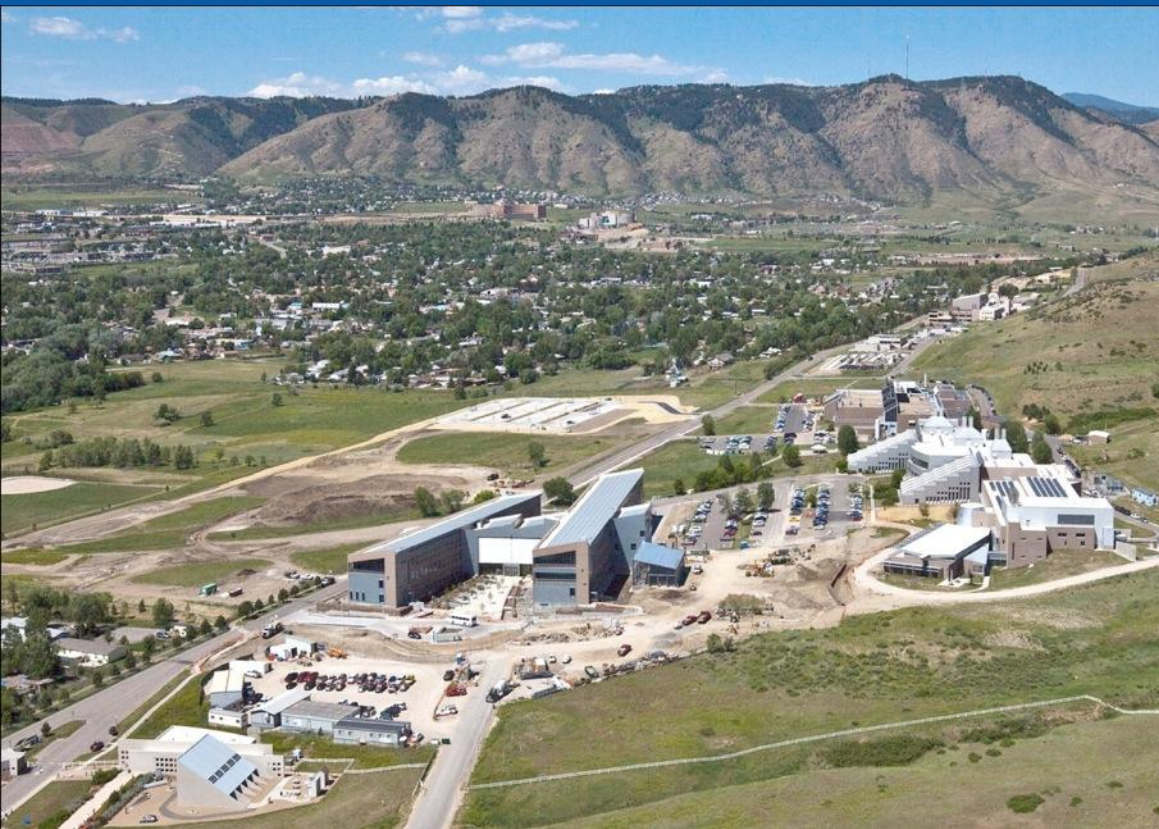


ARRA Fuel Cell Deployments: Operation Data Overview



**Hydrogen Safety Panel
Meeting**

Washington D.C.

**Jennifer Kurtz, Keith
Wipke, Sam Sprik, Todd
Ramsden, Chris
Ainscough, Genevieve
Saur**

4/7/2011

PR-5600-51574

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Contents

- NREL Data Analysis Objectives
- Overview of ARRA Fuel Cell Project
- Deployment, Performance, and Cross-Application CDPs

HSDC
NREL's Hydrogen Secure Data Center



NREL Data Analysis Objectives – ARRA Demonstrations



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

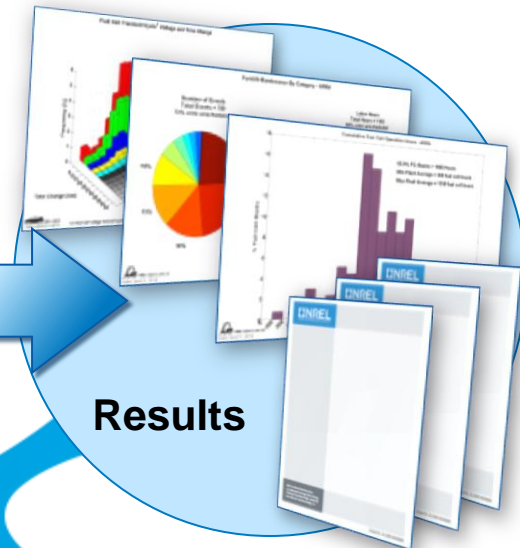
Bundled data (operation & maintenance/safety) delivered to NREL quarterly

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

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

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

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

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

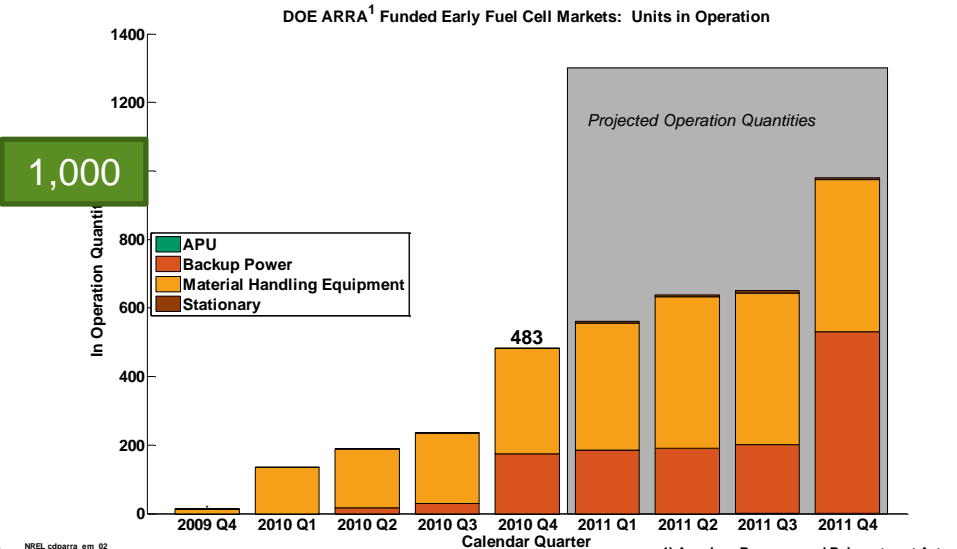
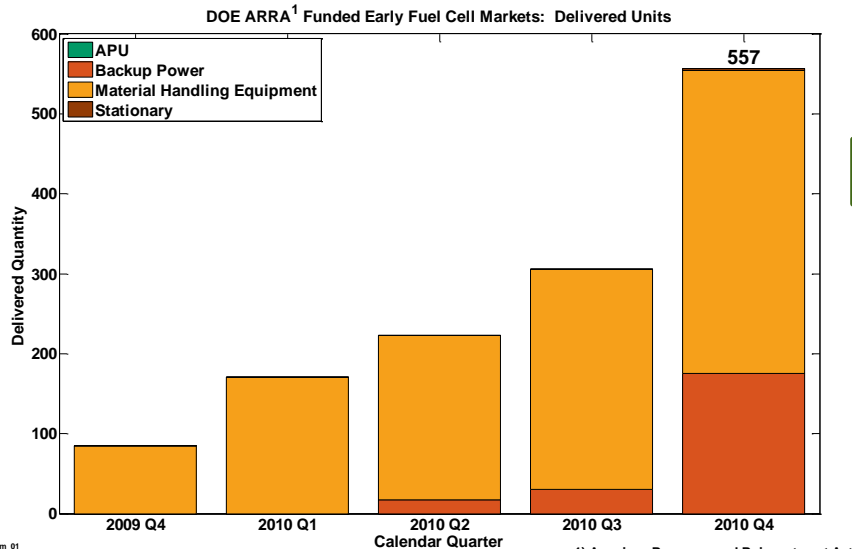
Material Handling: 308 units deployed, 307,433 hours accumulated, 38,863 fills, and 18,597 kg*

Backup Power**: 189 units deployed at 85 sites, 99.8% start success, and 218 operation hours*

*Through December 2010

**ARRA and IAA projects

Deployment CDPs Updated Quarterly



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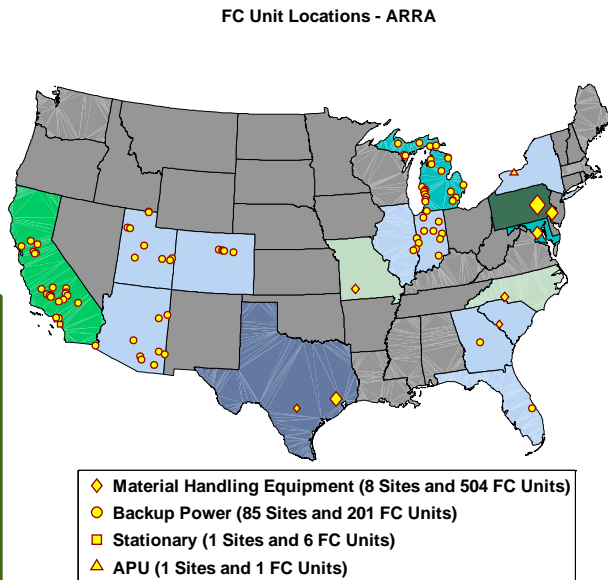
NREL cdparra_em_02
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Delivered Units
by Quarter &
Application

557 Units

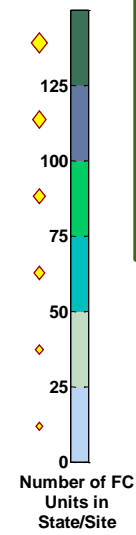
Location by
application &
unit count

16 states

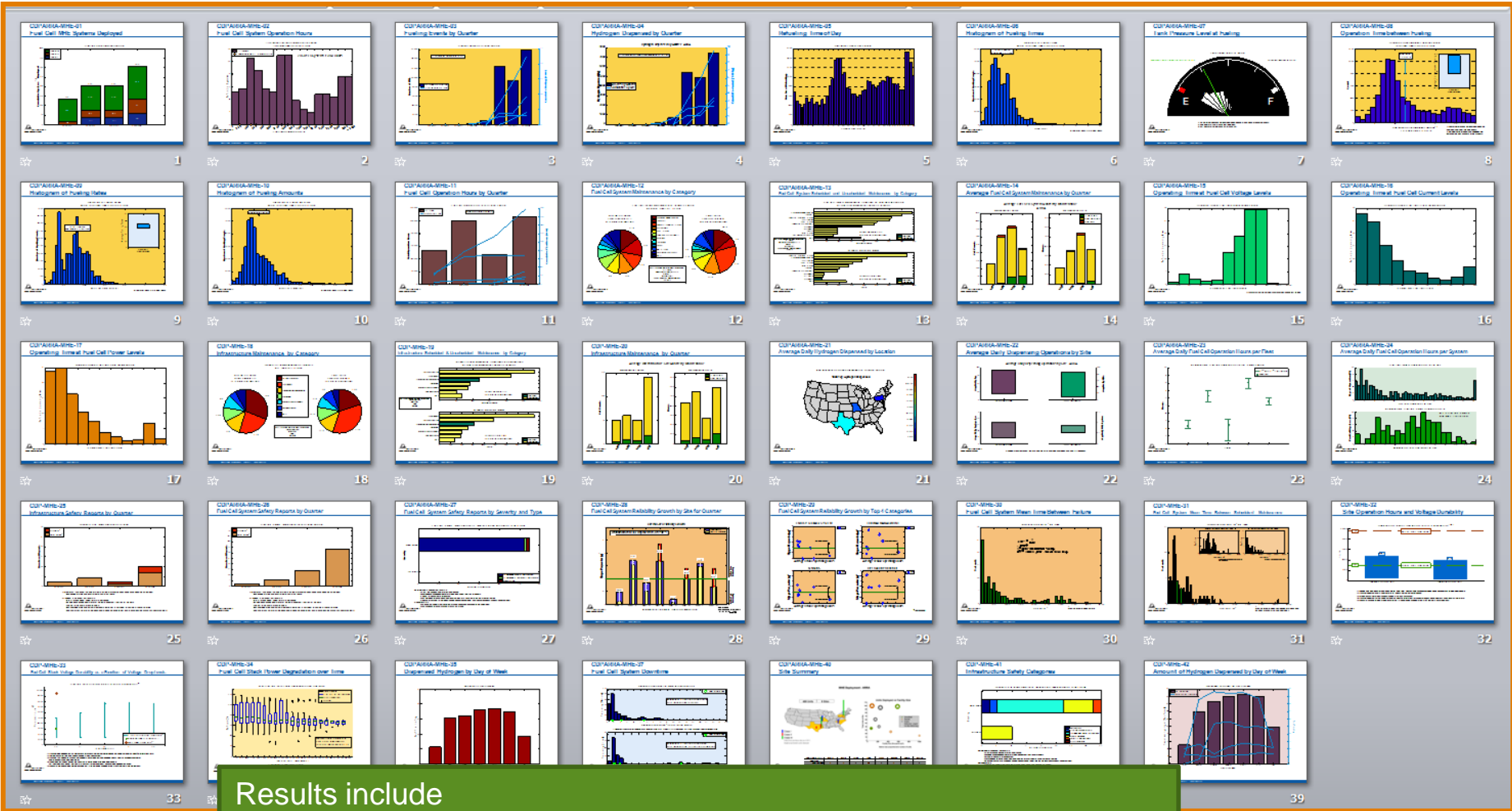


Units in Operation
by Quarter &
Application

483 Units



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 FC MHE Operation - ARRA



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



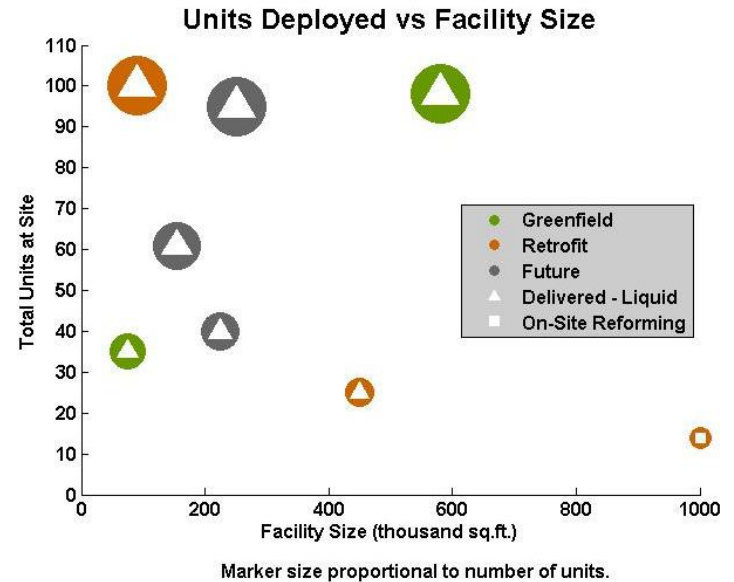
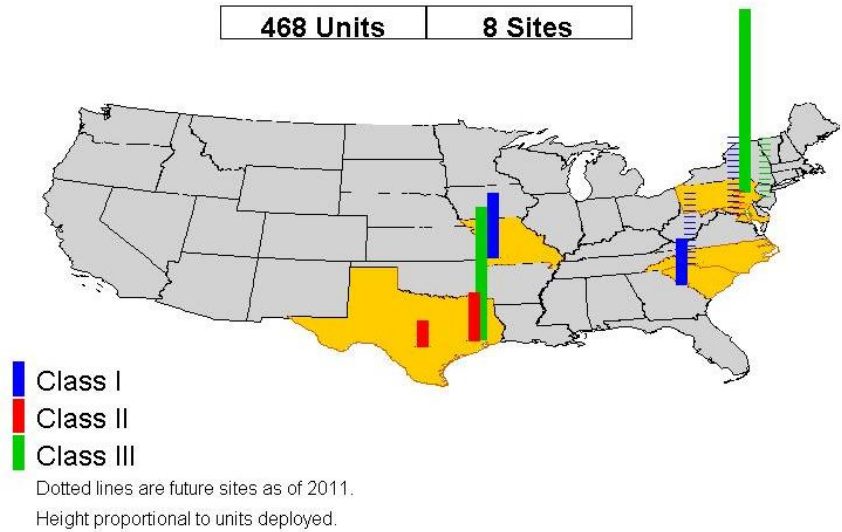
FCMHE operating at end user facilities, accumulating many hours and hydrogen fills safely, and already showing productivity improvements.

*Through December 2010

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

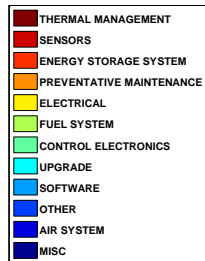
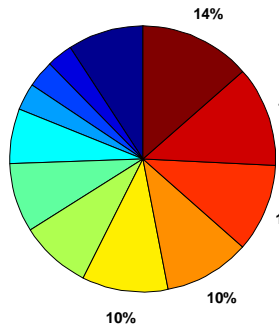
Maintenance Events

Collaboration with C&S teams – specifically through Carl Rivkin (NREL) and Jeff LaChance (SNL)

Fuel Cell System

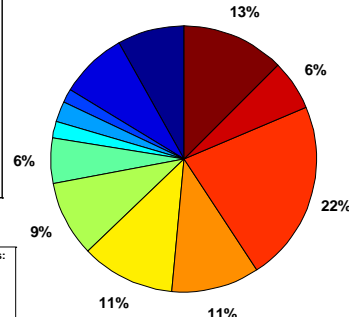
Fuel Cell System Maintenance By Category - ARRA
All ARRA Sites Thru 2010Q4

Number of Events
Total Events = 1149
83% were unscheduled



MISC includes the following categories:
FC STACK
MANUFACTURING DEFECT
VALVES
ACTUATORS
SERVICE
OPERATOR PROTOCOL

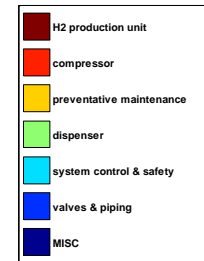
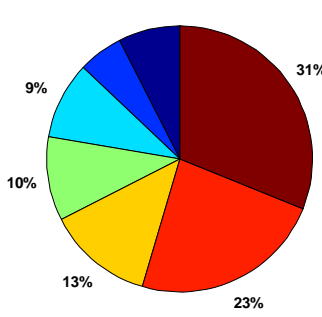
Labor Hours
Total Hours = 1676
87% were unscheduled



Infrastructure

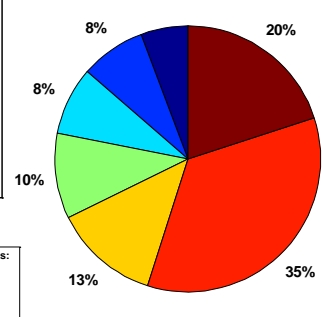
Infrastructure Maintenance By Category
All Sites Thru 2010Q4

Number of Events
Total Events = 363
87% were unscheduled

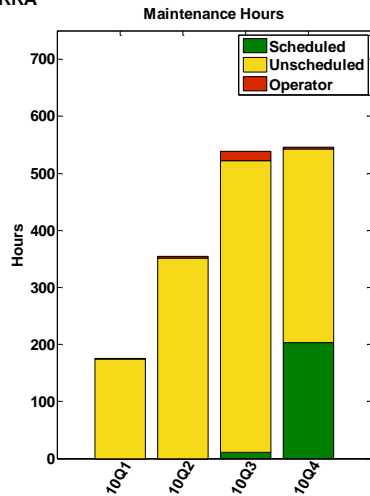
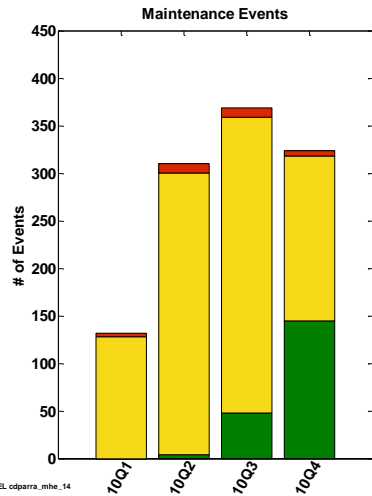


MISC includes the following categories:
Data collection
electrical
other
storage

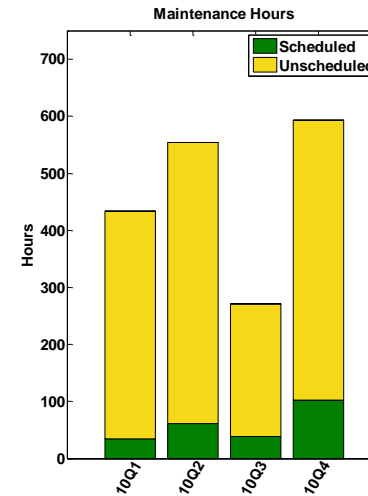
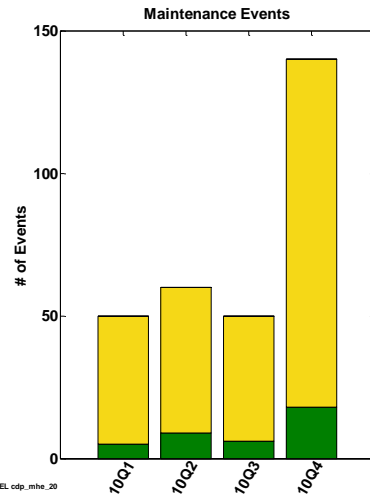
Labor Hours
Total Hours = 2427
87% were unscheduled



Average Fuel Cell System Quarterly Maintenance - ARRA

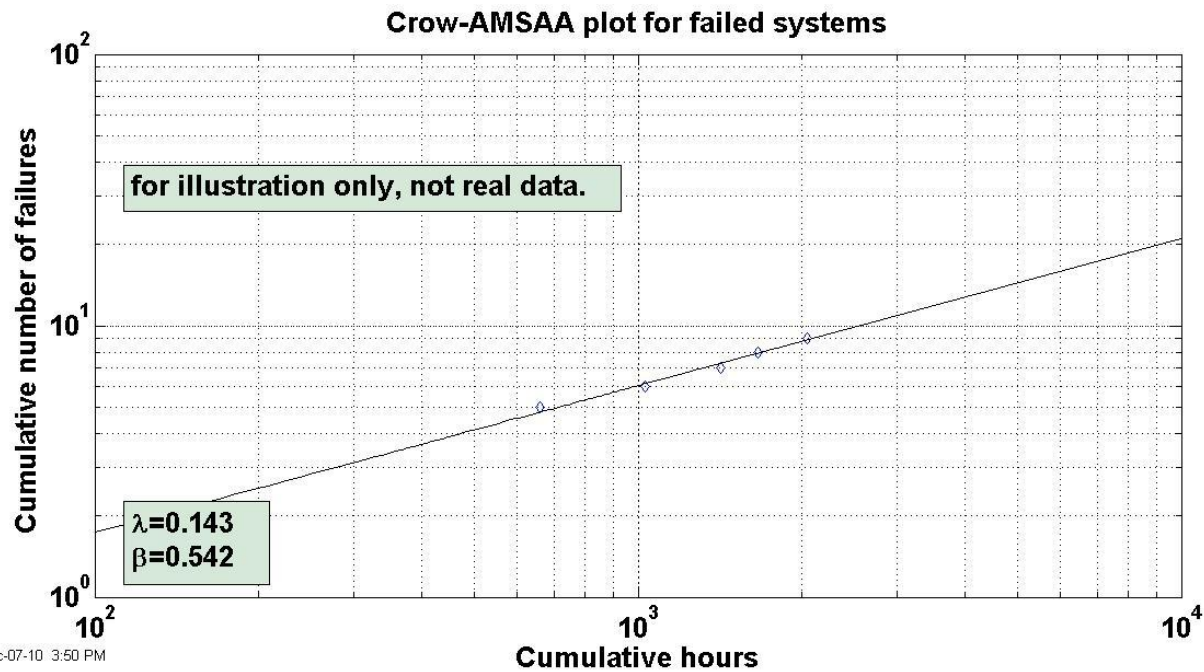


Average Infrastructure Site Quarterly Maintenance



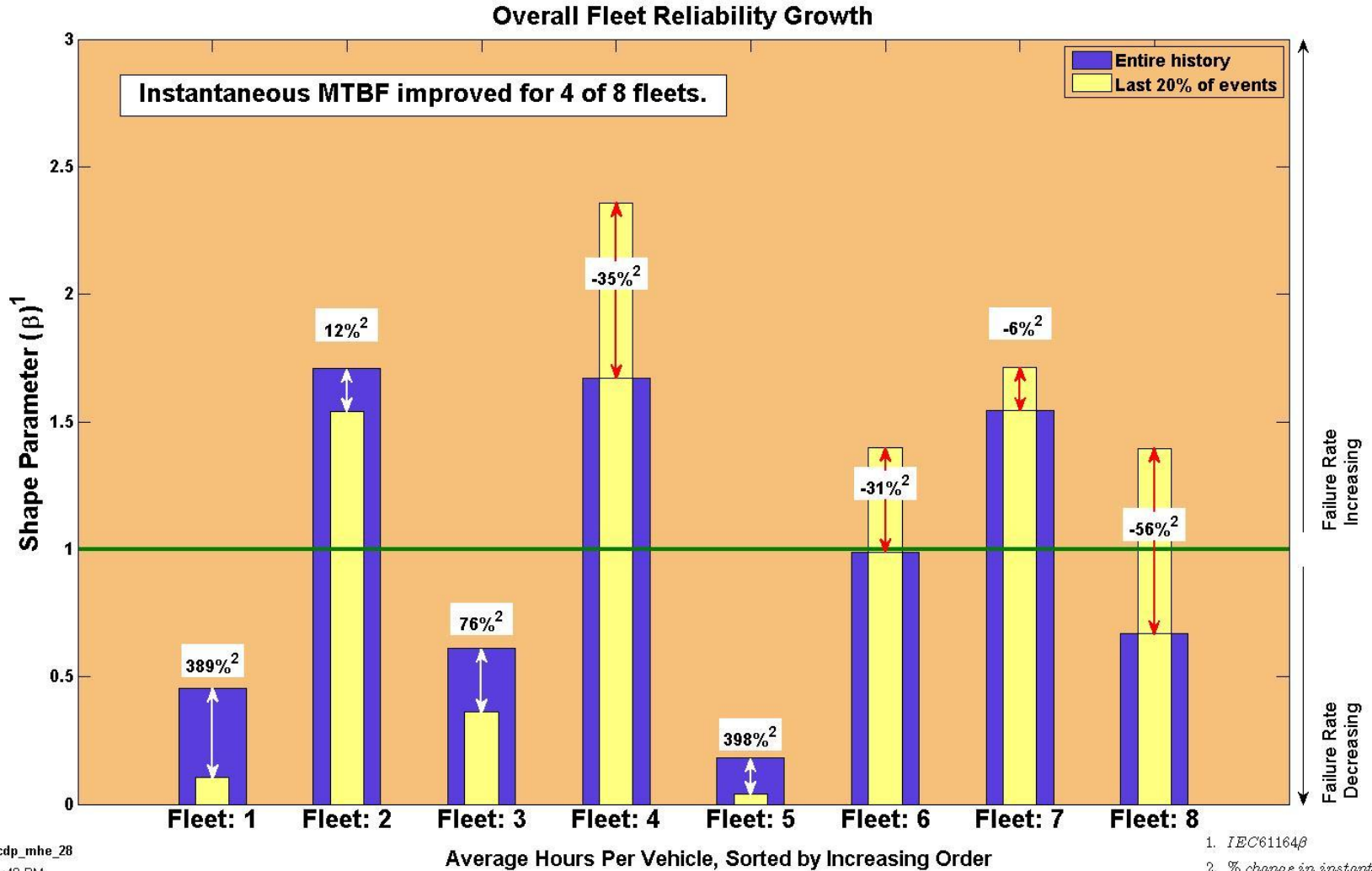
Fuel Cell System Reliability Analysis

- Failure events (i.e. unscheduled maintenance records) are tracked per unit and per fleet
- Crow-AMSAA analysis method^{1,2}
- Study failure rates (e.g Shape Parameter > 1 is an increasing failure rate)
- Highlight common failures per category and unit
- Tracks progress and reliability predictions



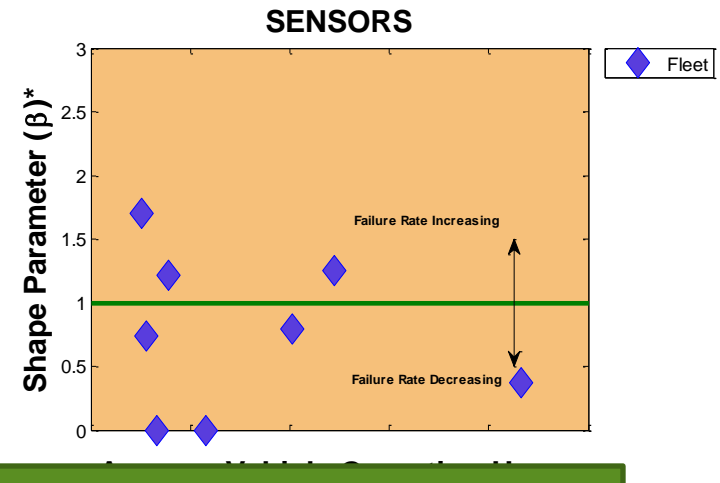
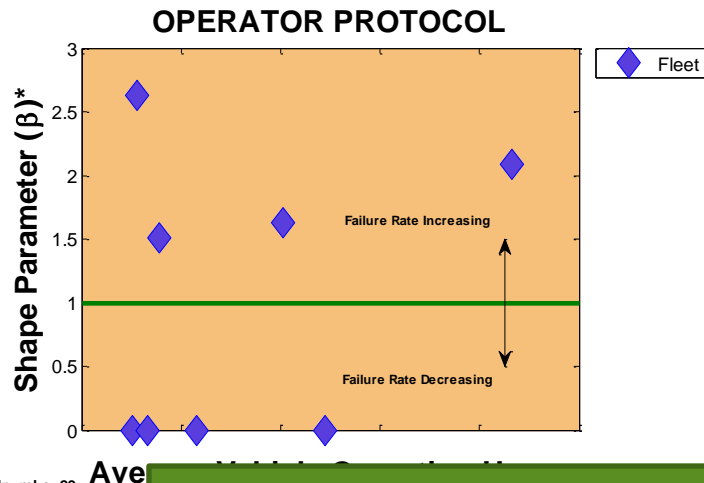
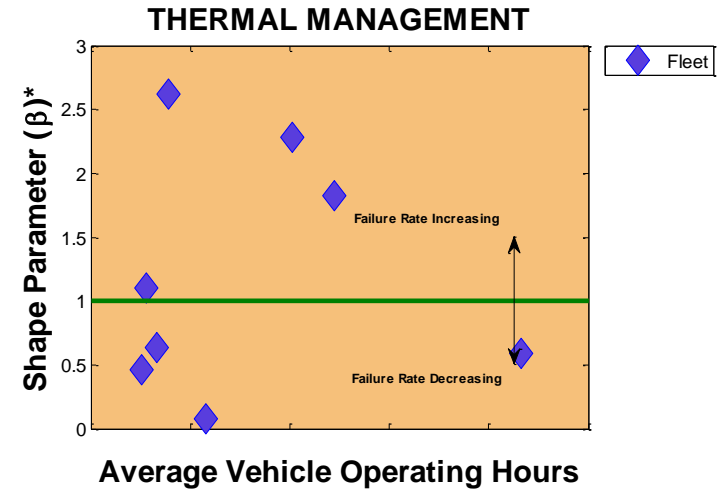
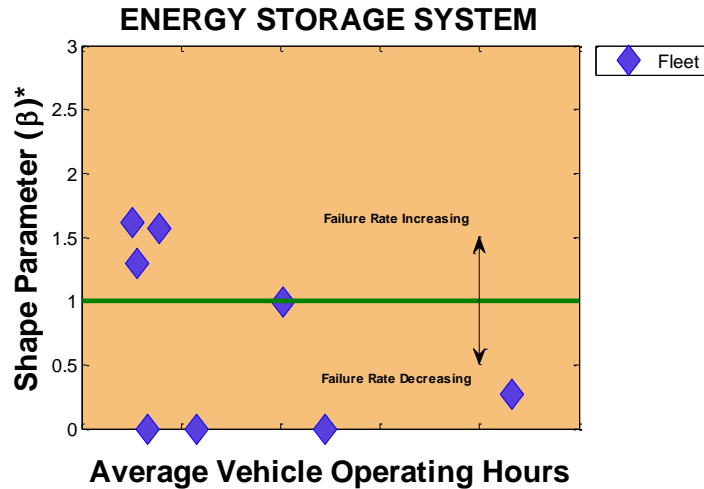
1. *The New Weibull Handbook*, 5th ed., Robert Abernethy, (2007)
2. *IEC 61164:2004, Reliability Growth – Statistical Estimation Methods*, International Electrotechnical Commission, (2004)

Site Reliability Growth



• 5 Fleets have a steady or decreasing failure rate overall, but 2 of those fleets have experienced an increasing failure rate for the last 20% of events.

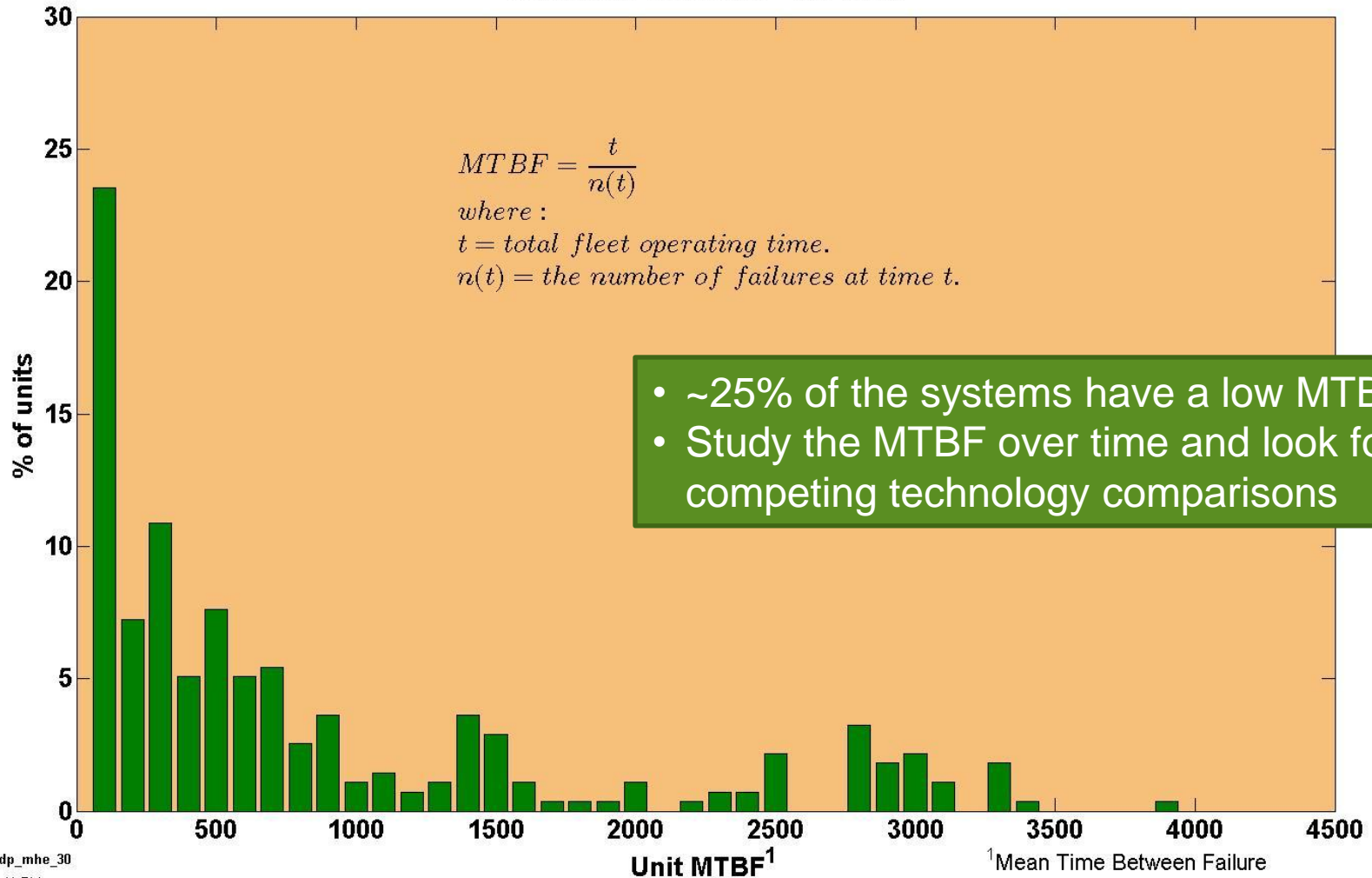
Site Reliability Growth by Top 4 Categories



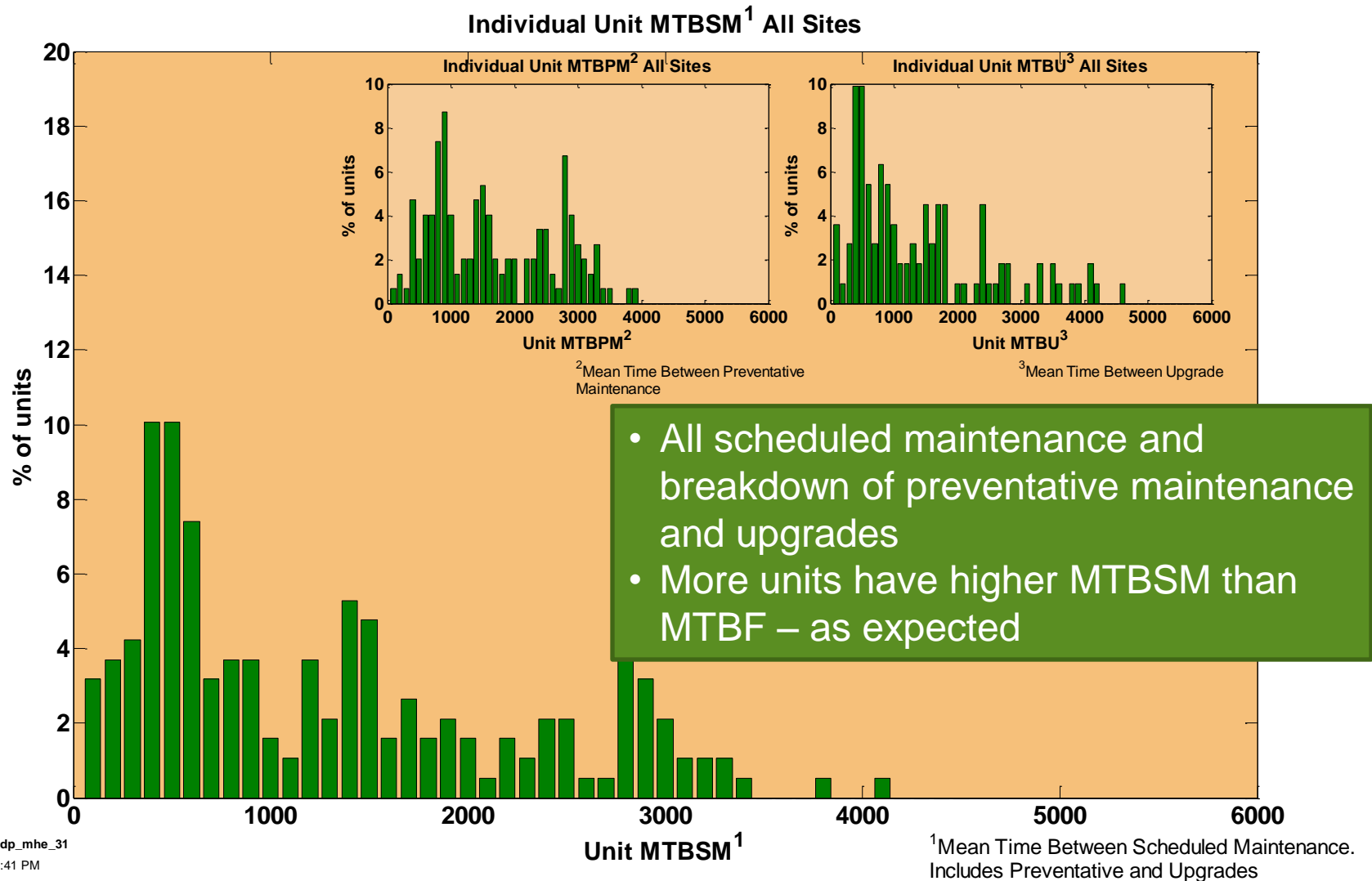
- Top 4 Categories based on all maintenance events
- Some fleets don't have any failures in a certain category
- Looking for trends by failure category

Fuel Cell System – Mean Time Between Failures

Individual Unit MTBF¹ All Sites



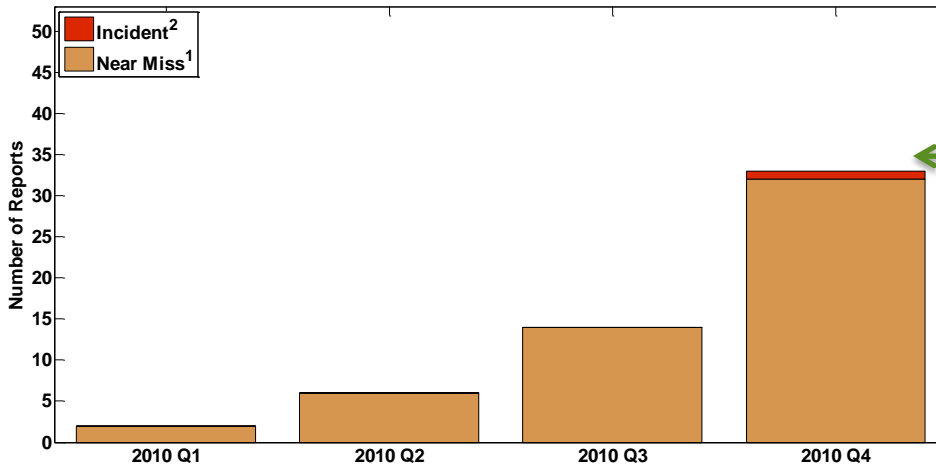
Fuel Cell System – Mean Time Between Scheduled Maintenance



Tracking Safety Reports – Fuel Cell System



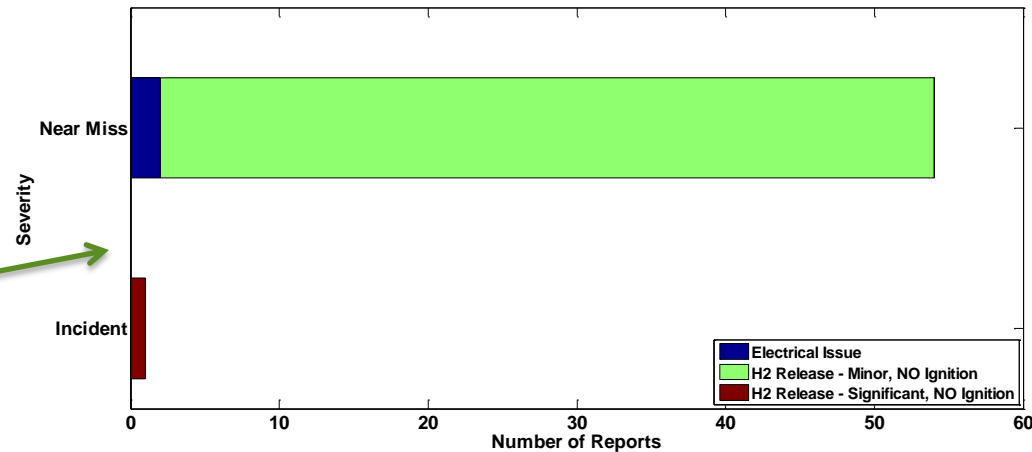
Fuel Cell System Safety Reports by Quarter - ARRA



• 308 systems, 307,433 operation hours with 54 safety reports categorized as Near Miss and 1 Incident

- 1) Near Miss is an event that under slightly different circumstances could have become an incident
 - unplanned H2 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
 - release of any volatile, hydrogen containing compound (other than the hydroc...

Fuel Cell System Safety Reports by Severity - ARRA and Report Type 2010Q4



• 94% of safety reports are classified as Minor Hydrogen Release

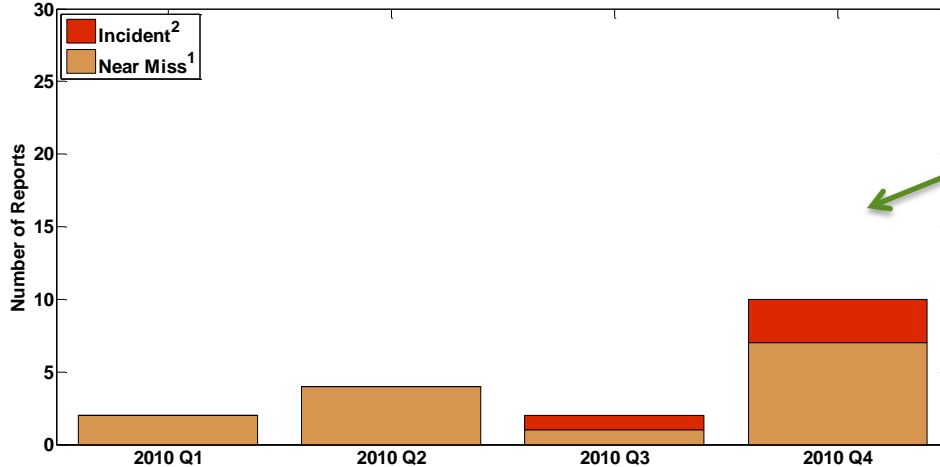
• 1 Incident classified as Significant Hydrogen Release – No Ignition

- An 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 used as common fuels)
- A NEAR-MISS is:
- an event that under slightly different circumstances could have become an incident
 - unplanned H2 release insufficient to sustain a flame

Tracking Safety Reports - Infrastructure



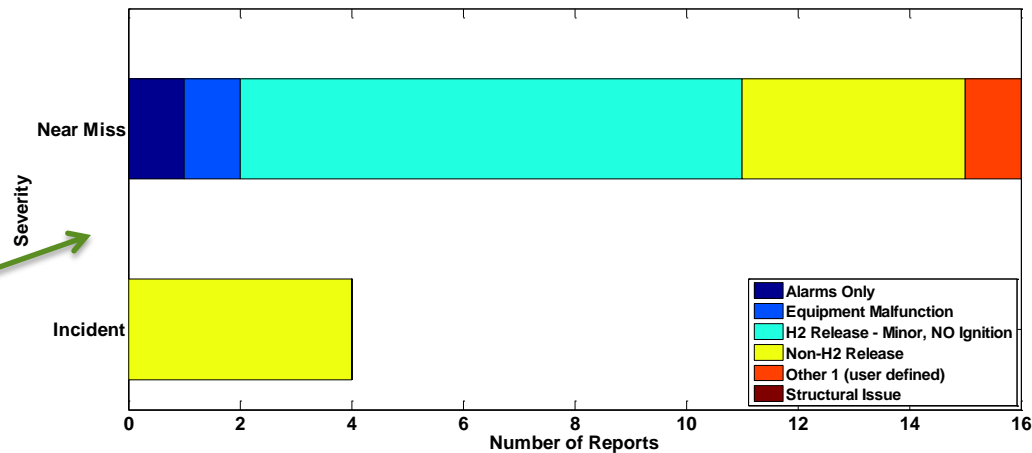
Infrastructure Safety Reports By Quarter



• 75,364 fills (ARRA & DLA projects) with 16 safety reports categorized as Near Miss and 4 incidents

- 1) Near Miss is an event that under slightly different circumstances could have become an incident
 - unplanned H2 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
 - release of any volatile, hydrogen containing compound (other than the hydroc:

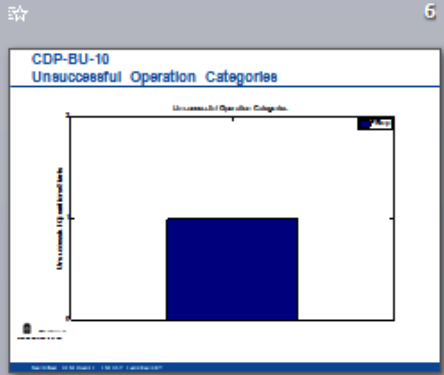
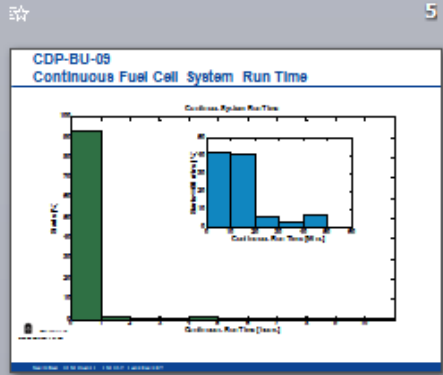
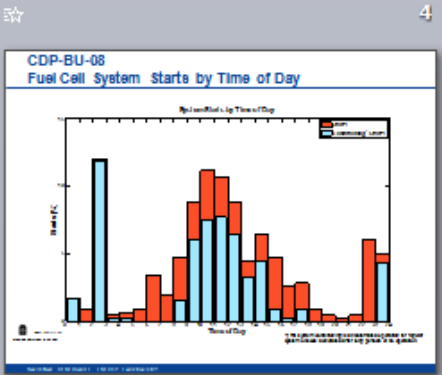
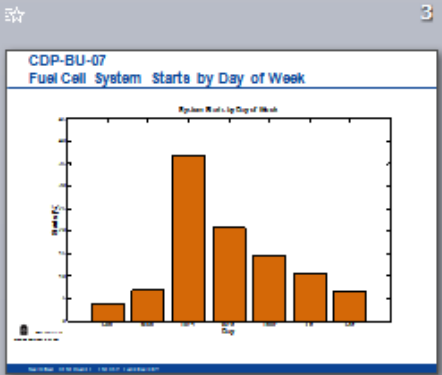
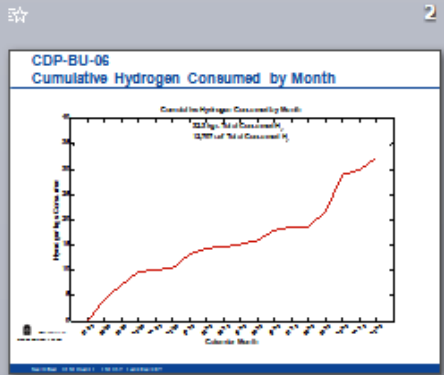
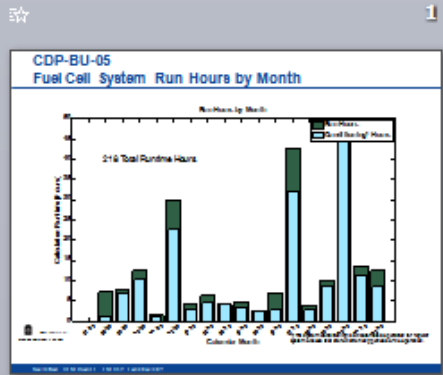
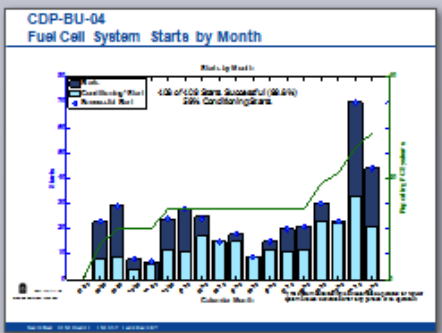
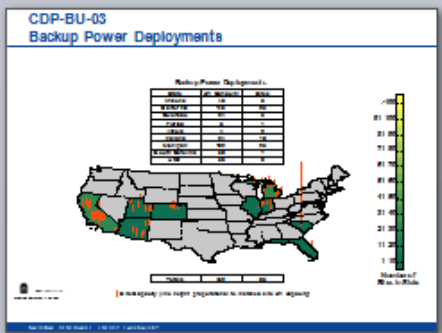
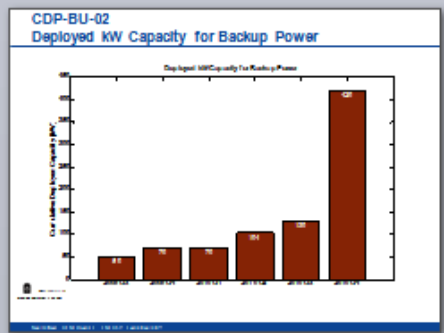
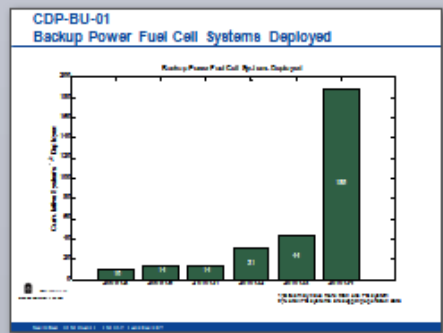
Infrastructure Safety Reports by Severity - All Sites and Report Type 2010Q4



• 4 safety incidents are classified as Non-Hydrogen Release (e.g. drive offs)

- An 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 used as common fuels)
- A NEAR-MISS is:
- an event that under slightly different circumstances could have become an incident
 - unplanned H2 release insufficient to sustain a flame

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

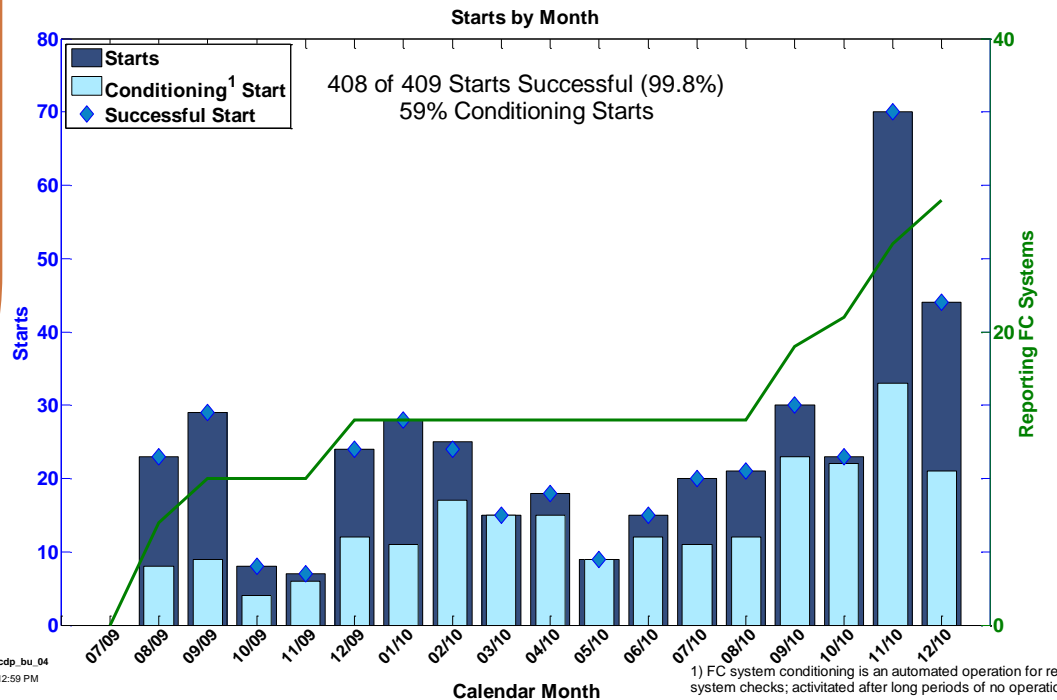
Summary of Backup Power System Operation



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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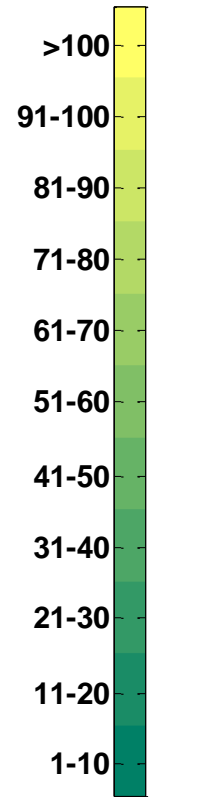
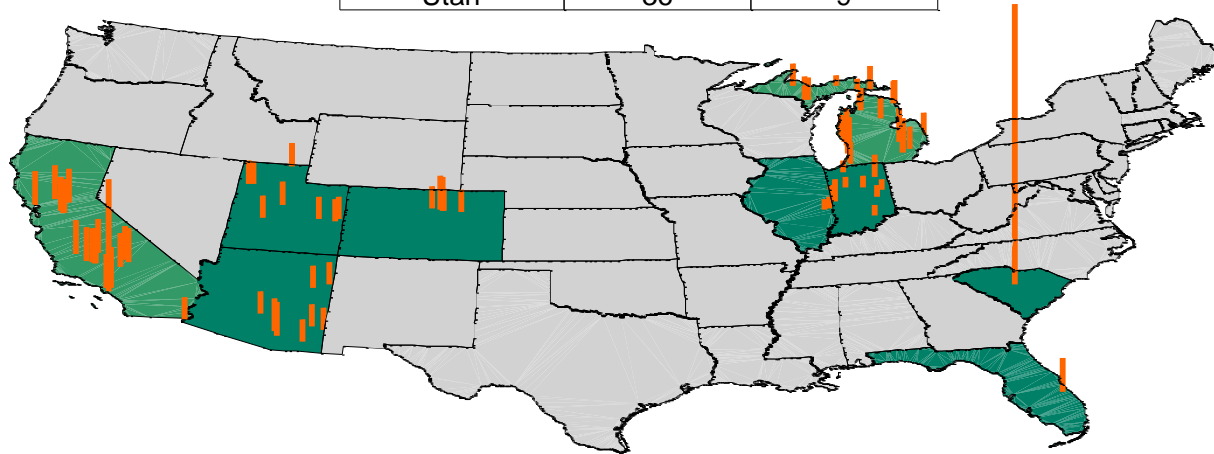
* Through December 2010

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

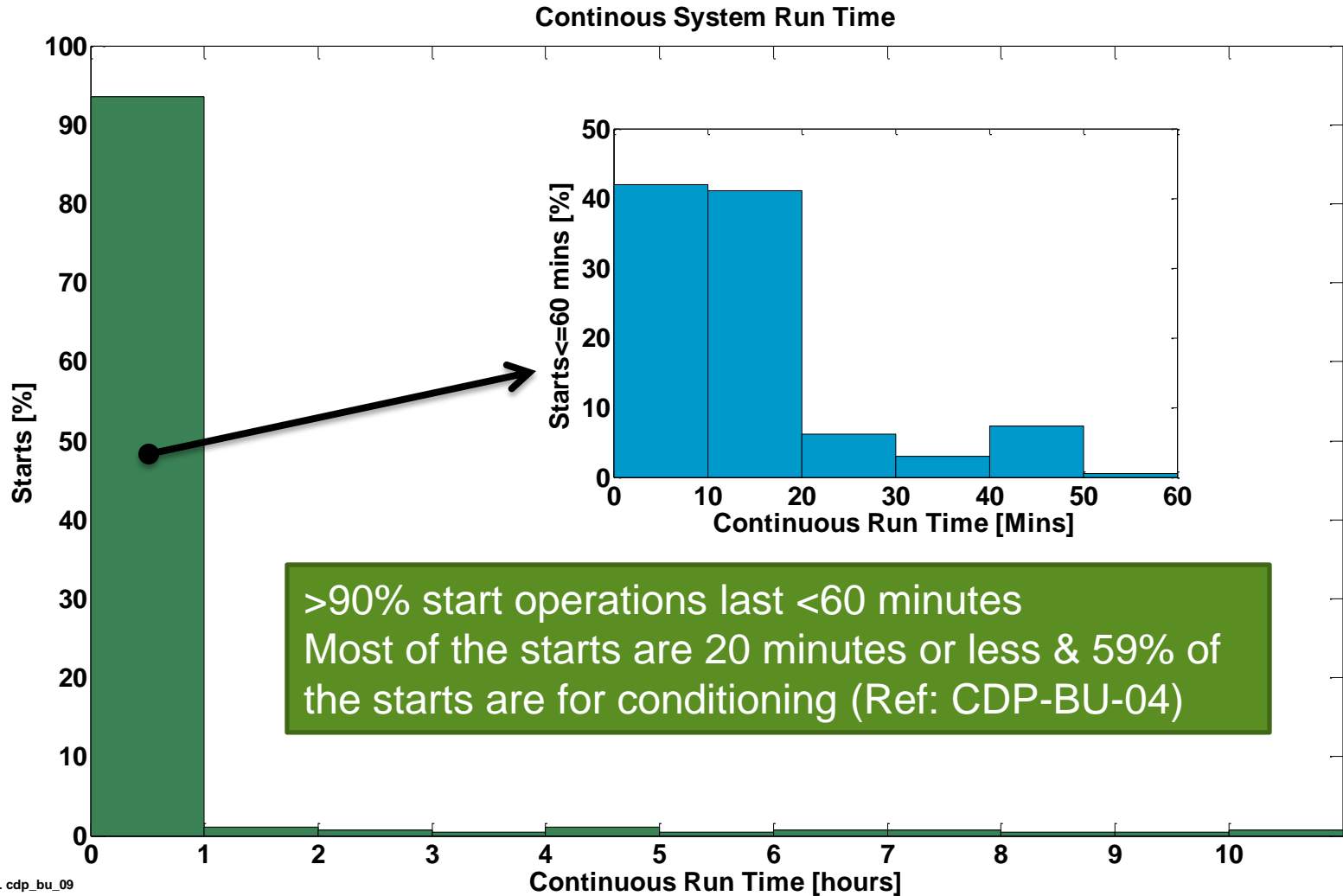


Totals	432	85
--------	-----	----

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

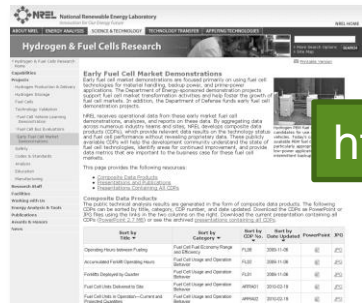
Number of Sites in State

Demonstrated Continuous Run Time





Summary

- Deployment CDPs (3) updated quarterly
- Two cycles of technical CDPs for material handling and backup power
 - 42 MHE specific CDPs
 - 10 Backup Power specific CDPs
- Conducted 2 safety panel site visits, 3 site visits, and 2 partner facility visits
- New, application specific analysis include continuous runtime, reliability, downtime, and durability
- All of the published results can be found at:



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

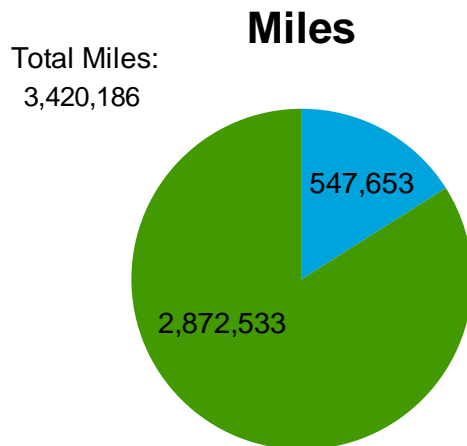
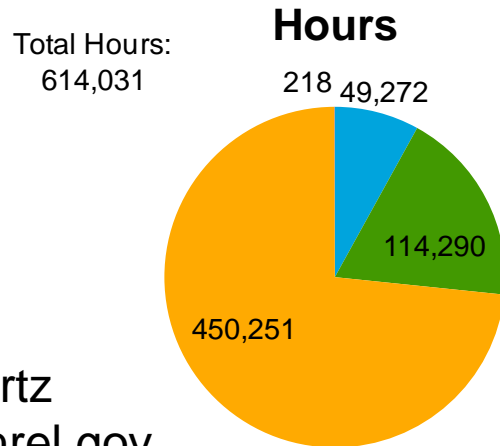
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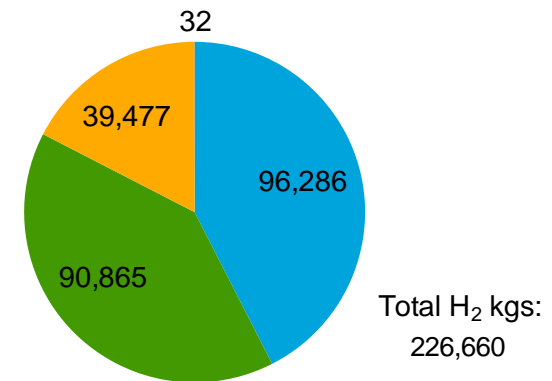
* Through December 2010

Contact Information

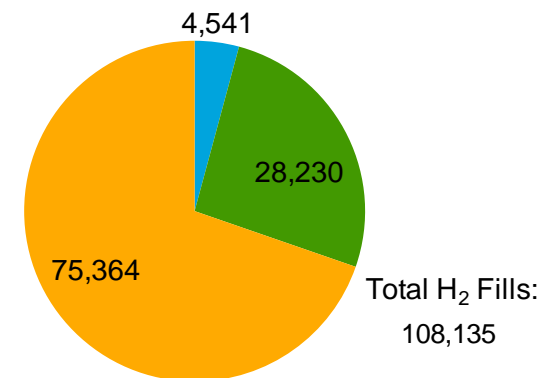
Jennifer Kurtz
 jennifer.kurtz@nrel.gov
 303-275-4061



Hydrogen Amount



Hydrogen Fills



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