NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Direct Methanol Fuel Cell Material Handling Equipment Demonstration

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MT004

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Overview

Timeline

- Start: June, 2010
- Contract Award February, 2011
- Finish: December, 2012
- 15% Complete

Budget

- Total Project Funding
  - NREL: $920K (40% cost share)
  - Oorja: $1.4M (60% cost share)
- Funding received in FY10: $1M
- Funding in FY11: $0

Barriers Addressed

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

Partners

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

Collaborations

- NREL is partnering with Oorja Protonics on a two-year project to deploy and demonstrate direct methanol fuel cells (DMFCs) to provide power for Class III pallet jacks in four commercial wholesale distribution centers

Oorja

- Lifts will be deployed in warehouses operated by:
  - Unified Grocers
  - Testa Produce
  - Earp Distribution

Unified Grocers

TESTA PRODUCE, INC.

EARP DISTRIBUTION®

Background – Relevance

- **Battelle Early Fuel Cell Markets study found that fuel cells can offer lower total cost of ownership in material handling applications compared to battery systems**
- **DOE and DLA are currently demonstrating the potential benefits of hydrogen polymer electrolyte membrane (PEM) fuel cells in material handling equipment (MHE) applications**
- **DMFCs hold promise to deliver many of the same operational benefits of hydrogen-powered fuel cell material handling equipment, including long runtimes, short refueling times, and increased productivity**
- **Liquid alcohol fuels like methanol offer reduced infrastructure costs and high fuel energy densities**

Photo courtesy of Oorja Protonics

Project Objectives – Relevance

- **The primary objective of this effort is to deploy and test fuel cell-powered MHE using renewable liquid fuels (in particular, methanol)**
- **A second objective is to compile operational data of DMFC fuel cells and validate their performance under real world operating conditions**
  - **Provide independent technology assessment focusing on fuel cell system and infrastructure performance, operation, and safety**
  - **Validation efforts will help illuminate the market viability of these fuel cell technologies – inform the business case for DMFCs**
- **Longer term objective is to help transform the market for fuel cells in material handling applications and provide information that enables successful deployments to be replicated**

DMFC Benefits – Relevance

Expected DMFC Benefits Over Battery MHE	
Longer runtimes between fueling/charging	Oorja predicts 12-14 hours of autonomy on one fill
Increased battery & lift reliability	Maintaining state-of-charge and eliminating deep discharge of batteries expected to extend battery life
Increased productivity	Due to reduced need for fills (vs. charging) and reduced time for fills (vs. charging) – 1-2 min/fill
Lower GHG emissions	Compared to charging batteries using a typical electric grid mix
Low cost infrastructure	Methanol storage/dispensing doesn't have high capital cost
Low cost of ownership	Based on productivity, reliability, and battery life gains

Project Overview – Approach

- **Oorja Protonics will collect data on 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**
  - **Expecting 5,000 total operation hours on each unit**
- **DMFC systems will operate on bio-derived (renewable) methanol provided by BioMCN**
- **NREL will compile and analyze data from the project**
  - **Provide a third-party assessment of the performance of DMFCs for material handling equipment**

Photo courtesy of Oorja Protonics

Project Tasks – Approach

Project Tasks & Timeframes		
Task 1 DMFC Powerpack Prototyping and Integration	• Ensure mechanical design compliance of DMFC with MHE • Ensure electrical interface of DMFC with battery • Develop data acquisition software • Ensure safety codes and standards compliance of DMFC & methanol fueling	2-3 months (concurrent with Task 2)
Task 2 DMFC MHE Manufacturing and Testing	• Conduct customer site & MHE analysis • DMFC system integration to meet specific customer needs • DMFC manufacturing • DMFC baseline performance, reliability and emissions testing • Methanol infrastructure installation	4-5 months (concurrent with Task 1)
Task 3 DMFC Deployment, Data Collection, and Reporting	• On-going DMFC MHE operation & maintenance • Monthly data reporting on DMFC usage • Project close-out and reporting	15-17 months

OorjaPac™ DMFC – Approach

- Oorja will build, test, and deploy direct-methanol fuel cell systems on Class III pallet jacks using its OorjaPac Model 3 DMFC power pack
- 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

Photo courtesy of Oorja Protonics

- The OorjaPac acts as an on-board battery charger, allowing:
  - Grid independence
  - Elimination of battery change-outs and quick refueling
  - Increased autonomy (up to 14 hours on single refueling)

Methanol Fueling Infrastructure – Approach

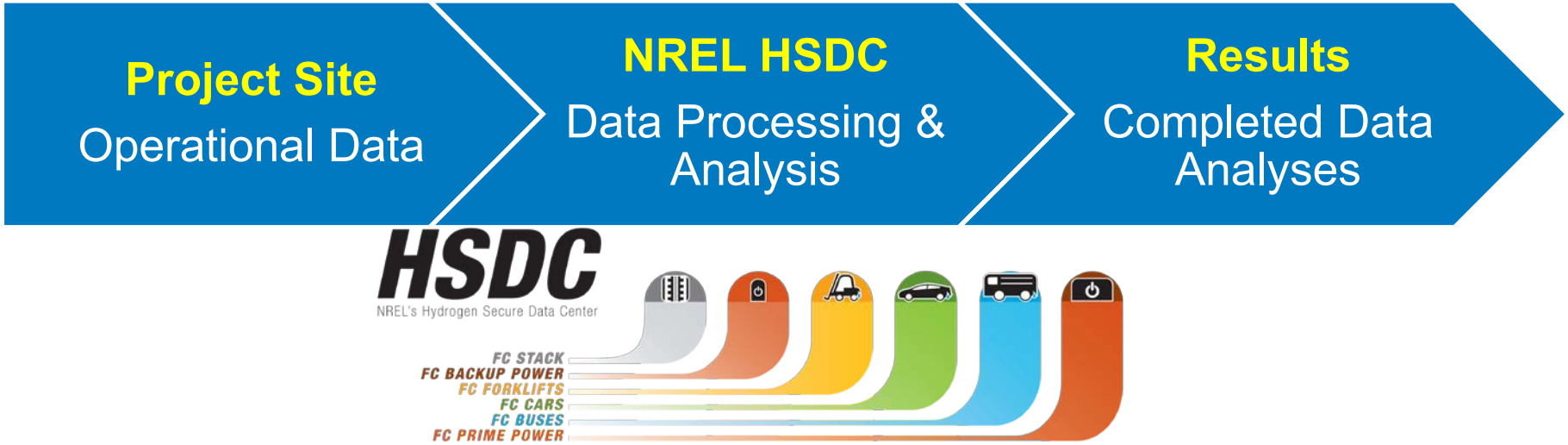
- **Bulk methanol outdoor storage**
  - **2,000-6,000 gallon UL-rated double-walled tanks meeting relevant NFPA codes for Class 1B flammable liquids**
- **Indoor dispensing via Oorja's OorjaRig™ methanol dispenser**
  - **OorjaRig designed for indoor methanol fueling of OorjaPac DMFCs**
  - **Equipped with methanol storage in two standard 55-gallon drums, pumps, safety connect dispenser nozzle, sensors**
  - **Cabinet is FM-rated for Class 1 Division 2 operation and meets NFPA Code 30**
- **Oorja estimates total infrastructure costs to be as low as $70K per site[1]**

[1] **http://www.oorjaprotonics.com/benefits/competition.html**

Photo courtesy of Oorja Protonics

NREL H2 Secure Data Center – Approach

- **Analyze fuel cell system and methanol infrastructure**
- **Establish a baseline of real-world operations**
- **Use HSDC data processing and analysis capabilities first developed for FCVs and expanded to MHEs**
- **Support FC market growth by analyzing technology and performance relevant to the value proposition**
- **Report on technology to FC & MHE stakeholders**



Contract Award – Accomplishments

Contract Award Process	
Pre-Solicitation	Investigated fuel cell manufacturers and determined which had necessary capabilities
Solicitation	Competitive RFP for direct-liquid fuel cell systems for MHE
Award	Oorja Protonics selected as subcontractor; Contract awarded in February 2011

Contract Hurdles:

- Small start-up companies – companies without experience with government contracting and approved invoicing systems may require different contract vehicles
- Methanol – liquid fuel, toxic air pollutant; requires significant NEPA-related review and oversight

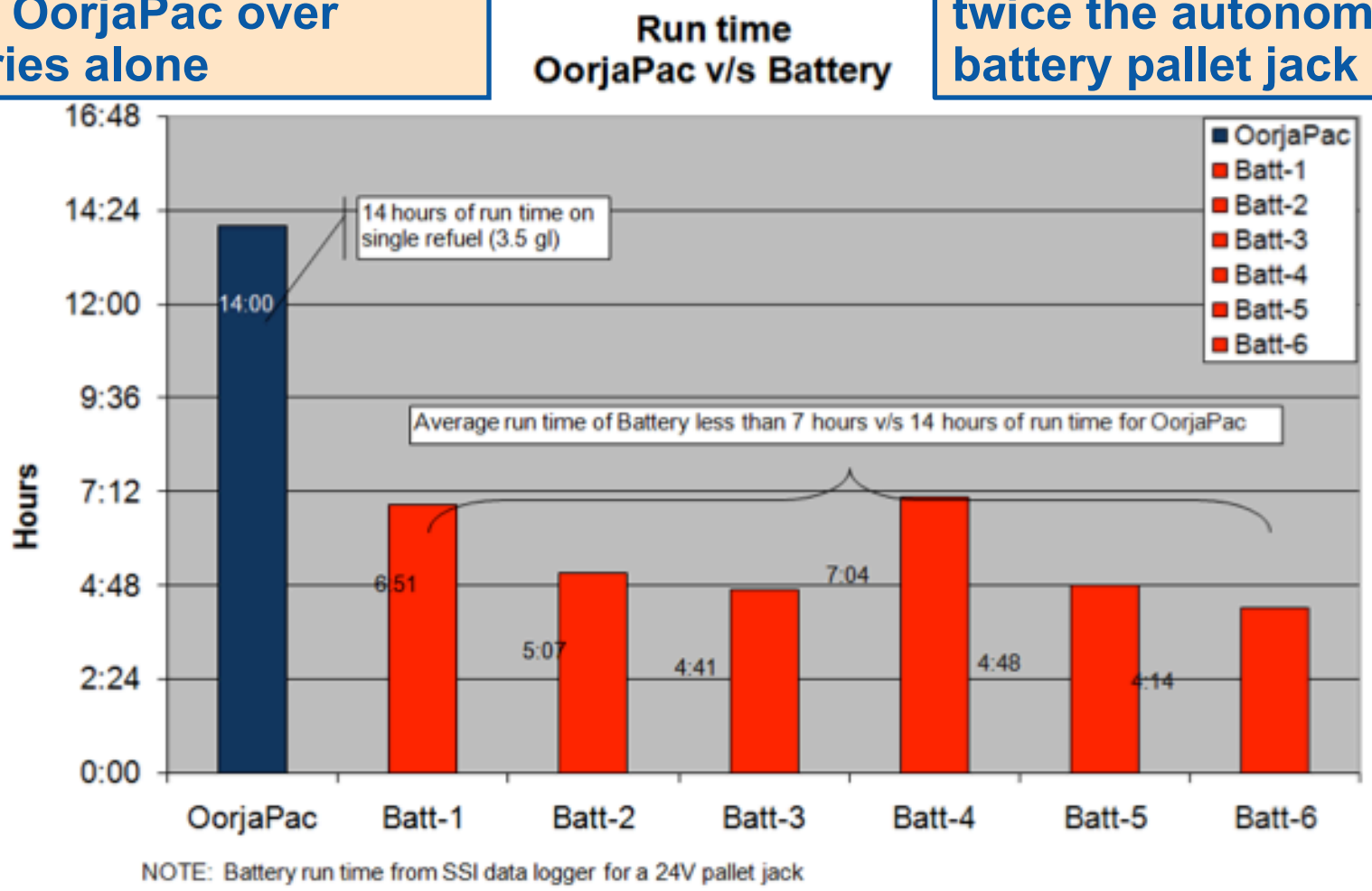
DMFC Integration & Manufacture – Accomplishments

- **Prototype OorjaPac DMFC systems tested for mechanical compliance with target customer MHE systems**
  - Proper mechanical linkage, safety, ergonomics, counter-balance
- **Completed OorjaPac systems integration with customer MHE to ensure proper performance and battery charging**
  - Installed and operated data loggers to benchmark performance
  - Determined necessary FC cell count to meet customer performance needs based on data-loggers at customer sites
  - Developed necessary system algorithms for hybridization
- **Additional project accomplishments:**
  - Developed algorithms and software for remote data acquisition
  - Ensured compliance of OorjaPac DMFC systems and methanol infrastructure with relevant federal, state, and local safety and environmental regulations
  - 24 of total 75 DMFCs in project have been built & delivered

Forklift Range Extension – Accomplishments

Oorja testing of Class 3 MHE using data loggers shows large improvement using OorjaPac over batteries alone

14 hours of operation on single refuel using OorjaPac, greater than twice the autonomy of a battery pallet jack

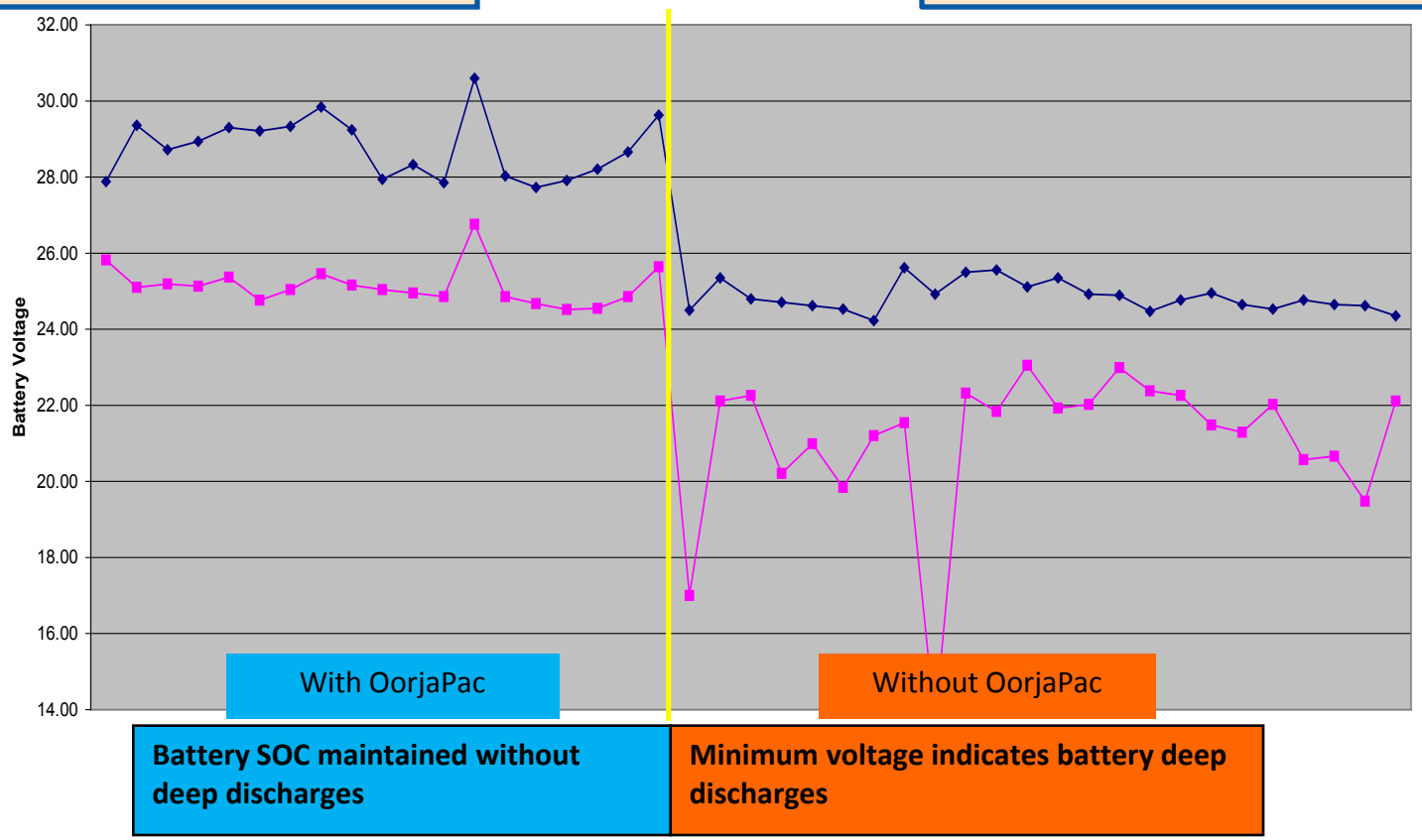


NOTE: Battery run time from SSI data logger for a 24V pallet jack

Enhanced Battery Life – Accomplishments

Oorja testing shows use of OorjaPac avoids deep discharge of battery pack typically seen in battery-only MHE

Oorja predicts maintaining battery state-of-charge and avoiding deep discharges will extend battery life by 50%



Note: Data from Oorja Protonics

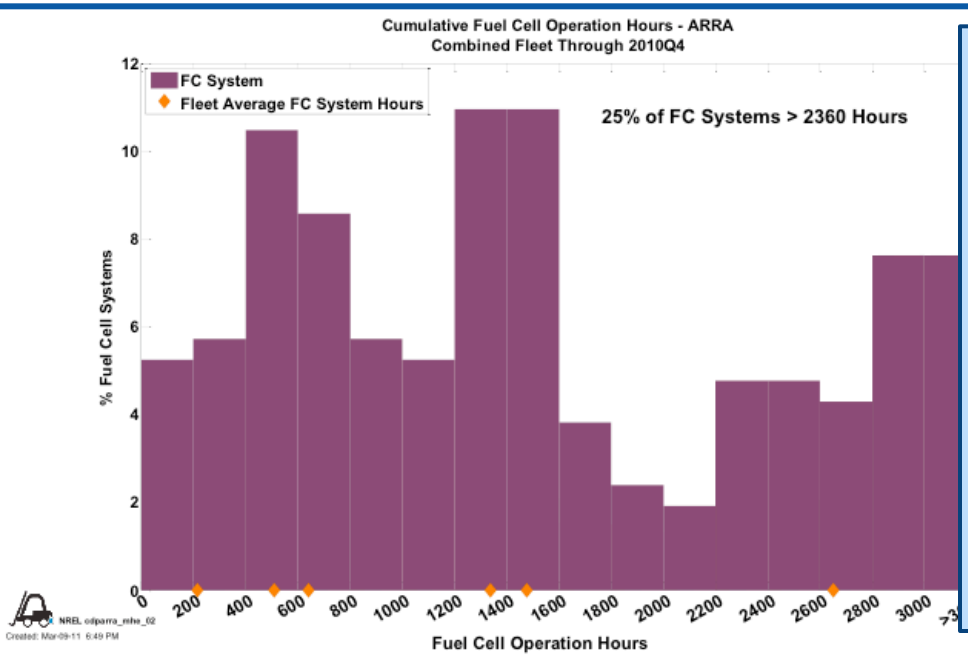
Next Steps & Project Schedule – Future Work

Future Project Work	
Late 3Q-Early 4Q FY2011	**DMFC Deployment Begins at All Sites** • OorjaPak DMFC powerpacks built & deployed • OorjaRig and methanol infrastructure deployed
Ongoing for 15 Months, Ending 4Q FY2012	**DMFC Deployment & Data Collection** • Ongoing DMFC use at all sites • Ongoing DMFC and infrastructure maintenance • Ongoing data collection and compilation • Quarterly project reporting • Detailed data analysis and reporting every 6 months NREL lead, with support of Oorja
1Q FY2013	**Project Close-Out** • Equipment de-commissioning or transfer as needed • Final Reporting [NREL lead, with support of Oorja]

Characterize Deployment Over Time – Future Work

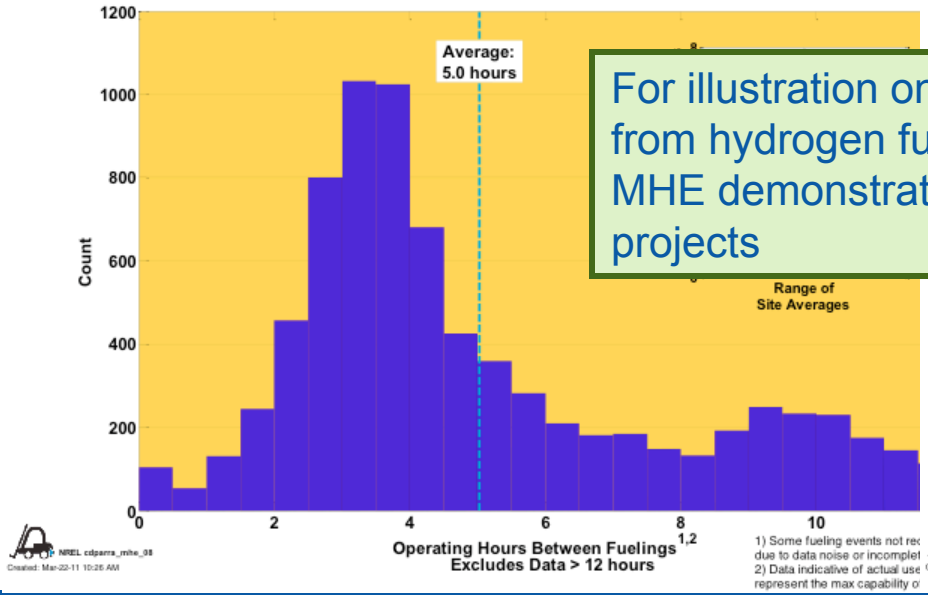
Performance Summary	
Site Operations	
Number of Fuel Cell Forklifts in Operation	75
Hours of Operation for the Combined Fleet	TBD
Amount of Methanol Dispensed (gal)	TBD
Number of Fueling Events	TBD
Infrastructure	
Average Fueling Time (minutes)	TBD
Average Fueling Rate (gal/min)	TBD
Safety Incidents	TBD
Forklifts	
Hours of Operation Between Fueling	TBD
Hours of Operation per gallon Methanol	TBD
Average Battery Life (months)	TBD

Analyses of Performance & Operation – Future

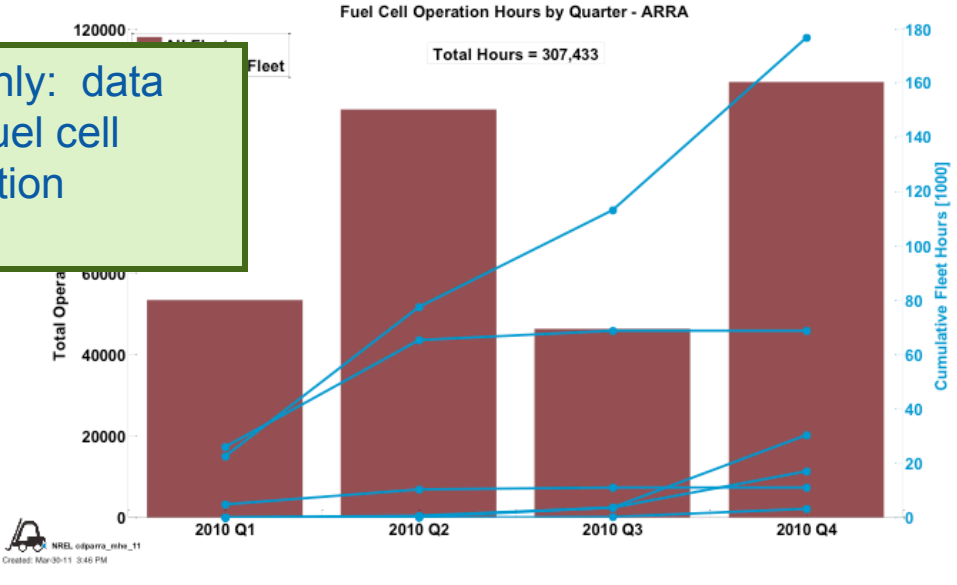


Fuel Cell System

- System Operating Hours
- Operating Hours Between Fuelings
- Average Daily Usage
- Battery State-of-Charge



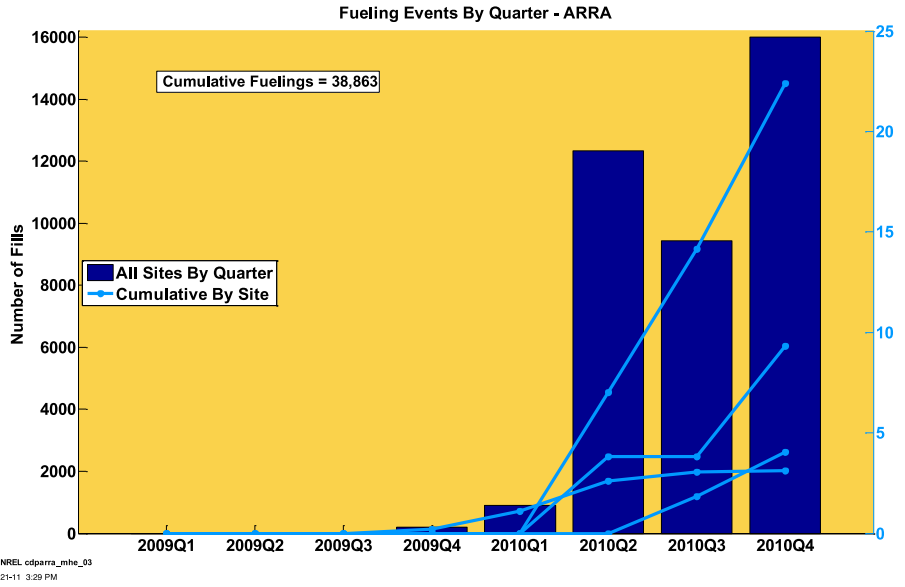
For illustration only: data from hydrogen fuel cell MHE demonstration projects

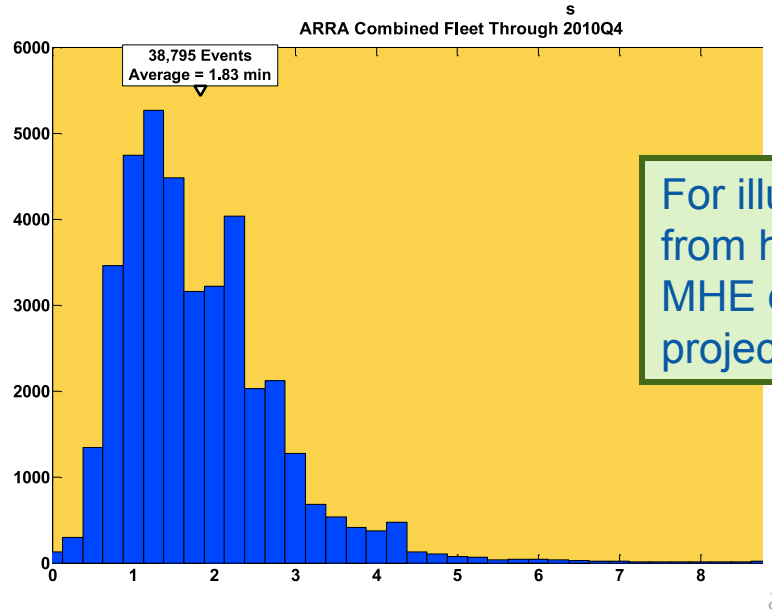


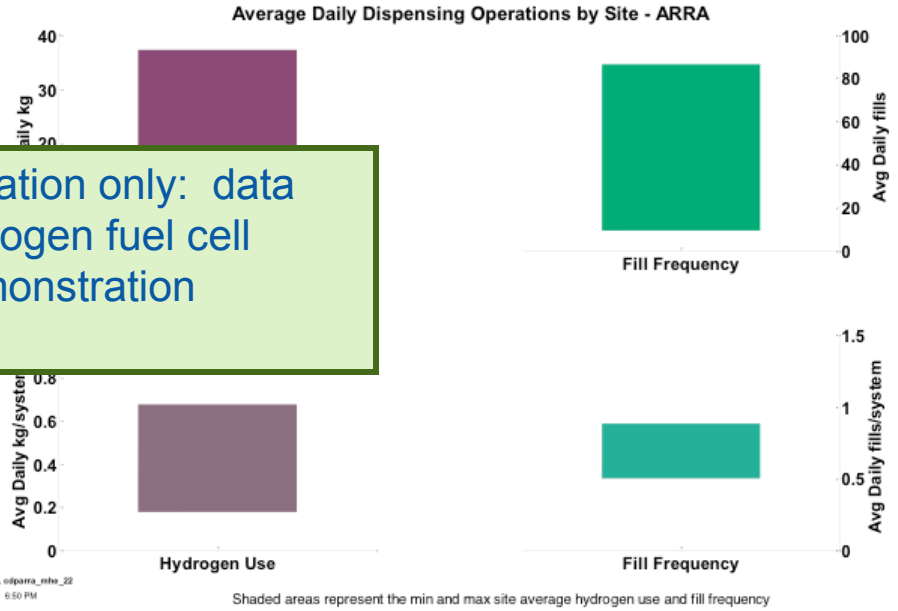
Analyses of Performance & Operation – Future

Methanol Infrastructure

- Fueling Events & Methanol Dispensed
- Fueling Time & Rate
- Daily Methanol Use
- Infrastructure Safety







For illustration only: data from hydrogen fuel cell MHE demonstration projects

Summary

- Collaborations
  - Subcontract with Oorja Protonics, DMFC MHE deployed at warehouses operated by Unified Grocers, Testa Produce, and Earp Distribution
- Relevance
  - Hydrogen-based fuel cell forklifts a rapid growth market segment for fuel cells; ongoing demonstration projects funded by DOE and DOD
  - Direct methanol fuel cell forklifts offer many of the same benefits (long runtimes, short refueling times, increased productivity)
- Approach
  - ~2 year project with 15-month deployments of 75 DMFC Class III MHEs in commercial warehouse and distribution operations
  - Collect, compile, and analyze operational data to establish performance baselines and evaluate the value proposition for DMFCs in MHE applications
- Technical Accomplishments and Progress
  - Contract awarded February 2011
  - Prototype testing and system integration completed
  - Initial testing shows improved operational range and improved battery life
- Future Work
  - Initiate deployment of DMFC units at all sites
  - Conduct data analyses to assess performance & validate value proposition

Question and Discussion

Thanks!!

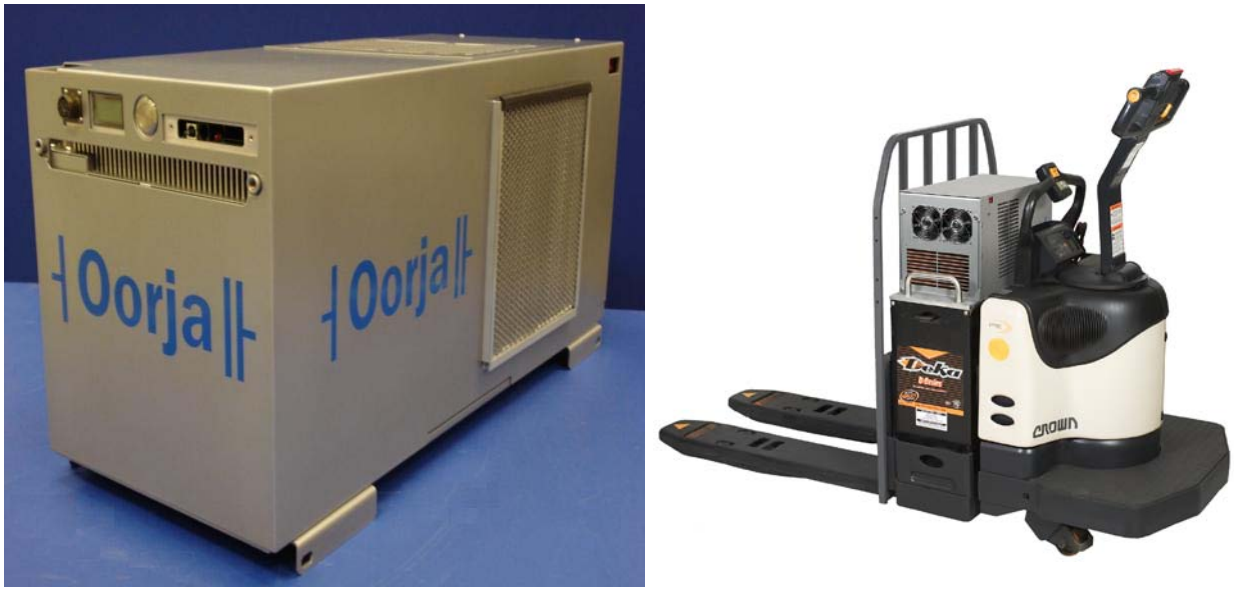


Photo courtesy of Oorja Protonics

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