing deployment barriers.

Objectives

- Increase fuel cell markets by developing and deploying various applications and increase hydrogen fuel demand.
- Catalyze key implementation projects and partnerships with federal, state, and local governments and other stakeholders.
- Develop technical-economic analysis associated with early markets and infrastructure.

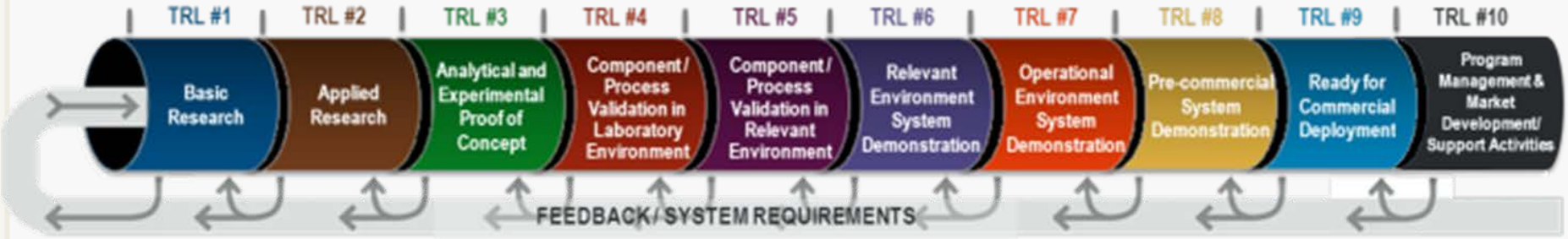


http://www.navigantresearch.com/research/

Challenges

U.S. DEPARTMENT OF ENERGY

- To test emerging applications at the Technology Readiness Level (TRLs) 6-9 level to expand user and servicing expertise



- To test new technology applications in user operating conditions to establish baseline energy efficiency and reliability performance and determine commercial viability

Examples:

A 1-kW fuel cell system providing power for this FAA radio tower near Chicago

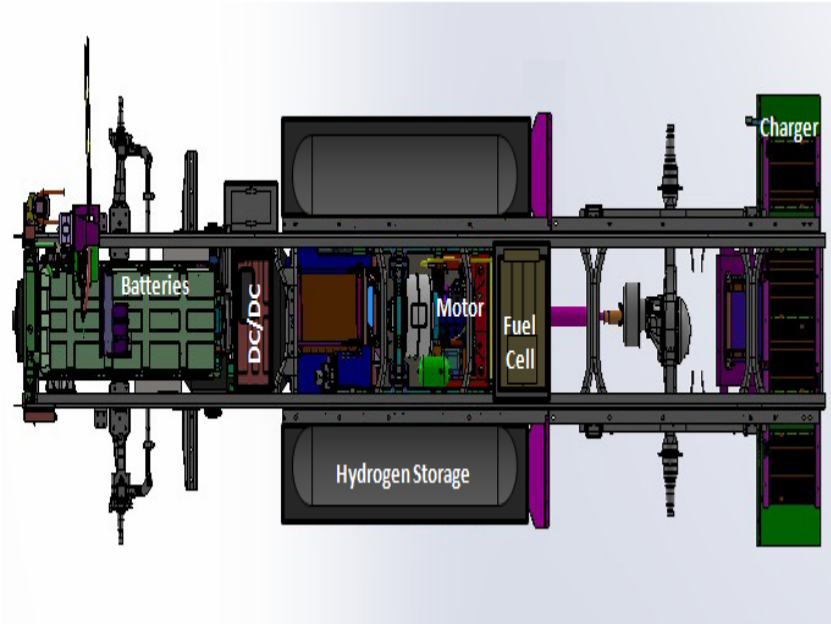
(Photo courtesy of ReliOn/Plug Power)

Material Handling Equipment at work in U.S. airports

(Photo courtesy of Hydrogenics)

Challenges

- To develop strategies to reduce commercial risks to ensure high hydrogen and system utilization and reliability under mass market penetration scenarios

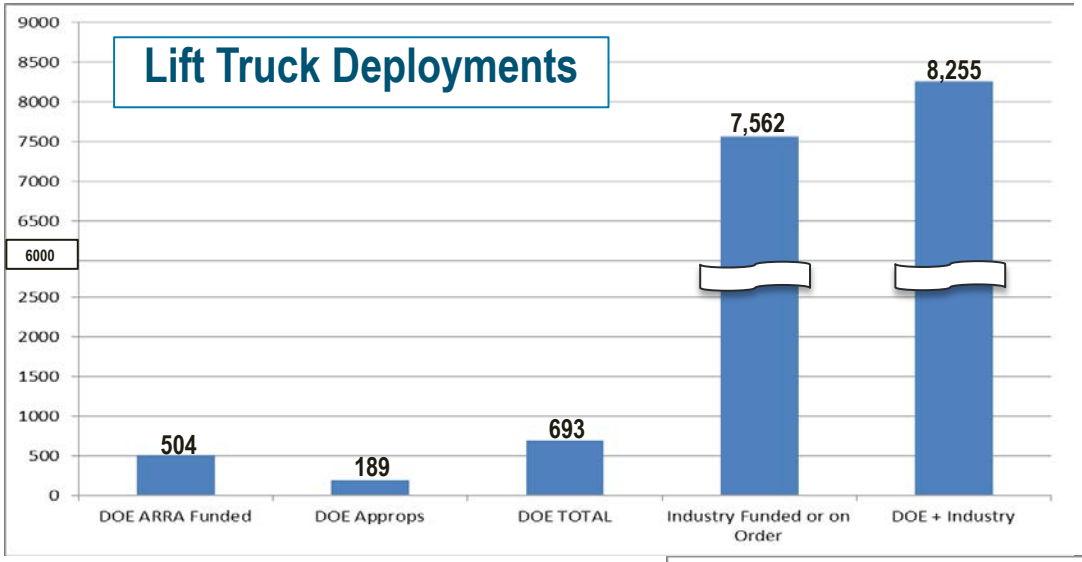


- To obtain data from operating experience and develop replicable business cases

Market Transformation Deployments

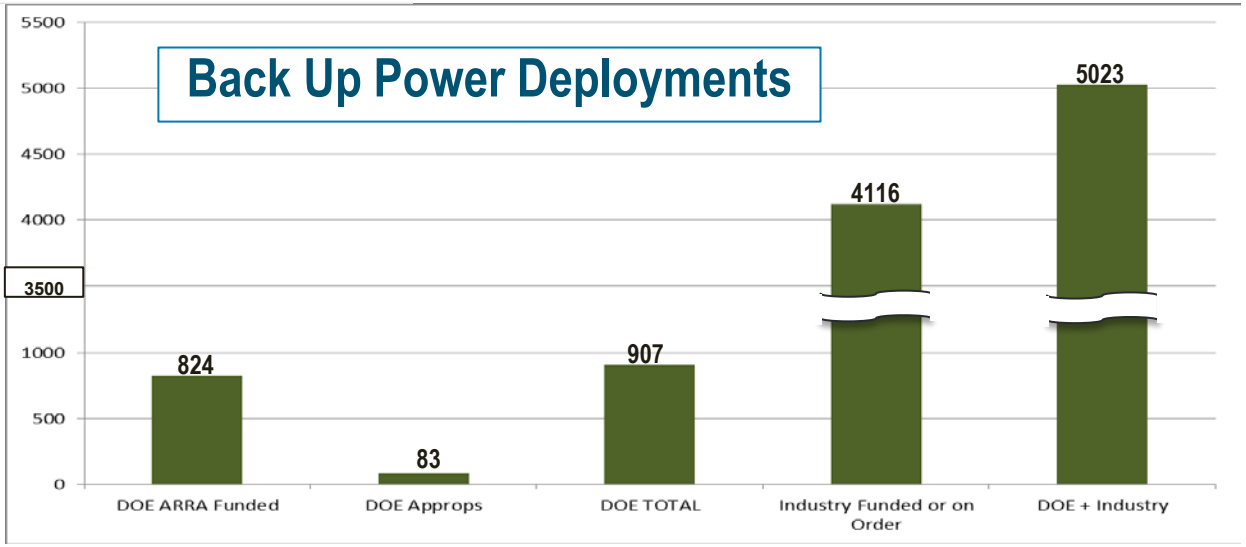
U.S. DEPARTMENT OF ENERGY

DOE investment in lift trucks and back up power has lead to thousands of industry installations.



The successful deployment of nearly 700 DOE fuel cell material handling units has led to over 7,500 industry installation and on order units with no DOE funding.

The funding of 907 DOE fuel cell backup power systems has led to over 4,100 industry installations and on-order backup power units with no DOE funding.



Accomplishments: Fuel Cell Forklifts

U.S. DEPARTMENT OF ENERGY

Business case verified for fuel cell forklift market based on real-world operation and cost data from high-use facilities.

Data for 2009 Q4 – 2013 Q4.

490

Units in operation*

**One project has completed*

4.4

Average operation hours between fills

2,005,680

Operation hours

329,834

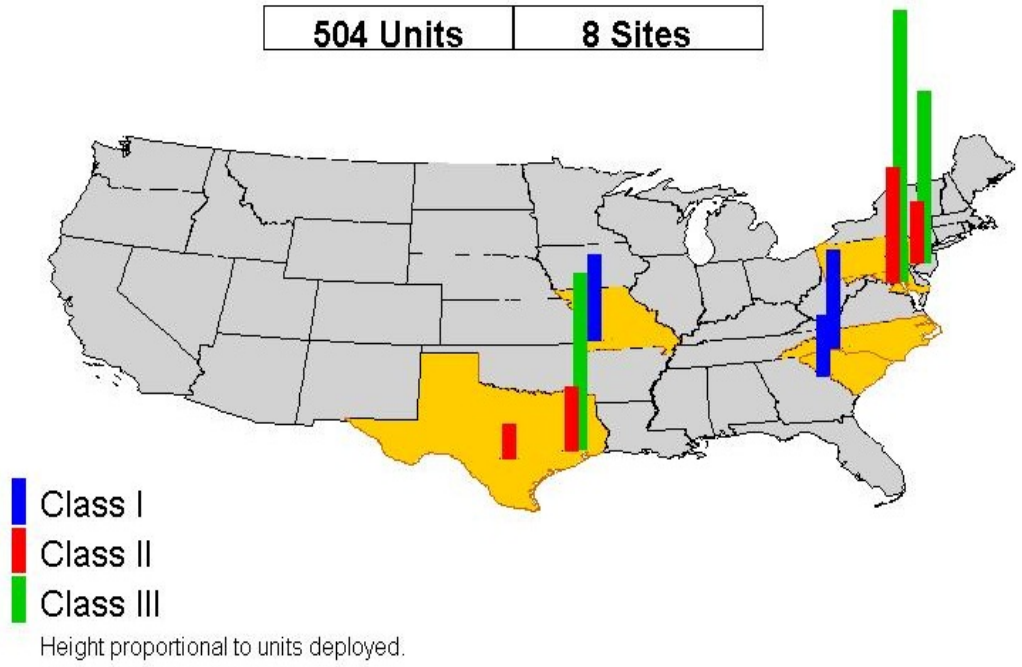
Hydrogen fills

0.7

Average fill amount in kg

275,520

Hydrogen dispensed in kg



2.3

Average fill time in minutes

Accomplishments: Fuel Cells for Back-up Power

U.S. DEPARTMENT OF ENERGY

Systems are operating reliably in 23 states. Reasons for unsuccessful starts include an e-stop signal, no fuel, and other operation failures.

Data for 2009 Q1 – 2013 Q4.

852
Systems in operation*

**Not all systems have detailed data reporting to NREL.*

1,749
Operation hours

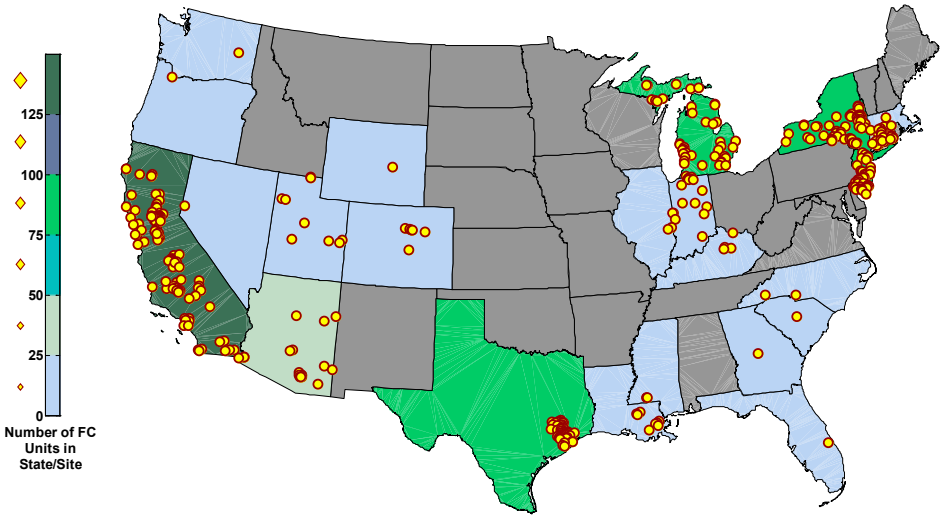
1.99
Installed capacity in MW

4–6
Average site capacity in kW

99.5%
Successful starts

2,578
Start attempts

65
Continuous run hours demonstrated

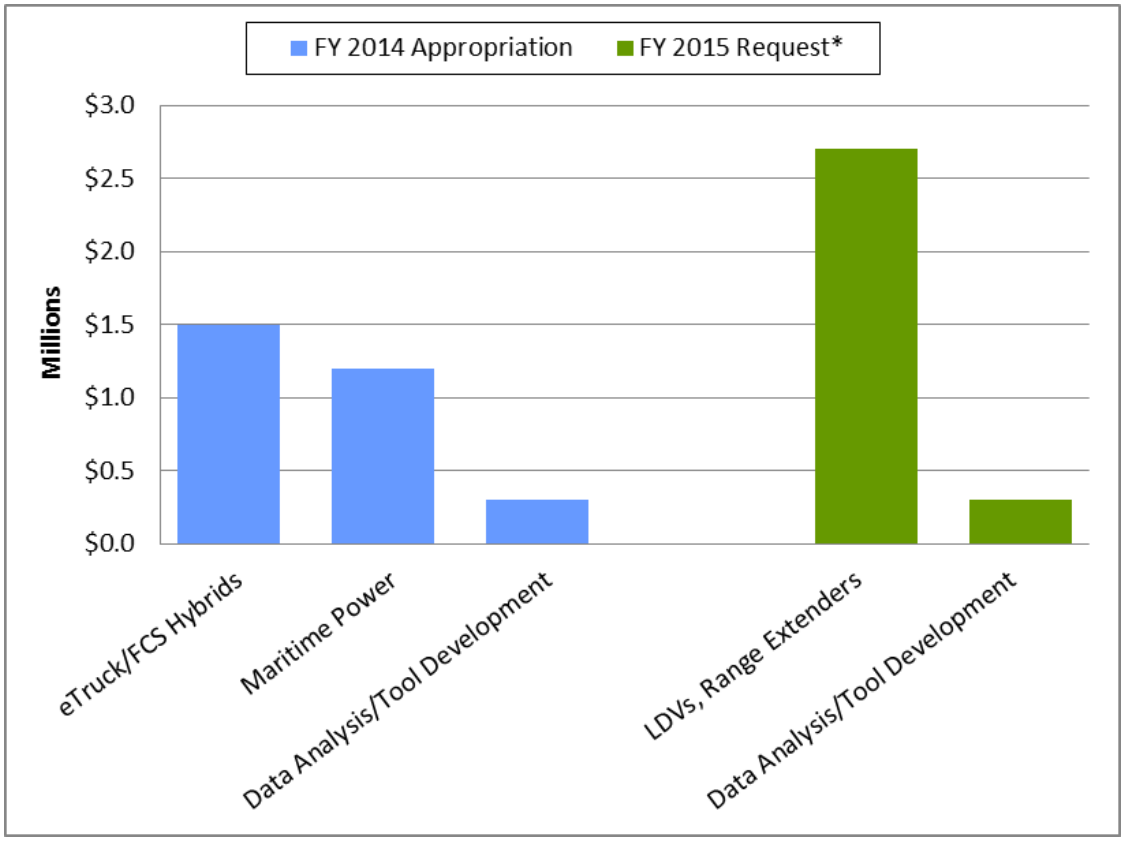


Budget

U.S. DEPARTMENT OF ENERGY

FY 2015 Request = $3M

FY 2014 Appropriation = $3M



*Subject to appropriations

EMPHASIS

- Conduct GSE demonstration and analyze business case
- Medium Duty Truck deployment testing
- New FOAs over the next few FYs to increase various vehicle class deployment and create hydrogen fuel demand agencies
- Continue developing models, tools and templates to support commercialization

Ground Support Baggage Tow Tractors

U.S. DEPARTMENT OF ENERGY

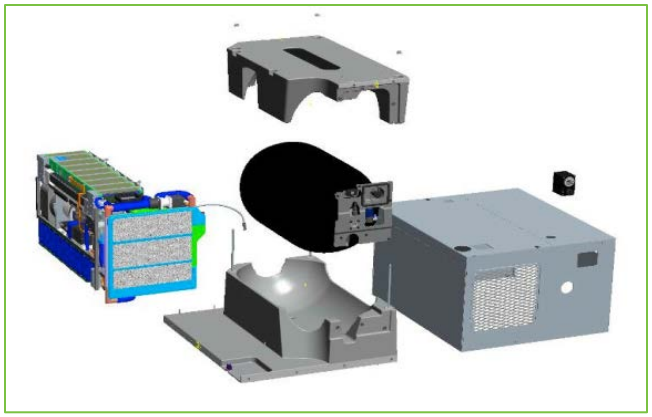
Designed and built 20 kW fuel cell system for airport ground support vehicle

Timeline

- Start: January 2013
- End: December 2015
- Kickoff Meeting – 3/27/13

Budget

- Total: $5.0M
  - DOE Share: $2.5M
  - Partners - $2.5M
  - Status: 19.5% Complete



Barriers

- Power upsizing for BTT app
- Outdoor operation

Partners

- Plug Power
- FedEx Express
- Charlatte
- Memphis-Shelby County International Airport

Accomplishment

- Designed, built, tested Alpha prototype

Marine generator for pier side and auxiliary sea vessel power

U.S. DEPARTMENT OF ENERGY

Developed a prototype design for a marine generator for pier side and auxiliary sea vessel power.

Timeline

- Start: Sept. 2013
- End: Dec. 2015
- 25% complete

Budget

- Total: $2.1M
  - DOE Share: $712k
    - $40k received in FY13
    - $672k received & planned in FY14
  - DOT/MARAD Share: $700k
    - Received in FY13
  - Contractor Share (est.): $700k

Barriers

- Inadequate standards
- Financing mechanisms (Lack of cost and performance data)
- Inadequate user experience

Partners

- Sandia *(project lead)*
- Young Brothers, Ltd.
- Foss Maritime
- Hydrogenics
- Hawaii Natural Energy Institute (HNEI)
- American Bureau of Shipping (ABS)
- US Coast Guard (USCG)

APUs for Refrigerated Trucks

U.S. DEPARTMENT OF ENERGY

Designed and developed 2 auxiliary power systems for refrigerated trucks

Timeline

- Project Start: April 2013
- Project End: Dec. 2015
- Percent complete: 37%

Budget

- FY13 DOE Funding: $800k
- Planned FY14 DOE Funding: $0k
- Total DOE Project Value: $1.6M Total (PNNL) Program
  - Includes $1.3M for subcontracts
  - Contractor cost share $1.6M

Barriers

- Inadequate private funds available for new applications
- Inadequate user experience for fuel cell applications
- Lack of value proposition awareness of applications

Partners

- Project Lead – Pacific Northwest National Lab
- System Integrators – Nuvera, Plug Power
- Transport Refrigeration Unit Developers
  - ThermoKing
  - Carrier Transicold
- System Demonstrators
  - HEB and Sysco
- H_2 Provider: Air Products

LFG gas to hydrogen technology

U.S. DEPARTMENT OF ENERGY

Proved LFG gas to hydrogen technology in making high purity (SAE J2719) fuel for motive power.

Timeline

- Project Start Date: 17 Jun 2011
- Project End Date: 30 Sep 2014
- Percent Complete: 85%

Budget

- Total Project Funding: $1,402K
  - DOE Share: $650K
  - Contractor Share: $752K
- FY13 Funding Received: $0

Barriers

- Lack of adequate technology to clean up LFG for PEM FC applications
- Lack of H2 infrastructure

Partners

- Project Lead: SCRA
- BMW
- Gas Technology Institute
- Ameresco, Inc.
- SC Hydrogen & Fuel Cell Alliance

Additional Collaborators

- American Nitrogen Rejection, LLC
- Urban Renewable H2 (final phase)

Accomplishments: Fuel Cell Hybrid Electric Medium-duty Trucks

U.S. DEPARTMENT OF ENERGY

Two new projects will deploy fuel cell hybrid electric medium-duty trucks.

FedEx Express –Memphis, TN airport with:

- **Smith Electric Vehicles:** 80 kWh eTruck, extending range from 56 to 150 miles
- **Plug Power:** 10 kW fuel cell

IMPACT*:

FedEx Express uses approximately 40,000 vehicles in its fleet, which could potentially be replaced with fuel cell hybrid vehicles. The 20 deployed vans could save 97,880 gallons diesel per year and 248 metric tons of CO_2 emissions per year.

Center for Transportation-Environment (UT Austin, TX) with:

- **United Parcel Service:** Sacramento, CA demo
- **Electric Vehicles International:** 99 kWh eVan, extending range from 75 to 125 miles
- **Hydrogenics USA:** 16 KW fuel cell

IMPACT*:

Fuel cell hybrid vehicles could potentially take the place of ~46,000 diesel walk-in vans in UPS' fleet alone. The deployed vans could save ~26,000 gallons of diesel per year and ~258 metric tons of CO_2 emissions per year.

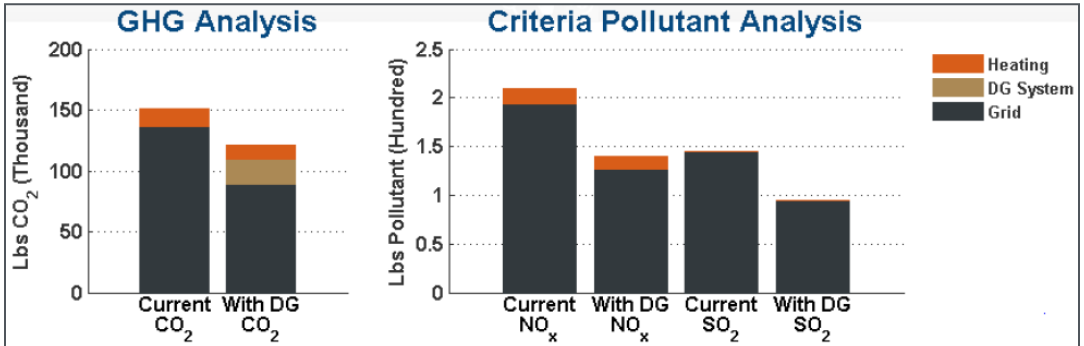
*Pending awards

Accomplishments

U.S. DEPARTMENT OF ENERGY

- Awarded to fuel cell electric waste hauling refuse truck develop and deploy SBIR projects (Vision and US Hybrid).
- Completed Refueling Site Study with GSA and FEMP for refueling station.
- Developed web tool (beta test version) to assess costs and benefits for stationary power with third party financing.
- Analyzed policies and worked with EPA to change Diesel Emissions Reduction Act solicitations to explicitly include fuel cell vehicles.
- Developed hydrogen refueling infrastructure plans and fleet deployments, working with states
  - Examples – Federal FCEV Fleet Strategy, and Hawaii Infrastructure Implementation plan.

Web Tool to Assess Costs



Annual GHG and Pollutant Production (lbs)

	CO_2		NO_x		SO_2	
	Current	With DG	Current	With DG	Current	With DG
Heating	13,945	11,580	14	12	0	0
DG System	0	20,537	0	0	0	0
Grid	136,838	89,526	194	127	144	94
Total	150,783	121,644	209	139	144	94

Hydrogen and Fuel Cell Initiatives at the State Level

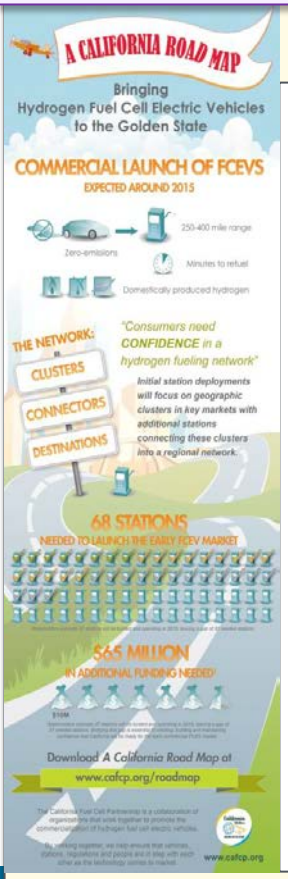
U.S. DEPARTMENT OF ENERGY

Several states have major hydrogen and fuel cell programs underway.

5/29/2014: 8 states approve Action Plan to put 3.3M zero-emission vehicles on roads by 2025

States include California, Connecticut, Massachusetts, Maryland, New York, Oregon, Rhode Island, & Vermont

- **Represents a new vehicle market penetration of ~15%**



California

Fuel Cell Electric Vehicles (FCEVs) and Fuel Cell Buses (FCBs)

- **> 560 vehicles** in operation since 1999 — ~230 currently operating
- **> 6 million miles** driven
- **> 1 million passengers** on fuel cell buses

H_2 Station Investment

- **$51.5M invested** *(CARB and CEC)*
- **~$13M invested** by SCAQMD
- **~$46.6M for 28 stations and 1 mobile refueler** (CEC PON 13-607)
- **$20M planned annually** thru 2023 for at least 100 stations (AB8)

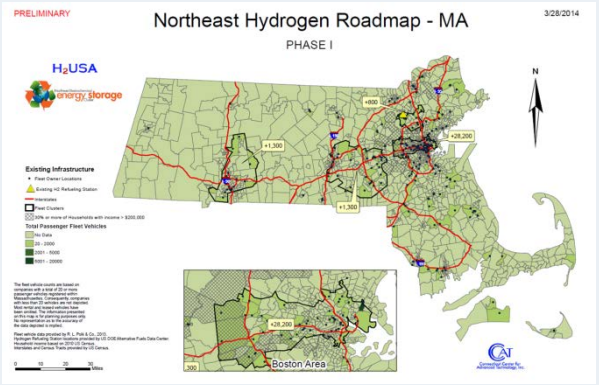
Northeast (e.g. MA, NY, CT)

Preliminary Plans:

H2 coalitions established in CT & MA

Initial-stage meetings held with several states (CT, MA, NY, RI) to develop action plans to deploy FCEVs -- incl. LDVs and MD & HD bus and truck fleets.

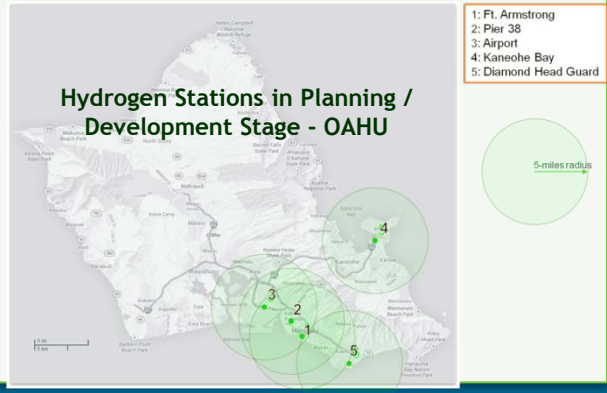
3 H2 stations in Boston metro by CYE 2014 -- assessing federal properties for siting new H2 stations using EULs



Hawaii

Agreement signed by 12 stakeholders—including GM, utilities, H2 providers, DOD, DOE—to establish hydrogen as a major part of the solution to Hawaii's energy challenges.

- **15 GM FCEVs currently in demonstrations with military**
- **Renewable hydrogen (from wind and geothermal energy) used for buses on Big Island**
- **Goals include a multi-site public access refueling infrastructure by 2020 to support initial deployments of FCEV and FCB fleets**
- **Completed Fort Armstrong feasibility study to create H2 fueling station in downtown Honolulu on GSA property.**

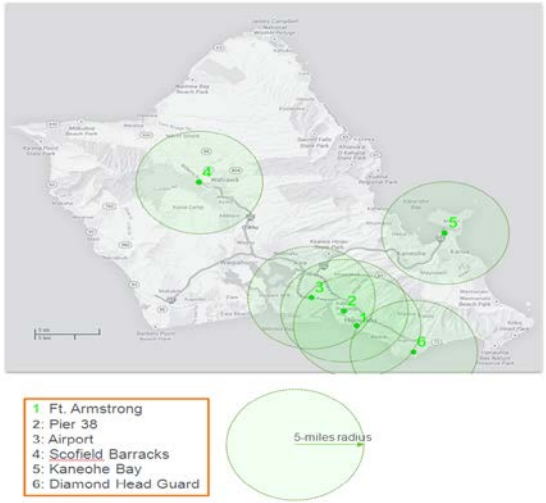


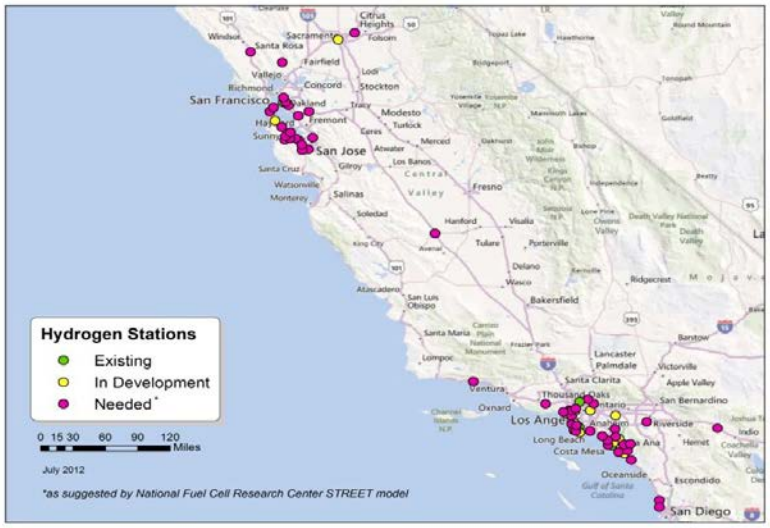
Federal FCEV Fleet Strategy in Development

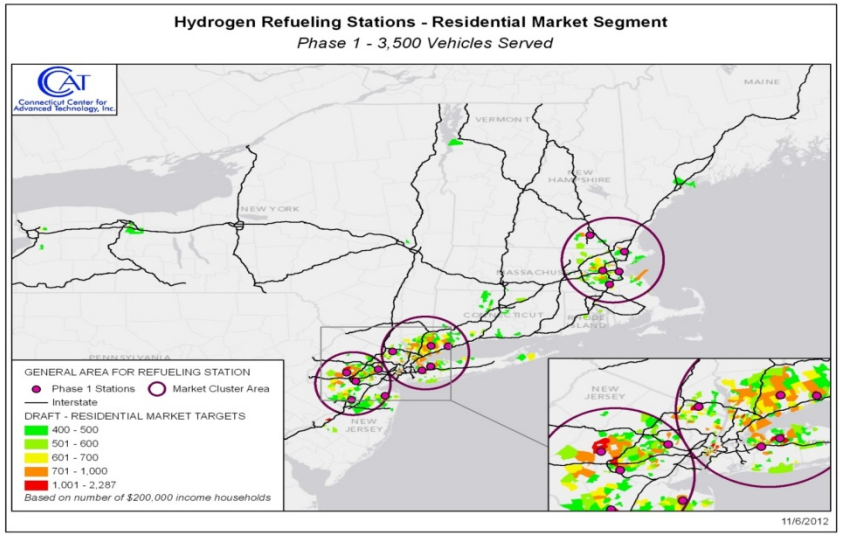
Five key actions to accomplishing this vision

Examples:

- ✓ Lease over 2,600 or more fuel cell electric vehicles by the federal government in the early market regions from 2015-2020. Multiply several-fold with state/local/private fleets.
- ✓ Cost-share the deployment of at least 35 fuel cell buses in early market regions from 2015-2020.
- ✓ Enable the development of at least five public hydrogen stations on suitably located on federal property by 2020.
- ✓ Initiate over 10 early market application deployments for motive fuel cells.
- ✓ Develop an acquisition process which will provide hydrogen for federal FCEV drivers.



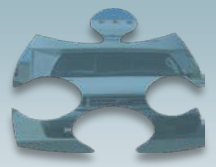




Infrastructure for FCEVs
The Key Pieces of the FCEV-H_2 Puzzle

Creating ZEV and H_2 station **incentives and cost share** opportunities

Establishing Initial Infrastructure: Coordinating with the right stakeholders



FCEV fleet planning

Harmonizing **codes and regulations**

Creating an **affordable hydrogen** system

Exercising the **Financing Options**

Form broad communities of interest to promote FCEVs and H_2 stations

Timely **Education & Outreach**

Upcoming RFI – Continuous On Board Recharging Application for Battery Electric LDVs

U.S. DEPARTMENT OF ENERGY

Upcoming RFI seeks information on the technical and economic feasibility of commercializing fuel cell range extenders for available BEVs in the United States market

U.S. commercial fleets are a large automotive market segment, with vehicle inventories totaling:

- ~11.7 million vehicles
- New car and light truck sales of about 2.6 million vehicles annually.

Commercial fleets include:

- Government owned vehicles (e.g. police cars)
- Company-owned vehicles
- Rental fleets
- Taxis
- Delivery vehicles

Renault HyKangoo EV with Fuel Cell Range Extender

In a survey of vehicle fleet operators, the fleet managers indicate that right-sizing vehicles to the job is the top priority in their efforts to reduce greenhouse gas emissions.

A study conducted by Argonne National Laboratory for DOE, "*The Benefits of Using a Fuel Cell Auxiliary Power Unit to Double the Range of Current Battery Electric Vehicles*," has evaluated the fuel consumption, cost trade-offs and other impacts of using a small fuel cell to extend the driving range of a battery electric vehicle, assessing the benefits for different fuel-cell-rated power and battery power ranges (ref. P. Sharer, A. Rousseau, "Benefits of Fuel Cell Range Extender for Medium-Duty Vehicle Applications", EVS27, Nov 17–20 2013).

EERE is specifically interested in information on BEV makes and models that are the most feasible for an after-market modification to extend the vehicle range using a PEM fuel cell system.

Collaborations

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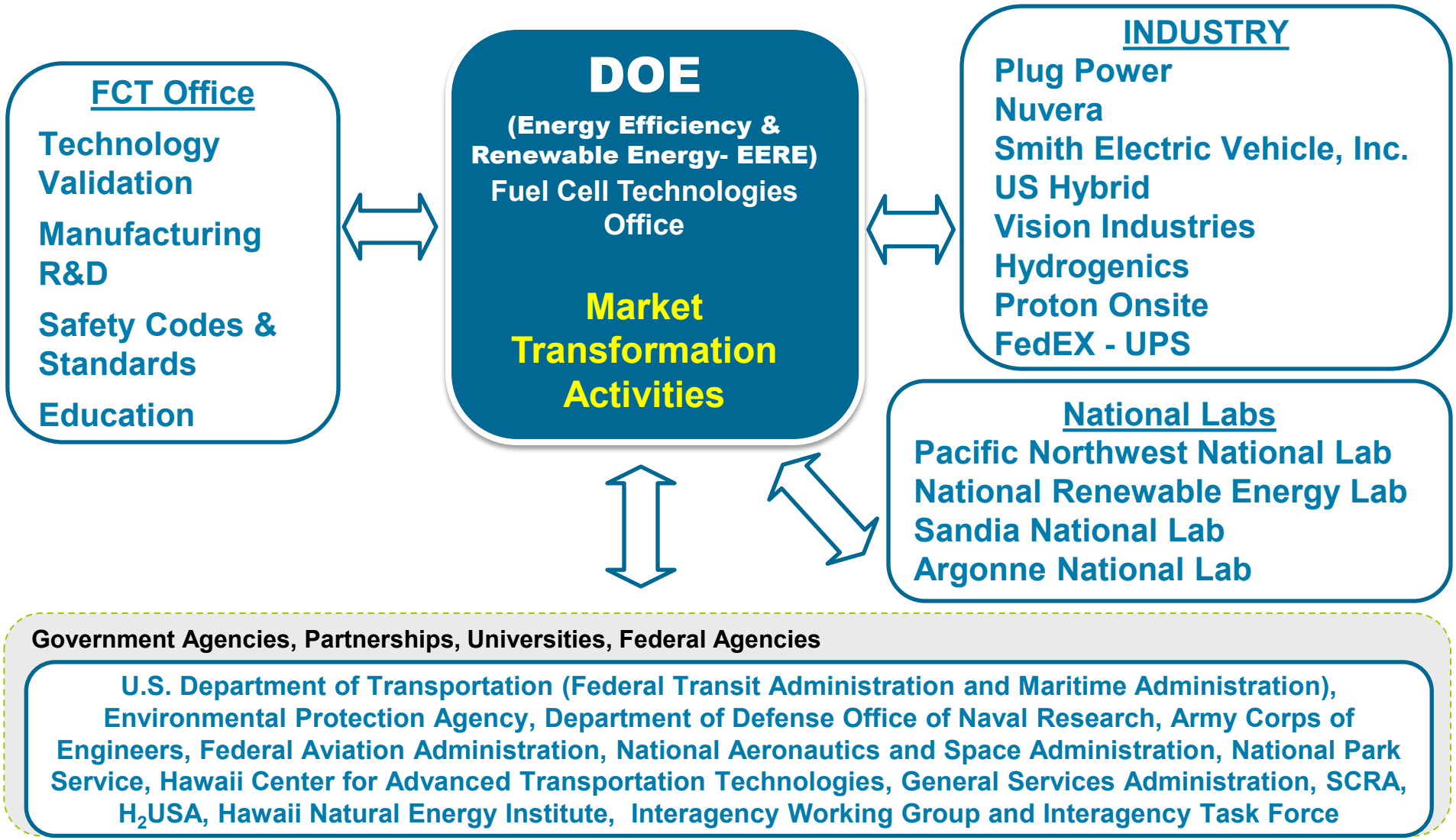
Activities are coordinated among various partners.



Government Agencies, Partnerships, Universities, Federal Agencies

U.S. Department of Transportation (Federal Transit Administration and Maritime Administration), Environmental Protection Agency, Department of Defense Office of Naval Research, Army Corps of Engineers, Federal Aviation Administration, National Aeronautics and Space Administration, National Park Service, Hawaii Center for Advanced Transportation Technologies, General Services Administration, SCRA, H_2USA, Hawaii Natural Energy Institute, Interagency Working Group and Interagency Task Force

Recent and Upcoming Activities

U.S. DEPARTMENT OF ENERGY

New investments in critical areas of early markets and infrastructure to support FCEV commercialization.

Early Markets

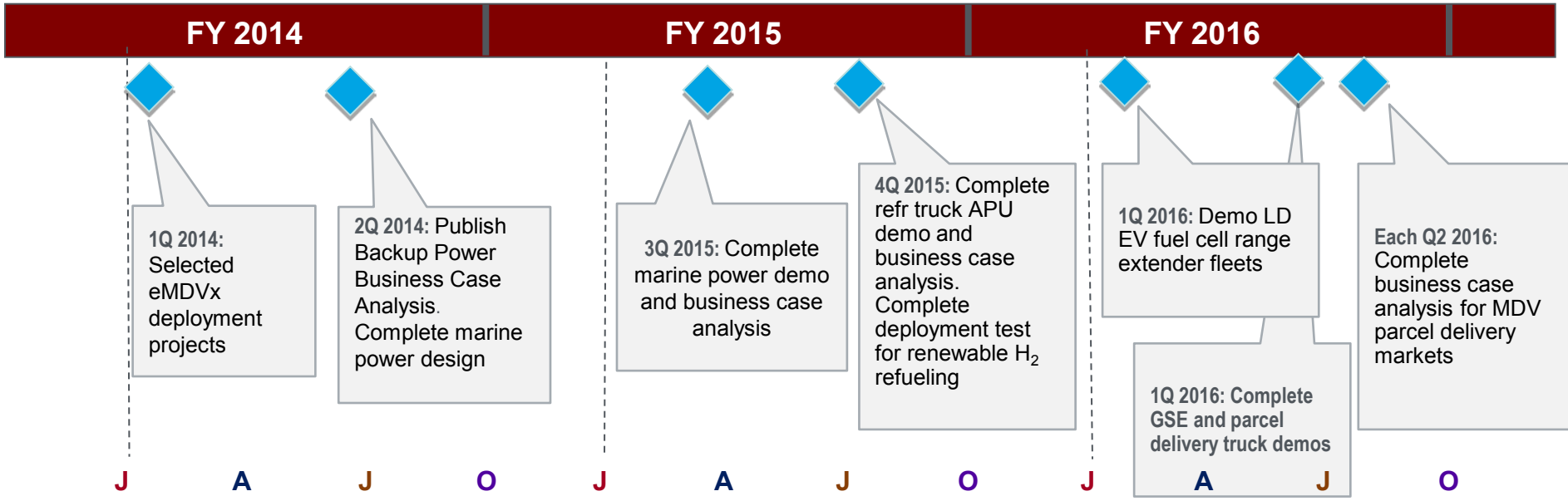
- Fuel cell-based forklifts and back-up power systems continue to demonstrate successful and reliable operations under real-world conditions.
- Stationary fuel cells demonstrate high availability; deployments increasing steadily, with most running on natural gas. However, prices for these systems remain high.
- Back up power business case completed showing economic viability of fuel cell power for this application.

Vehicles

- Two new projects selected to deploy fuel cell hybrid electric medium-duty trucks to evaluate the business case for this application.
- RFI for Light duty all electric fuel cell range extenders issued.

Stations

- Working with H2USA partners to plan and deploy infrastructure in Hawaii and New England states e.g. Massachusetts, Rhode Island , and Connecticut.



Contacts

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http://energy.gov/eere/fuelcells/fuel-cell-technologies-office