



Presentation
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Analysis Results of ARRA Fuel Cell Early Market Projects

Hydrogen + Fuel Cells 2011
May 17, 2011

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Contents

NREL Data Analysis Objectives

Overview of ARRA Fuel Cell Projects

Deployment and Performance Results

Backup Power

Material Handling Equipment

Assess the technology status in real world operations, establish performance baselines, report on fuel cell and hydrogen technology, and support market growth by evaluating performance relevant to the markets' value proposition for early fuel cell markets.

Assess Technology

- Independent technology assessment in real world operation conditions
- Focused on fuel cell system and hydrogen infrastructure: performance, operation, and safety
- Leverage data processing and analysis capabilities developed under the fuel cell vehicle Learning Demonstration project

Support Market Growth

- Analyses and results relevant to the markets' value proposition
- Reporting on technology status to fuel cell and hydrogen communities and other key stakeholders like end users

Early Fuel Cell Markets

- Material handling equipment, backup power, portable power, and stationary power.
- Analysis includes up to 1,000 fuel cell systems deployed with ARRA funds

Hydrogen Secure Data Center

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

Internal analysis completed quarterly



HSDC

NREL's Hydrogen Secure Data Center



Results

DDPs

CDPs

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

ARRA Early Market Fuel Cell Project – Evaluating deployments in many applications, sites, and regions

Enabling Fuel Cell Market Transformation

Accelerate the commercialization of fuel cells, manufacturing, installation, maintenance, and support service through 12 awards



**Deploy up to
1,000 FC
Units**

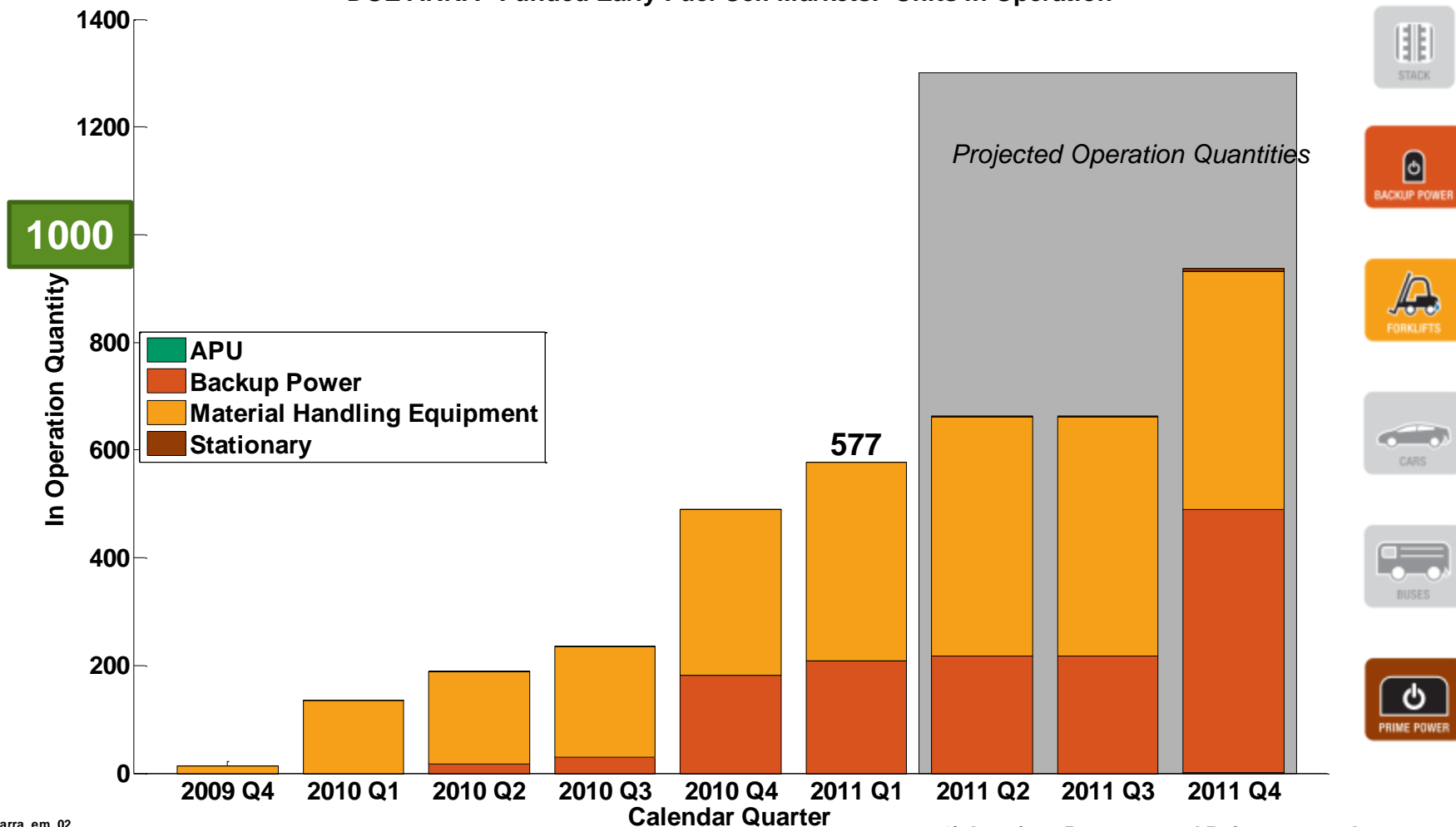
Material Handling,
Backup Power,
Combined Heat &
Power, Auxiliary Power,
and Portable Power

COMPANY	APPLICATION
Delphi Automotive	Auxiliary Power
FedEx Freight East	Specialty Vehicle
GENCO	Specialty Vehicle
Jadoo Power	Backup Power
MTI MicroFuel Cells	Portable
Nuvera Fuel Cells	Specialty Vehicle
Plug Power, Inc. (1)	CHP
Plug Power, Inc. (2)	Backup Power
Univ. of N. Florida	Portable
ReliOn Inc.	Backup Power
Sprint Comm.	Backup Power
Sysco of Houston	Specialty Vehicle

ARRA Fuel Cell Units in Operation

Current and Projected Quantities

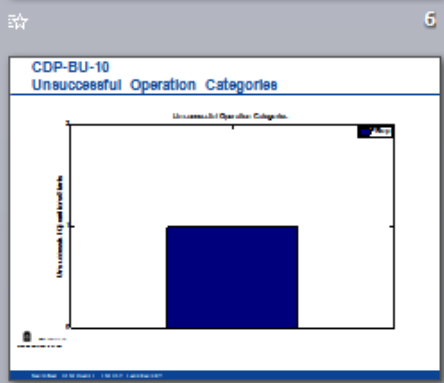
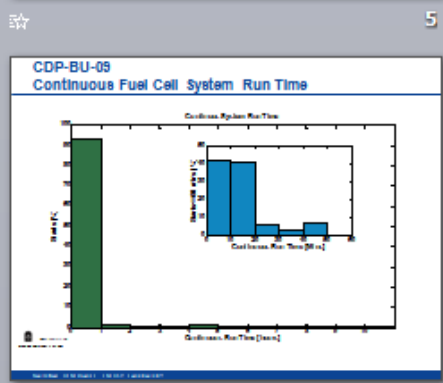
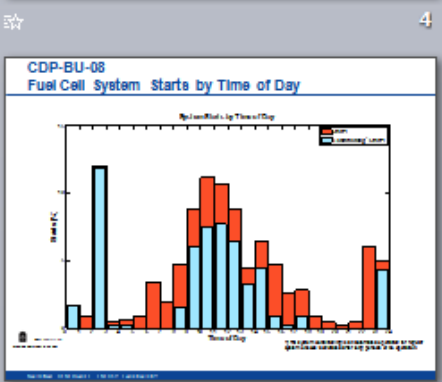
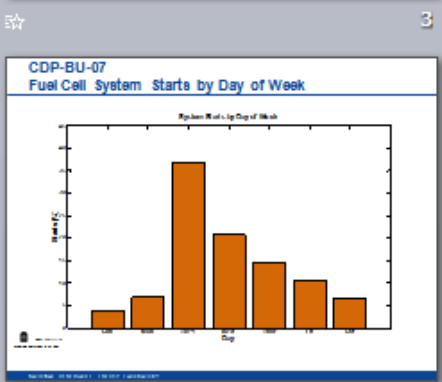
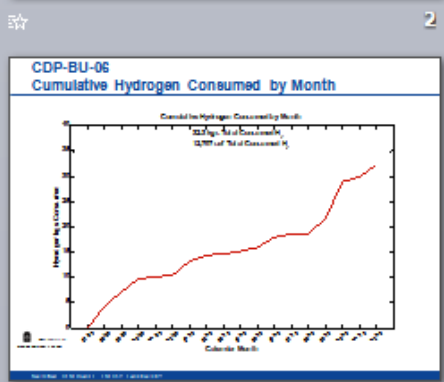
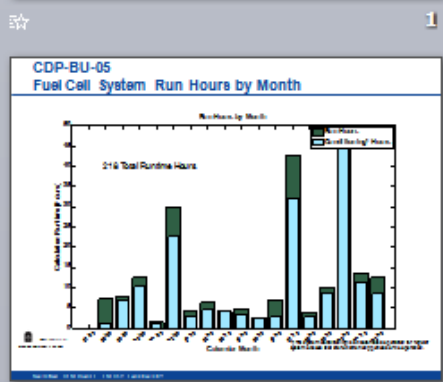
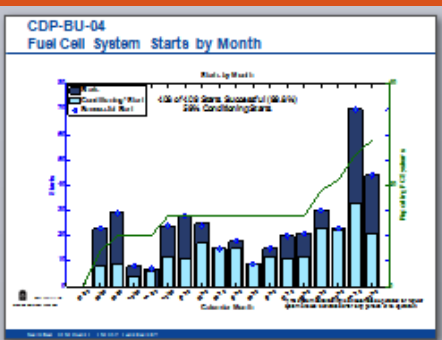
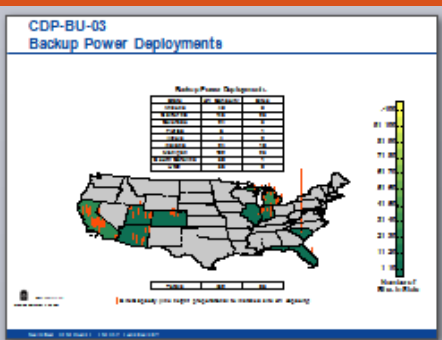
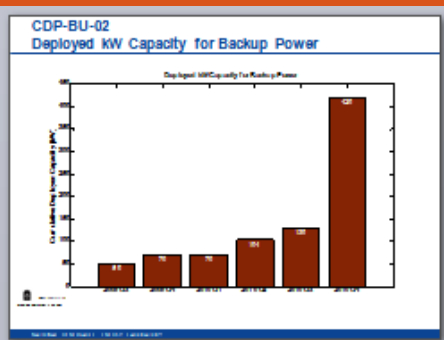
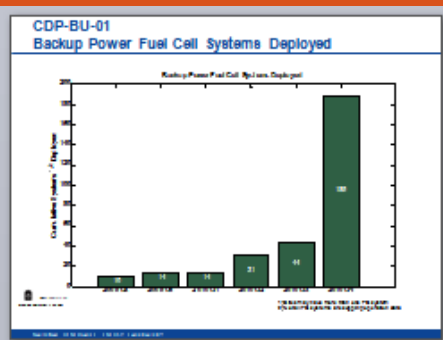
DOE ARRA¹ Funded Early Fuel Cell Markets: Units in Operation



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1) American Recovery and Reinvestment Act

FC Backup Power 10 CDPs



Results include

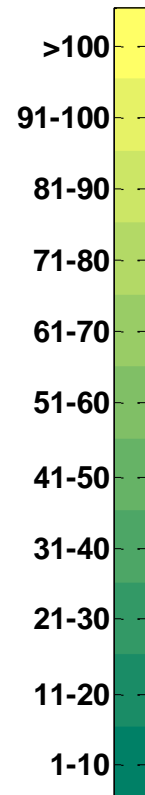
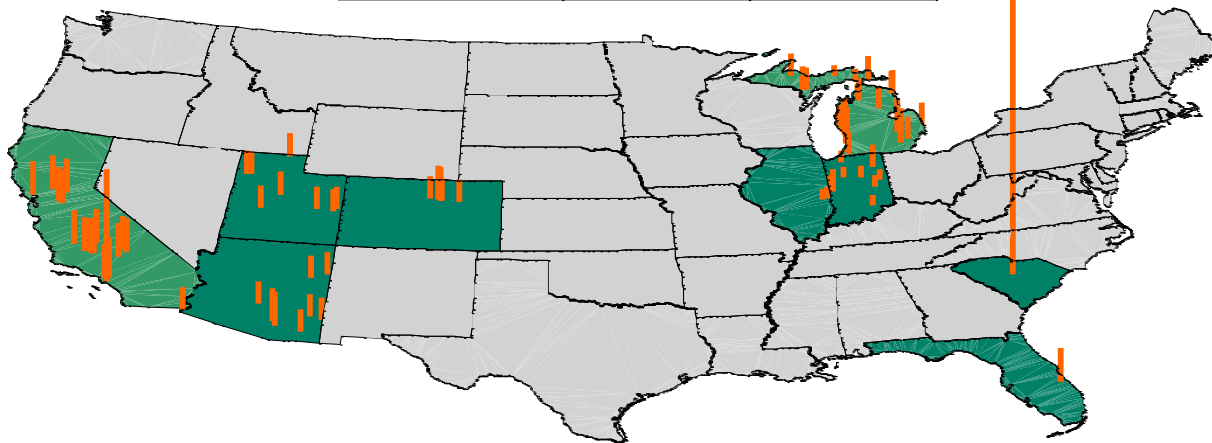
- Units deployed & deployed kW capacity
- Starts, hours, & continuous runtime
- Reasons for unsuccessful starts
- Hydrogen consumed
- Start trends by day of week & time of day

Site Location and Capacity

9 states with backup power sites

Backup Power Deployments

State	kW Capacity	Sites
Arizona	40	9
California	146	23
Colorado	24	5
Florida	6	1
Illinois	4	2
Indiana	24	10
Michigan	102	25
South Carolina	50	1
Utah	36	9



Totals	432	85
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| Site Capacity (line height proportional to installed site kW capacity)

Number of Sites in State

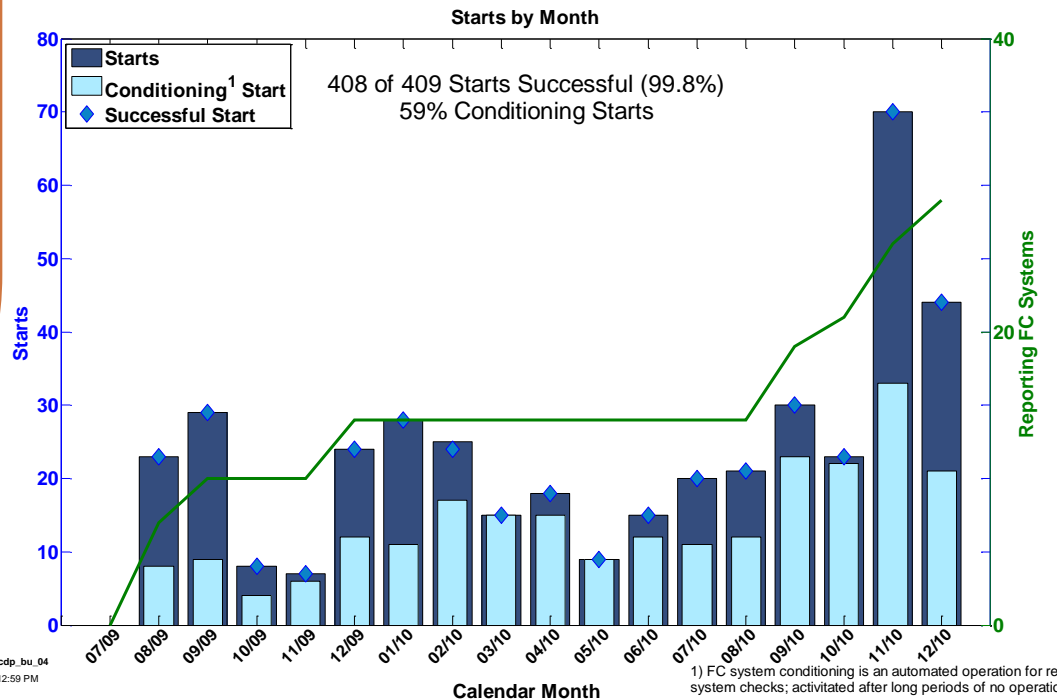
Summary of Backup Power System Operation



Sites	85	CDP-BU-#
Deployed Systems	189*	01
Total Successful Starts	408 (99.8%)*	04
Total Run Time	218 hours*	05
Total Hydrogen	32.3 kg*	06

Key Performance Metrics

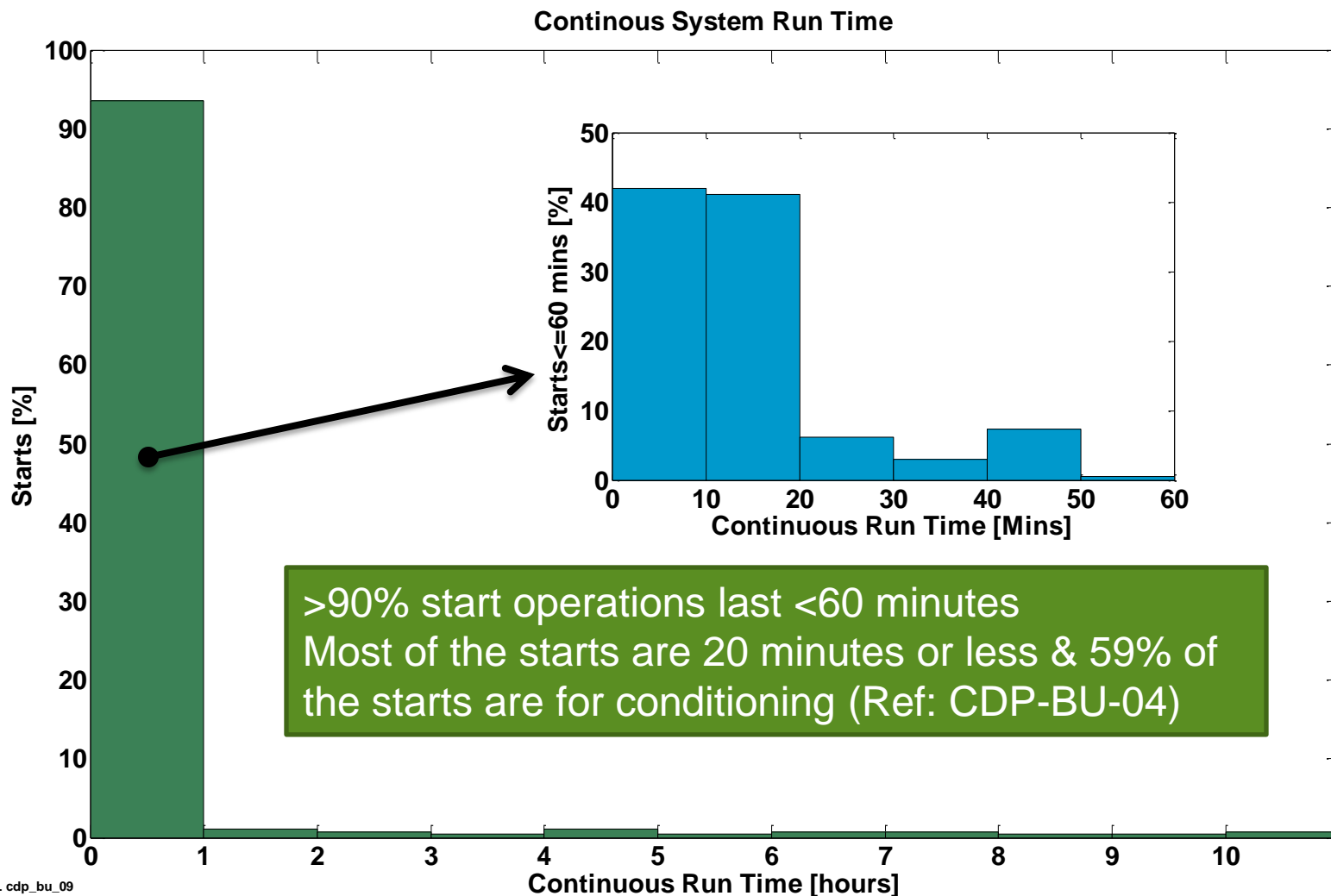
- Reliability
- Low Emissions
- Low Noise
- Ease of Use
- Remote Monitoring



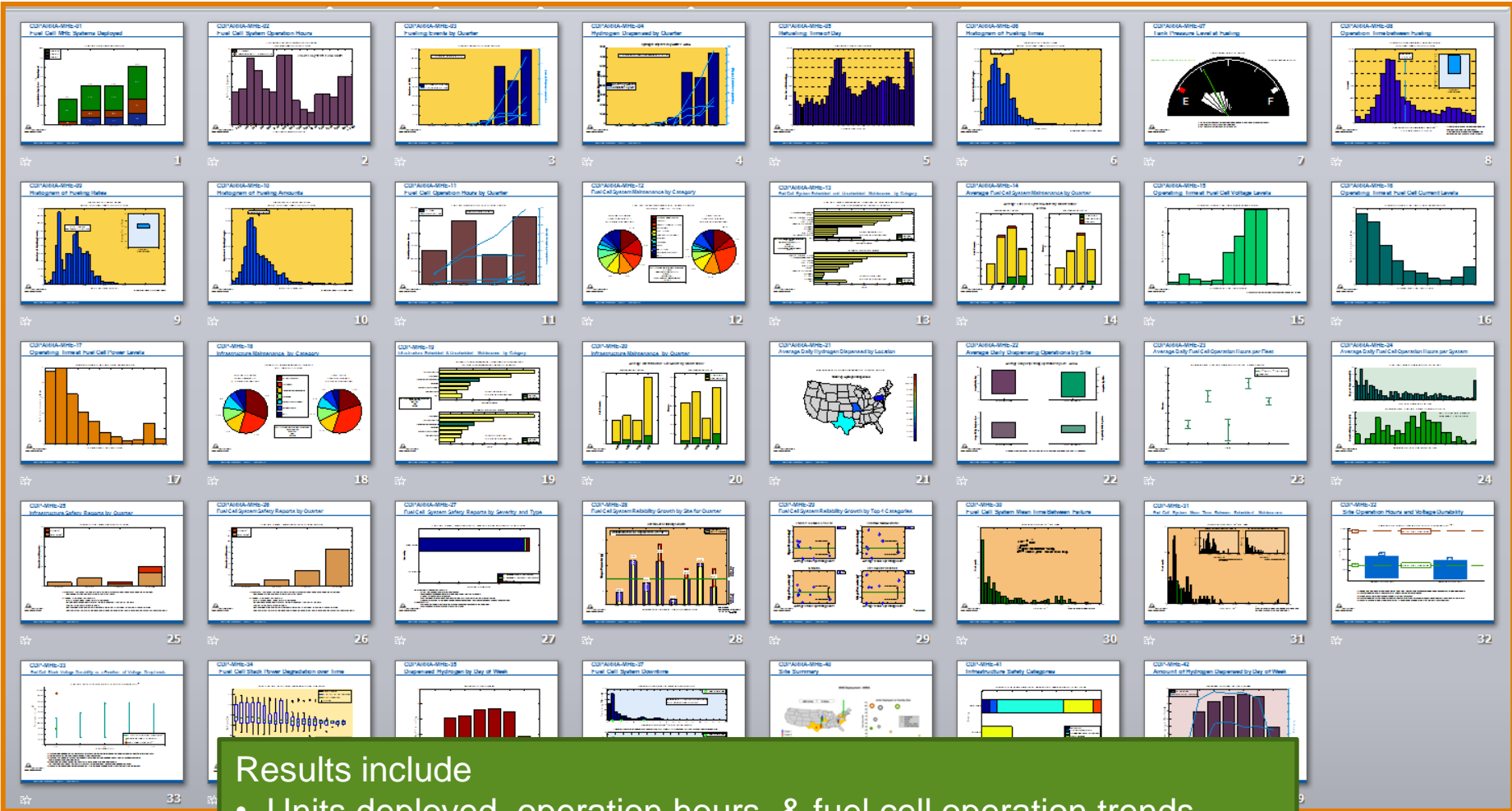
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* Through December 2010

Demonstrated Continuous Run Time



FCMHE 42 CDPs



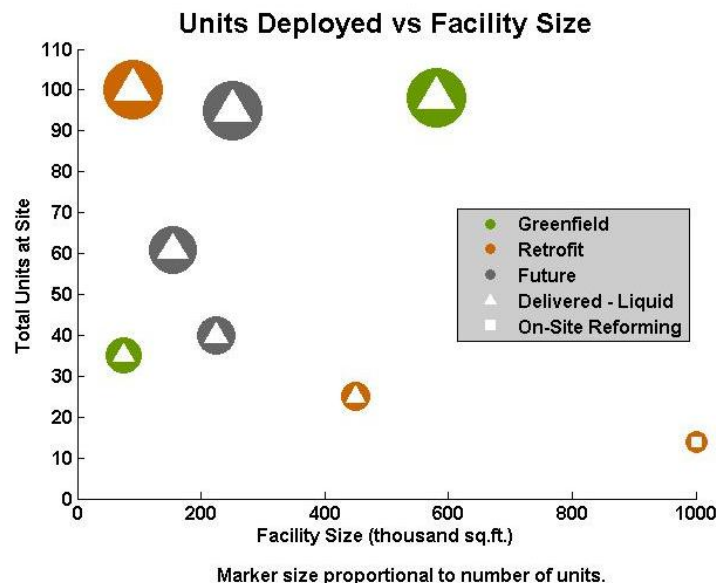
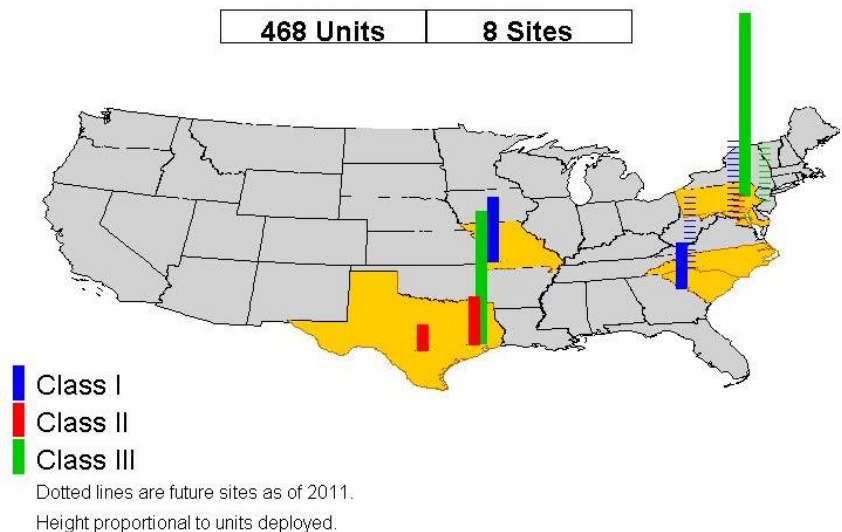
Results include

- Units deployed, operation hours, & fuel cell operation trends
- Hydrogen fill count, amount, time, & rate
- Tank level at fill & downtime from fill
- Fuel cell durability & reliability
- Fuel cell and infrastructure maintenance events & safety reports

Summary of the ARRA MHE Sites



MHE Deployment - ARRA



Forklift Units (I,II,III)	0,26,72	0,14,0	35,0,0	25,0,0	45,14,2	0,36,100	40,0,0	0,25,70
Operation								
<i>Shifts per Day</i>	2	2	3	1-2	3	2	2	3
<i>Hours per Shift</i>	8-10	9.5	8	10	8	8-10	8	8
<i>Days per Week</i>	6	N/A	N/A	7	7	6	6	6

Of the 8 sites

- Most use delivered liquid hydrogen
- Mix of greenfield and retrofit sites
- Some utilize more than one class of truck

Summary of FC MHE Operation



Sites	5	CDPARRA-MHE-#
Units in Operation (60 Class 1, 76 Class 2, 172 Class 3)	308*	01
Hours Accumulated	307,433 hrs*	11
FC Systems > 2360 hrs	25%*	02
Hydrogen Dispensed	18,597 kg*	04
Hydrogen Fills	38,863*	03
Average Fill Amount	0.48 kg/fill*	10
Average Fill Time	1.8 min/fill*	06



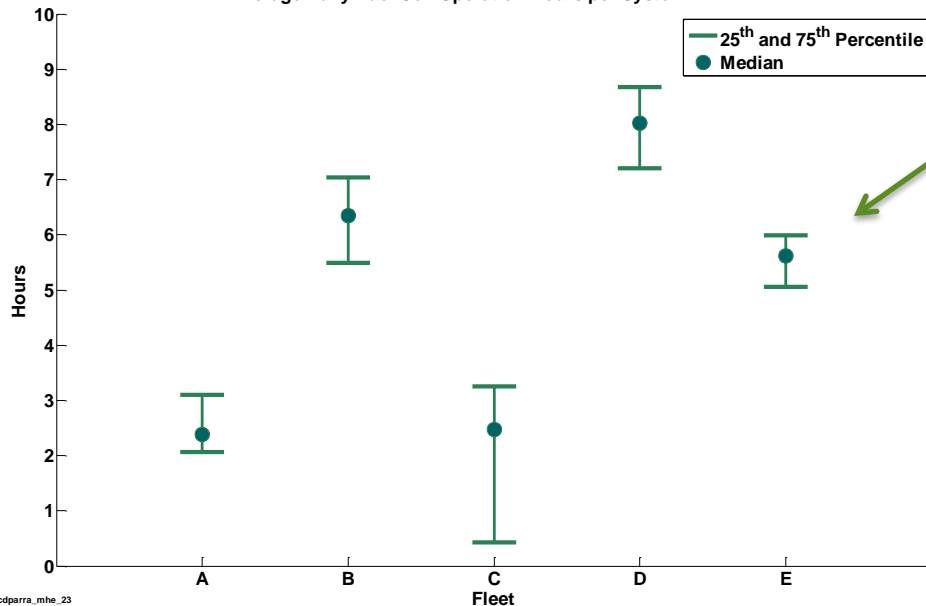
FCMHE operating at end user facilities, accumulating many hours and hydrogen fills safely, and already showing productivity improvements.

*Through December 2010

Daily Fuel Cell Operation Hours



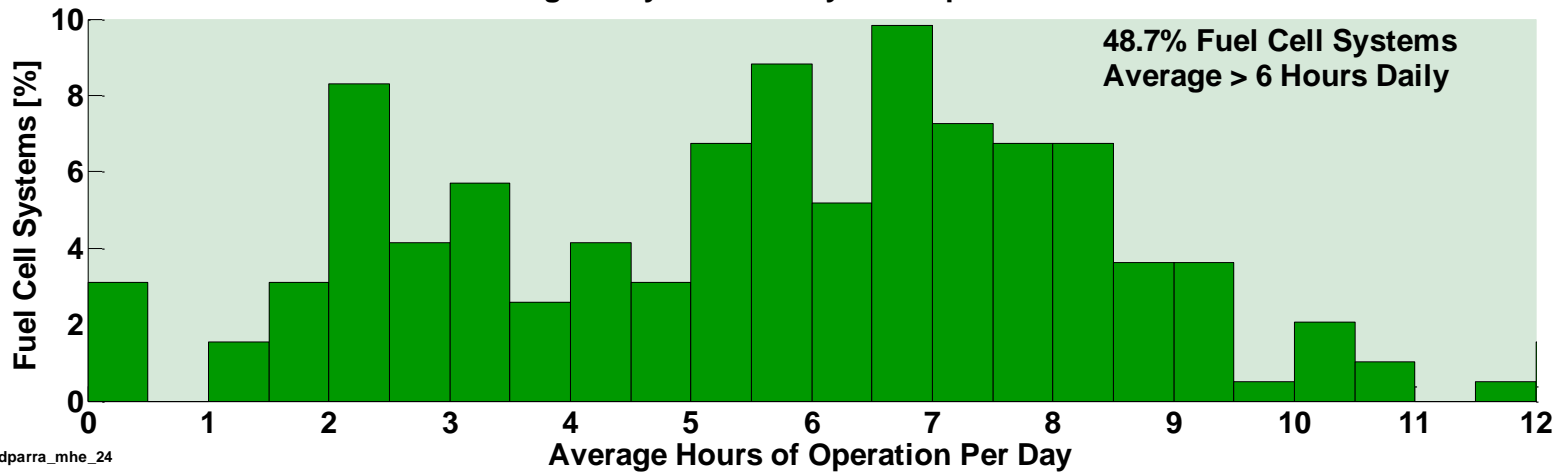
Average Daily Fuel Cell Operation Hours per System - ARRA



Range of Fleet Average Daily System Hours = 2 – 8 hours

48.7% of Systems Average > 6 hours a day

Average Daily Fuel Cell System Operation Hours



48.7% Fuel Cell Systems Average > 6 Hours Daily

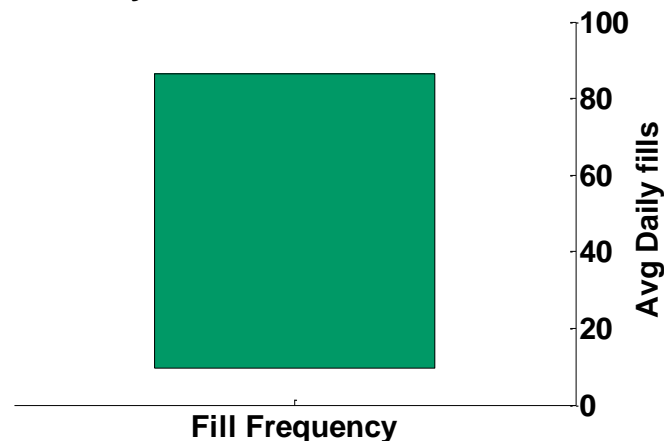
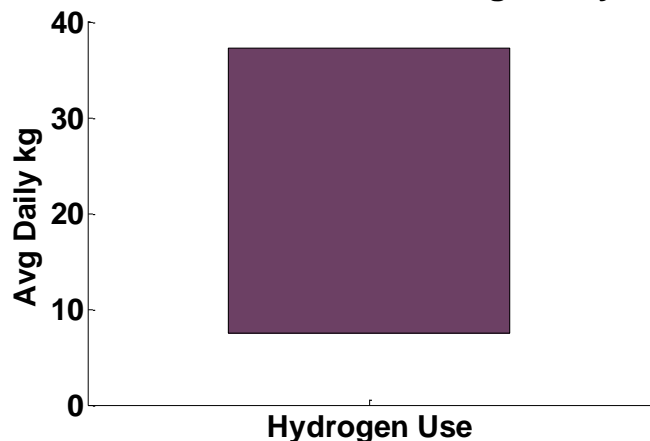
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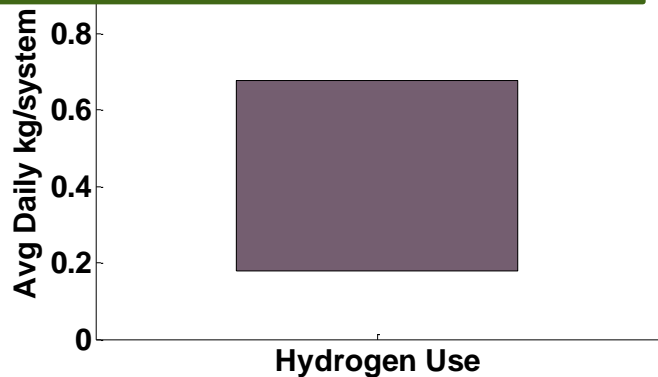
Average Daily Dispensing Operations by Site



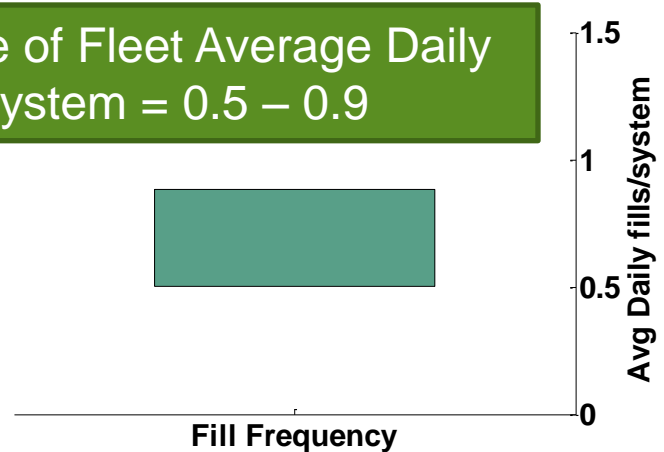
Average Daily Dispensing Operations by Site - ARRA



Range of Fleet Average Daily kgs/System = 0.2 – 0.7



Range of Fleet Average Daily Fills/System = 0.5 – 0.9

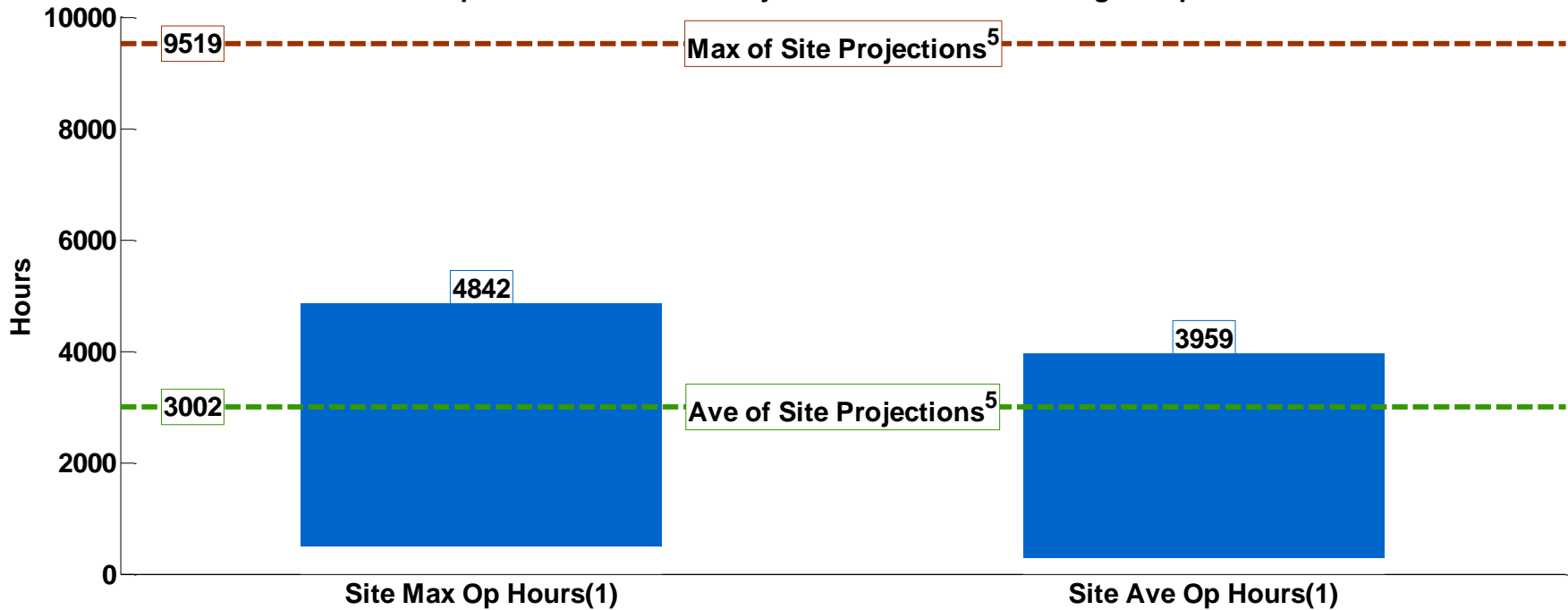


Shaded areas represent the min and max site average hydrogen use and fill frequency

Fuel Cell Voltage Durability Analysis



Operation Hours and Projected Hours to 10% Voltage Drop⁽²⁻⁴⁾



- (1) Range bars created using one data point for each fleet. Some stacks have accumulated hours beyond 10% voltage degradation.
- (2) 10% voltage drop level is a DOE metric for assessing fuel cell performance.
- (3) Projections using field data and calculated at a high stack current.
- (4) 10% voltage drop is NOT an indication of an OEM's end-of-life criteria and projections do not address catastrophic stack failure.
- (5) Each site has one voltage projection value that is the weighted average of the site's fuel cell stack projections.



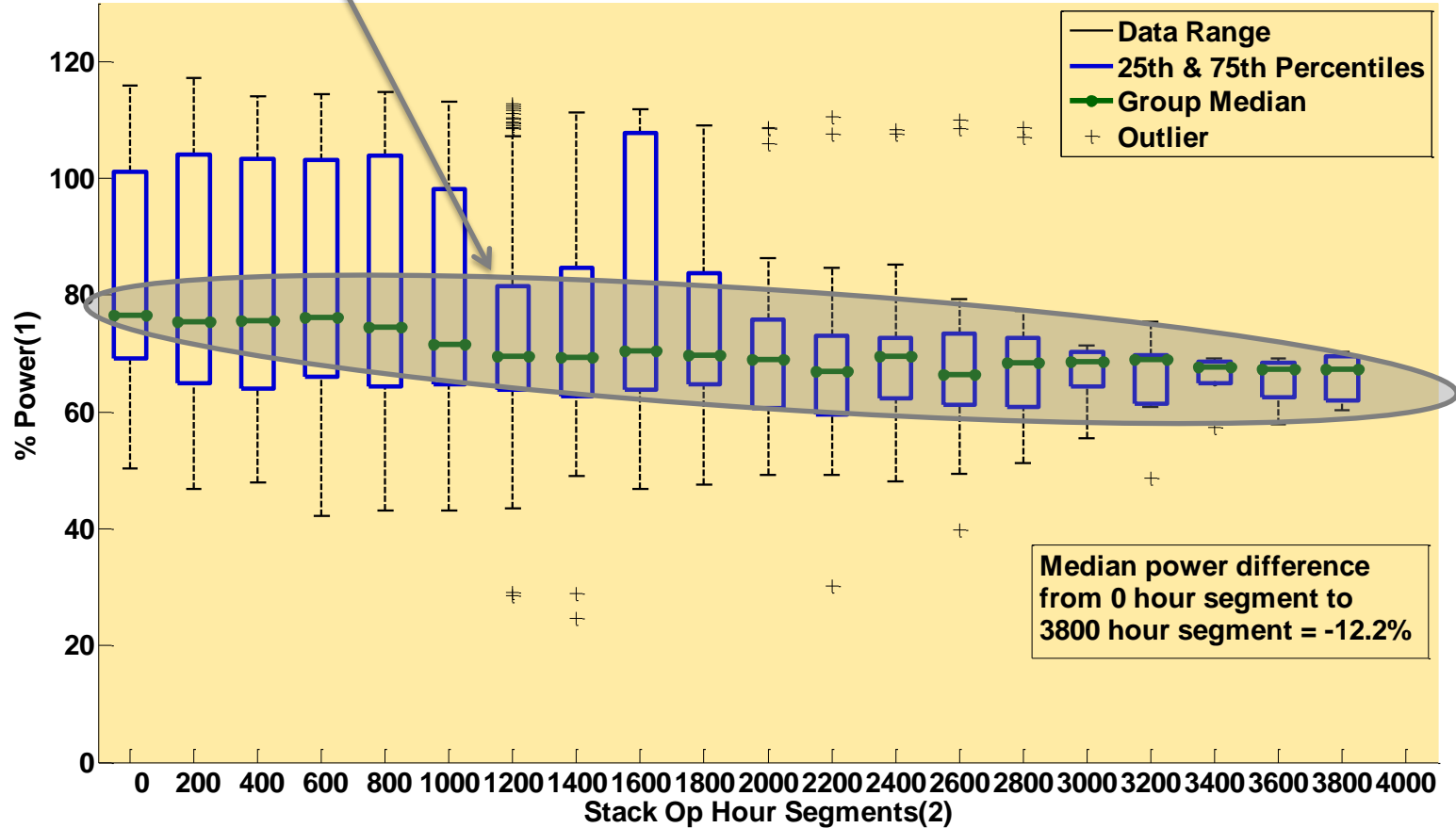
Each site has a weight average time to 10% voltage drop

- Average of the sites is 3002 hours
- Maximum of the sites is 9519 hours

Fuel Cell Stack Power Degradation over Time

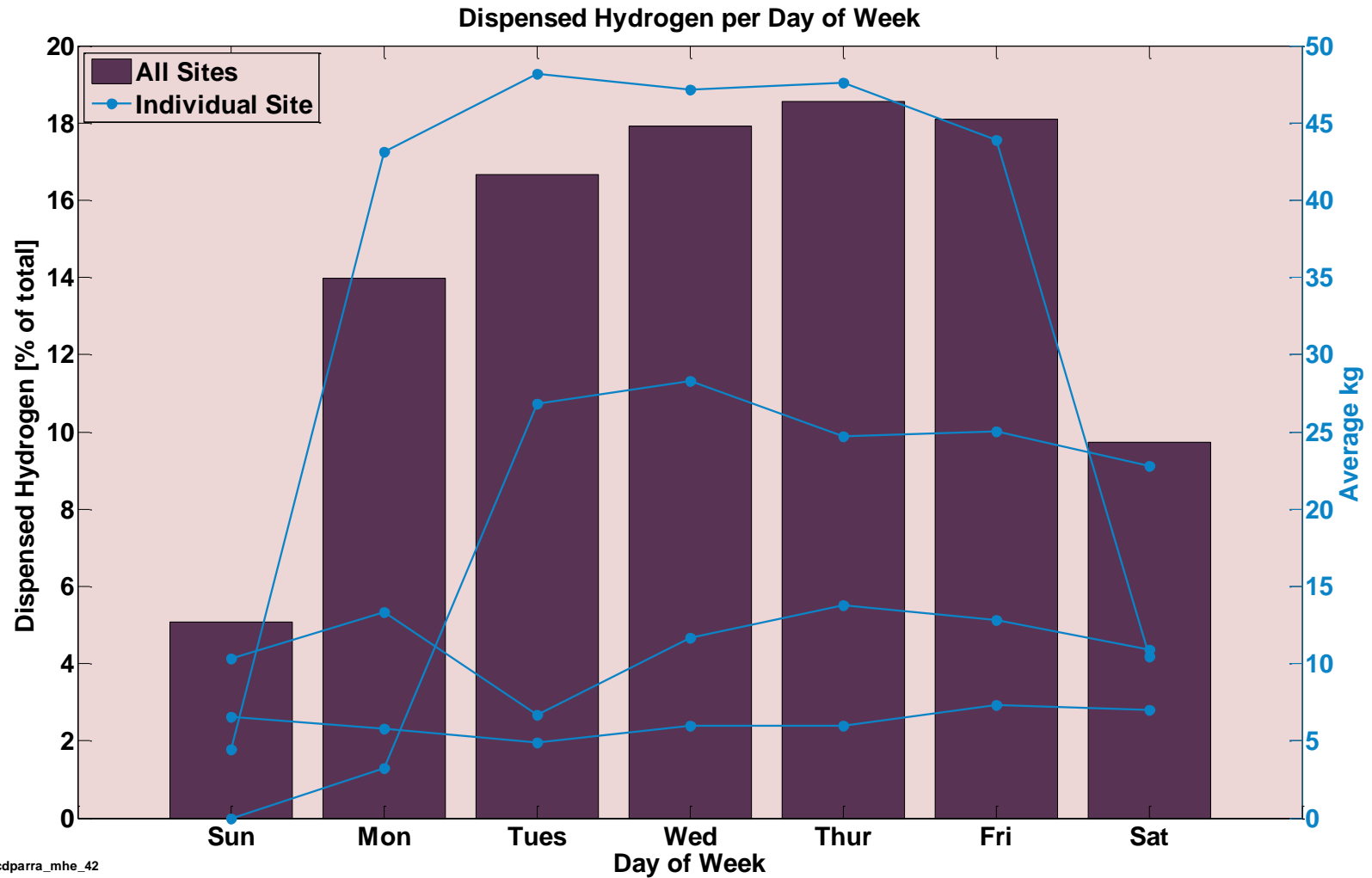
Little max power degradation over 4,000 operation hours (median drop ~12%)

Max Fuel Cell Stack Power Degradation Over Operation



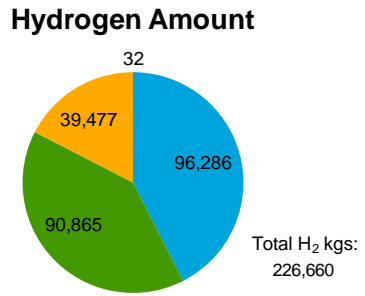
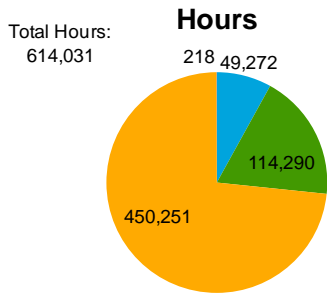
1) Normalized by fleet maximum power.
2) Each segment point is median FC power (+/-100 hrs).
Box not drawn if fewer than 3 points in segment.

Refueling Trends by Day of Week and Site

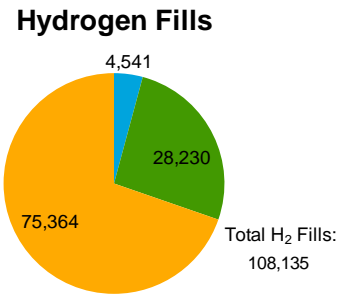


- Most of the dispensed hydrogen is Monday – Friday
- Individual site dispensing is fairly consistent Monday - Friday

Summary



189 units at 85 sites
99.8% Successful Starts



368 units at 7 sites
> 450,200 Hours
> 90,800 H₂ kgs

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2004

2005

2006

2007

2008

2009

2010

2011
On-going

Contact Information & Website

http://www.nrel.gov/hydrogen/proj_fc_market_demo.html

Jennifer Kurtz
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 303-275-4061



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Early Fuel Cell Market Demonstrations

Early fuel cell market demonstrations are focused primarily on using fuel cell technologies for material handling, backup power, and prime-power applications. The Department of Energy-sponsored demonstration projects support fuel cell market transformation activities and help foster the growth of fuel cell markets. In addition, the Department of Defense funds early fuel cell demonstration projects.

NREL receives operational data from these early market fuel cell demonstrations, analyzes, and reports on these data. By aggregating data across numerous industry teams and sites, NREL develops composite data products (CDPs), which provide relevant data results on the technology status and fuel cell performance without revealing proprietary data. These publicly available CDPs will help the development community understand the state of fuel cell technologies, identify areas for continued improvement, and provide data metrics that are important to the business case for these fuel cell markets.

This page provides the following resources:

- [Composite Data Products](#)
- [Presentations and Publications](#)
- [Presentations Containing All CDPs](#)

Composite Data Products

The public technical analysis results are generated in the form of composite data products. The following CDPs can be sorted by title, category, CDP number, and date updated. Download the CDPs as PowerPoint or JPG files using the links in the two columns on the right. Download the current presentation containing all CDPs ([PowerPoint 2.7 MB](#)) or see the archived [presentations containing all CDPs](#).

Sort by Title ▼	Sort by Category ▼	Sort by CDP No. ▼	Sort by Date Updated ▼	PowerPoint	JPG
Operating Hours between Fueling	Fuel Cell Fuel Economy Range and Efficiency	FL08	2009-11-06		JPG
Accumulated Forklift Operating Hours	Fuel Cell Usage and Operation Behavior	FL02	2009-11-06		JPG
Forklifts Deployed by Quarter	Fuel Cell Usage and Operation Behavior	FL01	2009-11-06		JPG
Fuel Cell Units Delivered to Site	Fuel Cell Usage and Operation Behavior	ARRA01	2010-02-19		JPG
Fuel Cell Units in Operation—Current and Projected Quantities	Fuel Cell Usage and Operation Behavior	ARRA02	2010-02-19		JPG

Hydrogen PEM fuel cells are leading candidates for use in fuel cell vehicles. Today's commercially available PEM fuel cells are particularly appropriate for low-power applications requiring intermittent backup.