

# Direct Methanol Fuel Cell Material Handling Equipment Deployment



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# Overview

## Timeline

- **Start: June, 2010**
  - Contract Award February, 2011
- **Finish: June, 2013\***
- **98% Complete**

## Budget

- **Total Project Funding: \$2.58M**
  - Oorja cost share: \$1.4M (60%)
  - DOE share for deployment: \$920K
  - NREL project management & analysis (FY10-FY13): \$255K

\*Sub-contract deployment completed in December 2012

## Barriers Addressed

- **Non-technical issues preventing full commercialization of fuel cell systems**

## Collaborators

- **Oorja Protonics**
- **Demonstration Sites:**
  - Unified Grocers
  - Earp Distribution
  - Testa Produce

# Project Objectives

## Oorja Protonics:

- **Deploy and operate DMFC powered MHE and methanol infrastructure**
- **Compile operational and maintenance data and deliver to NREL**

## NREL:

- **Validate performance under real world conditions and provide independent technology assessment**
  - **Reliability and durability of fuel cell systems**
  - **Performance of infrastructure**
  - **Overall value proposition**
- **Support the market for fuel cells in material handling applications by providing relevant results for the key stakeholders**

# Project Overview

## Oorja Protonics:

- Operate and maintain 75 DMFC-based Class III pallet jacks operating in four commercial wholesale distribution centers
- 15-month deployment at each site
- Two shifts per day, 6 days per week
- Target 3,500–5,000 total operation hours on each unit
- Use data loggers to provide detailed tracking of DMFC system performance

## NREL:

- Manage competitive solicitation and subcontract
- Validate performance of systems and infrastructure
- Assess value proposition

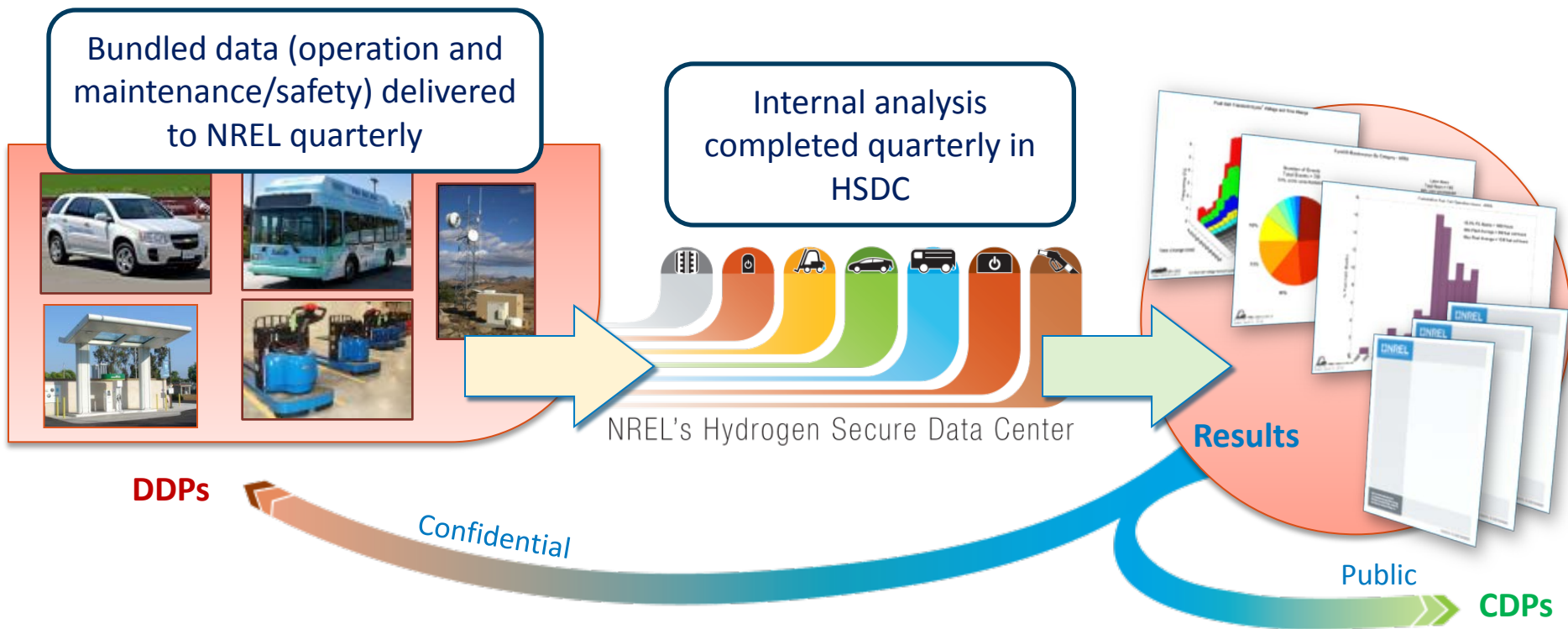


Photo courtesy of Oorja Protonics

# Incorporation of Learnings

- **As reported last year, initial deployment of 75 units experienced failures due to methanol sensors and other design issues**
- **As a result, many learnings were gained and new system designs were implemented**
  - **However, the project budget did not allow for complete overhaul of the initial 75 units**
  - **In a follow-on commercial order, a second fleet of systems was deployed, which incorporated the design updates resulting from the initial 75 unit deployment**
    - **Fleet of 35+ units at separate end-user distribution site**

# Analysis and Reporting of Real-World Operation Data



## Detailed Data Products (DDPs)

- Individual data analyses
- Identify individual contribution to CDPs
- Shared every six months only with the partner who supplied the data<sup>1</sup>

## Composite Data Products (CDPs)

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

1) Data exchange may happen more frequently  
 2) Results published via NREL technology validation website, conferences, and reports  
 ([http://www.nrel.gov/hydrogen/proj\\_learning\\_demo.html](http://www.nrel.gov/hydrogen/proj_learning_demo.html))

# Collaborations

- **Oorja Protonics:**
  - Built and maintained DMFC Class III MHE systems for customer sites
  - Provided operational data to NREL
- **Commercial food distribution warehouses:**
  - Unified Grocers
  - Testa Produce
  - Earp Distribution
- **Fourth end-user agreed to provide data from separate deployment**



Photo courtesy of Oorja Protonics

# Methanol Fueling Infrastructure Deployed

- **Indoor dispensing via Oorja's OorjaRig™ methanol dispenser**
  - OorjaRig designed for indoor methanol fueling of OorjaPac™ DMFCs
  - Equipped with methanol storage in two standard 55-gallon drums, pumps, safety connect dispenser nozzle, sensors
  - Cabinet is FM-rated for Class 1 Div 2 operation, meets NFPA code
- **Bulk methanol outdoor storage in 2,000 gallon UL-rated, double-walled tanks meeting relevant NFPA codes**

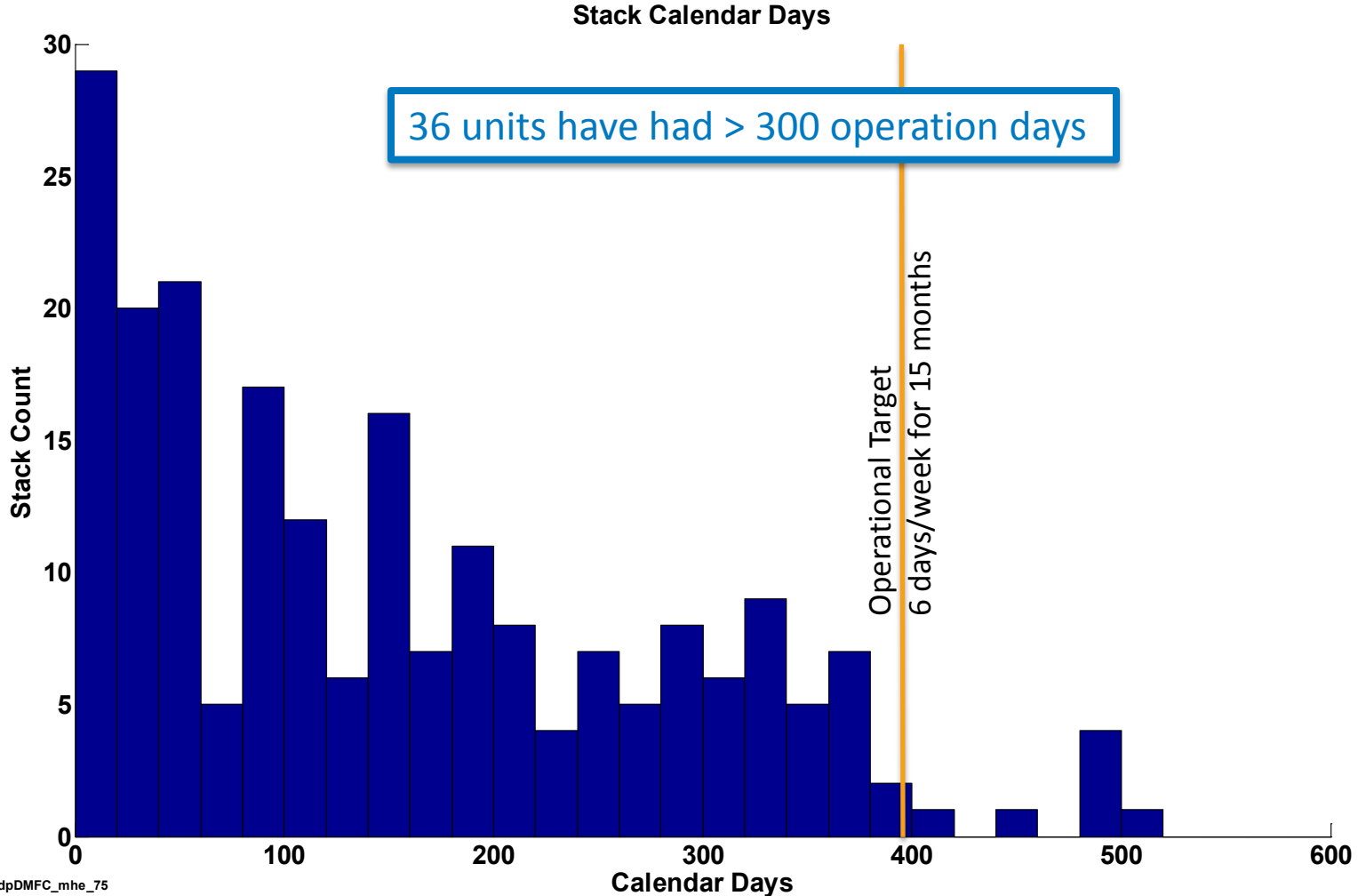


Photo courtesy of Oorja Protonics

*Data  
previously  
shown*

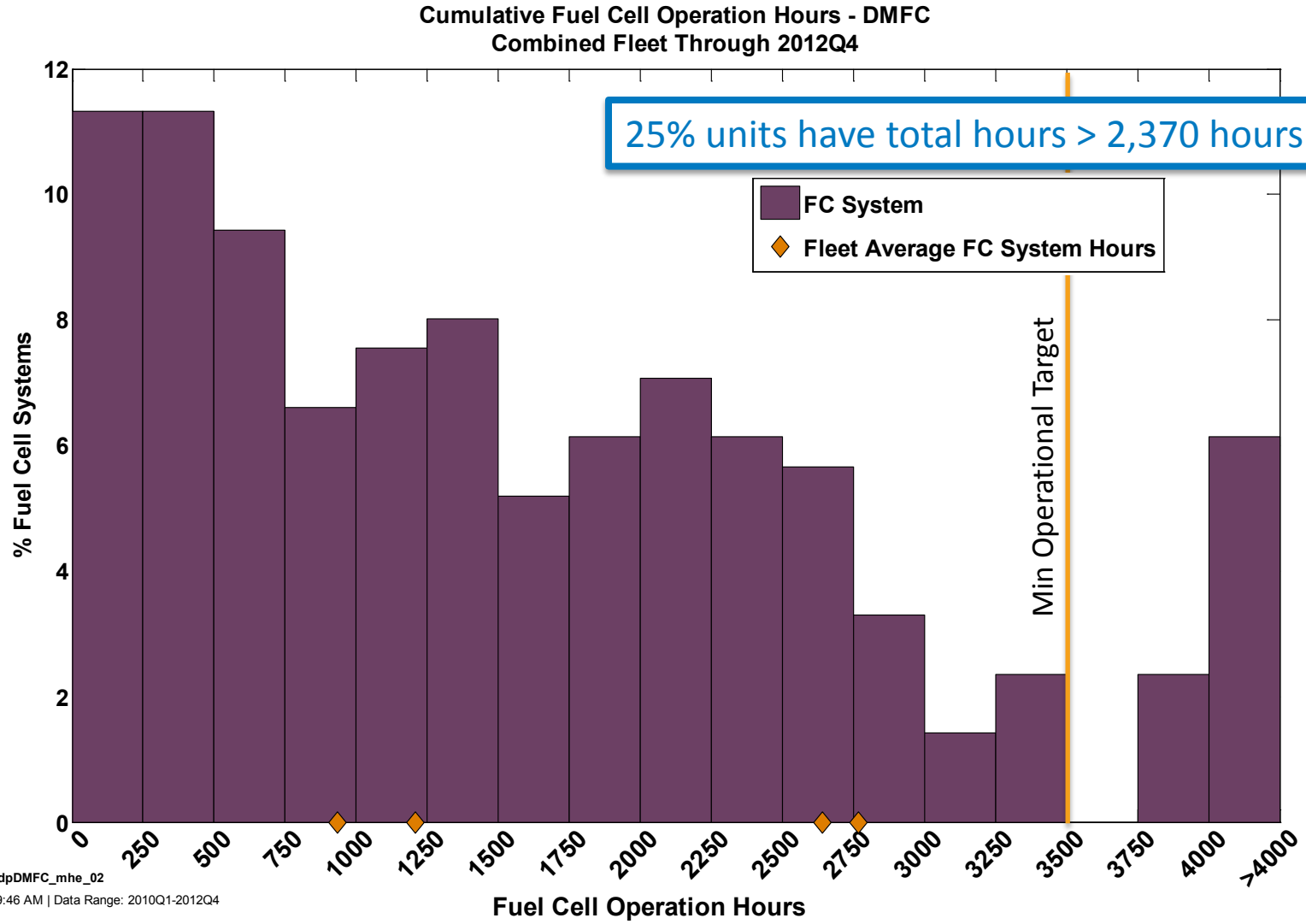


# Fuel Cell Unit Elapsed Calendar Days of Operation



 NREL cdpDMFC\_mhe\_75  
Created: Apr-30-13 3:19 PM | Data Range: 2010Q1-2012Q4

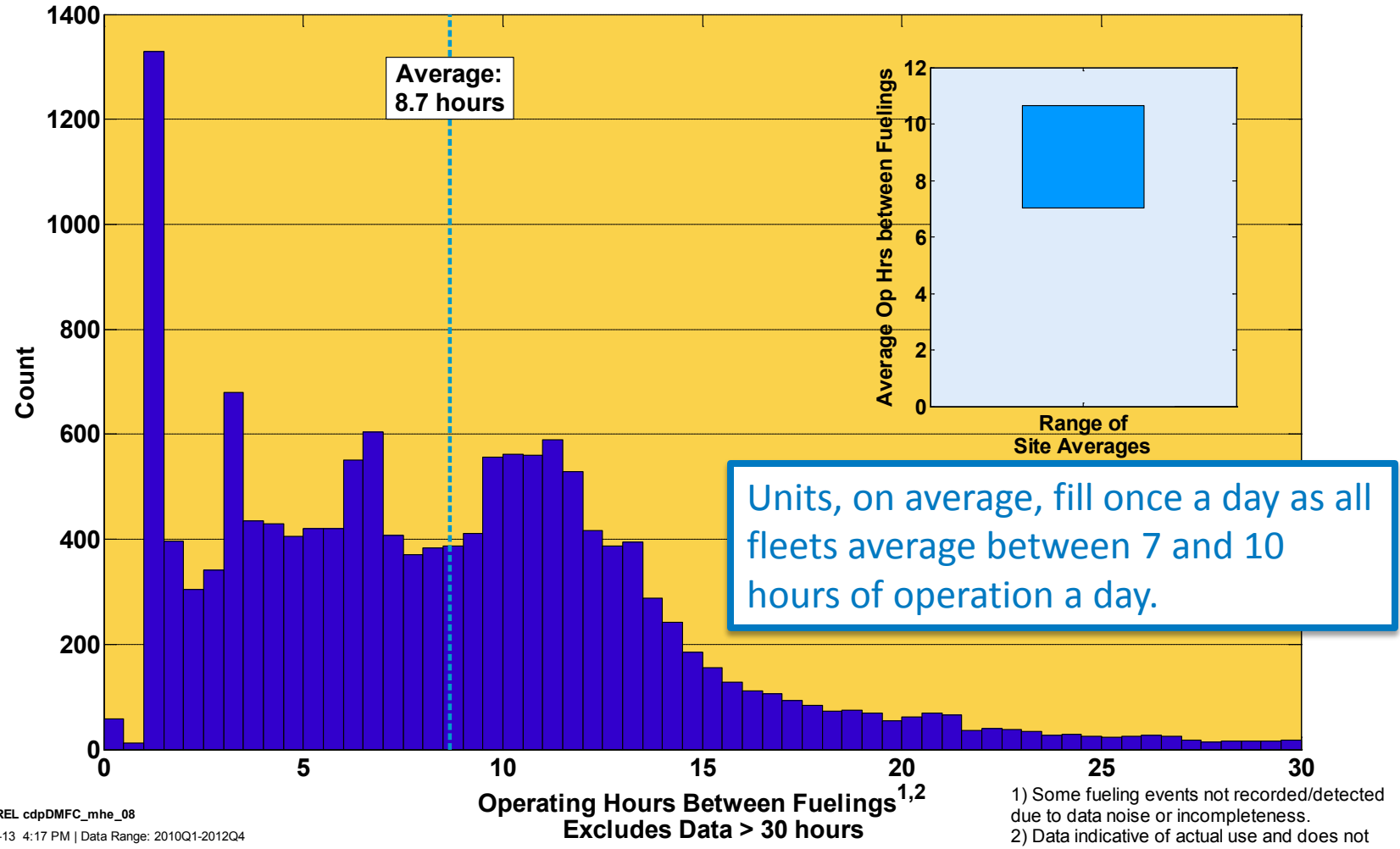
# Fuel Cell Unit Operational Hours



NREL cdpDMFC\_mhe\_02  
Created: May-02-13 9:46 AM | Data Range: 2010Q1-2012Q4

# Fuel Cell Unit Operation Time Between Fills

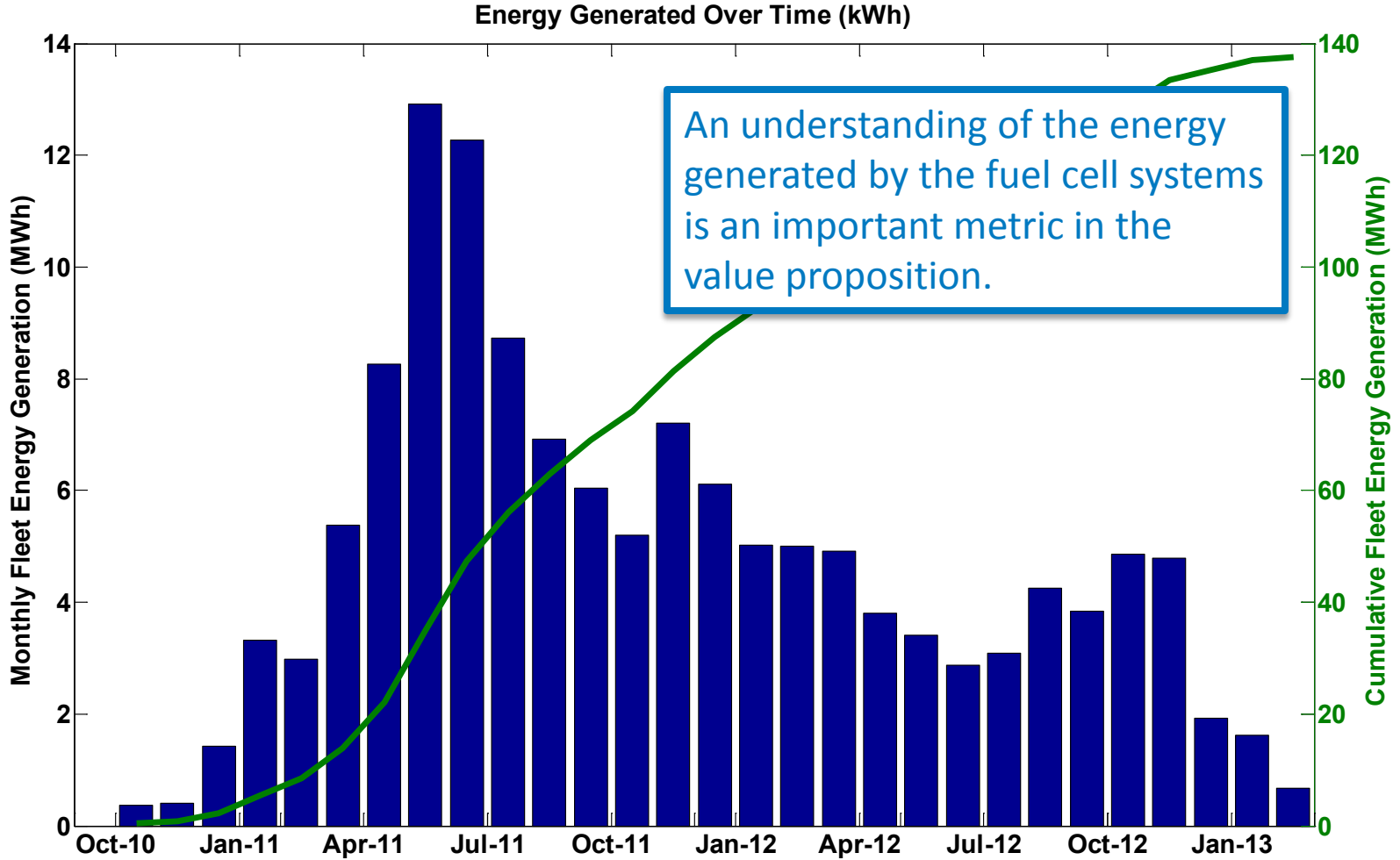
Operating Time Between Fuelings - DMFC  
Combined Fleet



 NREL cdpDMFC\_mhe\_08  
Created: Apr-24-13 4:17 PM | Data Range: 2010Q1-2012Q4

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.

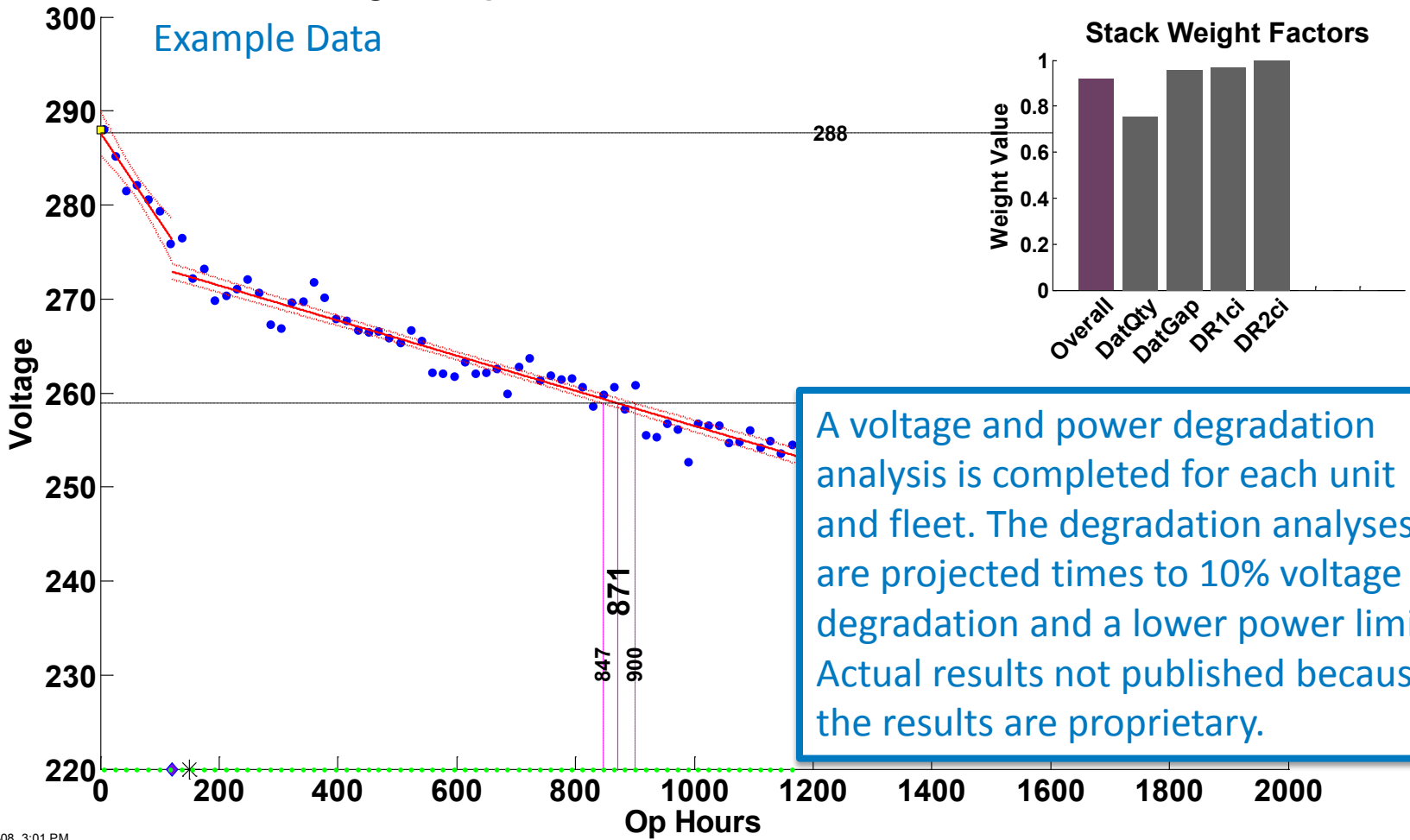
# Fuel Cell Unit MWh Generated



 NREL cdpDMFC\_mhe\_74  
Created: Apr-30-13 2:48 PM | Data Range: 2010Q1-2012Q4

# Fuel Cell Voltage Degradation Analysis

Voltage vs. Operation Hours at 300A: Vehicle19-Stack1



A voltage and power degradation analysis is completed for each unit and fleet. The degradation analyses are projected times to 10% voltage degradation and a lower power limit. Actual results not published because the results are proprietary.

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# DMFC Maintenance Data

- **Summary of maintenance data provided by Oorja Protonics in FY11-12**

Maintenance Area	Maintenance Description	Symptom / Fault
<b>Improper Methanol Concentration</b>	Install new methanol concentration sensor	Improper concentration
	Install new methanol pump	Fuel cell low voltage
	Update methanol concentration sensor firmware	
<b>Electronics Failure</b>	Upgrade electronics subsystem	Fuel cell low voltage
<b>Low Fuel Cell Voltage</b>	Intall new air pump controller card	Fuel cell low voltage during startup
	Install new methanol concentration sensor	
	Install new solution controller card	Fuel cell low voltage during normal operation
<b>Mixer Temperature</b>	Replace fan on liquid radiator side; install better grills	High Temperature at mixer
	Replace anode and cathode heat exchangers	High temperature at anode loop
<b>Fuel Leak</b>	Replace quick disconnect fitting	Methanol leak from fuel tank

*Data previously shown*

# Summary

<b>Performance Summary</b>	
Sites	5
Number of fuel cell forklift power units analyzed	131
Total hours of operation	251,000
Total methanol fueling events	>14,000
Average hours of operation between fueling	~9
Average daily hours of operation per system	8-10
Average daily methanol fills per system	~1
Median DMFC system hours of operation	1391

## Validation:

- **Technology Durability – Analysis completed**
- **Technology Reliability – Not yet completed due to insufficient data**
- **MHE Value Proposition – Not yet completed due to insufficient data**
- **Re-design performance benchmark – In progress**

## Proposed Next Steps

- **Demonstration completed in December, 2012**
- **Project close-out and final reporting between NREL, Oorja, and DOE**
- **Maintenance data to be provided by Oorja for FY12-13**
- **Pending sufficient data and continued project funding, evaluations on**
  - Value proposition
  - Reliability
  - Safety
  - Benchmark system re-design performance



# Questions and Discussion

Thanks!!



Photo courtesy of Oorja Protonics

# Backup Slides

# Relevance: Project Background

- **Fuel cells can offer lower total cost of ownership in material handling applications compared to battery systems**
  - Battelle Early Fuel Cell Markets study found that fuel cells can lower total cost of ownership of MHE compared to batteries
  - DOE and NREL are currently evaluating the use of hydrogen PEM fuel cells in MHE applications
  - Considering all costs, NREL estimates that H2 PEM fuel cell Class III MHE can yield \$700 in annual savings per lift compared to traditional battery MHE
- **DMFCs hold promise to deliver many of the same operational benefits of hydrogen PEM fuel cell MHE**
  - Notably, long runtimes, short refueling times, increased productivity
- **Liquid fuels like methanol offer reduced infrastructure costs**

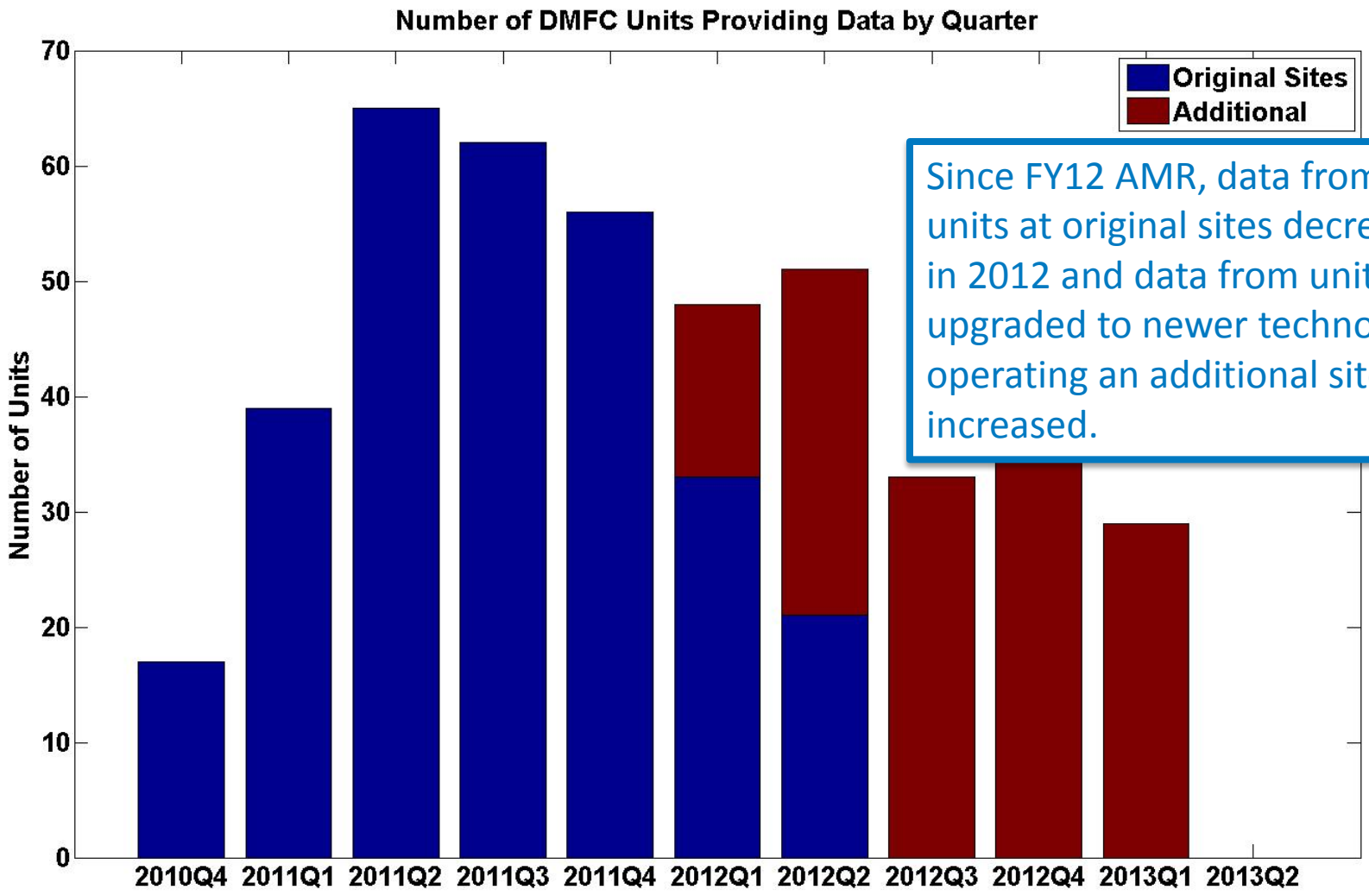
# OorjaPac™ DMFC Systems Deployed

- Oorja built and deployed 75 direct-methanol fuel cell systems on Class III pallet jacks using its OorjaPac Model 3 DMFC power pack
  - All units deployed as of June 2011
- OorjaPac is a variant of a PEM fuel cell system that uses an anode catalyst to extract hydrogen from the methanol molecule
- OorjaPac Model 3 specifications include:
  - Power output: 1.5kW
  - Output voltage: 24V/36V/48V
  - Methanol tank volume: 12 liters
  - Energy output: 20kWh per tank
- The OorjaPac acts as an on-board battery charger, allowing:
  - Grid independence
  - Elimination of battery change-outs and quick refueling
  - Increased autonomy (up to 12-14 hours on single refueling)



Photo courtesy of Oorja Protonics

# Fuel Cell Units Providing Data



Since FY12 AMR, data from units at original sites decreased in 2012 and data from units upgraded to newer technology operating an additional site increased.

Units not reporting data does not necessarily indicate a retired system.