



# ARRA Fuel Cell Deployment and Operation



**FC Seminar**

**COM34-4**

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**NREL/PR-5600-49764**

# Contents

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Overview of ARRA Fuel Cell Project

NREL Data Analysis Objectives

Deployment CDPs

Backup Power CDPs

Material Handling Technical CDPs

Summary

# American Recovery and Reinvestment Act (ARRA) Fuel Cell Early Market Project

## Project Objective

Deploy ~1,000 fuel cells to **accelerate the commercialization** and deployment of fuel cells and fuel cell manufacturing, installation, maintenance, and support services



12 awards with >\$40 million  
ARRA & ~\$53 million cost share

COMPANY	AWARD	APPLICATION
Delphi Automotive	\$2.4 M	Auxiliary Power
FedEx Freight East	\$1.3 M	Specialty Vehicle
GENCO	\$6.1 M	Specialty Vehicle
Jadoo Power	\$2.2 M	Backup Power
MTI MicroFuel Cells	\$3.0 M	Portable
Nuvera Fuel Cells	\$1.1 M	Specialty Vehicle
Plug Power, Inc. (1)	\$3.4 M	CHP
Plug Power, Inc. (2)	\$2.7 M	Backup Power
Univ. of N. Florida	\$2.5 M	Portable
ReliOn Inc.	\$8.5 M	Backup Power
Sprint Comm.	\$7.3 M	Backup Power
Sysco of Houston	\$1.2 M	Specialty Vehicle

# HSDC Data Flow

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

Internal analysis completed quarterly



DDPs

Results

CDPs

## Detailed Data Products (DDPs)

- Individual data analyses
- Identify individual contribution to CDPs
- Only shared with partner who supplied data every 6 months<sup>1</sup>

## Composite Data Products (CDPs)

- Aggregated data across multiple systems, sites, and teams
- Publish analysis results without revealing proprietary data every 6 months<sup>2</sup>

1) Data exchange may happen more frequently based on data, analysis, & collaboration

2) Results published via NREL Tech Val website, conferences, and reports

# NREL Data Analysis Objectives – ARRA Demonstrations

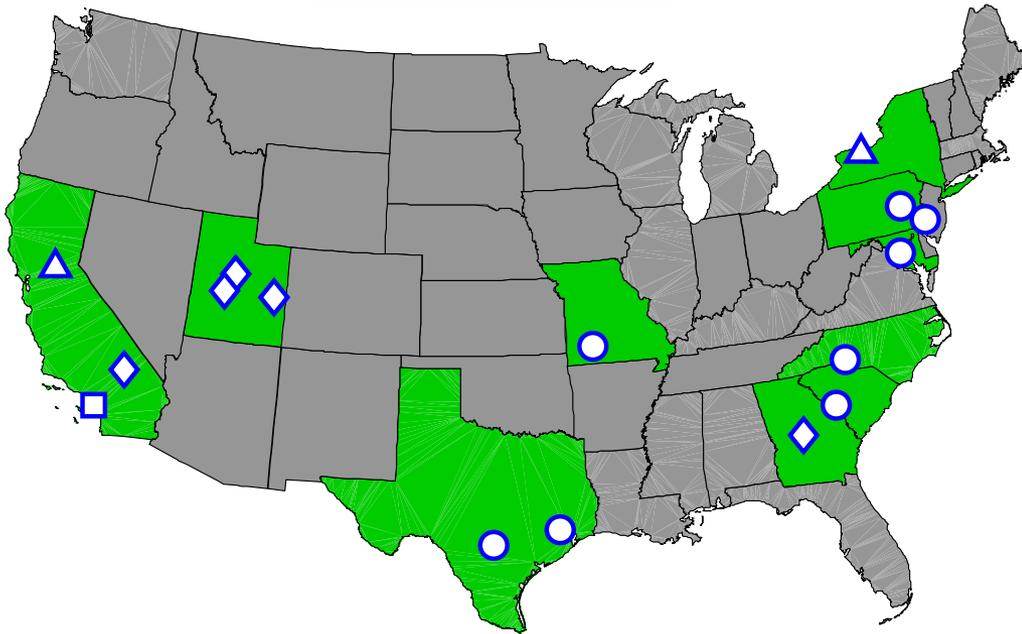
- Independent technology **assessment**; focused on fuel cell system and hydrogen infrastructure: performance, operation, and safety.
- Leverage** data processing and analysis capabilities developed from the fuel cell vehicle Learning Demonstration project and DoD Forklift Demo.
- Establish a **baseline** of real-world fuel cell operation and maintenance data and identify technical/market barriers.
- Support market growth** through analyses relevant to the **value proposition** and reporting on **technology status** to fuel cell and hydrogen communities and **stakeholders**

**HSDC**  
NREL's Hydrogen Secure Data Center



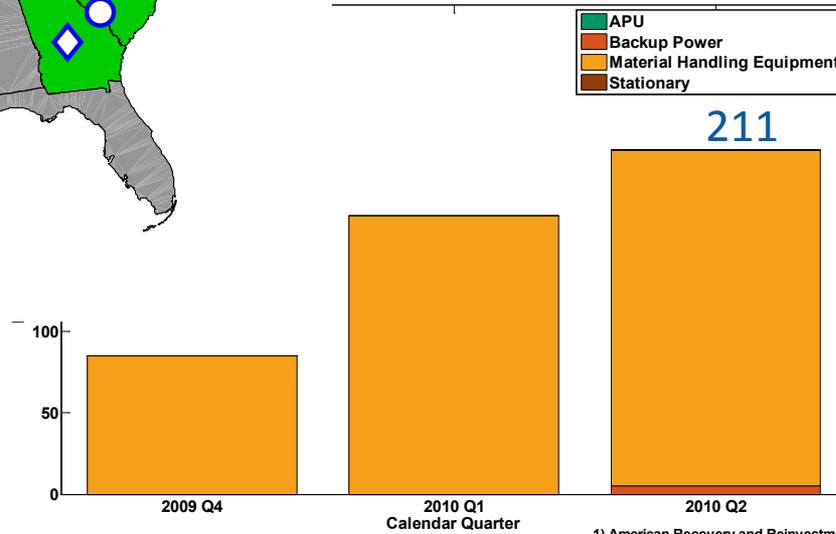
# Delivered Fuel Cell Units & Deployment Sites

- ARRA Forklift Site
- ◇ ARRA Backup Site
- ARRA Stationary Site
- △ ARRA APU



Some site locations TBD

Delivered Early Fuel Cell Markets: Delivered Units



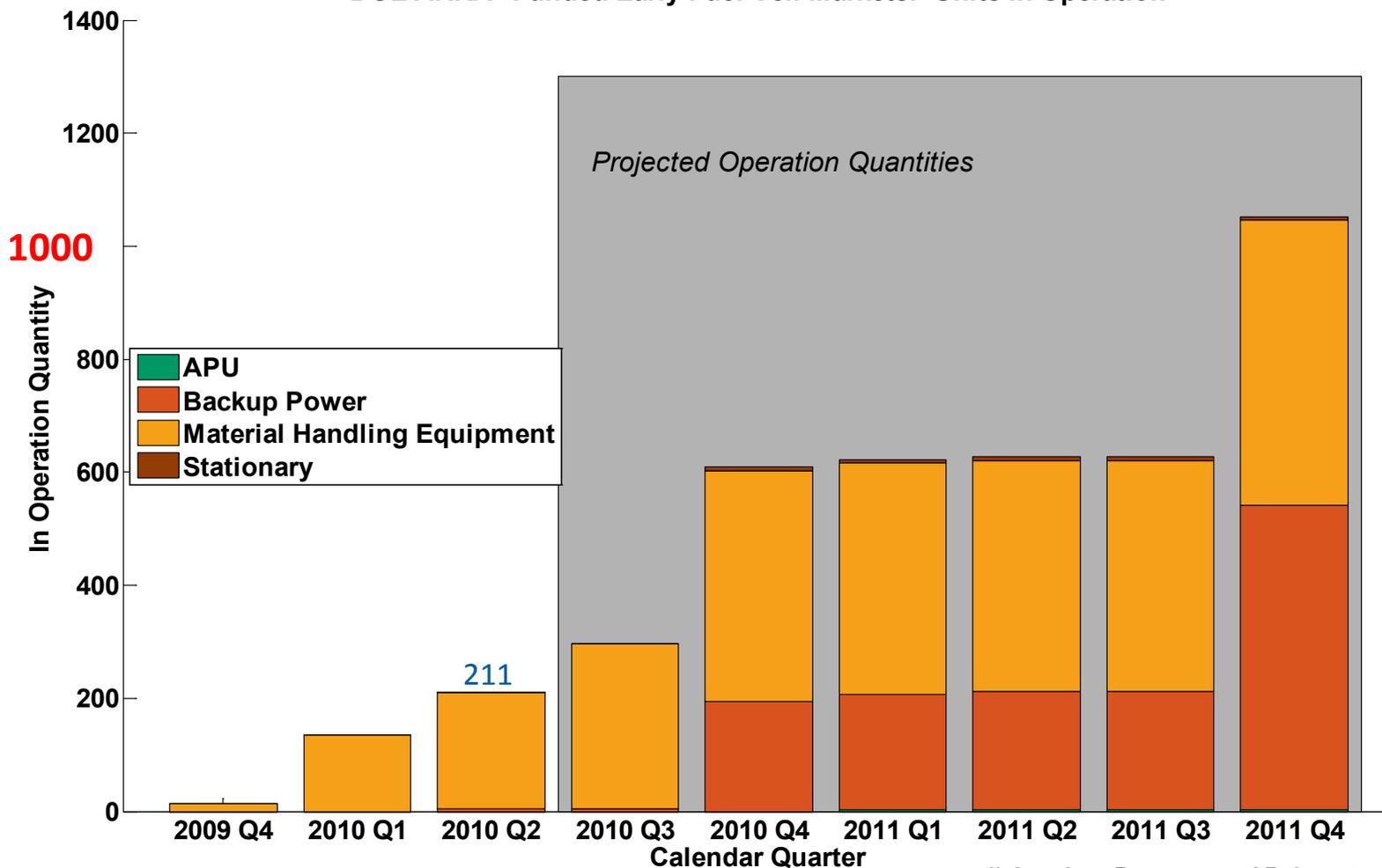
1) American Recovery and Reinvestment Act



# Fuel Cell Units in Operation

## Current and Projected Quantities

DOE ARRA<sup>1</sup> Funded Early Fuel Cell Markets: Units in Operation



- STACK
- BACKUP POWER
- FORKLIFTS
- CARS
- BUSES
- PRIME POWER

1) American Recovery and Reinvestment Act

# FC Backup Power

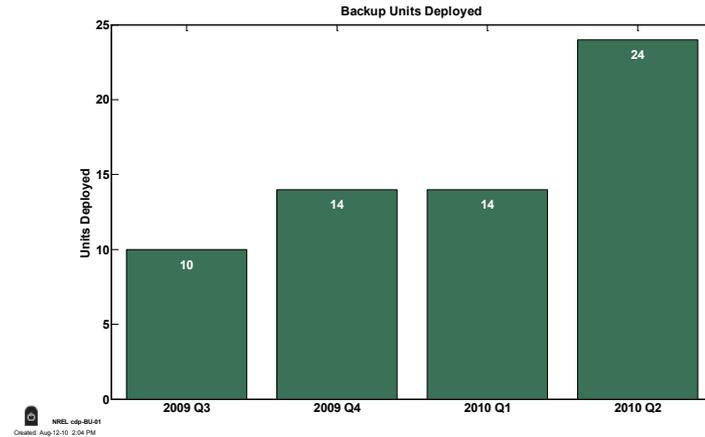
Deployment & Operation Data



High level summary of operation  
First cycle of CDPs (IAA & ARRA Sites)  
Trends still developing  
Many additional analyses planned for future  
CDP cycles

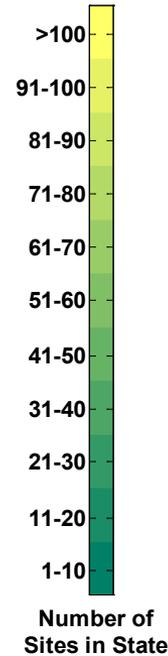
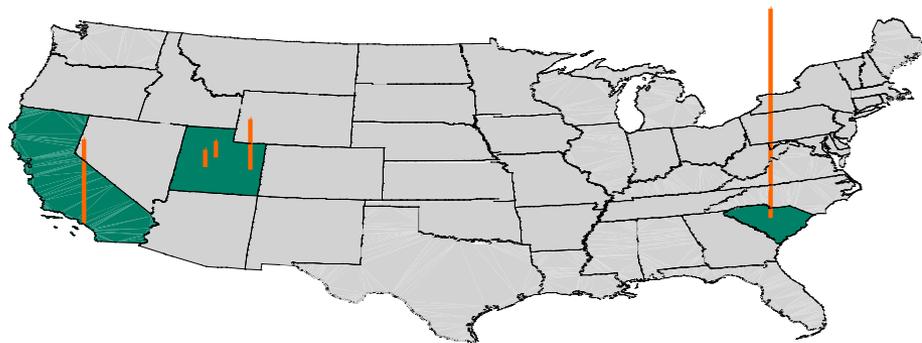
# Backup Power Sites

Units Deployed	24
Sites	5
Total Capacity	90 kW



## Backup Power Deployments

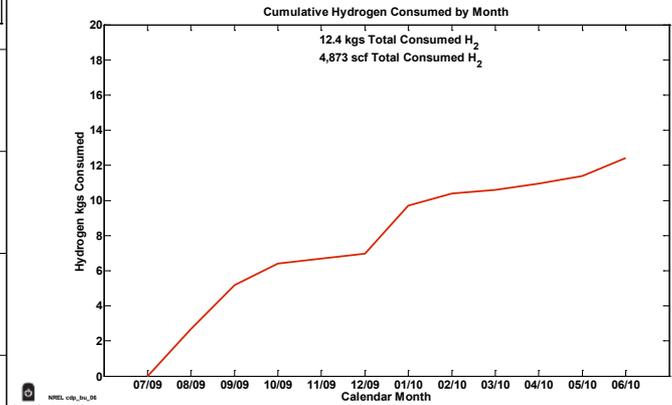
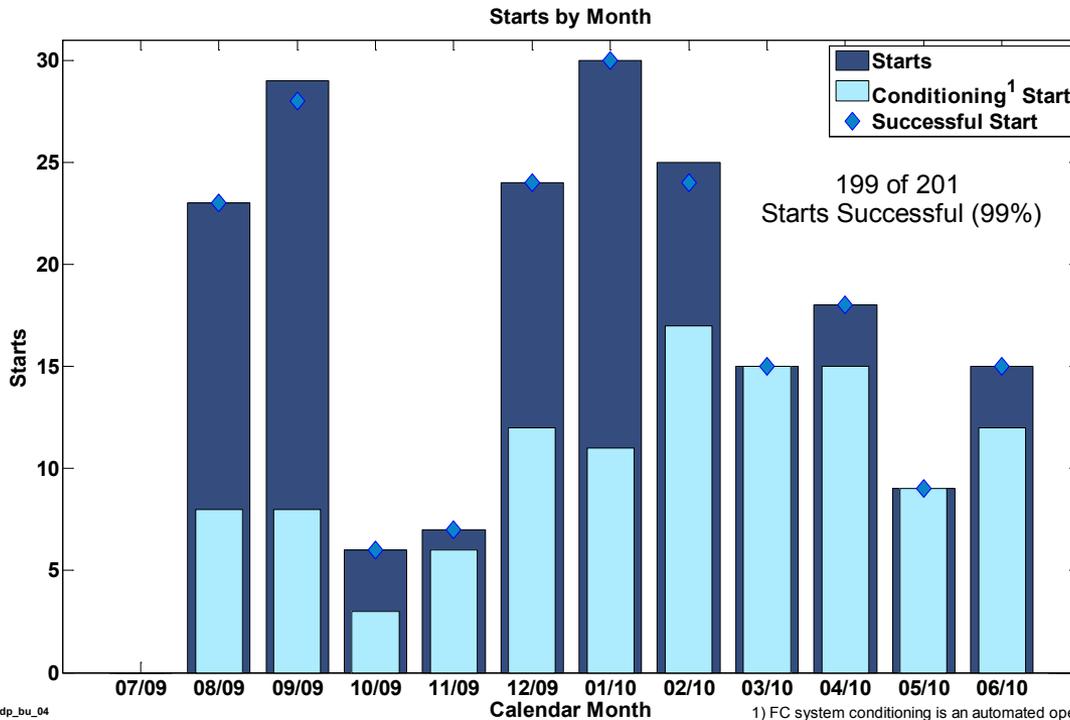
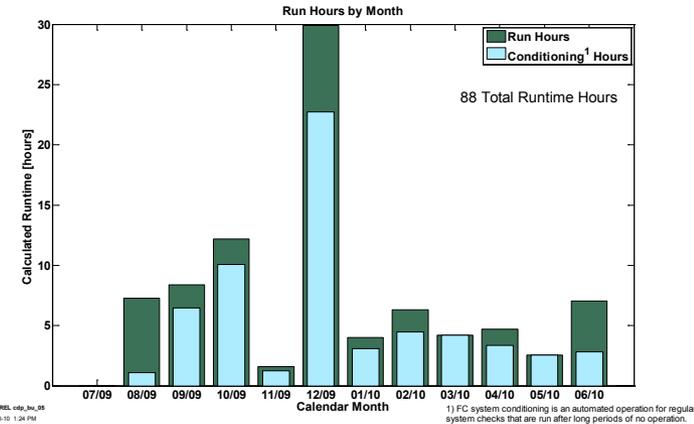
State	kW Capacity	Sites
California	20	1
South Carolina	50	1
Utah	20	3



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

# Backup Power Starts and Run Time

<b>Total Starts (Thru June 2010)</b>	<b>201</b>
<b>Total Successful Starts</b>	<b>199 (99%)</b>
<b>Total Run Time</b>	<b>88 hours</b>
<b>Total Hydrogen</b>	<b>12.4 kg</b>



# FC Material Handling Equipment

Deployment & Operation Data



High level summary of operation

First cycle of CDPs

Trends still developing

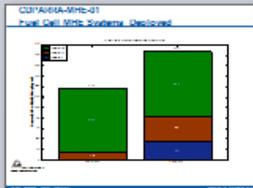
Many additional analyses planned for future

CDP cycles

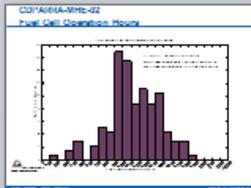
# FCMHE Fall 2010 CDPs



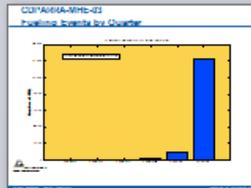
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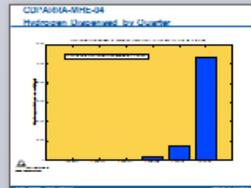
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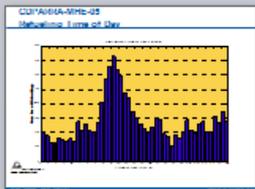
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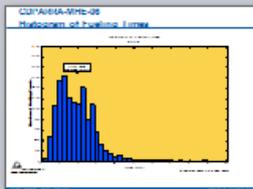
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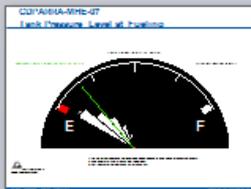
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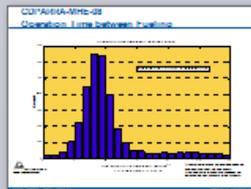
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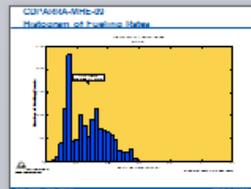
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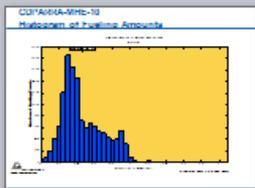
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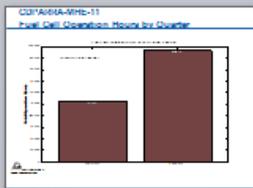
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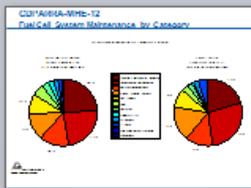
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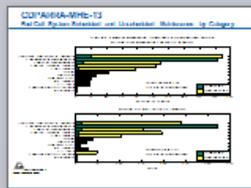
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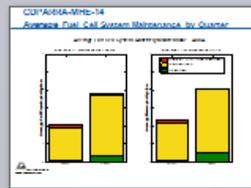
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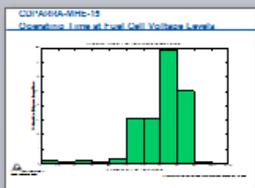
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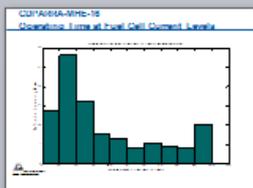
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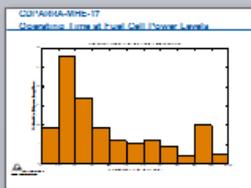
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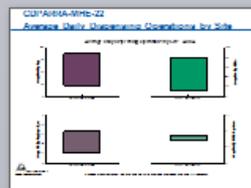
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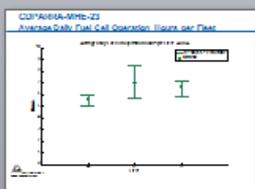
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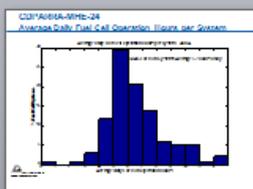
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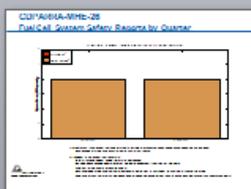
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21



22



23

## Analysis Topics

Units Deployed,  
Operation Hours,  
Refueling,  
Maintenance, Safety,  
FC Performance, Site  
Usage

## ARRA FCHMHE CDPs

22

## ARRA & DLA Infrastructure CDPs

4

## Data Files Analyzed

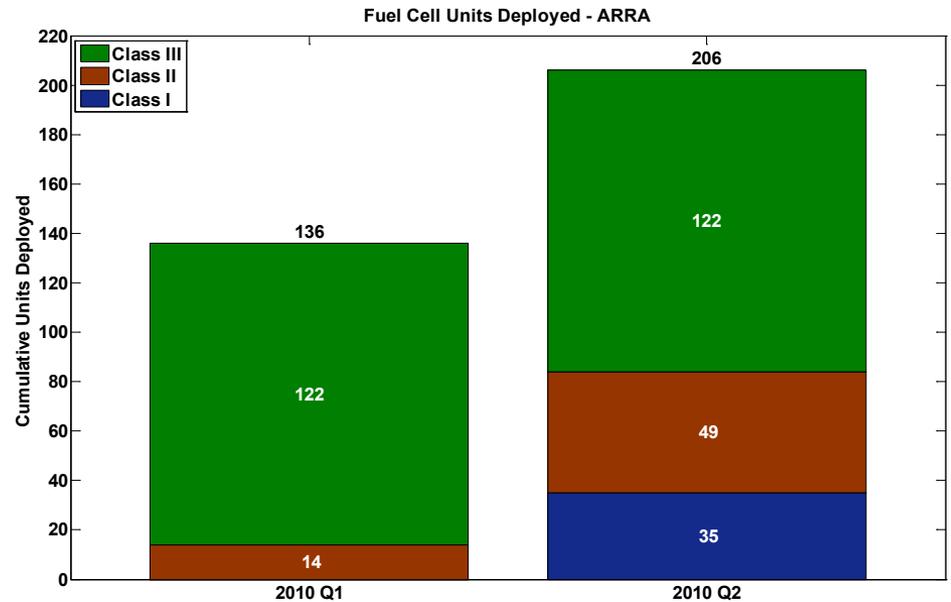
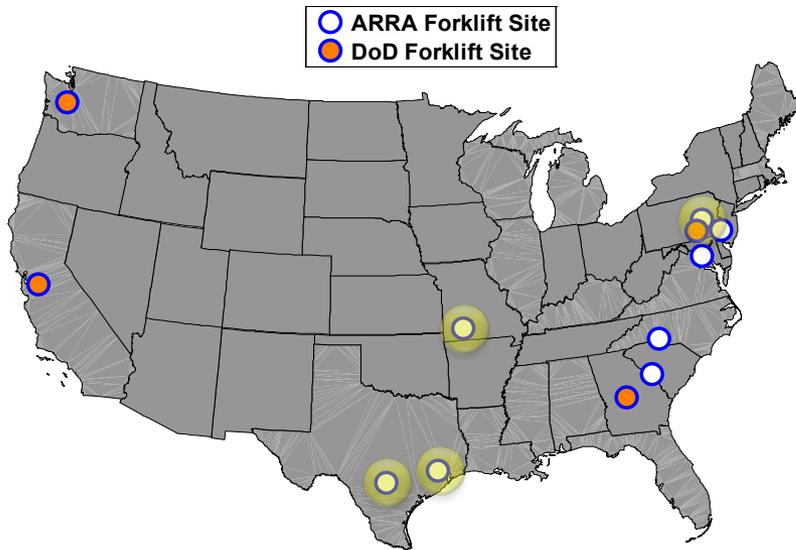
23,307 (1.7GB)

# MHE FC Units & Sites

## Sites

4

Operational MHE Units/Site	14	35	59	98
Operating Shifts/Site	2	3	2	2
	9 hrs	8 hrs	8-10 hrs	9 hrs
Facility Square Footage (1,000)	1,000	75	90	580
FC Units/MHE Unit	1.0	1.0	1.0	1.0

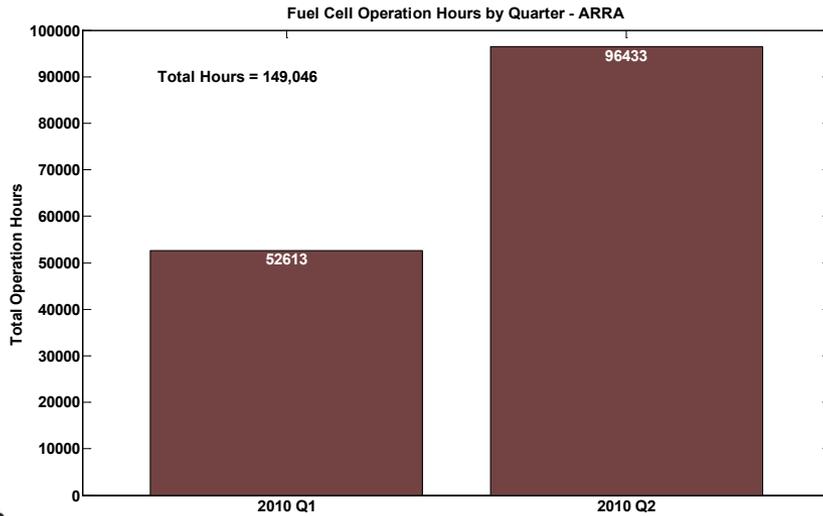


# FC Operation Summary

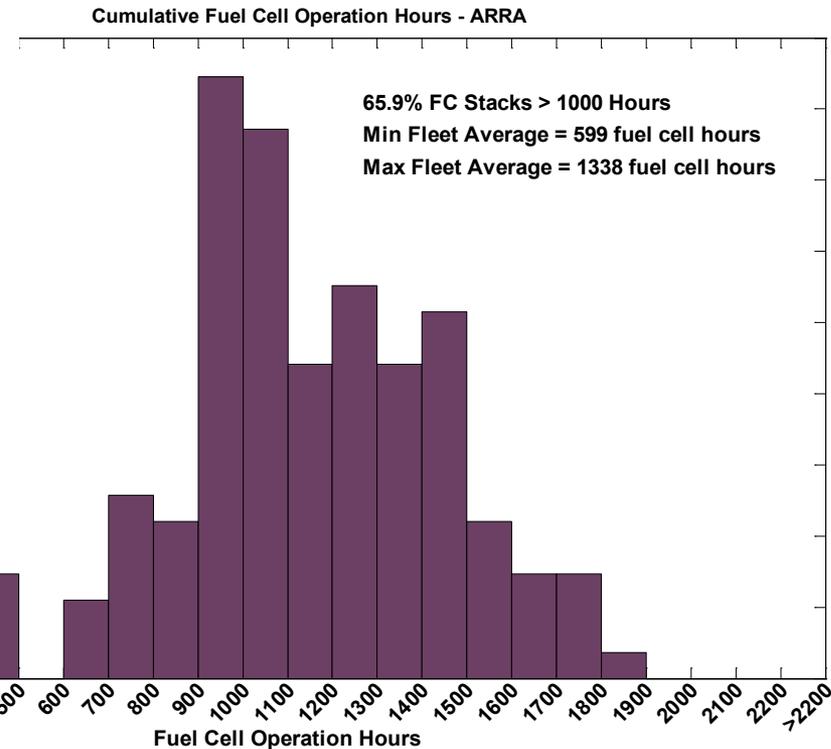
149,046

Total Hours Accumulated

66% FC Stacks > 1000 hours

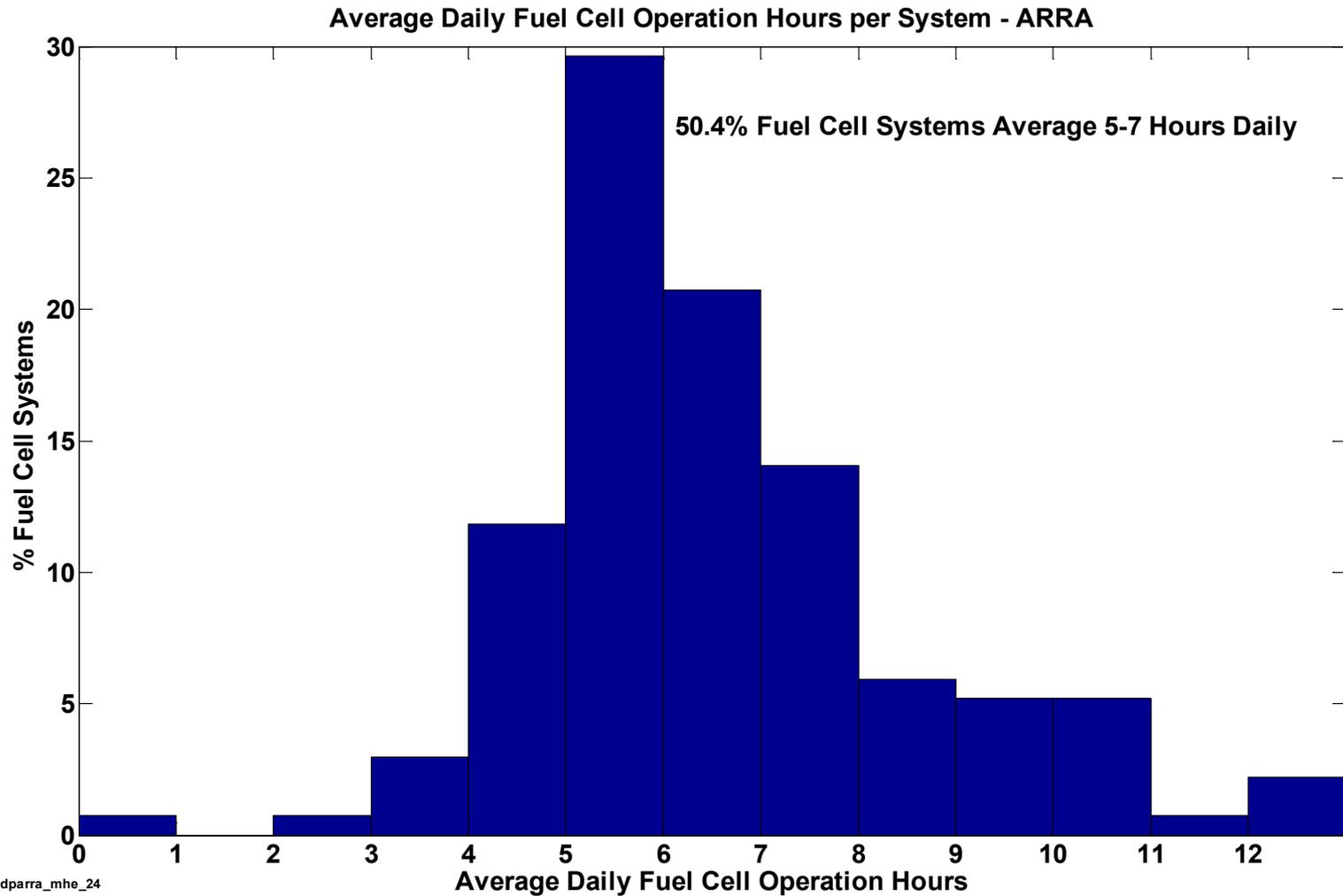


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# FC Daily Operation



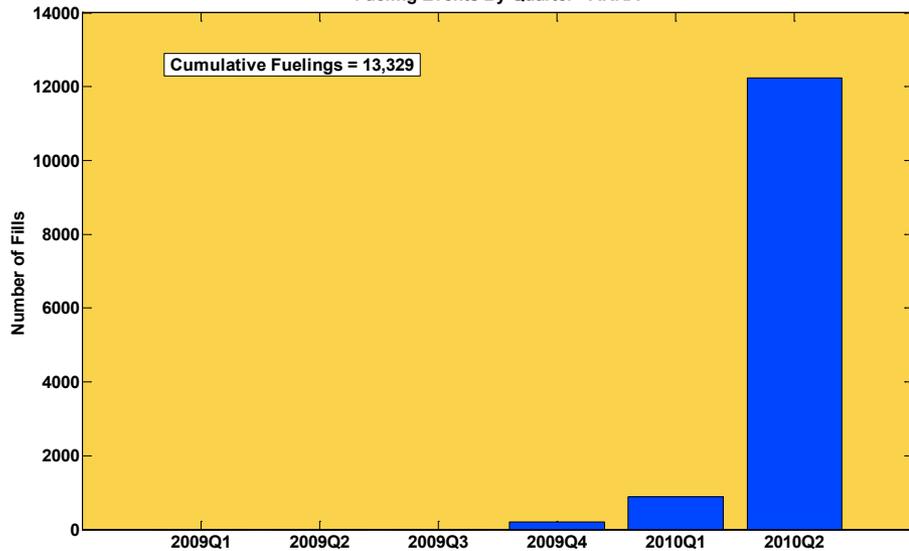
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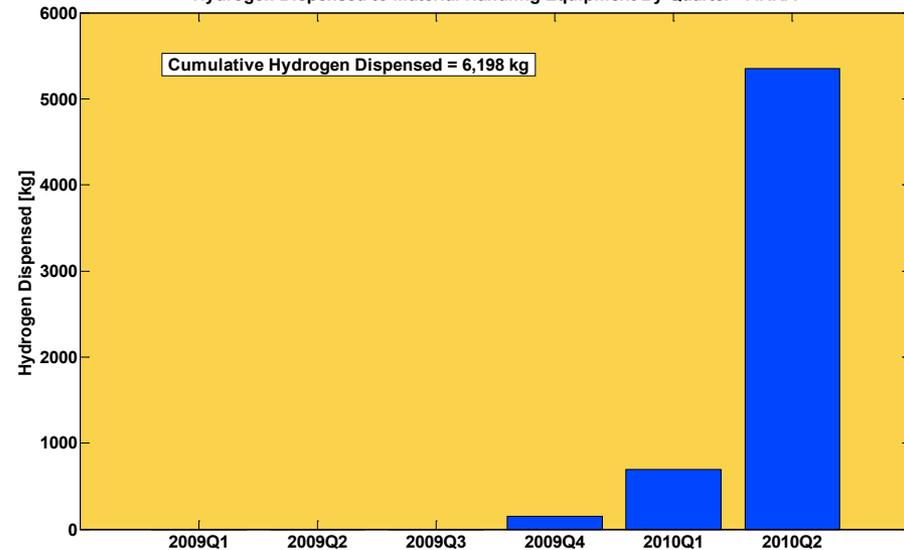
# Hydrogen Fill Event Summary

Total Hydrogen Dispensed	6,198 kg
Total Hydrogen Fill Events	13,329 fills

Fueling Events By Quarter - ARRA



Hydrogen Dispensed to Material Handling Equipment By Quarter - ARRA



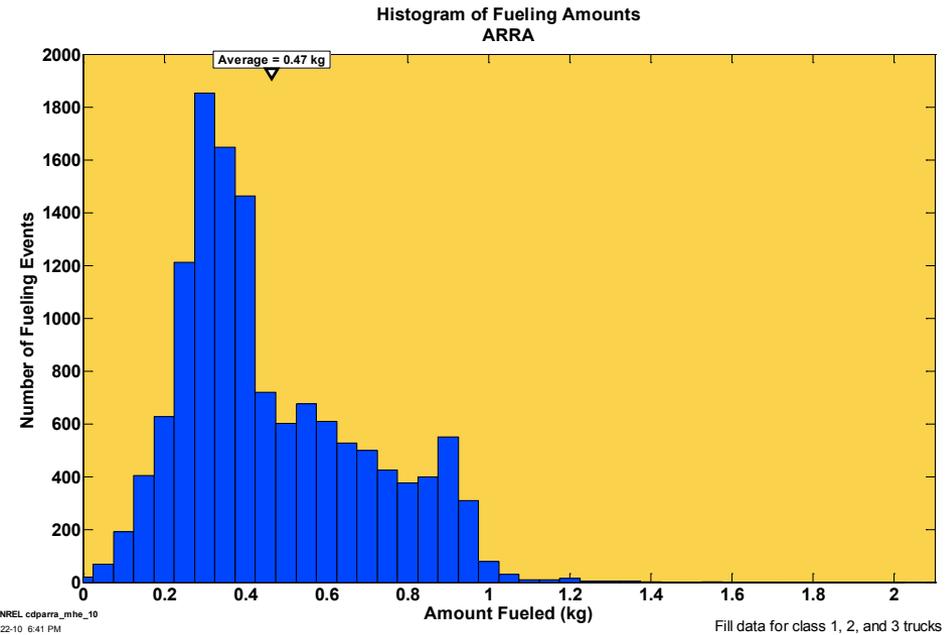
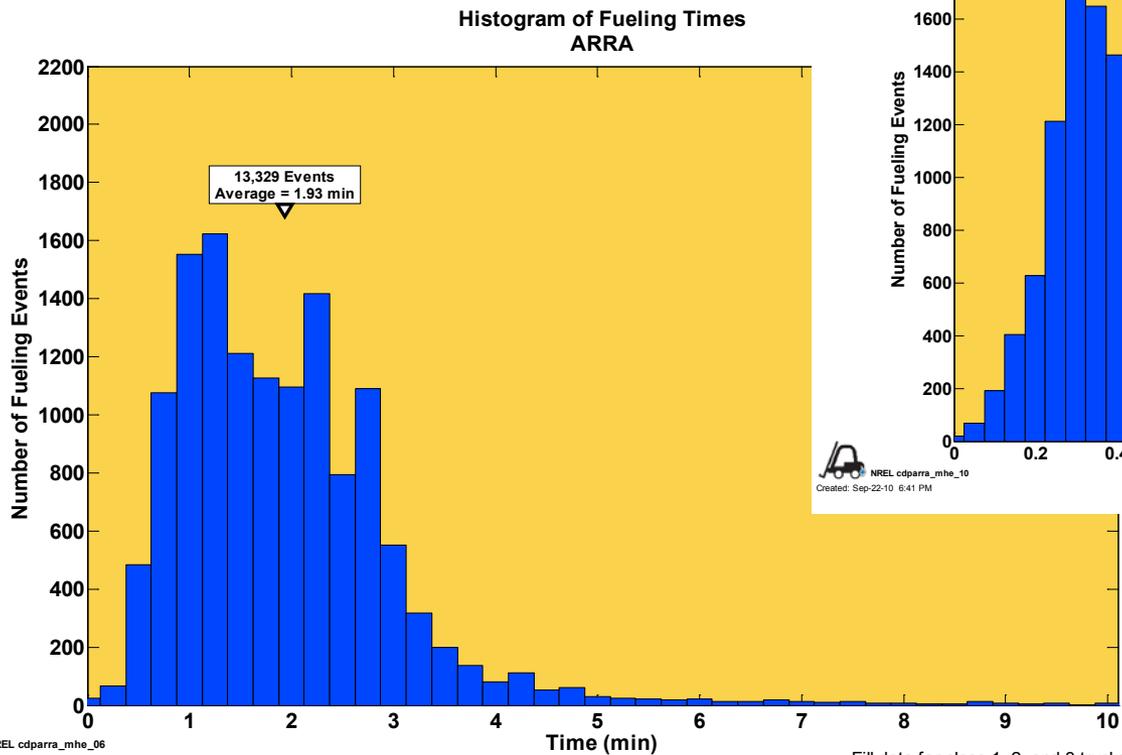
# Hydrogen Fill Event Rates and Amounts

Average Fill Time

1.9 minutes

Average Fill Amount

0.47 kg



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Fill data for class 1, 2, and 3 trucks

Fill data for class 1, 2, and 3 trucks

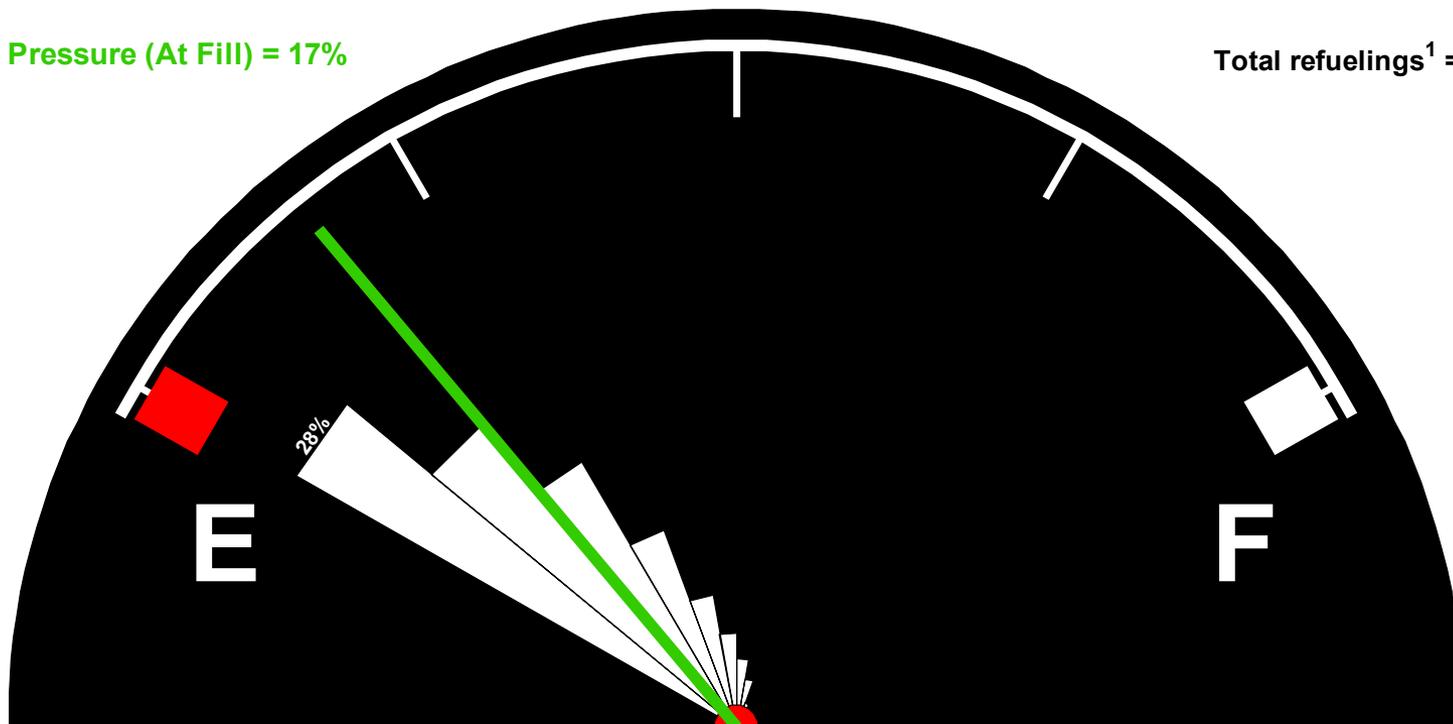
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# Tank Pressure Level at Fueling

Median Tank Pressure (At Fill) = 17%

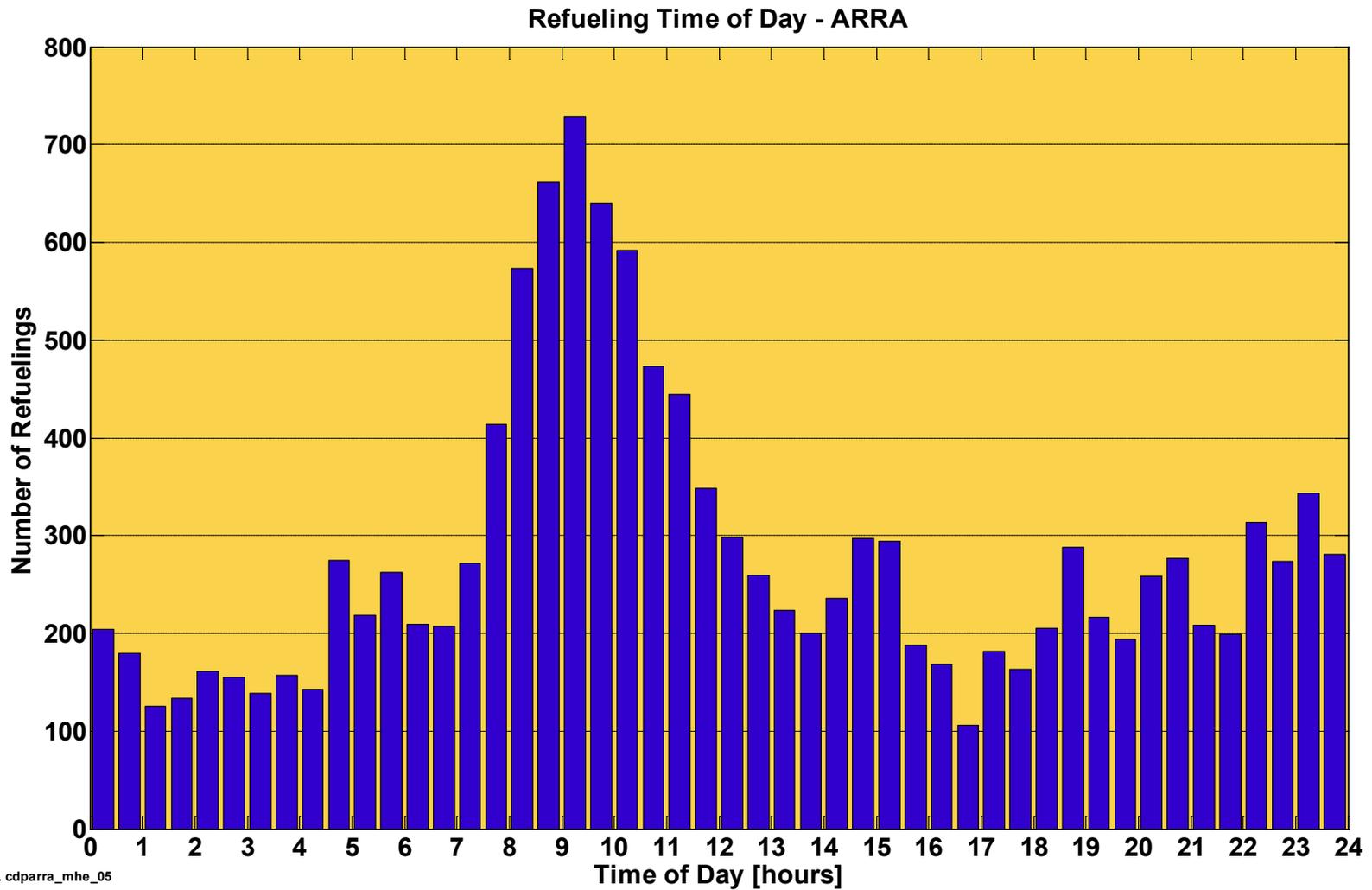
Tank Pressure At Fill: ARRA

Total refuelings<sup>1</sup> = 4106



1. Some refueling events not recorded/detected due to data noise or incompleteness.
2. The outer arc is set at 40% total refuelings.
3. Full Pressure is either 3600 psi or 5000 psi.

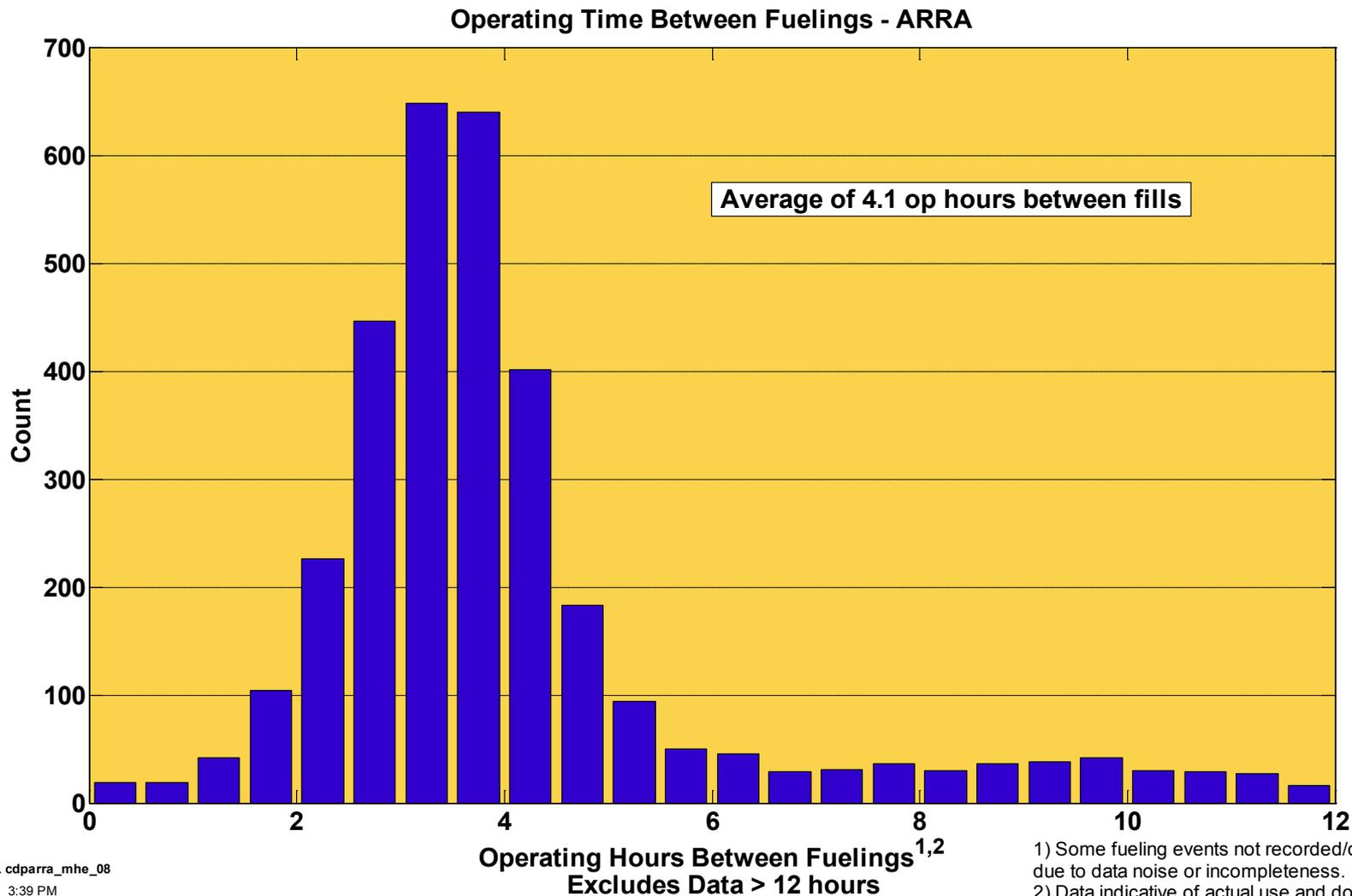
# Refueling Time of Day



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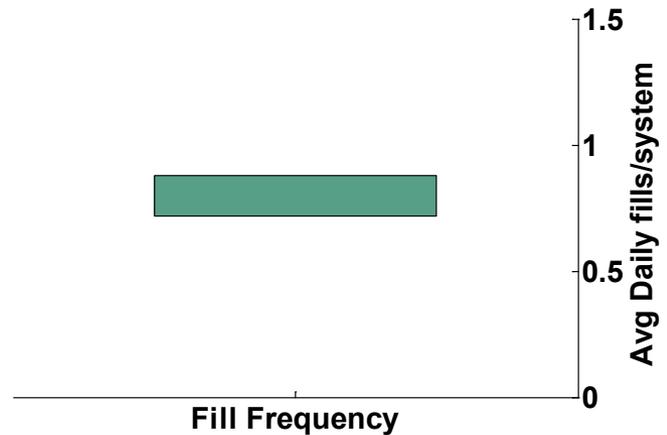
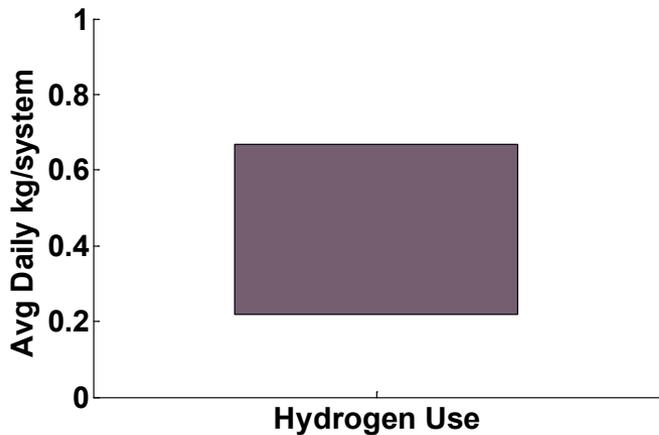
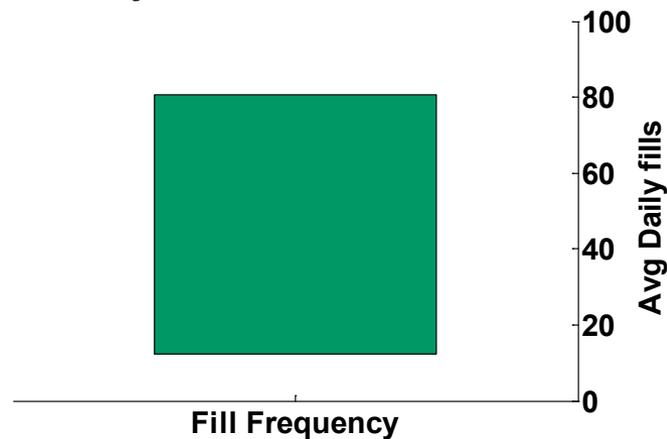
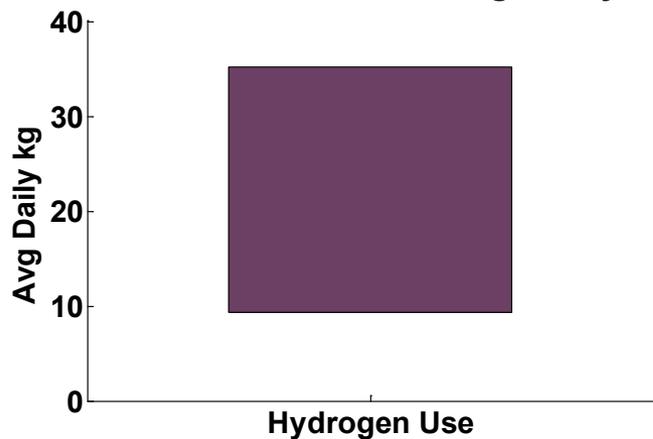
# Operation Time between Fueling



1) Some fueling events not recorded/detected due to data noise or incompleteness.  
2) Data indicative of actual use and does not represent the max capability of the systems.

# Average Daily Site H2 Dispensing

## Average Daily Dispensing Operations by Site - ARRA



NREL cdparra\_mhe\_22

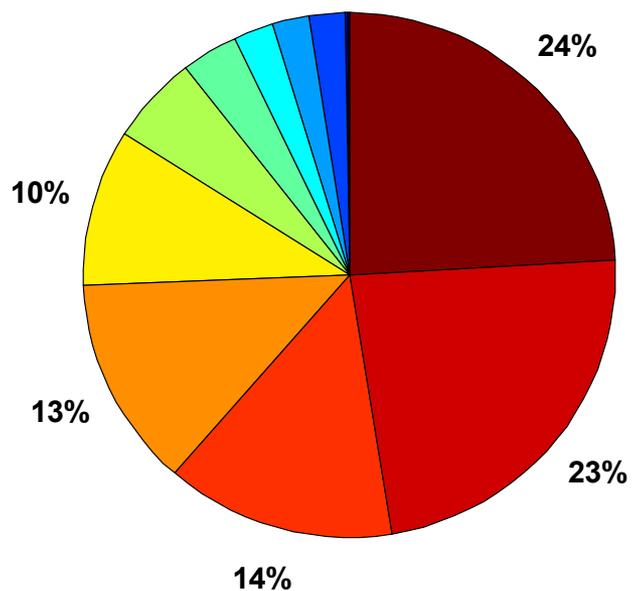
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Shaded areas represent the min and max site average hydrogen use and fill frequency

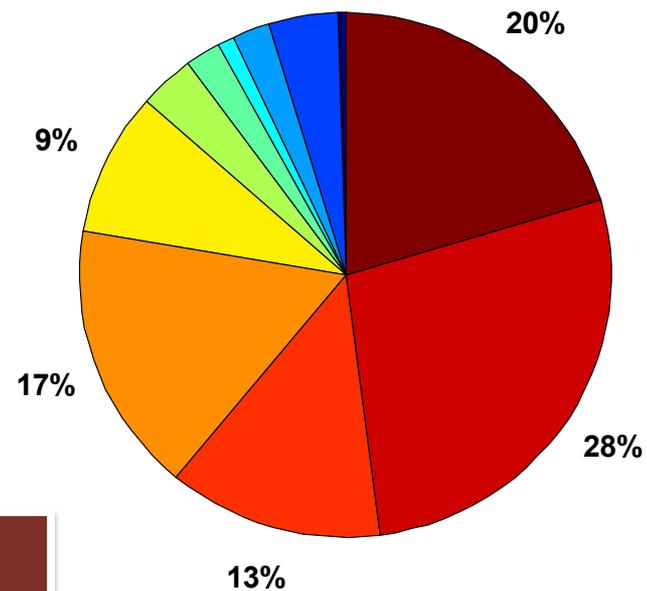
# Fuel Cell System Maintenance by Category

## Forklift Maintenance By Category - ARRA

**Number of Events**  
**Total Events = 789**  
**73% were unscheduled**



**Labor Hours**  
**Total Hours = 1165**  
**69% were unscheduled**

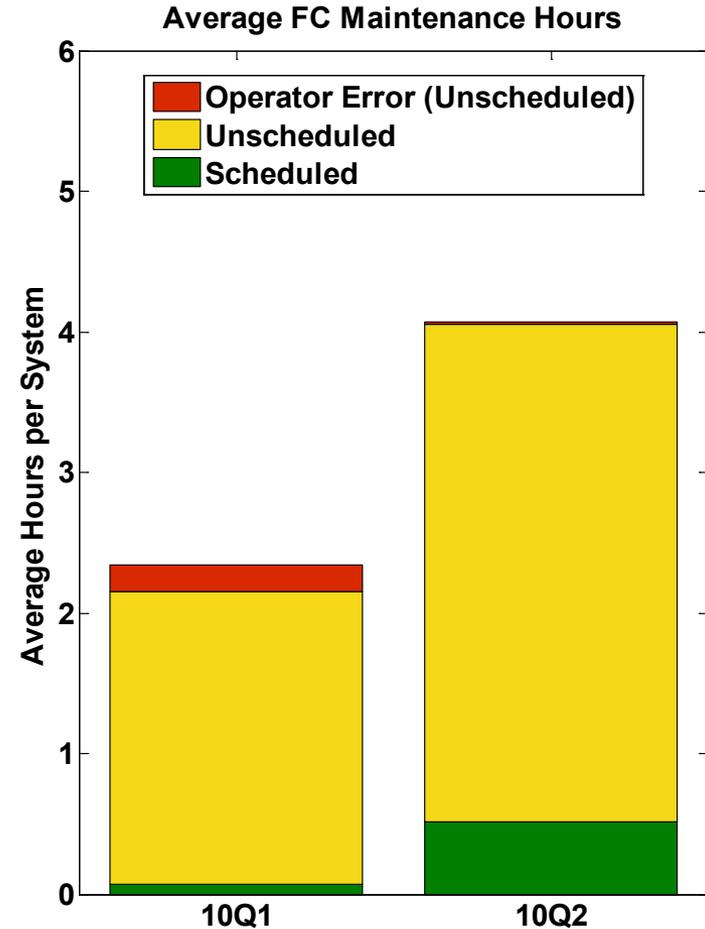
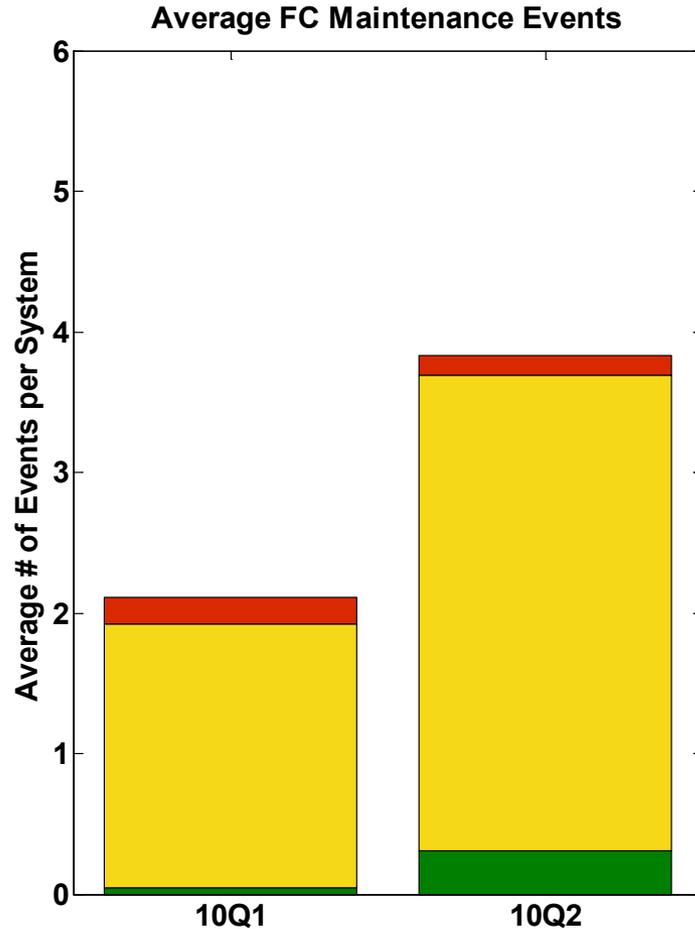


**73% Unscheduled  
 Maintenance Events**

**38% Events for Controls,  
 Electronics, Sensors or  
 Thermal Mgmt**

# Average Fuel Cell System Maintenance by Quarter

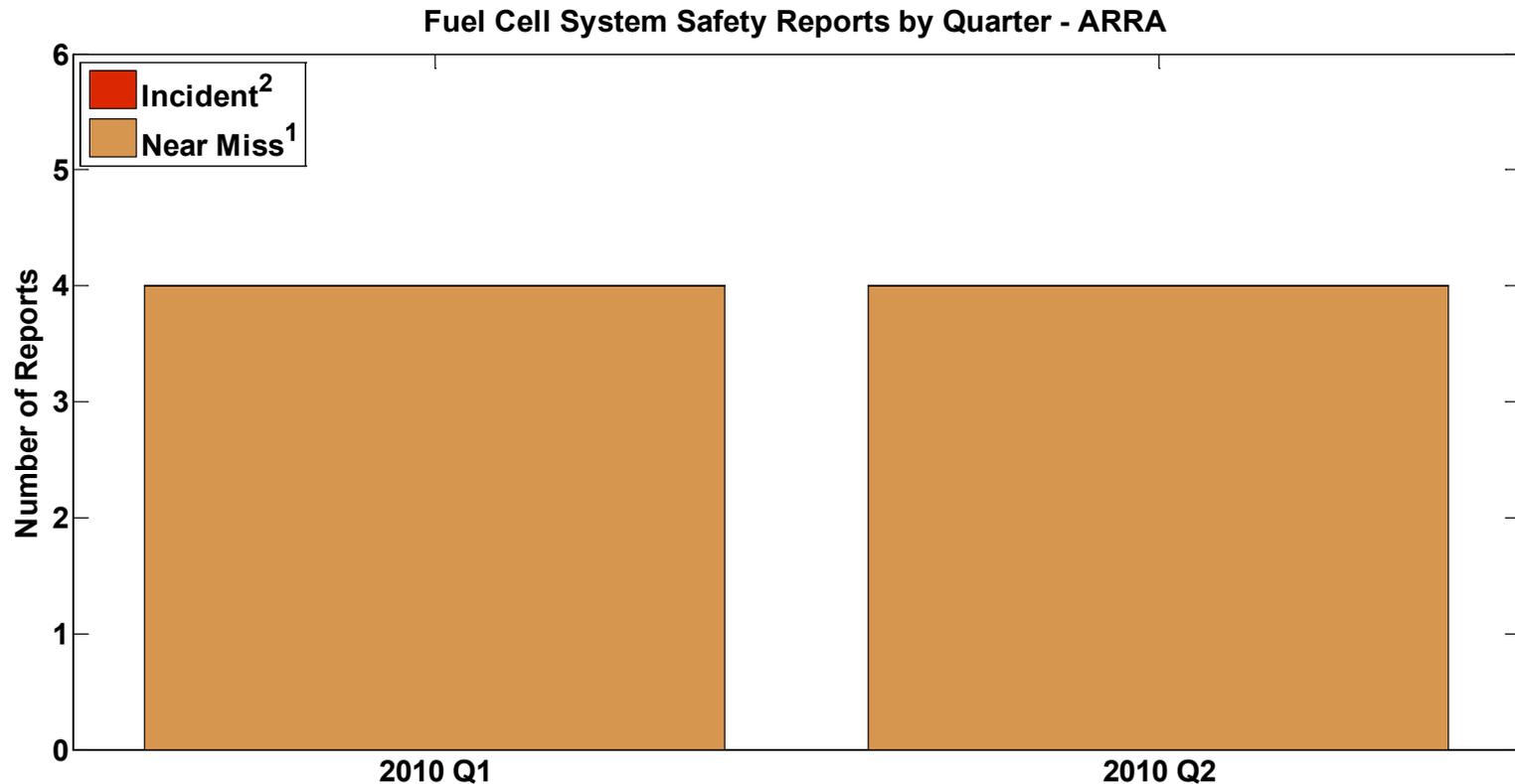
## Average Fuel Cell System Quarterly Maintenance - ARRA



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# Fuel Cell System Safety Reports by Quarter



- 1) Near Miss is an event that under slightly different circumstances could have become an incident
  - unplanned H<sub>2</sub> release insufficient to sustain a flame
- 2) Incident is an event that results in:
  - a lost time accident and/or injury to personnel
  - damage/unplanned downtime for project equipment, facilities or property
  - impact to the public or environment
  - any hydrogen release that unintentionally ignites or is sufficient to sustain a flame if ignited
  - release of any volatile, hydrogen containing compound (other than the hydrocarbons uses as common fuels)

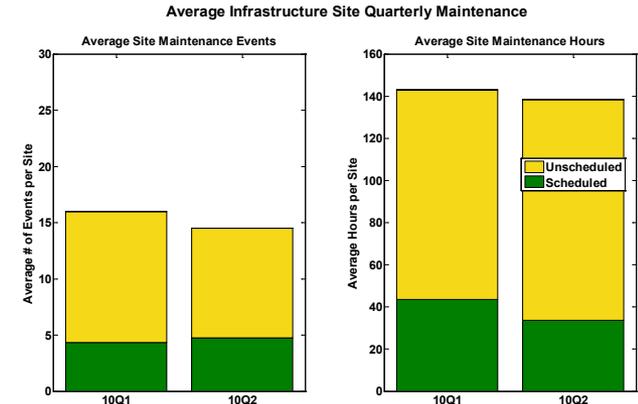


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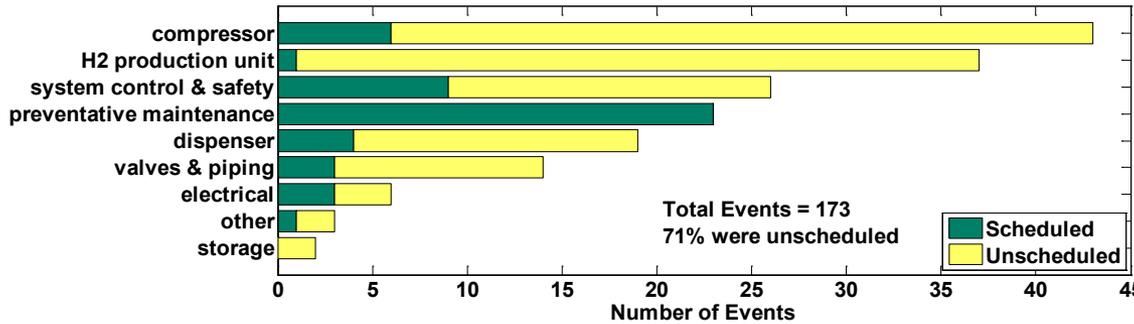
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# Infrastructure Maintenance

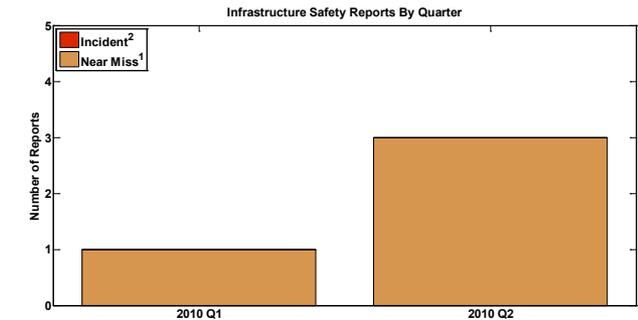
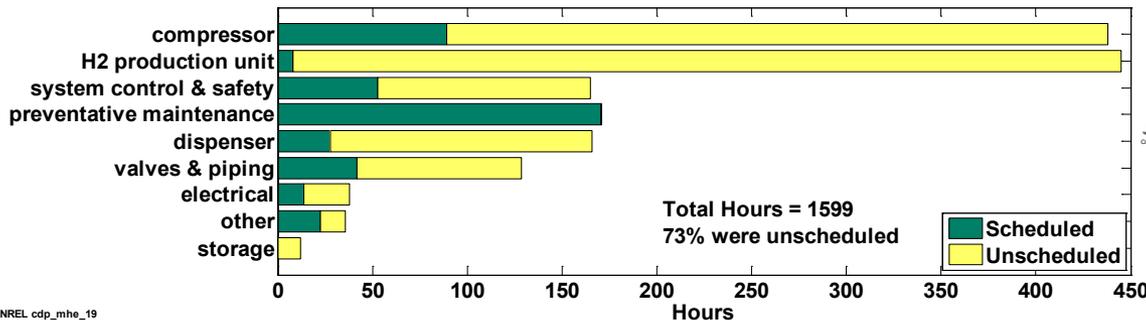
Total Hydrogen Dispensed	19,831 kg
Total Hydrogen Fill Events	36,468 fills
Total FC Hours	251,177 hours
Maintenance Events	173 (71% Unscheduled)
Safety Incidents	0



**Infrastructure Maintenance Scheduled vs. Unscheduled  
Number of Maintenance Events by Category**



**Number of Labor Hours by Category**



- Near Miss is an event that under slightly different circumstances could have become an incident  
-unplanned H2 release insufficient to sustain a flame
- Incident is an event that results in:
  - a lost time accident and/or injury to personnel
  - damage/unplanned downtime for project equipment, facilities or property
  - impact to the public or environment
  - any hydrogen release that unintentionally ignites or is sufficient to sustain a flame if ignited
  - release of any volatile, hydrogen containing compound (other than the hydrocarbons uses as common fuels)

**ARRA & DLA Sites Combined**

*Innovation for Our Energy Future*

# Summary

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- 206 MHE Units in operation at 4 sites with more than 13,300 fills, 6,200 kgs dispensed, and 149,000 hours accumulated without a safety incident.
- 24 BU Units (90 kW installed capacity) in operation at 5 sites with 199 of 201 Starts successful and 88 total hours run time.
- Operation trends unclear because we are in early stage of deployment and analysis
- Many more sites coming on-line in the next 6-12 months
- Many more planned analyses like fuel cell durability, system reliability, and application value proposition

# Contact Information & Website

[http://www.nrel.gov/hydrogen/proj\\_fc\\_market\\_demo.html](http://www.nrel.gov/hydrogen/proj_fc_market_demo.html)

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 303-275-4061



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## Hydrogen & Fuel Cells Research

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**Capabilities**

**Projects**

- Hydrogen Production & Delivery
- Hydrogen Storage
- Fuel Cells
- Technology Validation
- Fuel Cell Vehicle Learning Demonstration
- Fuel Cell Bus Evaluations
- Early Fuel Cell Market Demonstrations
- Safety
- Codes & Standards
- Analysis
- Education
- Manufacturing

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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	2009-11-08		
Accumulated Forklift Operating Hours	Fuel Cell Usage and Operation Behavior	FL02	2009-11-08		
Forklifts Deployed by Quarter	Fuel Cell Usage and Operation Behavior	FL01	2009-11-08		
Fuel Cell Units Delivered to Site	Fuel Cell Usage and Operation Behavior	ARRA01	2010-02-18		
Fuel Cell Units in Operation—Current and Projected Quantities	Fuel Cell Usage and Operation Behavior	ARRA02	2010-02-18		



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.