

Data Analysis of Early Fuel Cell Market Demonstrations



**Fuel Cell Seminar
Palm Springs, CA**

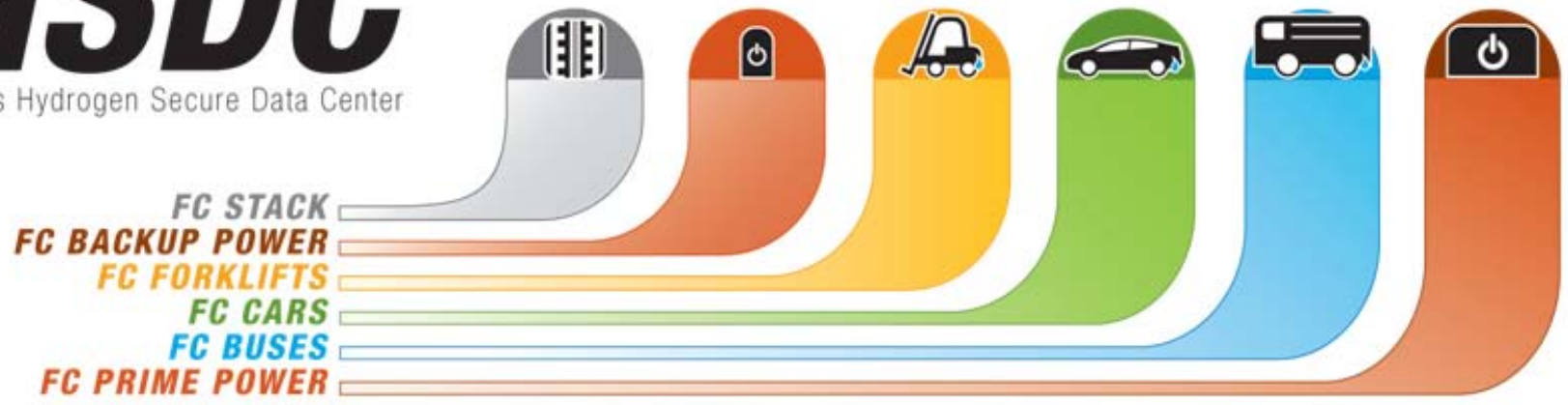
November 17, 2009

Jen Kurtz, Todd Ramsden,
Keith Wipke, Sam Sprik

NREL/PR-560-47192

HSDC

NREL's Hydrogen Secure Data Center



Fuel Cell & Infrastructure Data Collection, Processing, & Analysis

Demonstrations

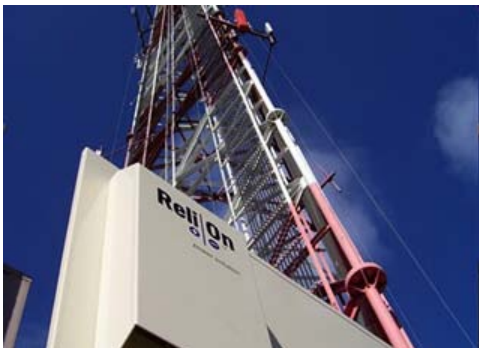
Objectives

Methodology

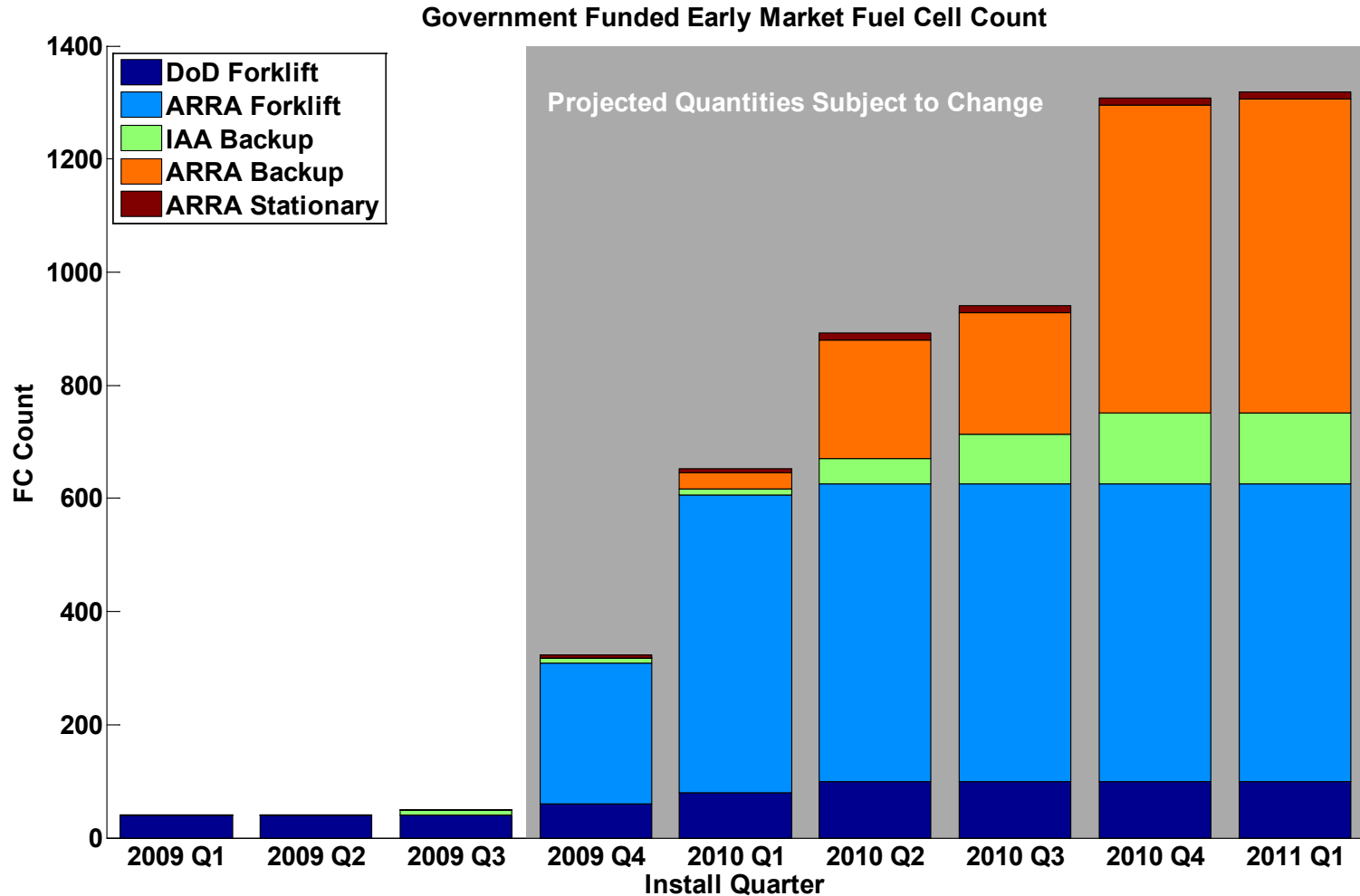
Results

Government Funded Early Fuel Cell Markets

- Funding sources include DOD Defense Logistics Agency, DOE American Recovery and Reinvestment Act (ARRA), and DOE Interagency Agreement (IAA)
- Diverse collection of early market fuel cell applications, project partners, and end users
- Expected fuel cell deployment: >1,000 units
- Fuel cell applications cover fuel cell forklifts, backup power, micro-CHP, APU, and portable power



Government Funded Fuel Cell Early Market Deployments – Separated by Funding Source & Application

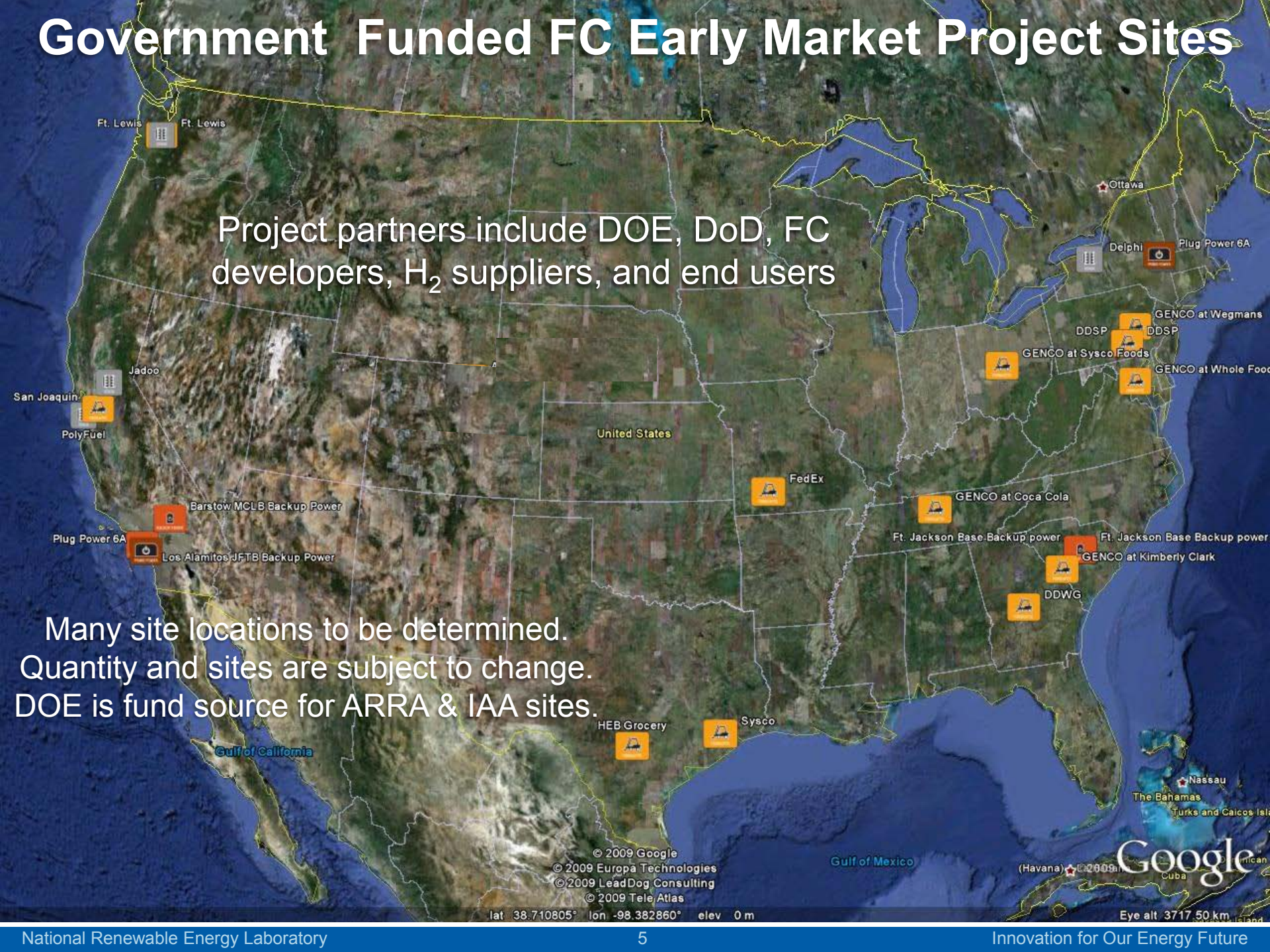


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Government Funded FC Early Market Project Sites

Project partners include DOE, DoD, FC developers, H₂ suppliers, and end users

Many site locations to be determined.
Quantity and sites are subject to change.
DOE is fund source for ARRA & IAA sites.



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lat 38.710805° lon -98.382860° elev 0 m

Google

Eye alt 3717.50 km

Early Fuel Cell Market Data Analysis Objectives

- Independent technology **assessment**; focused on fuel cell system and hydrogen infrastructure: performance, operation, and safety.
- **Leverage** data processing and analysis capabilities 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 of fuel cell technologies by reporting on technology features relevant to the **value proposition**
- Report on technology to fuel cell and hydrogen communities, R&D, and **stakeholders**

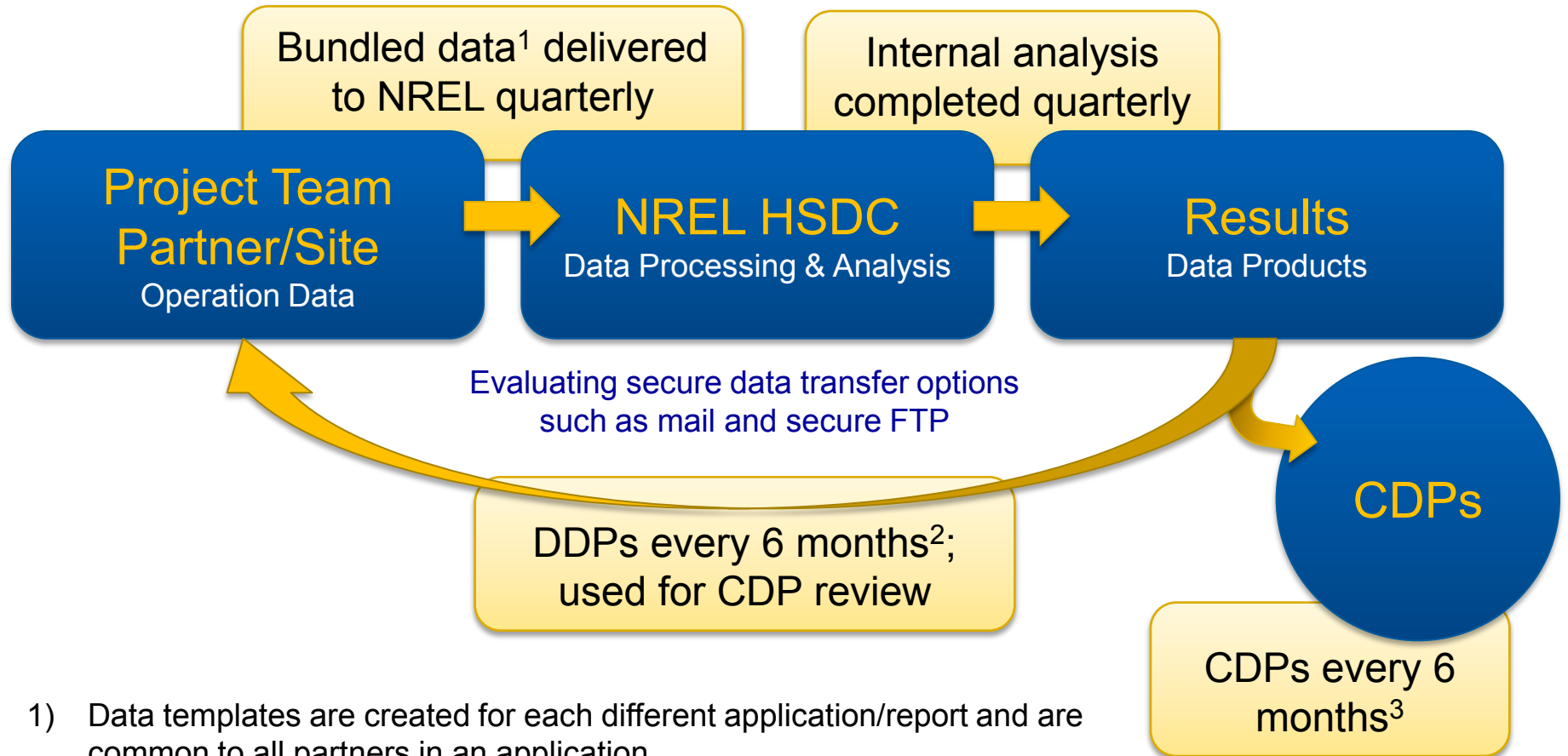
- Individual data analyses for each FC system and site
- Identify individual contribution to CDPs
- Only shared with partner who supplied data

Detailed
Data
Products
(DDPs)

Composite
Data
Products
(CDPs)

- Aggregated data across multiple systems, sites, and teams
- Publish analysis results without revealing proprietary data

Data Flow



- 1) Data templates are created for each different application/report and are common to all partners in an application.
- 2) Data exchange may happen more frequently based on data, analysis, & collaboration
- 3) Results published via NREL Tech Val website, conferences, and reports

Data Reporting – Fuel Cell Forklift Example



- Fuel cell forklift application represents a significant early market opportunity for fuel cells



- 40 fuel cell forklifts in operation at DLA's Defense Depot, Susquehanna Pennsylvania



- 9 months of detailed data available, including over 10,000 hydrogen fills



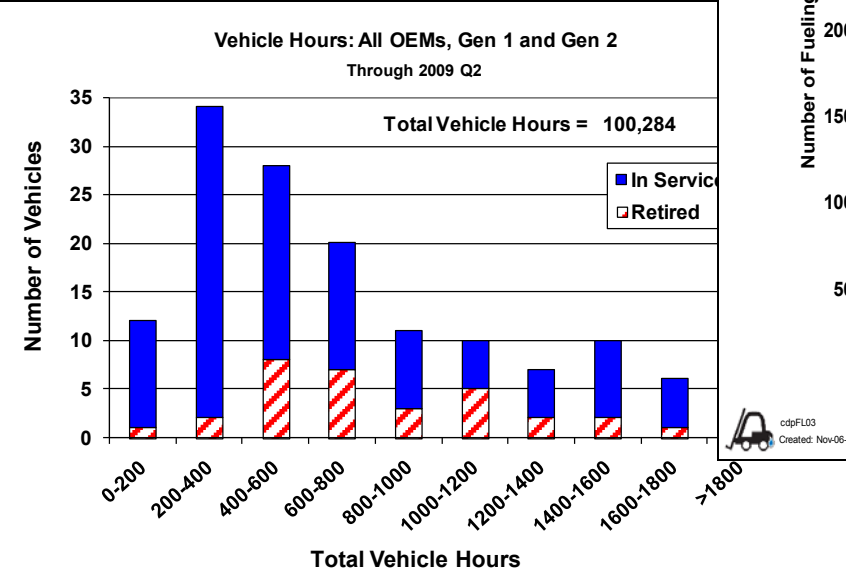
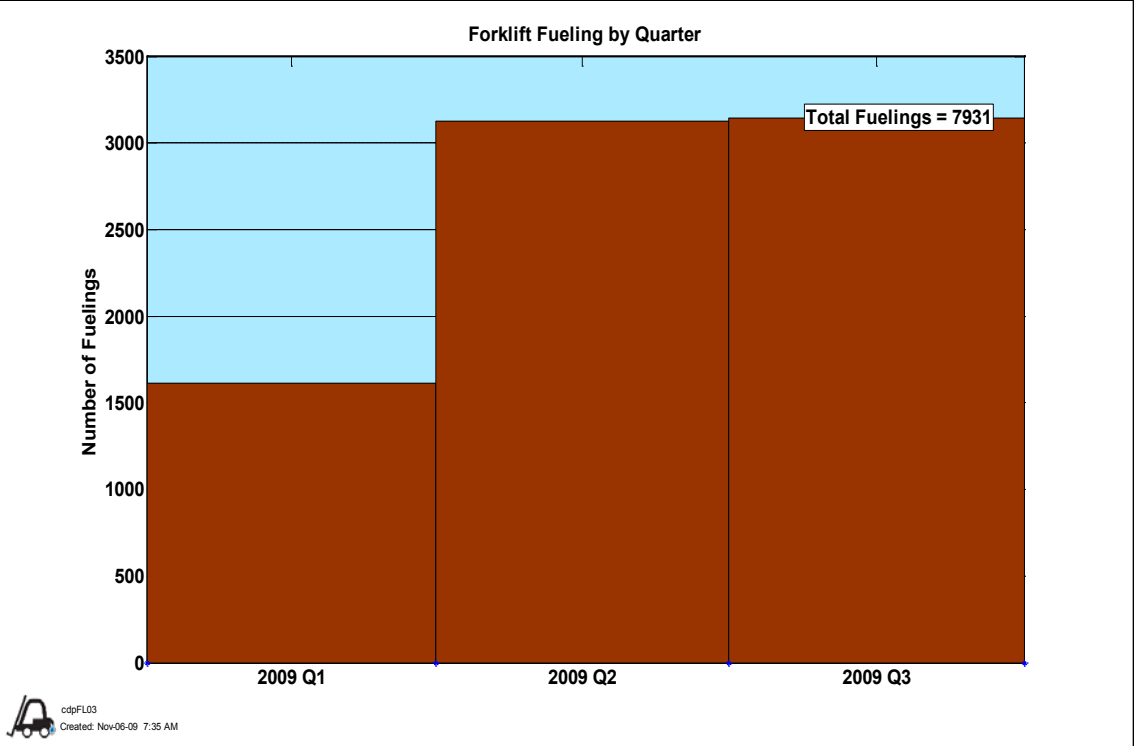
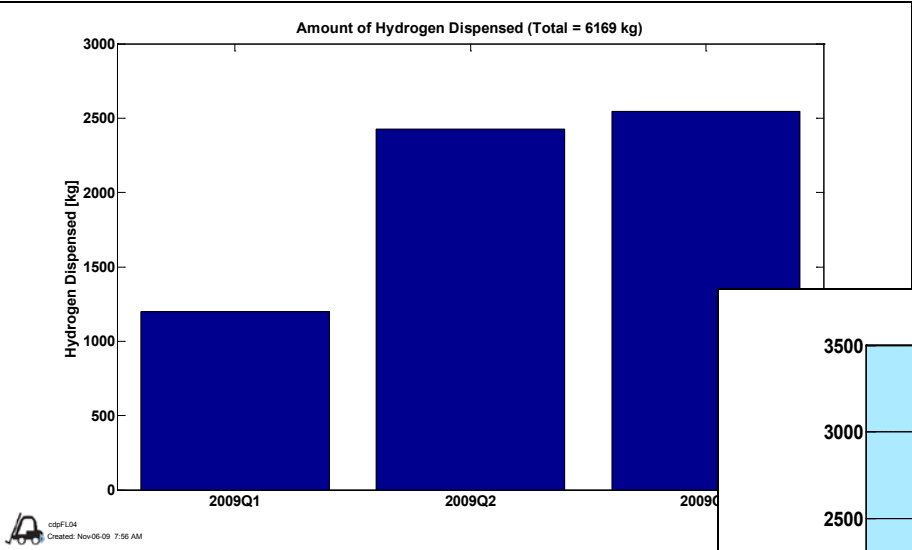
- Available data provides a real-world understanding of fuel cell forklift operations



- Data from this forklift installation and upcoming future installations will be used to develop Composite Data Products on early market deployments of fuel cell forklifts



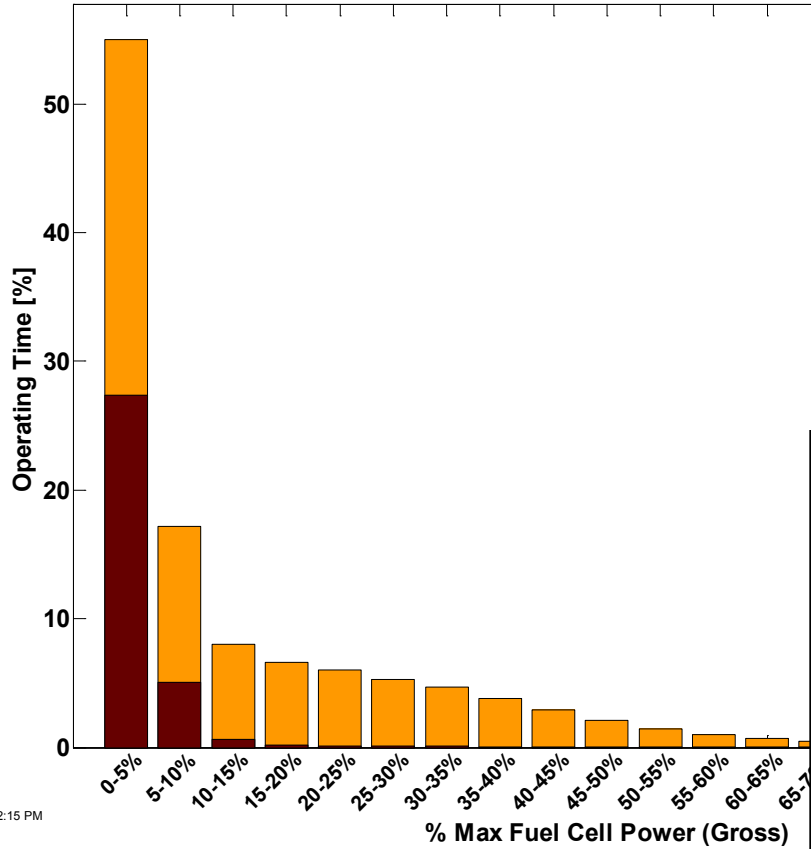
Data on Deployments and Usage



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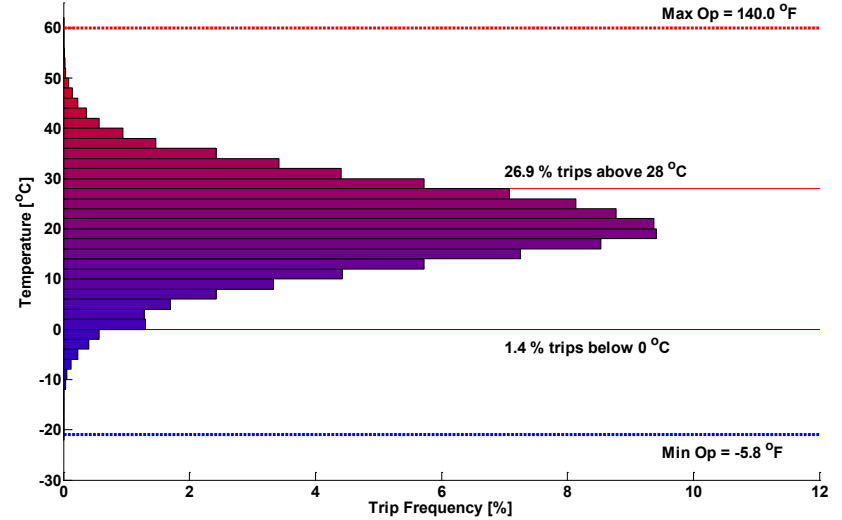
Data on Deployments and Usage (cont.)

Time at Fuel Cell Stack Power Levels:



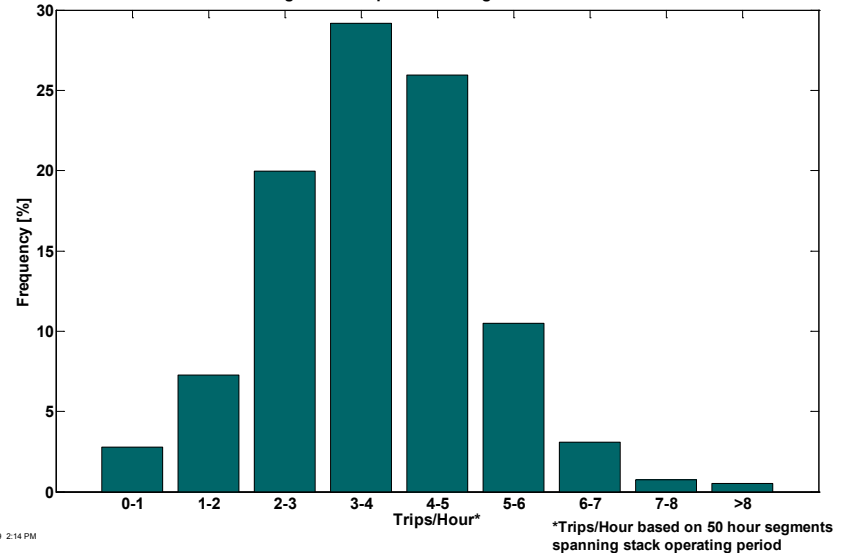
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Average Ambient Trip Temperature: DOE Fleet



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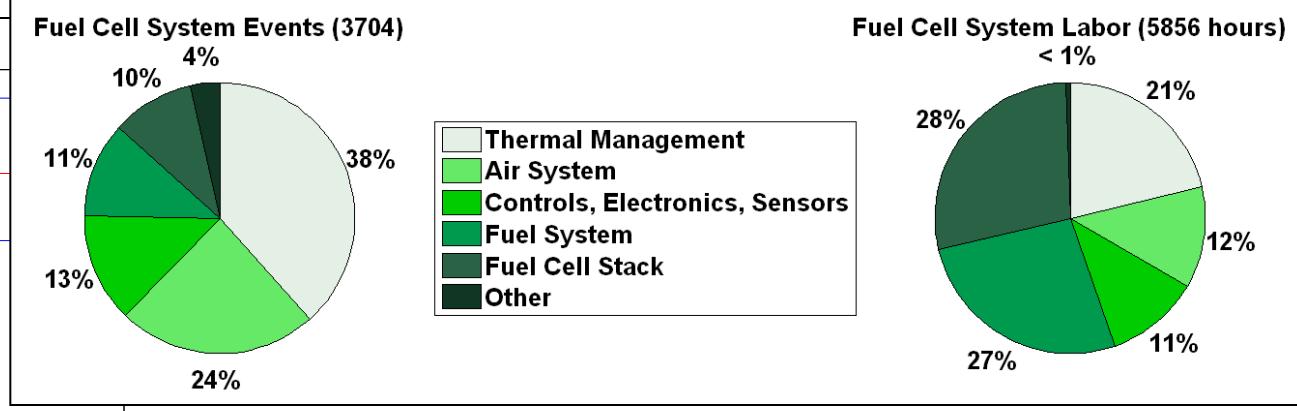
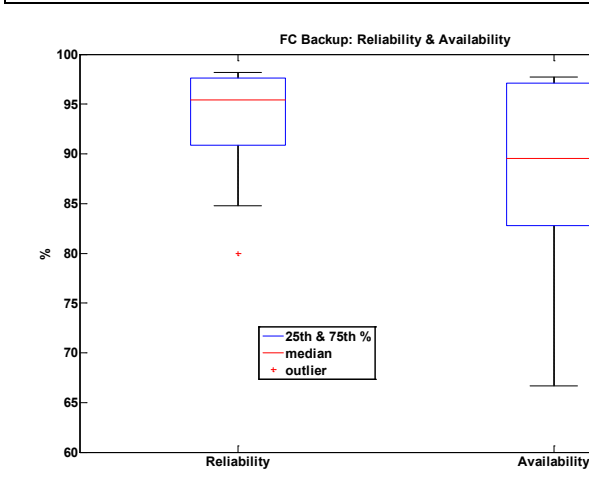
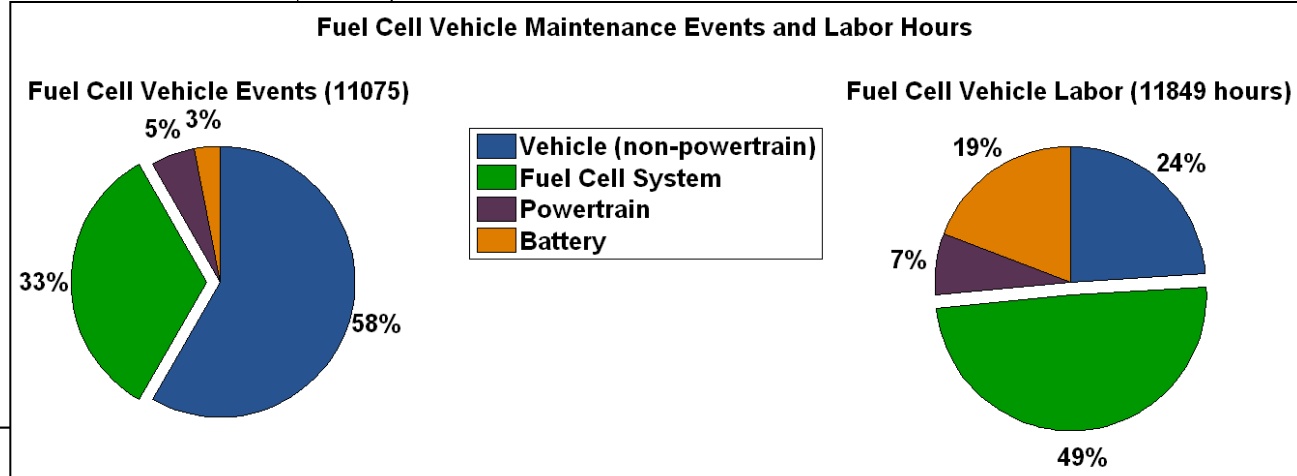
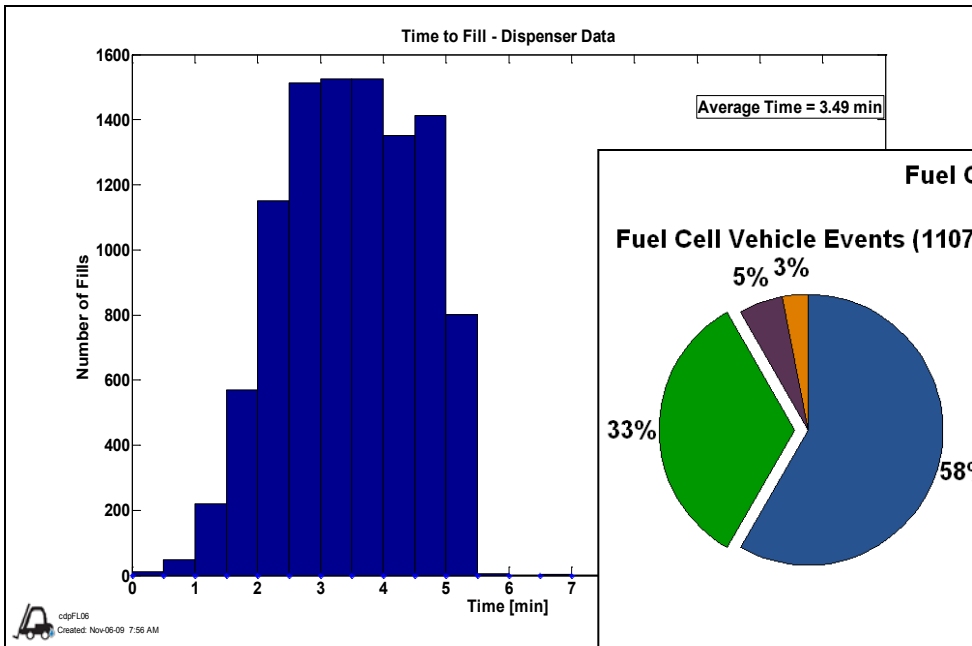
Segmented Trips/Hour Histogram: DOE Fleet



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*Trips/Hour based on 50 hour segments spanning stack operating period

Data on Fuel Cell Value Proposition



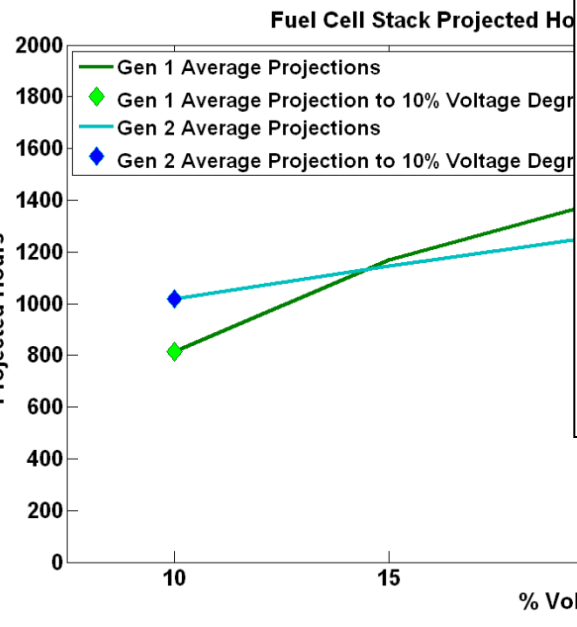
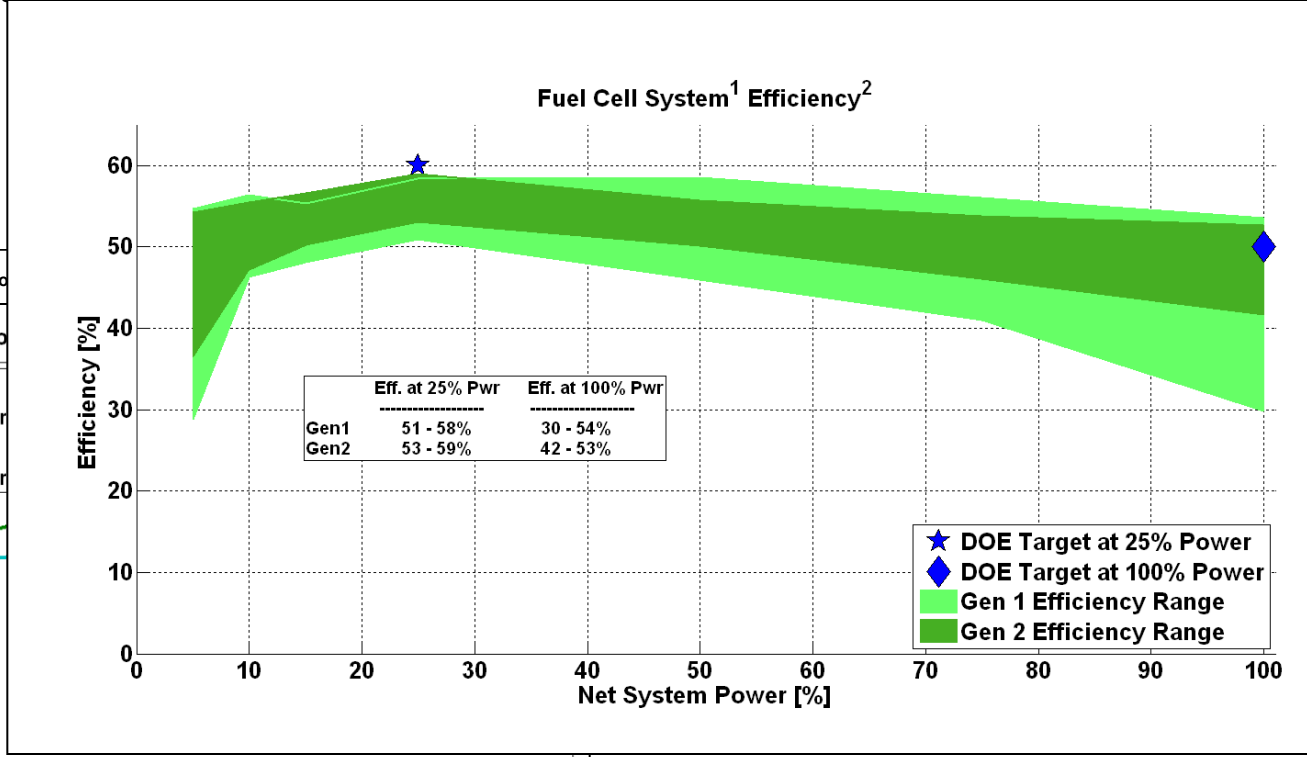
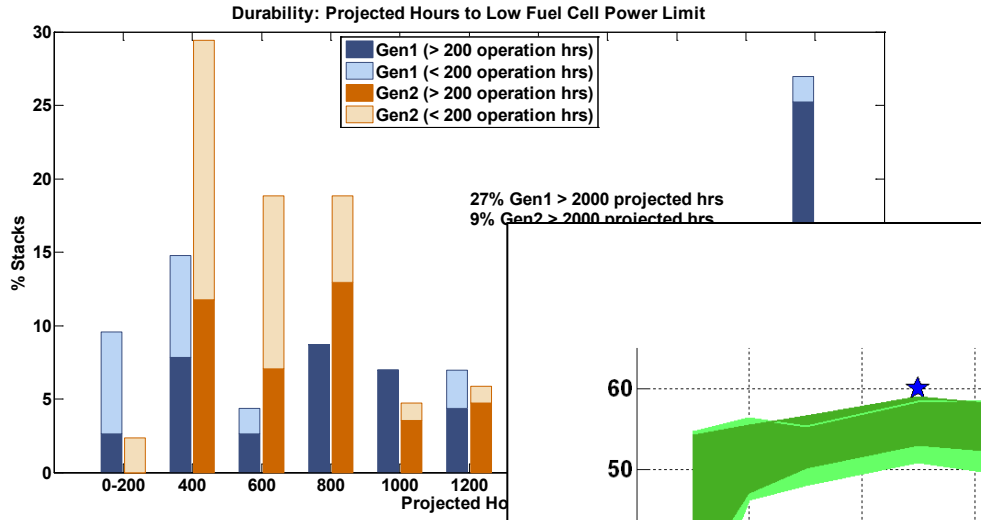
Fuel Cell System Labor (5856 hours)

- Thermal Management 21%
- Fuel System 27%
- Fuel Cell Stack 28%
- Air System 12%
- Other 11%

Fuel Cell System Labor (5856 hours) < 1%

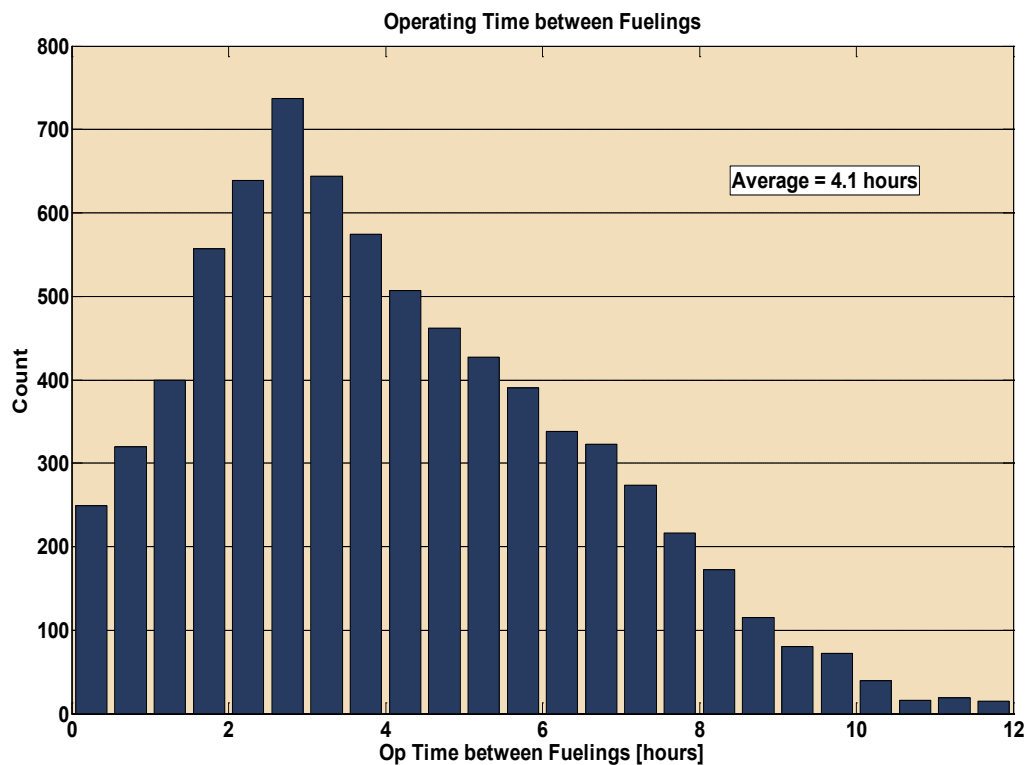
- Thermal Management < 1%
- Fuel System < 1%
- Fuel Cell Stack < 1%
- Air System < 1%
- Other < 1%

Data on Fuel Cell Technology



Understanding H2 Tank Cycle Life in FC Forklifts

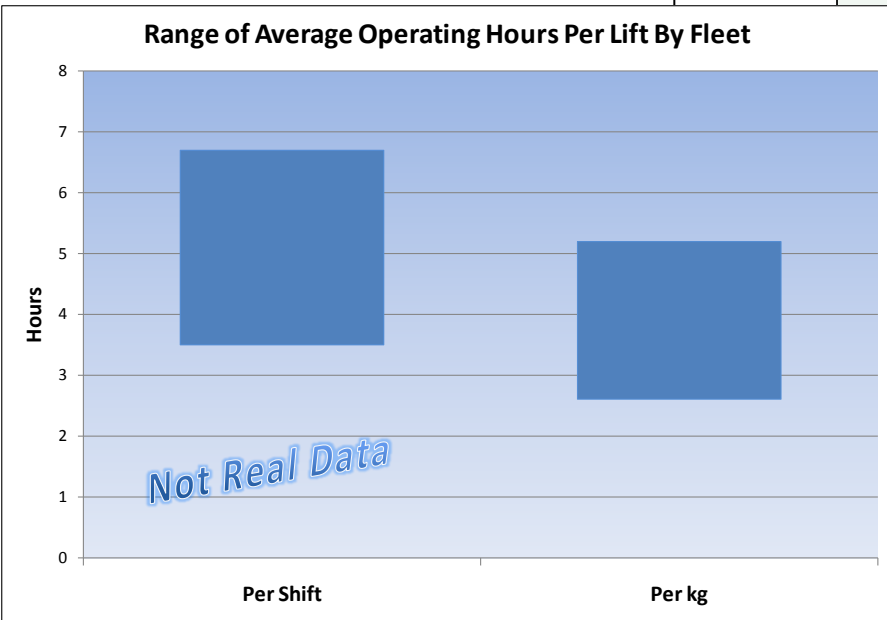
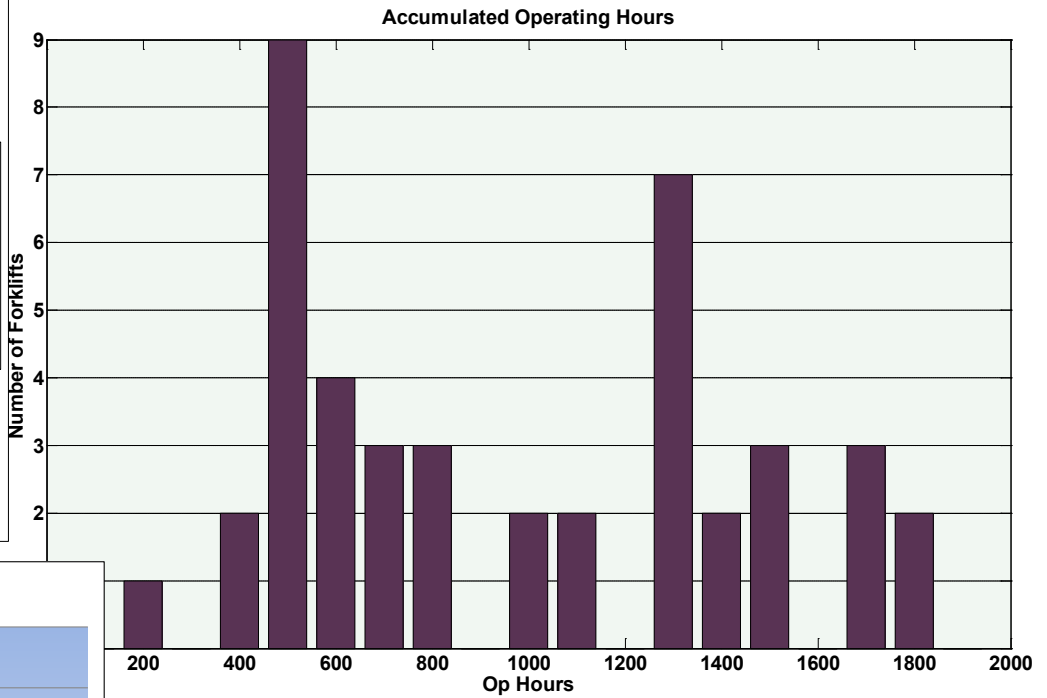
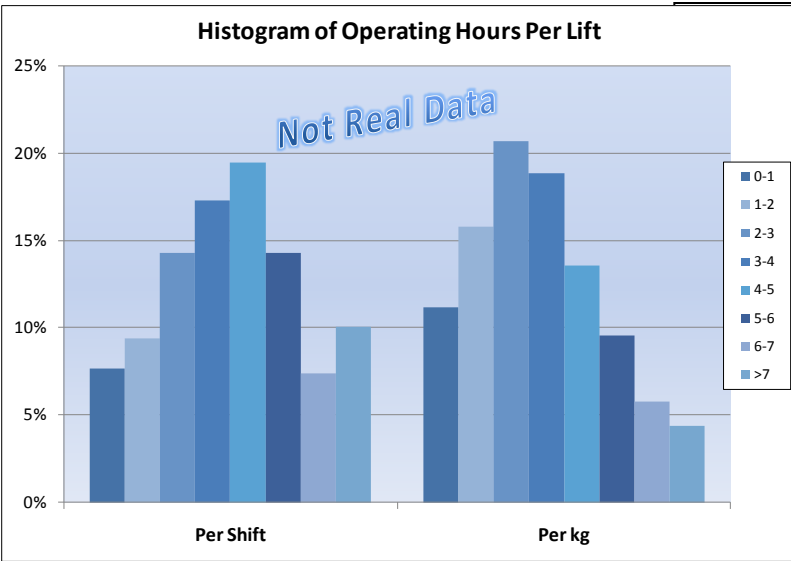
- Need to better understand expected H2 tank filling cycles in forklift applications
- Data currently being collected can inform that discussion
- Can aggregate data on operating hours per fill and per shift to better predict tank cycling
- Tank life is important factor in business case if shorter than the life of the lift



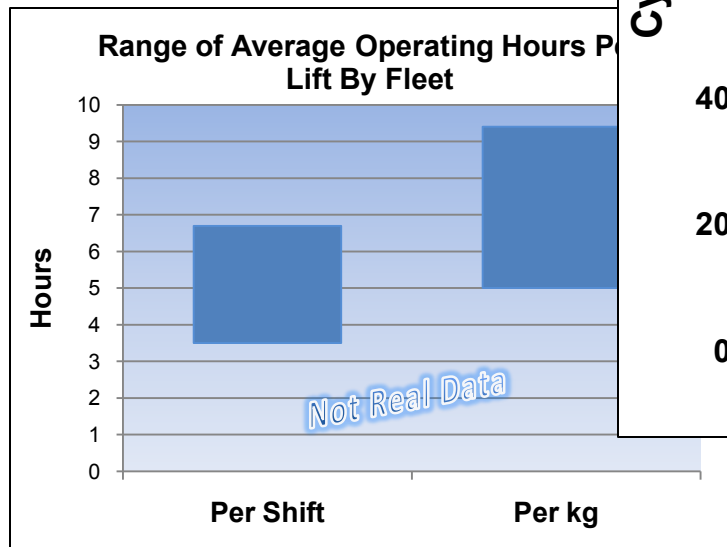
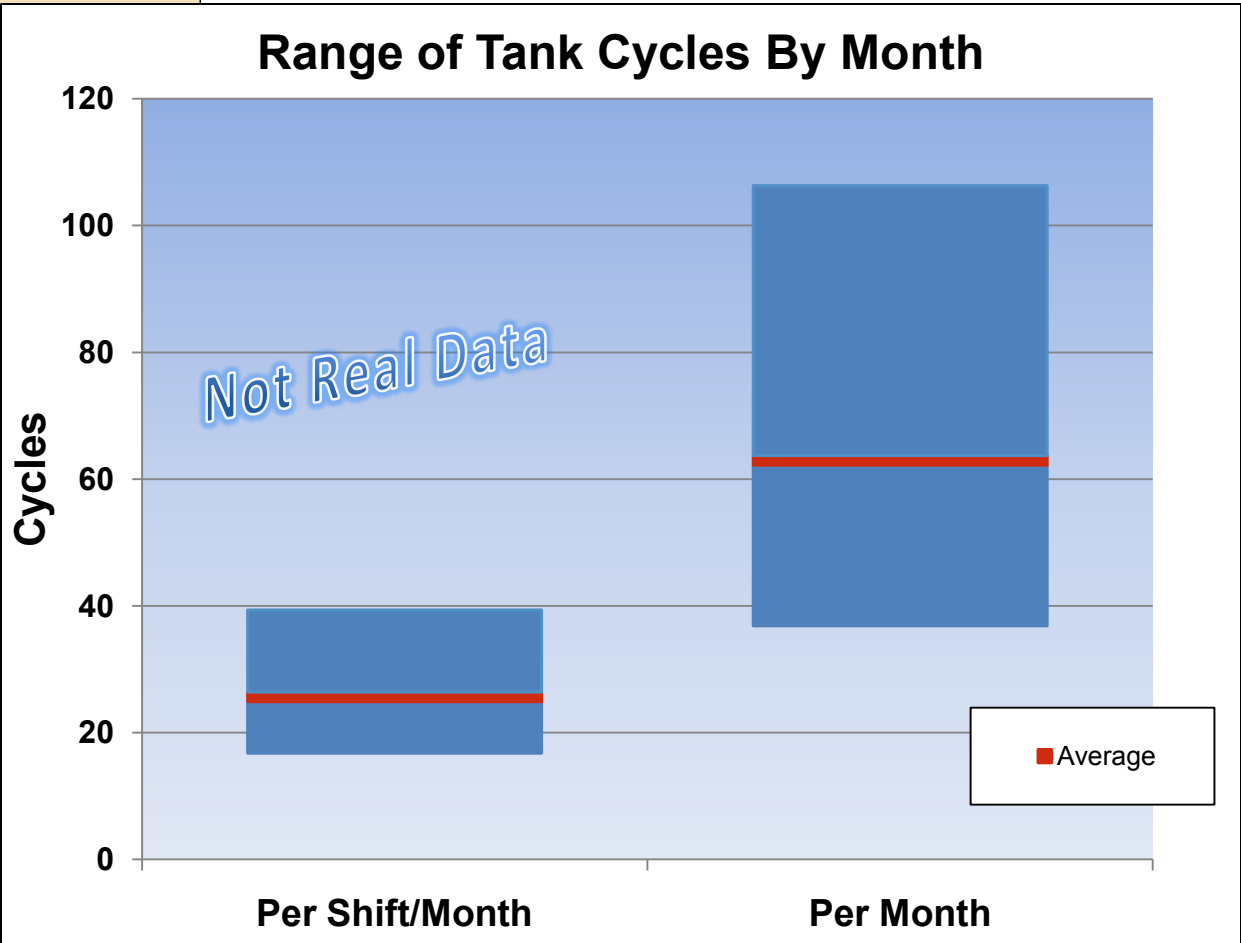
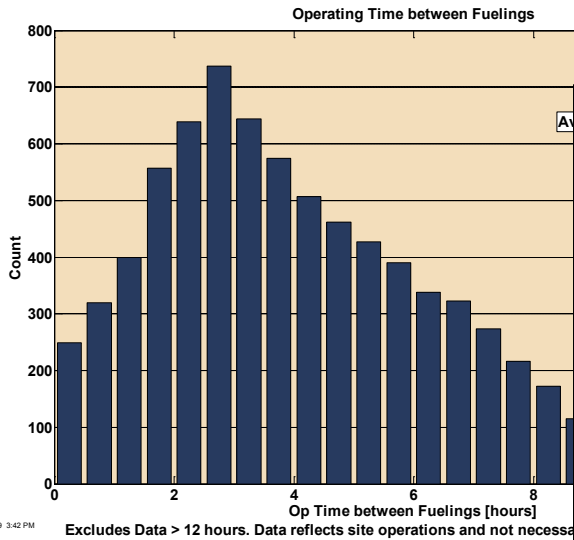
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Excludes Data > 12 hours. Data reflects site operations and not necessarily total available runtime.

Tank Cycling: Forklift Operations Per Shift & Per kg

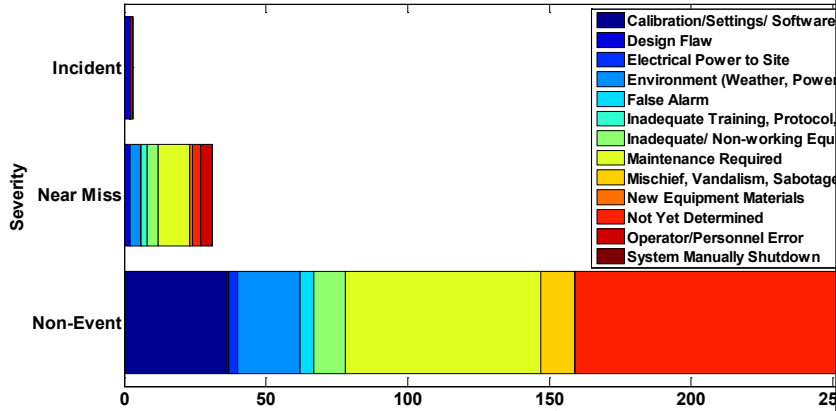


Tank Cycling: Real-World Tank Cycles Per Month

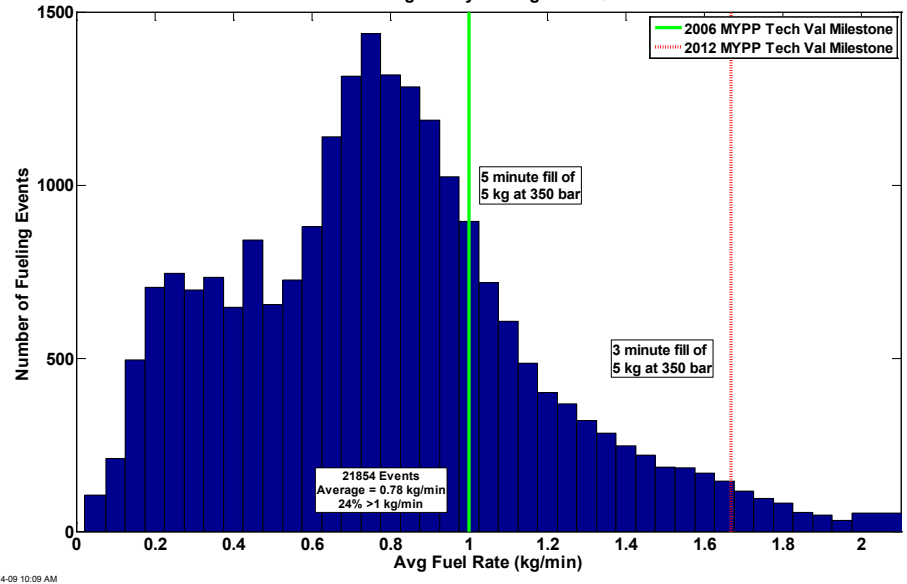


Likely CDPs & Comparable FC Vehicle CDPs

Primary Factors of Infrastructure Safety Reports Through 2009 Q2



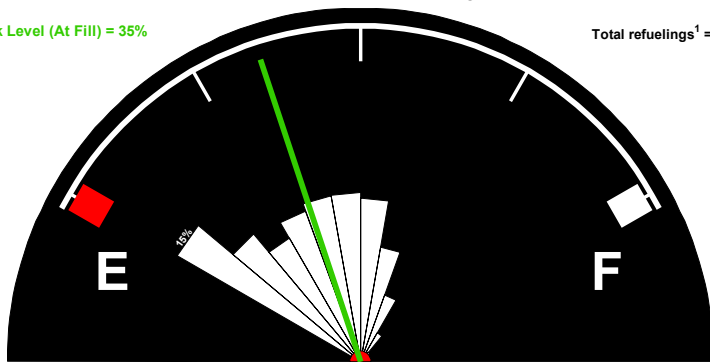
Histogram of Fueling Rates All Light Duty Through 2009Q2



Tank Pressures before Refueling

Median Tank Level (At Fill) = 35%

Total refuelings¹ = 7931



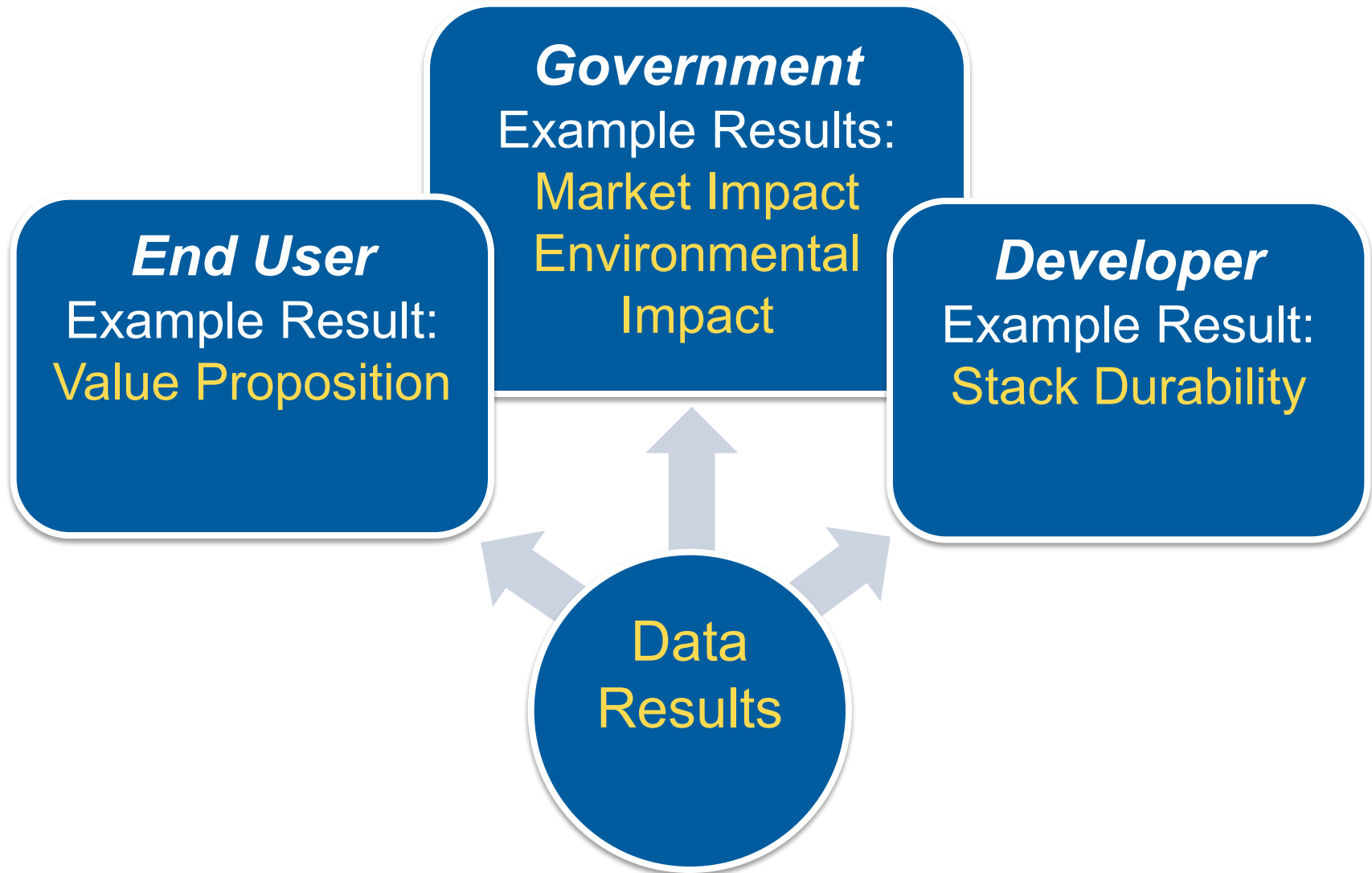
- Some refueling events not recorded/detected due to data noise or incompleteness.
- The outer arc is set at 25% total refuelings.
- Full = 5000 psi

Other Likely CDPs

- Durability
- Efficiency
- Power, Voltage, Energy
- Safety
- Reliability
- Maintenance
- Cost (installation and operation)
- Market Application Comparisons

FCV Learning Demo has **72** Data Results

Data Results Reported to Multiple Stakeholders



Comparison of Fuel Cell and Battery Powered Forklifts – Cost Metrics

PEM Fuel Cell Powered Class 1 Forklift to Comparable Battery Powered Forklift

Parameter	Performance/Cost of Fuel Cell Version Compared to Battery	Fuel Cell Advantage
Forklift Vehicle Cost & Life	No Difference	N/A
Powerpack Cost (FC or Battery)	3x – 6x Higher	-
Powerpack Life (FC or Battery)	1 – 1.7x Longer	+
# Powerpacks Needed	1/Lift vs 1/Shift/Lift	+
H2/Electricity Fuel Costs	4x – 6x Higher	-
H2 Fueling vs Battery Change	3x – 5x Faster	+
Powerpack Maintenance/Repair	??	TBD
H2 vs Charger Infrastructure (Capital + O&M)	??	TBD

Source: Assessments based on *Identification and Characterization of Near-term Direct Hydrogen Proton Exchange Membrane Fuel Cell Markets* [Battelle Memorial Institute (April 2007)] coupled with forklift manufacturer industry information. Future progress reporting will be based on actual data from DOE and DOD fuel cell forklift demonstrations as reported to NREL.

Comparison of Fuel Cell Forklifts – Other Performance Metrics

PEM Fuel Cell Forklift to Conventional Forklift

Parameter	Advantage for Fuel Cell vs. Battery
Ambient Operating Temperature Range	+
Consistent Power Availability Over Shift	+
Continuous Runtime	+
Ease of Use	+
Safety	?

Parameter	Advantage for FC vs. Diesel/Propane
Direct Emissions (Criteria Air Pollutants)	+
Lifecycle Greenhouse Gas Emissions	+
Noise	+

Source: Assessments based on relevant literature coupled with forklift manufacturer industry information. Future progress reporting will be based on actual data from DOE and DOD fuel cell forklift demonstrations as reported to NREL.

Tech Val NREL Website & Contact Info

www.nrel.gov/hydrogen/proj_tech_validation.html

Hydrogen & Fuel Cells Research

Hydrogen Technology Validation

Technology validation is defined as confirmation that component and system technical targets have been met under realistic operating conditions. NREL's technology validation team is working to validate hydrogen fuel cell vehicles and refueling infrastructure as part of DOE's hydrogen technology validation activity.

Technology validation projects involve gathering extensive data from the systems and components under real-world conditions, analyzing this detailed data, and then comparing results to technical targets. While the raw data is protected by NREL, analysis results are aggregated into public results called composite data products. These public results show the status and progress of the technology, but don't identify individual companies.

Three major hydrogen technology validation efforts are underway at NREL:

- [Hydrogen Fuel Cell Vehicle and Infrastructure Learning Demonstration](#)
Access the latest analysis results, papers, and presentations from NREL's work on DOE's Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project.
- [Hydrogen Fuel Cell Bus Evaluations](#)
Access detailed reports and analysis results from all of NREL's fuel cell vehicle bus evaluations.
- [Early Fuel Cell Market Demonstrations](#)

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

Todd Ramsden
todd.ramsden@nrel.gov
303-275-3704

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