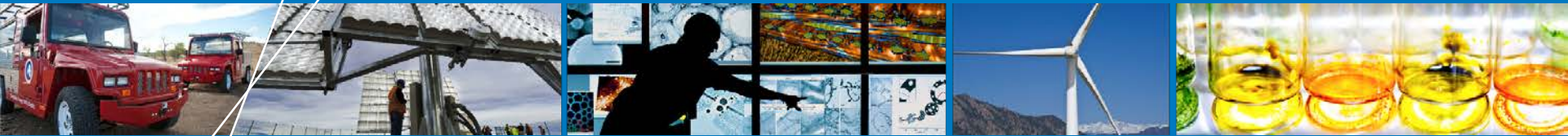


Material Handling Equipment Data Collection and Analysis



**Chris Ainscough, P.E. (PI/Presenter),
Jennifer Kurtz**

NREL

June 7th, 2016

Project ID #TV021

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

Overview

Timeline

- **Total DOE funds received to date: \$940**
- **Project start date: Oct. 2012**
- **Project end date: Oct. 2016***

Budget

- **FY15 DOE funding: \$70k**
- **FY16 planned DOE funding: \$75k**

***Project continuation & direction determined annually by DOE.**

Barriers

Barriers addressed

- Commercialization of fuel cells in key early markets

Partners

- **Interactions/collaborations**
- **Project lead: NREL**
- **See collaborations slide**

Relevance: Objectives



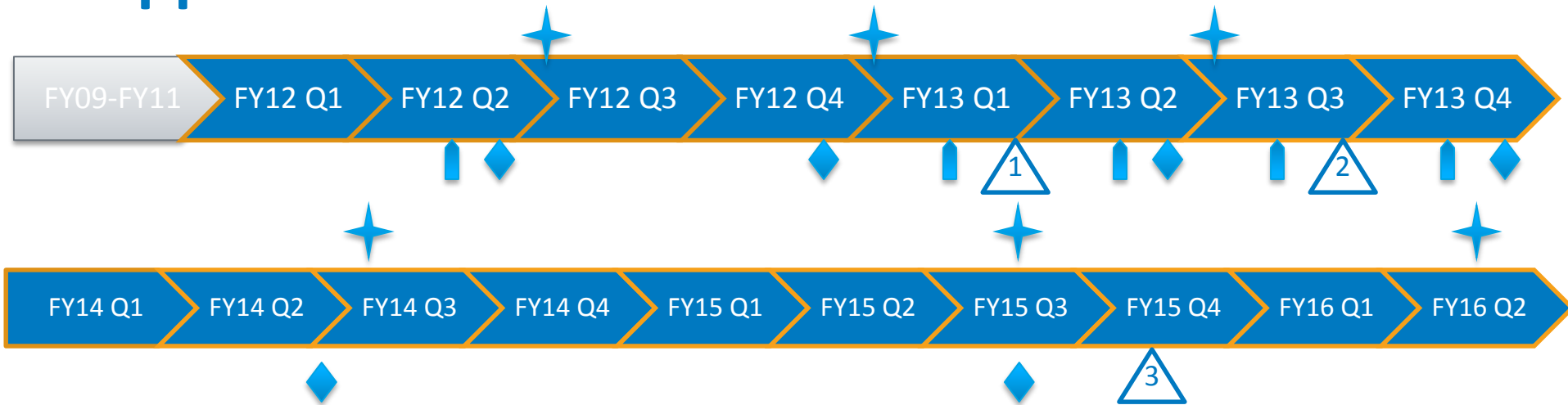
Assess the technology status in real-world operations, establish performance baselines, report on fuel cell and hydrogen technology, and support market growth by evaluating performance relevant to the markets' value proposition.

- **Assess technology**
 - Perform independent technology assessment in real-world operation conditions
 - Focus on fuel cell system performance, and operation
 - Leverage data processing and analysis capabilities developed under the fuel cell vehicle Learning Demonstration project
 - Evaluate material handling equipment (MHE) and backup power
 - Analysis includes up to 1,000 fuel cell systems deployed with ARRA funds plus thousands deployed privately.
- **Support market growth**
 - Provide analyses and results relevant to the markets' value proposition
 - Report on technology status to fuel cell and hydrogen communities and other key stakeholders like end users

Approach

- The design and manufacture of fuel cell MHE continues to evolve, and we need to keep updated status on developments
- ARRA project data collection has come to an end but . . .
- The ARRA phase collected data on hundreds of MHE units, with over 2-million total vehicle operation hours
- Leverage the massive amount of data collected under ARRA (1.7 TB, 13-million analysis & data files) to continue status monitoring of MHE on a voluntary basis with OEMs.
- We produced updated data products with ARRA as a backdrop.

Approach: Milestones



 Deployment composite data products

 Analysis of operation data for fuel cell systems

 Technical composite data products

 1 Hydrogen Safety Panel Final Report (FY13 Q1)

 2 Interim draft report of status and performance of fuel cell MHE and backup power systems

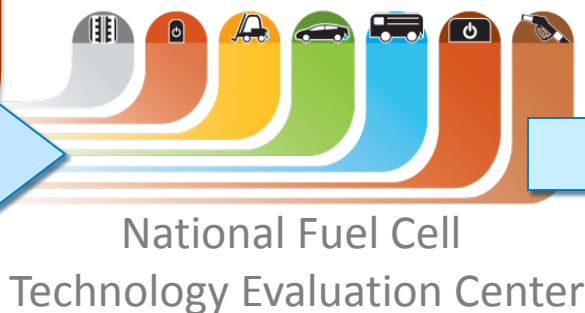
 3 Final report of status and performance of fuel cell backup power

Approach: NFCTEC Analysis and Reporting of Real-World Operation Data

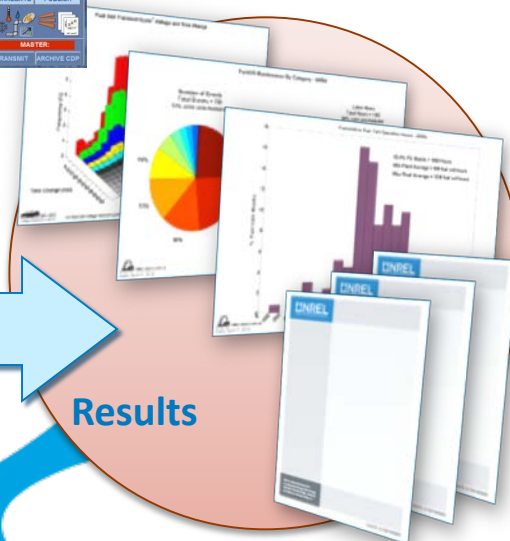
Bundled data (operation & maintenance/safety) delivered to NREL quarterly



Internal analysis completed quarterly in NFCTEC



Results



DDPs

Confidential

Public

CDPs

Detailed Data Products (DDPs)

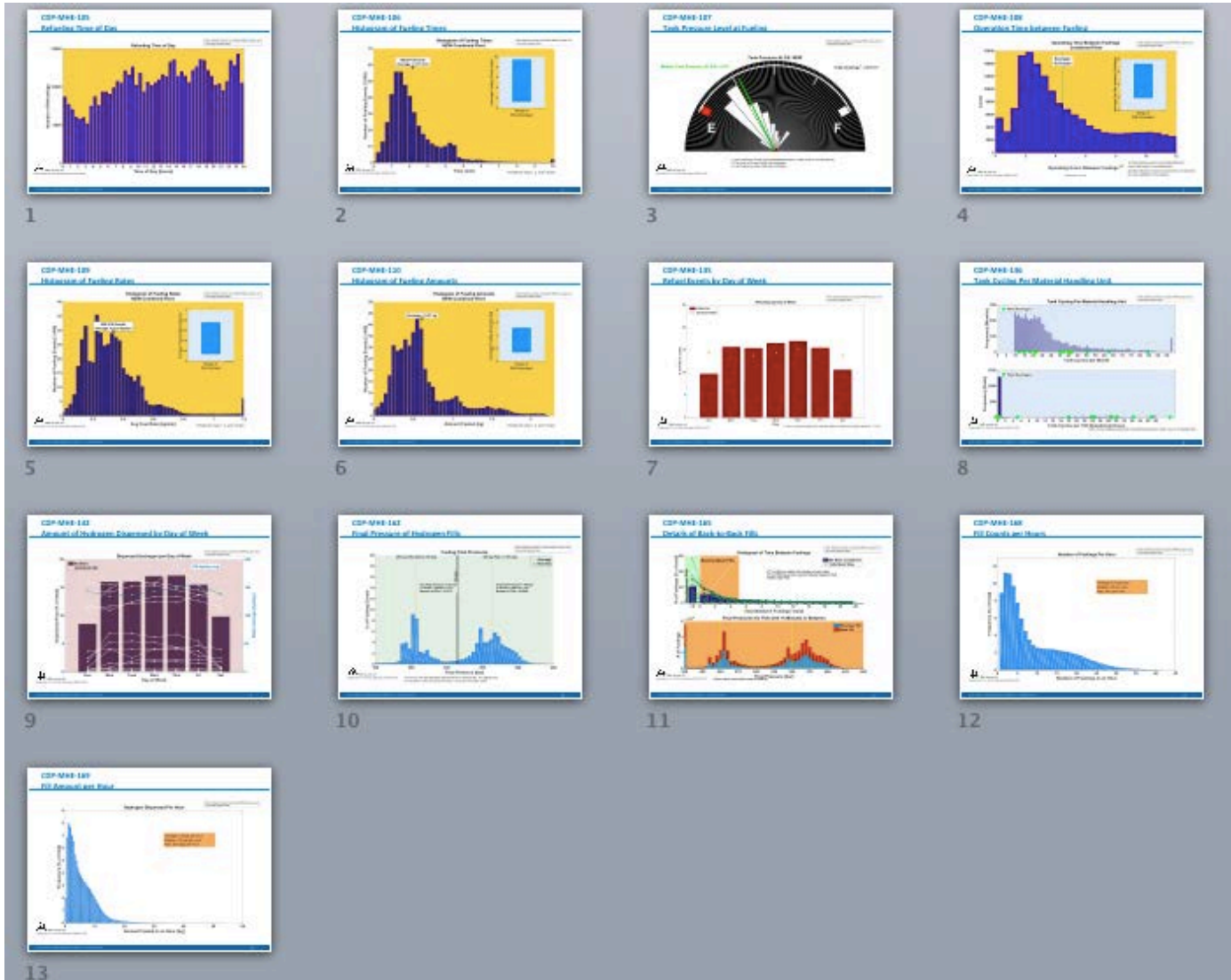
- Individual data analyses
- Identify individual contribution to CDPs
- Shared every six months only with the partner who supplied the data

Composite Data Products (CDPs)

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

www.nrel.gov/hydrogen/proj_tech_validation.html

13 Updated MHE & Infrastructure CDPs



Accomplishments: MHE Operation Summary 2009 Q4 – 2015 Q2



456,914

Hydrogen fills

4.5

Average operation hours
between fills

Validation of MHE is based on
real-world operation data
from high-use facilities.

287,967

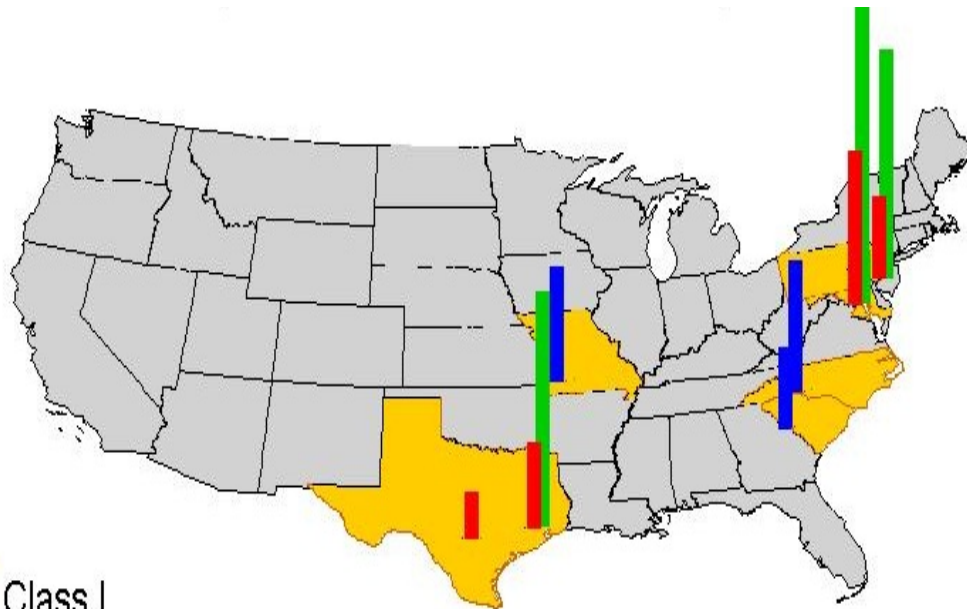
Hydrogen dispensed
in kg

0.61

Average fill amount
in kg

2.2

Average fill time
in minutes



- Class I
- Class II
- Class III

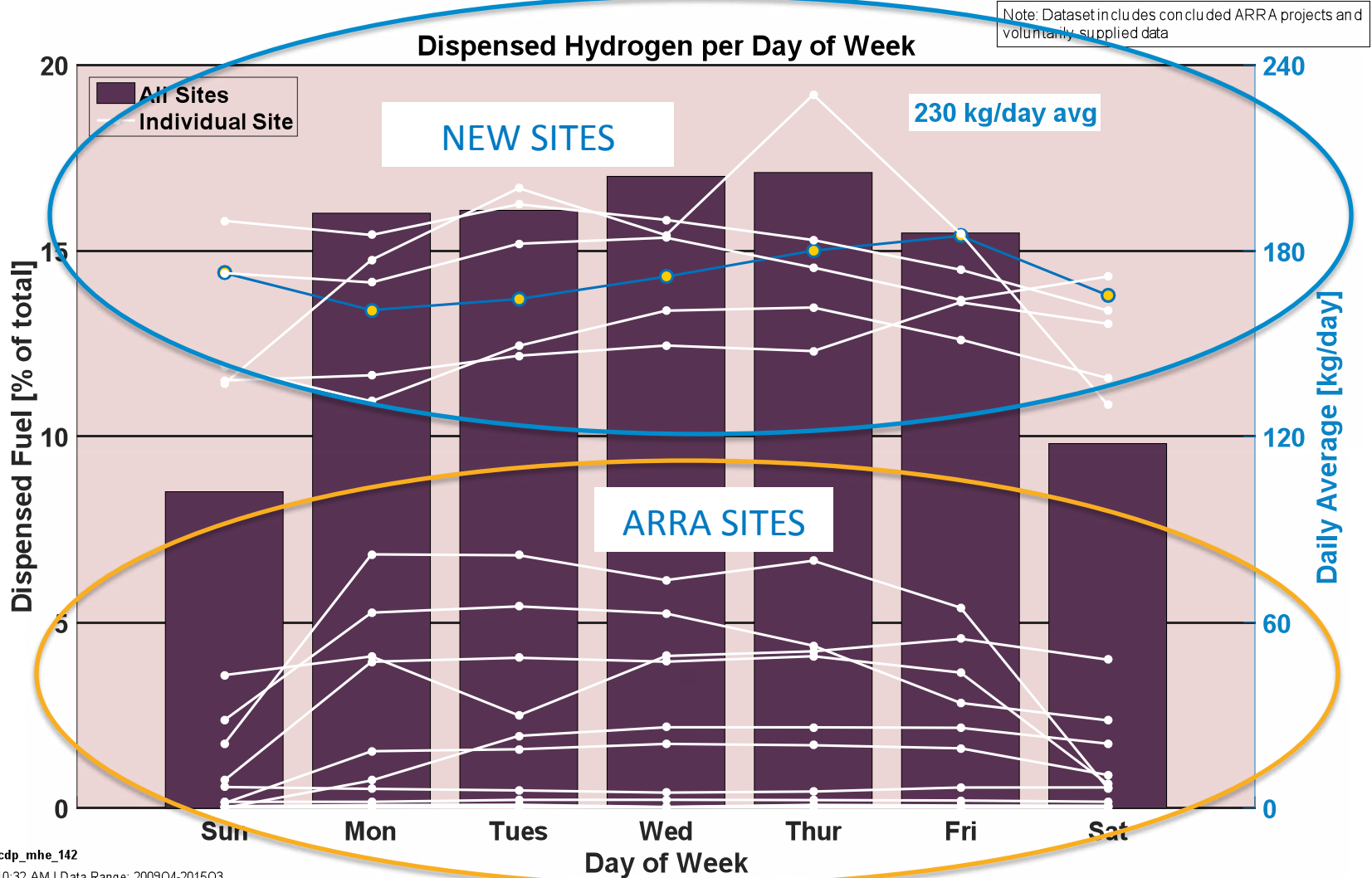
Height proportional to units deployed.

*Only ARRA locations shown

Accomplishments: Deployments Grow Larger



Amount of hydrogen dispensed per day is much greater at new systems compared to ARRA.



NREL cdp_mhe_142

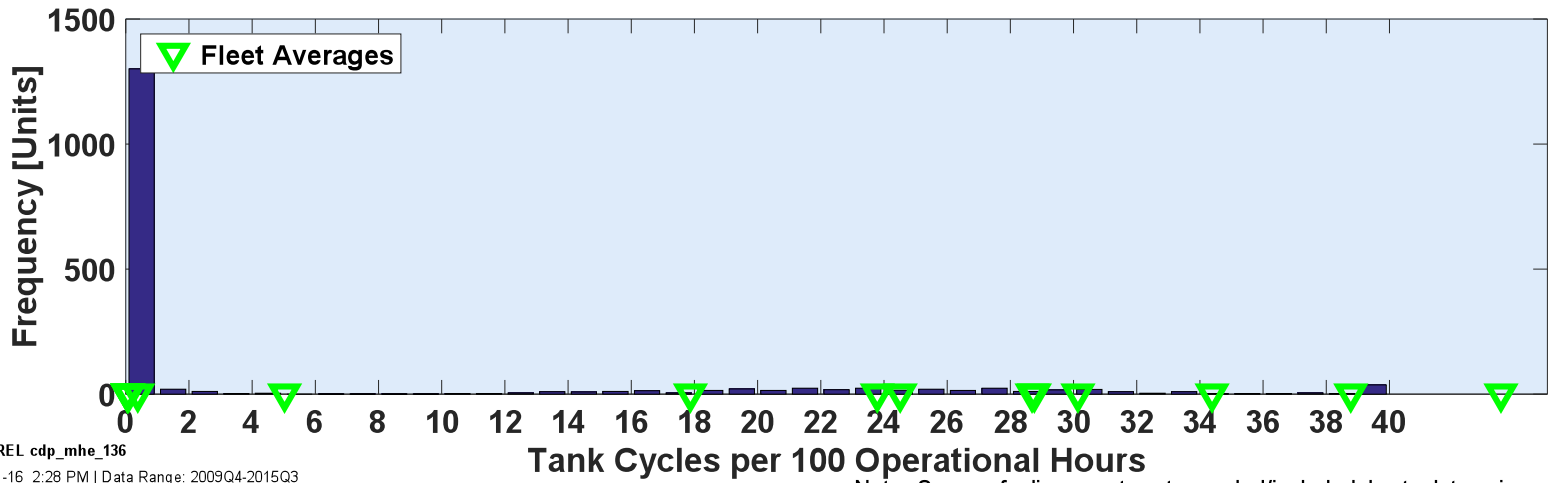
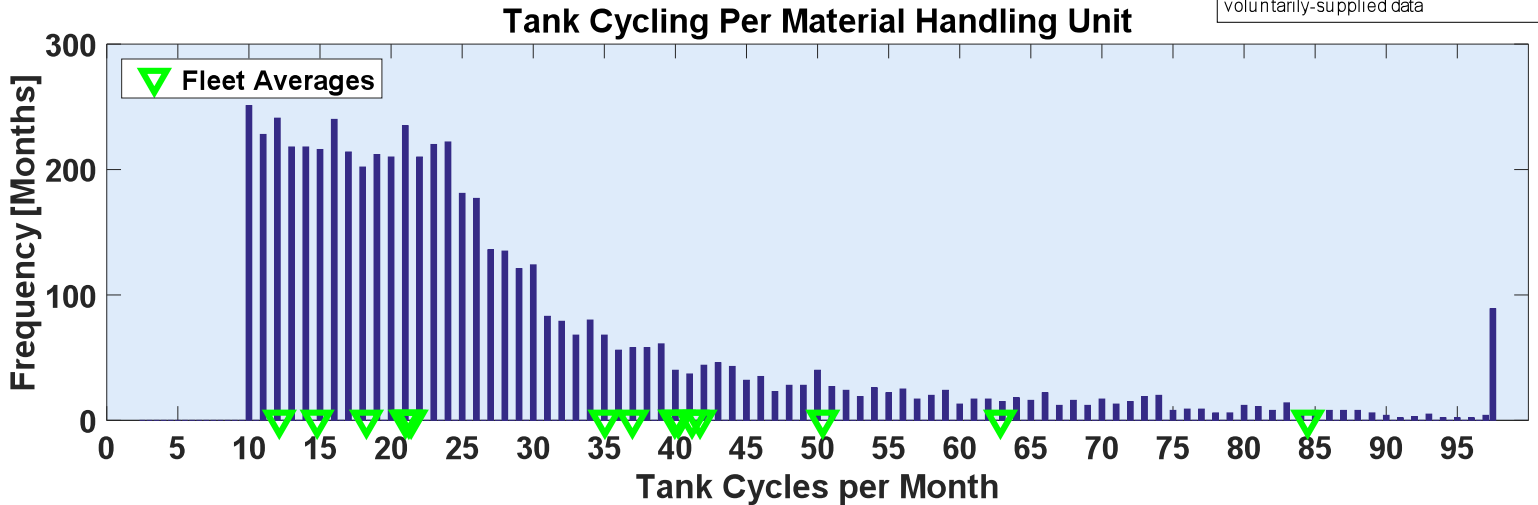
Created: Mar-31-16 10:32 AM | Data Range: 2009Q4-2015Q3

Accomplishments: Tank Cycling



Fleets cycle their on-board storage tanks between 12 and 85 times per month.

Note: Dataset includes concluded ARRA projects and voluntarily-supplied data



Note: Some refueling events not recorded/included due to data noise or incompleteness



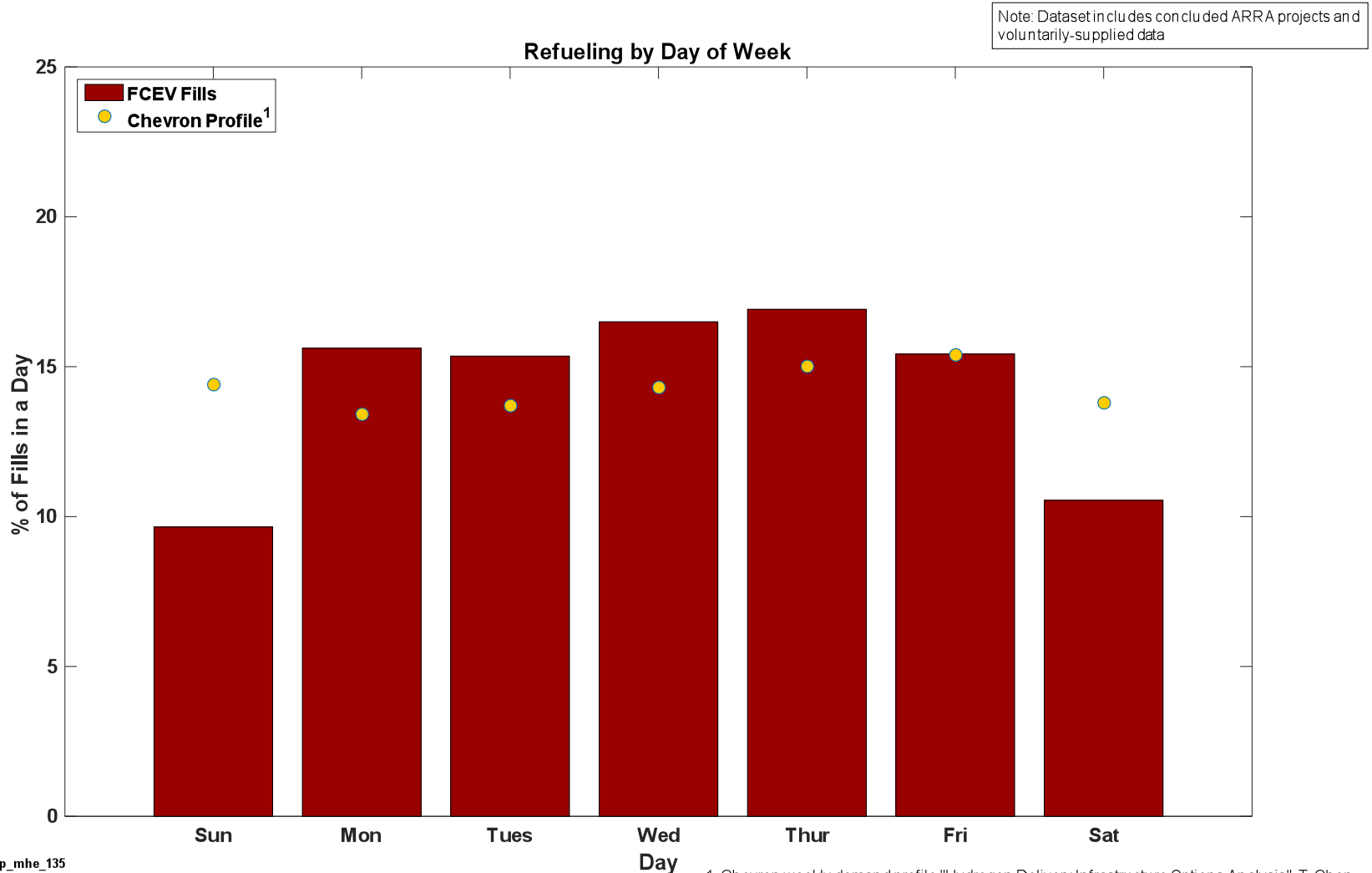
NREL cdp_mhe_136

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Accomplishments: Fueling Behavior



Owners use systems every day of the week, more heavily Monday – Friday.



NREL cdp_mhe_135

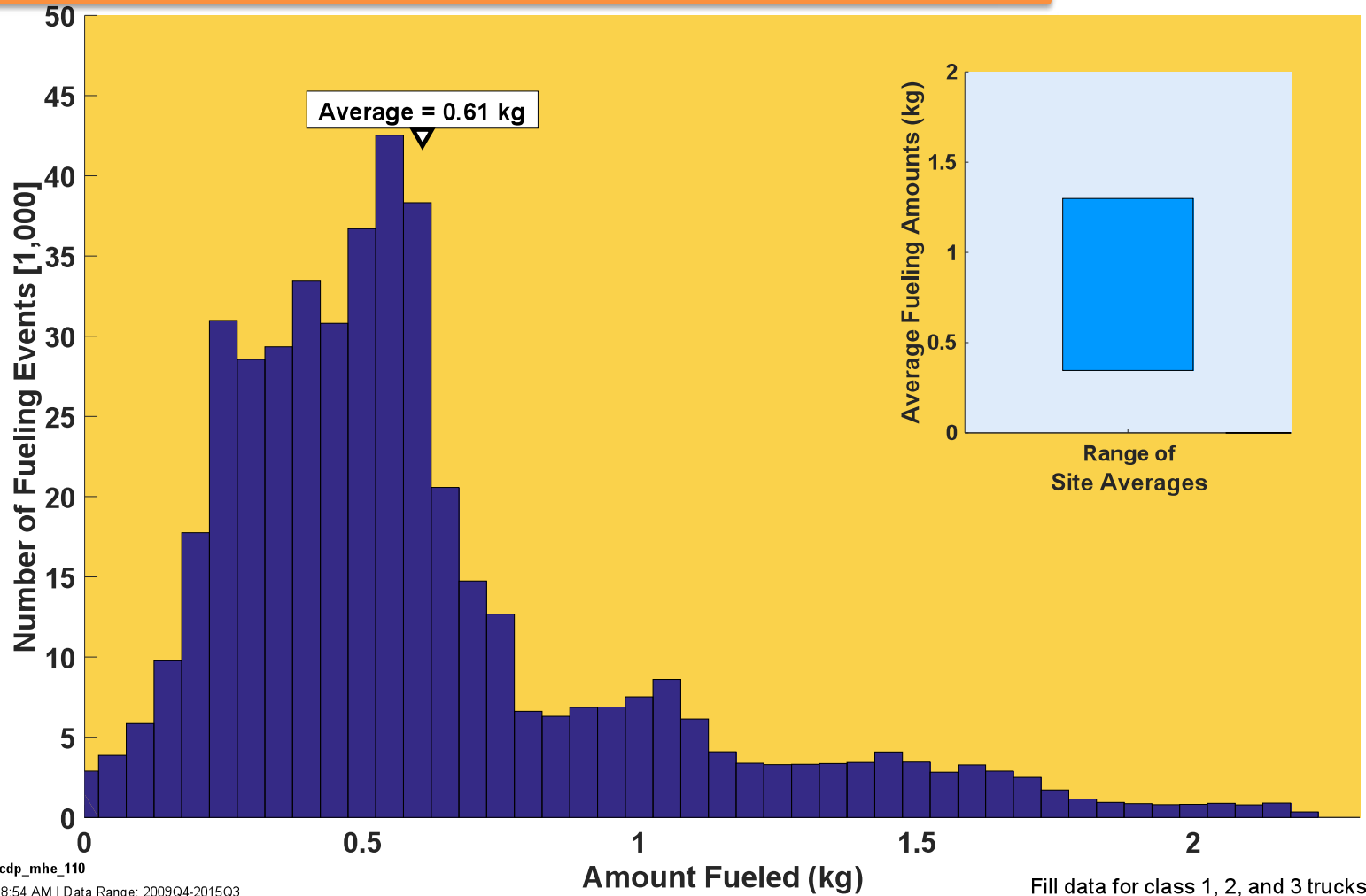
Created: Mar-31-16 10:54 AM | Data Range: 2009Q4-2015Q3

1. Chevron weekly demand profile "Hydrogen Delivery Infrastructure Options Analysis", T. Chen.

Accomplishments: Fueling amounts

Fueling amounts average about 600 grams per fill, generally less than 1250 grams.

Note: Dataset includes concluded ARRA projects and voluntarily-supplied data



NREL cdp_mhe_110

Created: Mar-31-16 8:54 AM | Data Range: 2009Q4-2015Q3

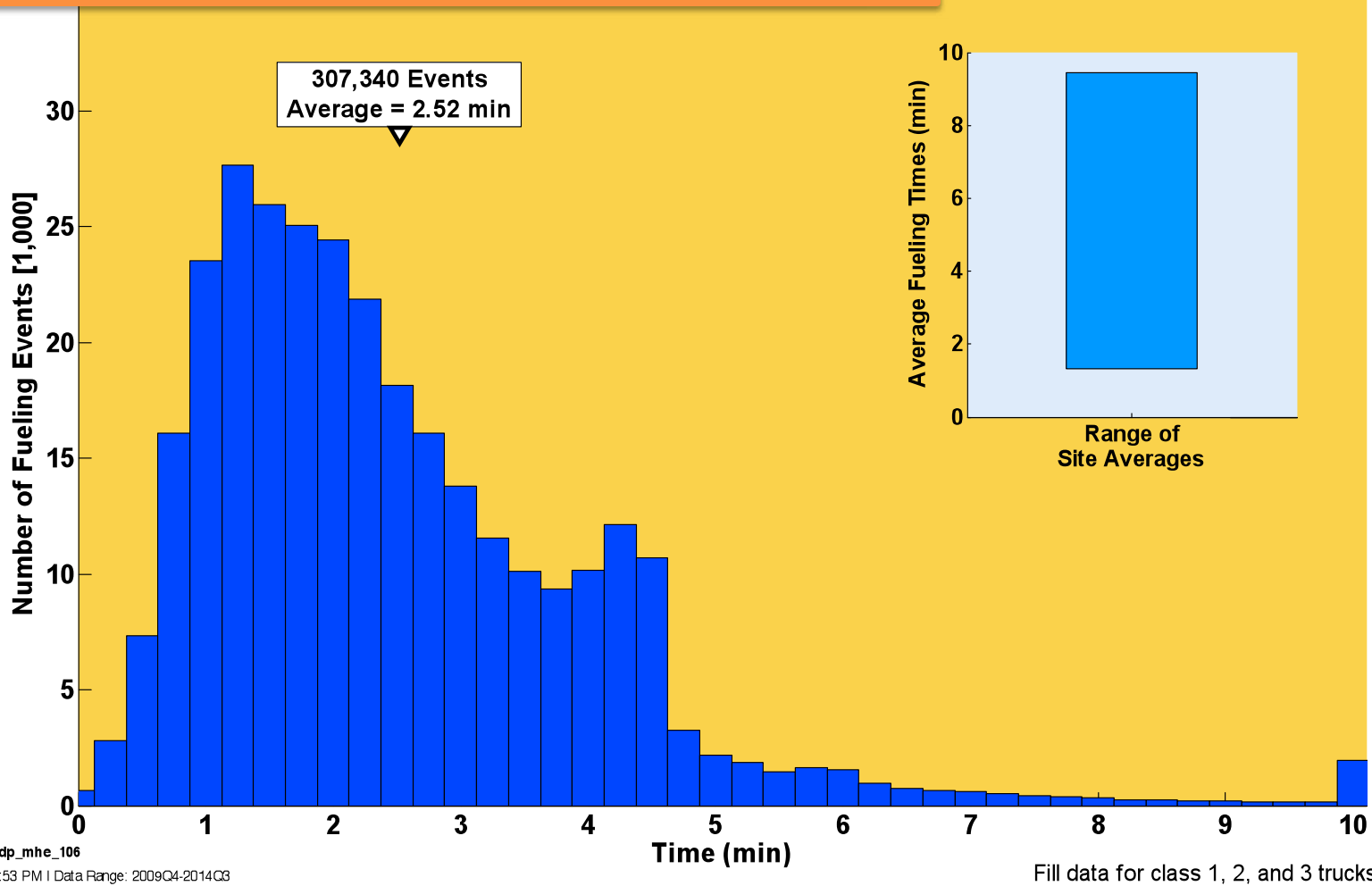
Fill data for class 1, 2, and 3 trucks

Accomplishments: Study of Fueling Times



Fueling times have decreased over 13%. Fast fueling is key to the MHE value proposition.

Note: Dataset includes concluded ARRA projects and voluntarily-supplied data



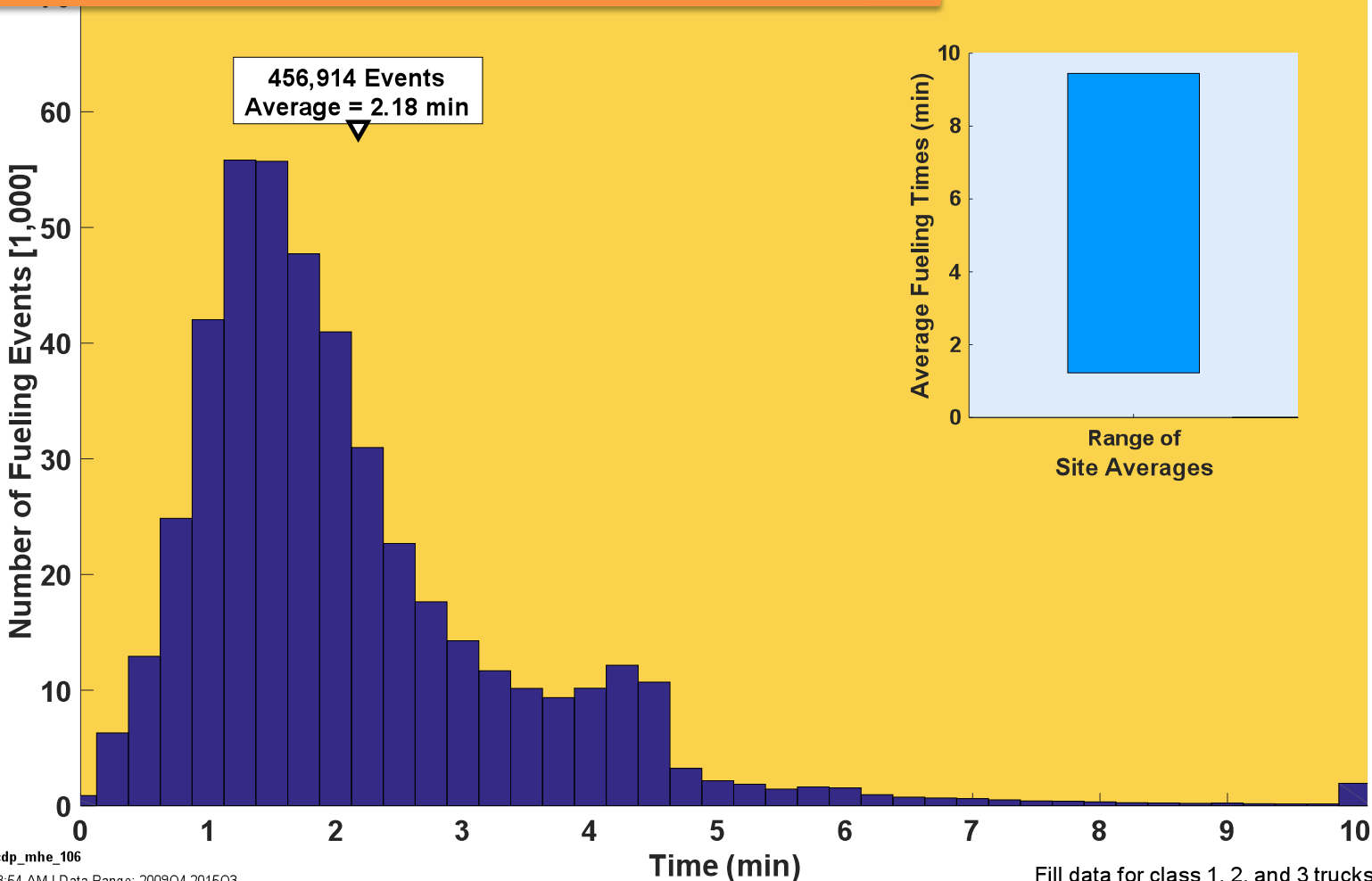
Fill data for class 1, 2, and 3 trucks

Accomplishments: Study of Fueling Times



Fueling times have decreased over 13%. Fast fueling is key to the MHE value proposition.

Note: Dataset includes concluded ARRA projects and voluntarily-supplied data



NREL cdp_mhe_106
Created: Mar-31-16 8:54 AM | Data Range: 2009Q4-2015Q3

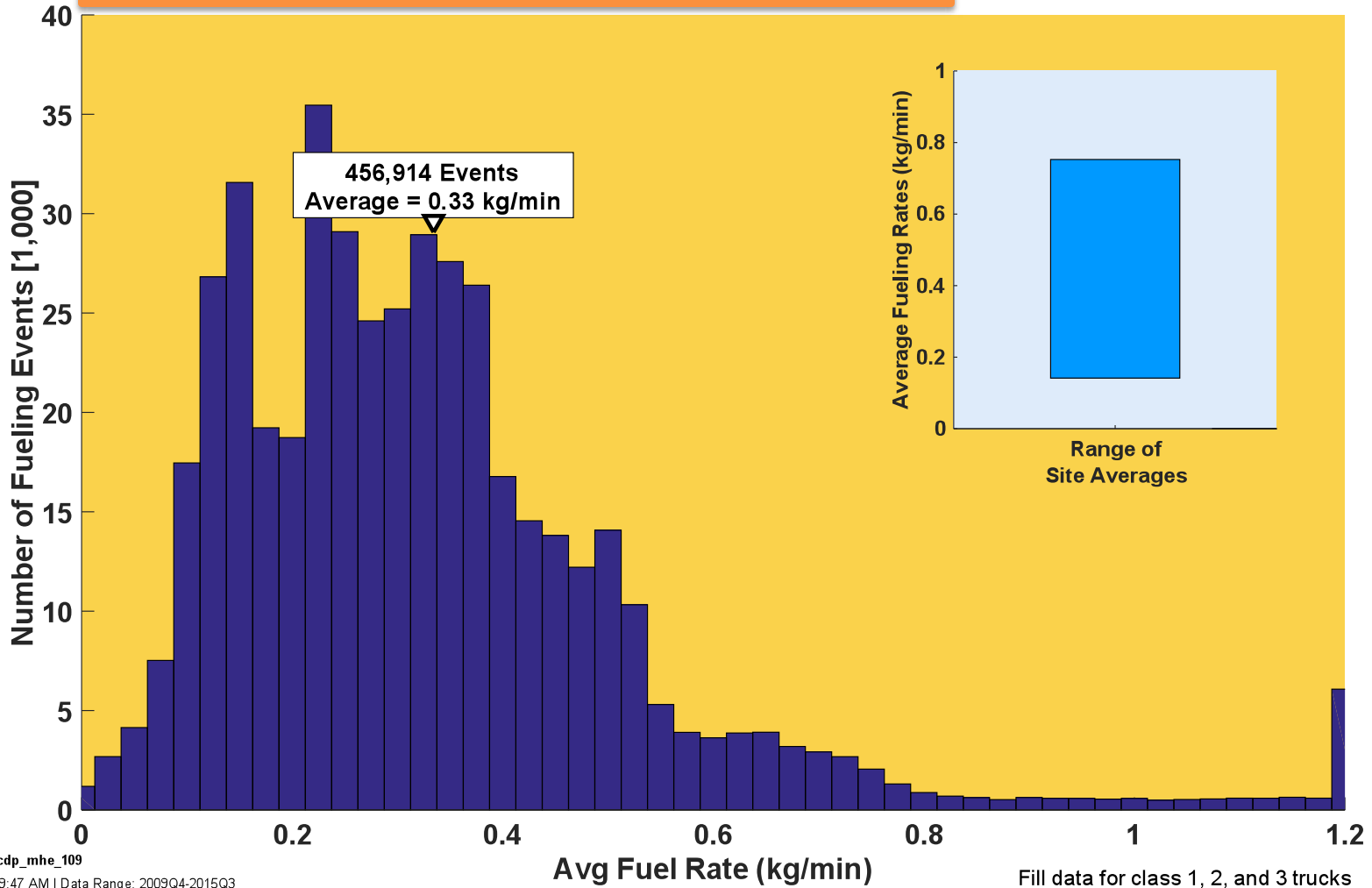
Fill data for class 1, 2, and 3 trucks

Accomplishments: Fueling rates



Fueling rates allow 1 kg every three minutes.

Note: Dataset includes concluded ARRA projects and voluntarily-supplied data



NREL cdp_mhe_109

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CDP-MHE-107

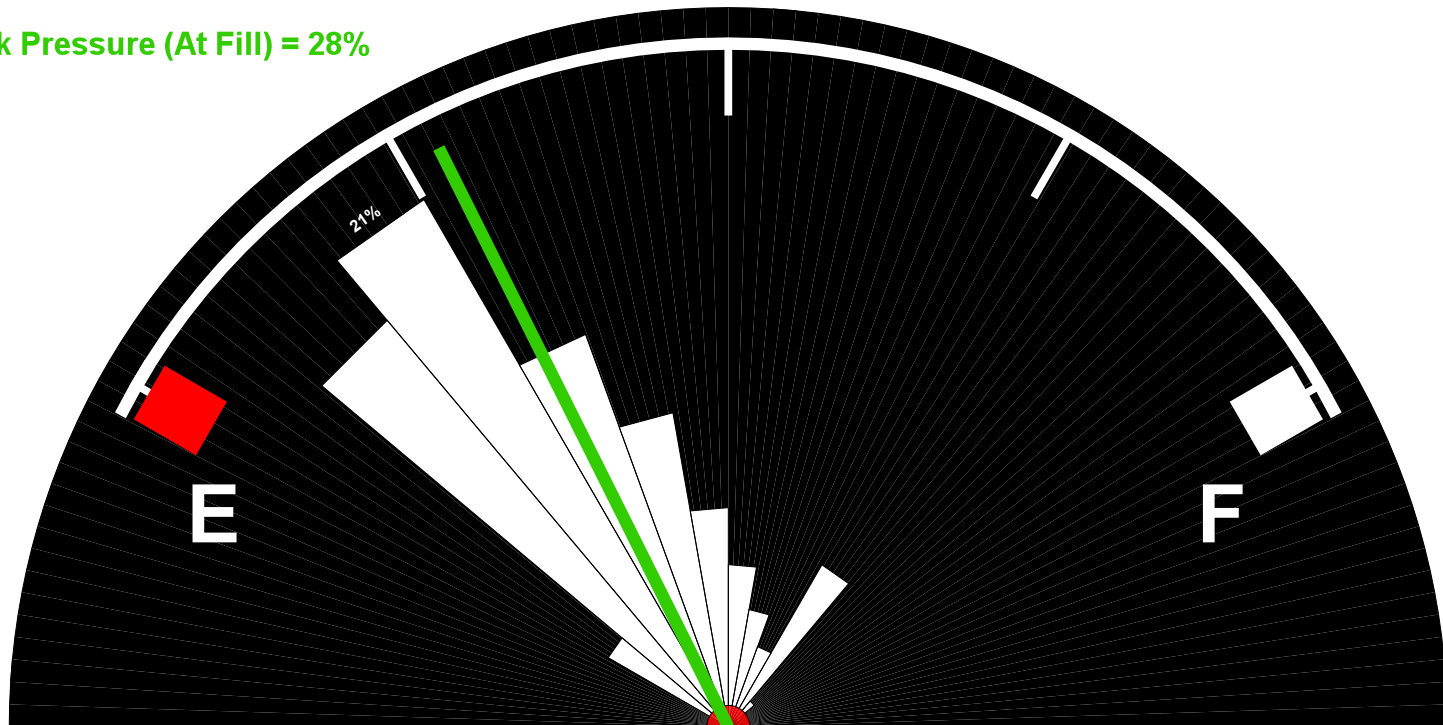
Tank Pressure Level at Fueling

Operators use about 2/3 of each tank before refueling.
Median pressure at refill has increased from 24% to 28% since last year.

Note: Dataset includes concluded ARRA projects and voluntarily-supplied data

Tank Pressure At Fill: NEW

Median Tank Pressure (At Fill) = 28%



1. Some refueling events not recorded/detected due to data noise or incompleteness.
2. The outer arc is set at 25% total refuelings.
3. Full Pressure is either 3600 psi or 5000 psi.



NREL cdp_mhe_107

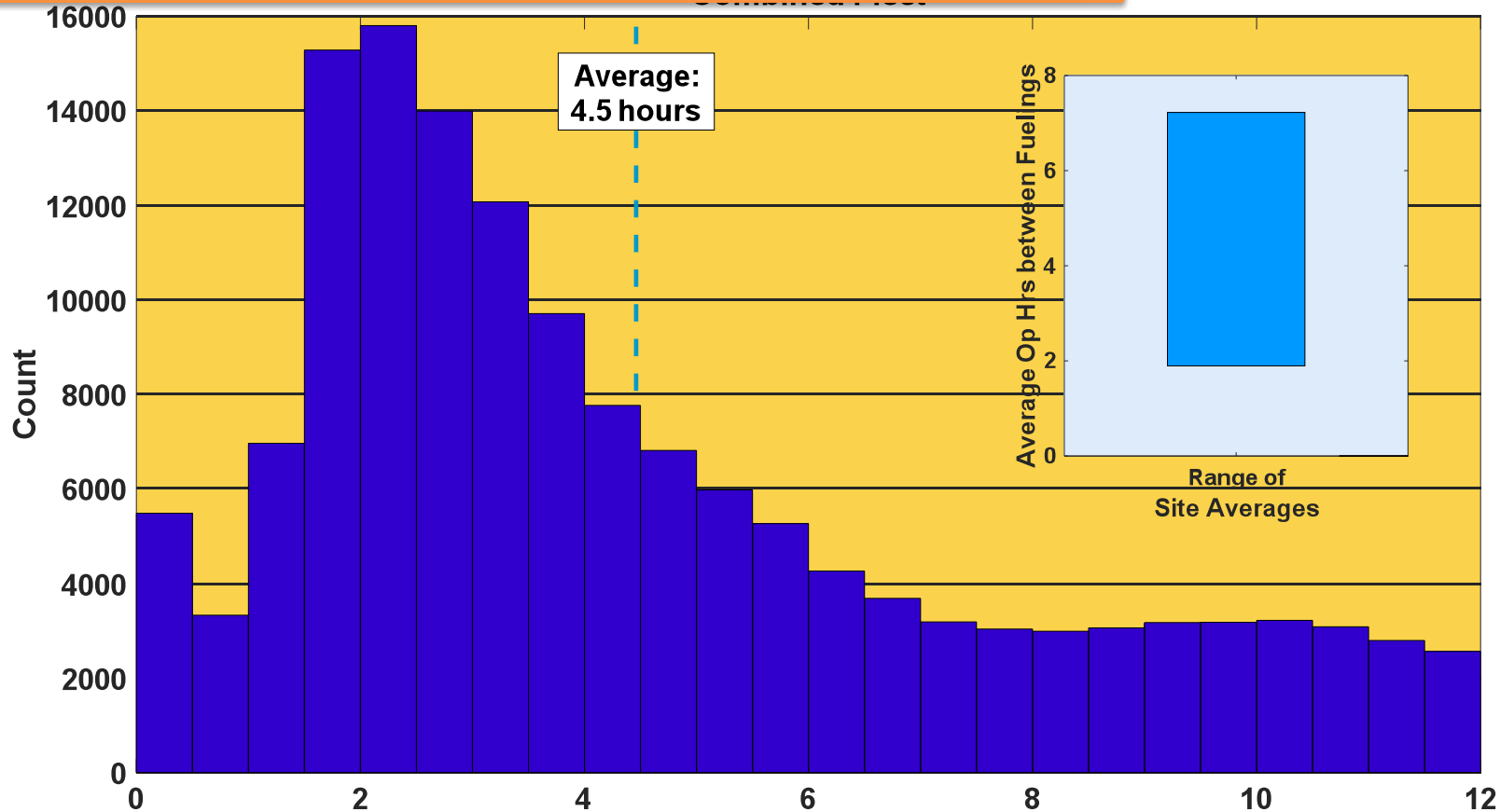
Created: Mar-31-16 12:25 PM | Data Range: 2009Q4-2015Q3

Accomplishments: Study of Operation Times



Average operation times have increased 22% since last year.
NOTE: Indicative of actual use, not vehicle maximum capability.

Note: Dataset includes concluded ARRA projects and voluntarily-supplied data



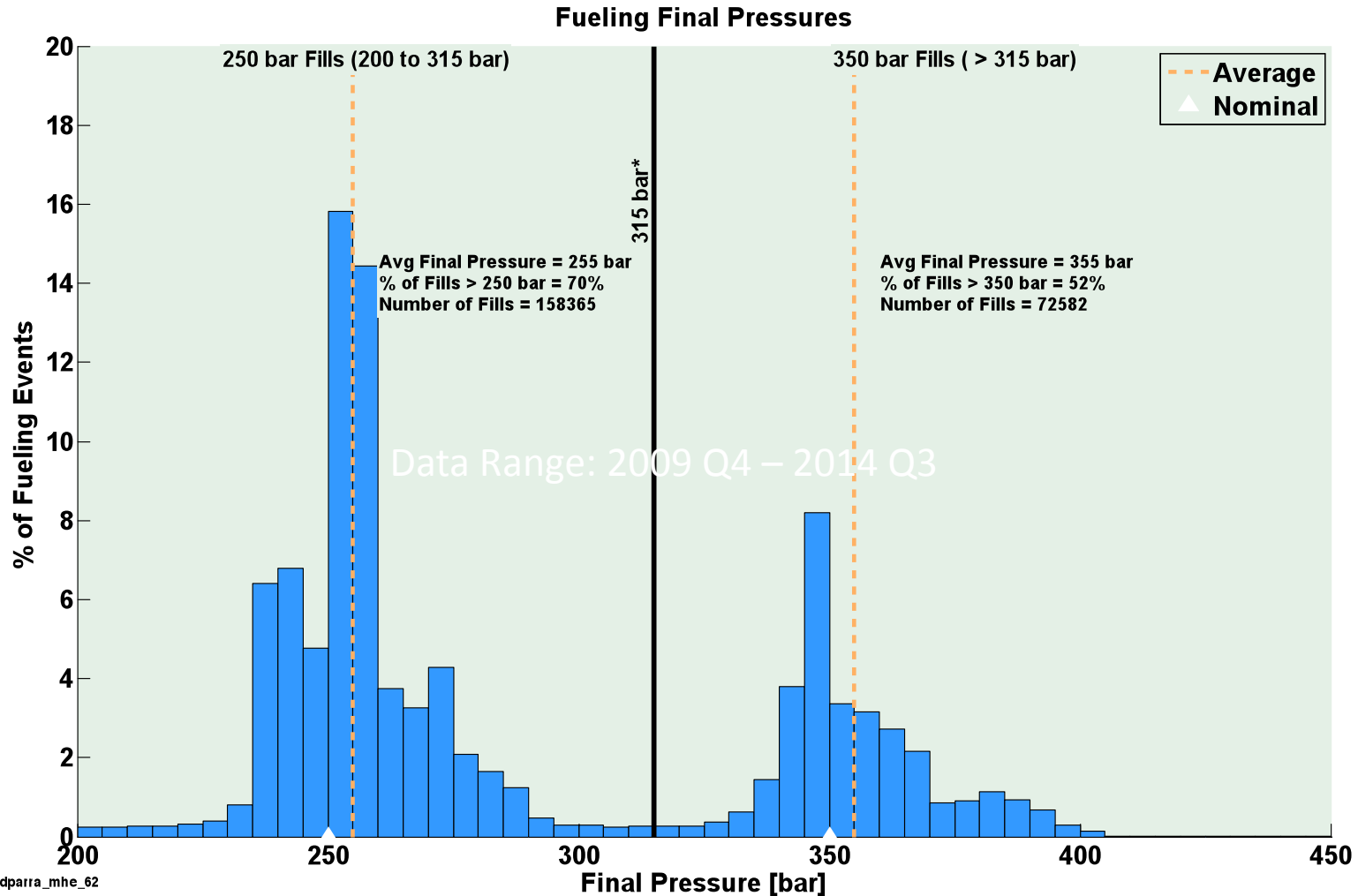
Operating Hours Between Fuelings^{1,2}

- 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.

Accomplishments: Study of Fueling Pressure



Market continues move to 350-bar fueling.



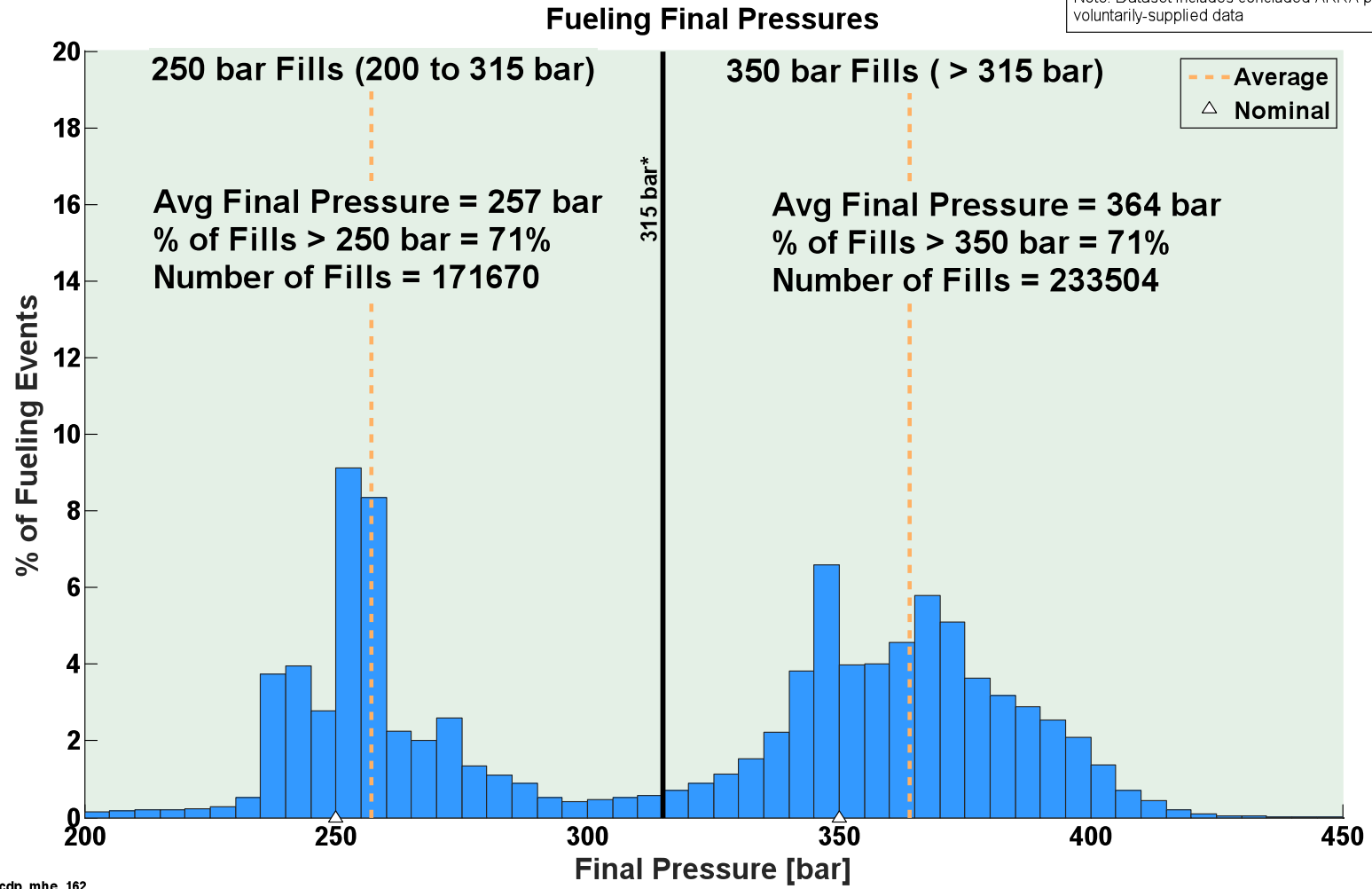
*The line at 315 bar separates 250 bar fills from 350 bar fills. It is slightly over the allowable 125% of nominal pressure (312.5 bar) from SAE J2601.

Accomplishments: Study of Fueling Pressure



Market continues move to 350-bar fueling.

Note: Dataset includes concluded ARRA projects and voluntarily-supplied data



NREL cdp_mhe_162

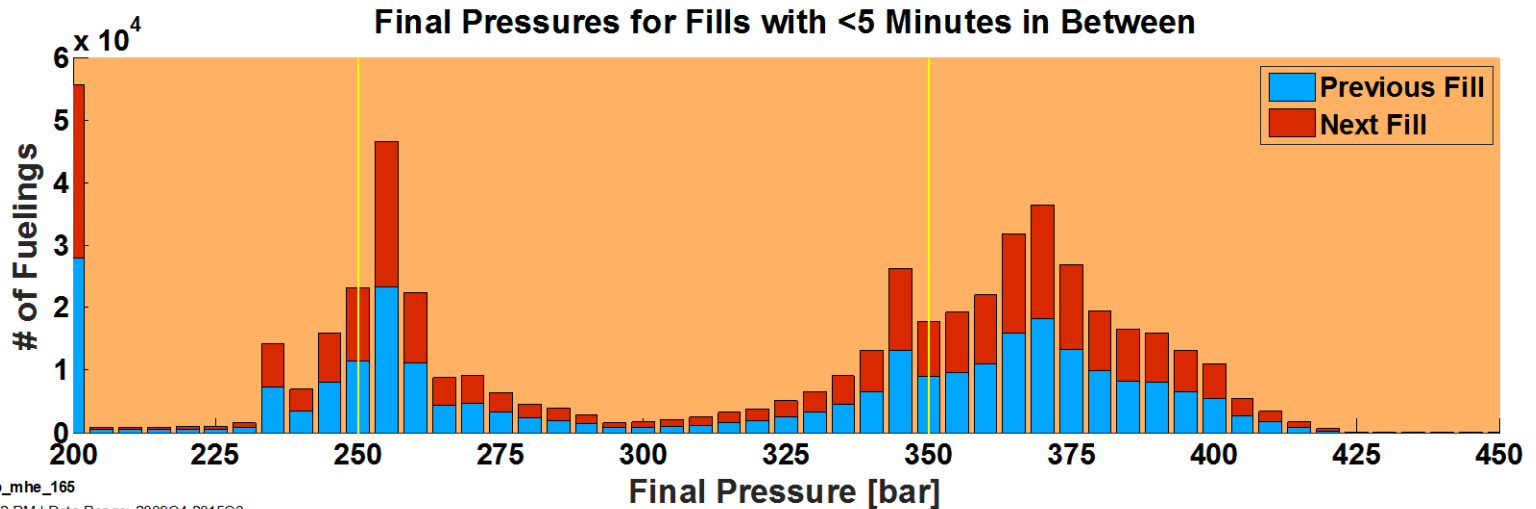
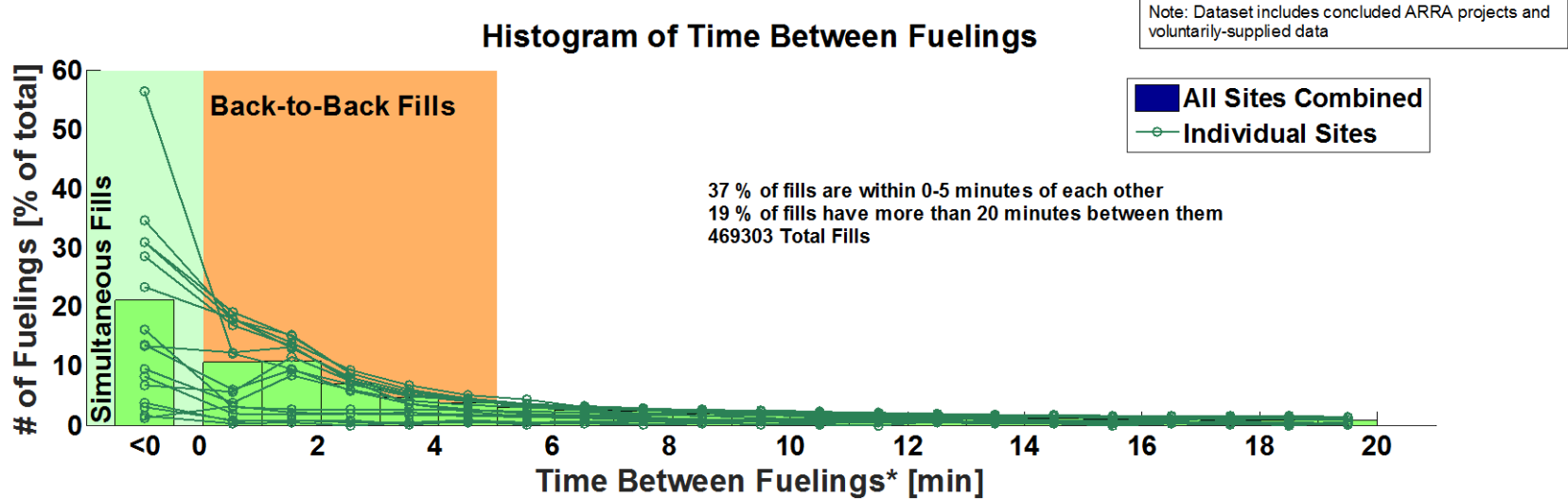
Created: Mar-31-16 10:41 AM | Data Range: 2009Q1-2015Q3

*The line at 315 bar separates 250 bar fills from 350 bar fills. It is slightly over the allowable 125% of nominal pressure (312.5 bar) from SAE J2601.

Accomplishments: Study of Fueling Behavior



Over 1/3 of fills are back-to-back (within 5 min.) 19% within 20 minutes of each other.



NREL cdp_mhe_165

Created: Mar-31-16 5:32 PM | Data Range: 2009Q4-2015Q3

*Time is from end of fill to start of next fill.

Accomplishments: Response to Previous Year Reviewer's Comments

“...The partners' cooperation in providing and evaluating the data is a key component for this project's great success. ”

- Since the closing of the ARRA projects, this project has benefitted from the continued participation of industry, resulting in the largest data set ever processed by NREL.

“[The] dramatic decrease in the number of operation hours being reported on per quarter seems to jeopardize the project's continued ability to provide statistically significant results for the MHE portion of the NFACTEC's work. ”

- Data by quarter, while processed by NREL, was not published in order to protect data anonymity.

“There has been a major reduction in data being reported subsequent to completion of the Recovery Act- funded projects.”

- This is actually not true. This project has received more data in the last year than over its entire history.

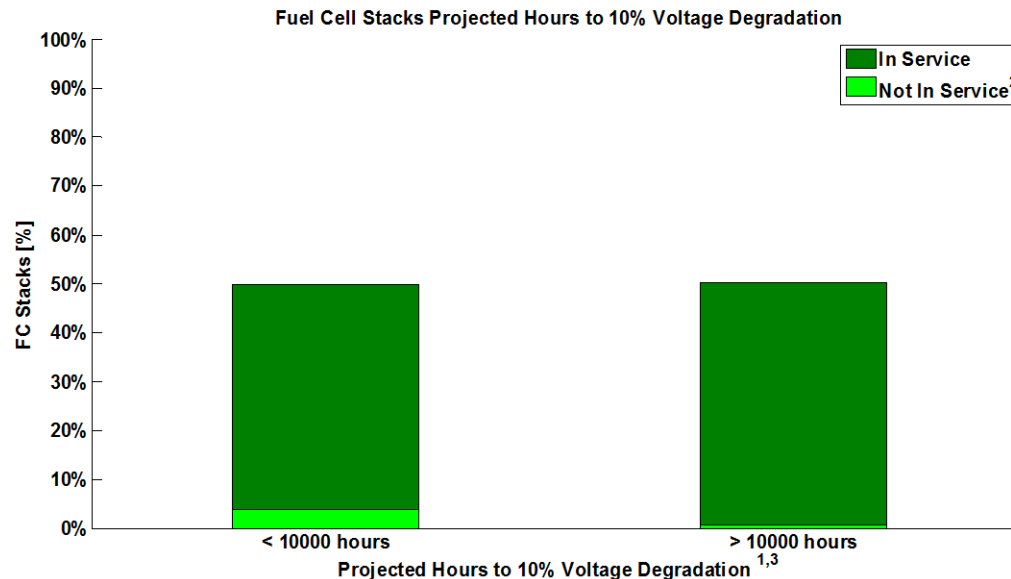
Collaborations

Data Sharing and Analysis Partners

Air Products	Plug Power
FedEx	ReliOn
GENCO	Sprint
Nuvera Fuel Cells	Sysco Houston
Company Name Redacted	

Remaining Challenges and Barriers

- Improvements need to be made in stack durability so that substantially more than 50% of stacks have more than 10,000 hours projected to 10% decay.*



1) Projection using field data, calculated at high stack current, from operation hour 0.

Projected hours may differ from an OEM's end-of-life criterion and does not address "catastrophic" failure modes.

2) Indicates stacks that are no longer accumulating hours either a) temporarily or b) have been retired for non-stack performance related issues or c) removed from DOE program.

3) Projected hours limited based on demonstrated hours.



NREL odp_mhe_97

Created: Apr-01-15 11:44 AM | Data Range: 2009Q1-2014Q3

* 2015 result

Future Work

Remaining FY16 tasks

- Project is completed

Project Summary

Relevance: 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.

Approach: Leverage capabilities established under other technology validation activities (NRELFAT) and industry collaborations. Aggregate data for concise reporting on large data sets from multiple project partners.

Accomplishments: Published the ninth set of technical CDPs on performance, operation, and safety for MHE, with 13 updated results. All results and publications are available on NREL's technology validation website that also includes monthly highlights.

Collaborations and Future Work: Project is complete

NFCTEC Contacts

Website

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

Hydrogen & Fuel Cell Research

Fuel Cell and Hydrogen Technology Validation

Technology validation is defined as confirmation that component and system technical targets have been met under realistic operating conditions. The NREL technology validation team works on validating hydrogen fuel cell electric vehicles; hydrogen fueling infrastructure; and fuel cell use in early market applications such as material handling, backup power, and prime-power applications. The team also analyzes the current status of state-of-the-art laboratory fuel cell technologies, with a focus on performance and durability. This work supports the Department of Energy's hydrogen and fuel cell technology validation activity.

Learning Demonstration Validates Hydrogen Fuel Cell Vehicles and Infrastructure in a Real-World Setting

NREL analyzed seven years of real-world validation data, validated key DOE technical targets, and published key on-site data products.

- Hydrogen Fuel Cell Electric Vehicle Learning Demonstration
- Hydrogen Fuel Cell Bus Evaluations
- Early Fuel Cell Market Demonstrations
- Fuel Cell Technology Status Analysis
- Hydrogen Fueling Infrastructure Analysis
- Stationary Fuel Cell Systems Analysis



Email

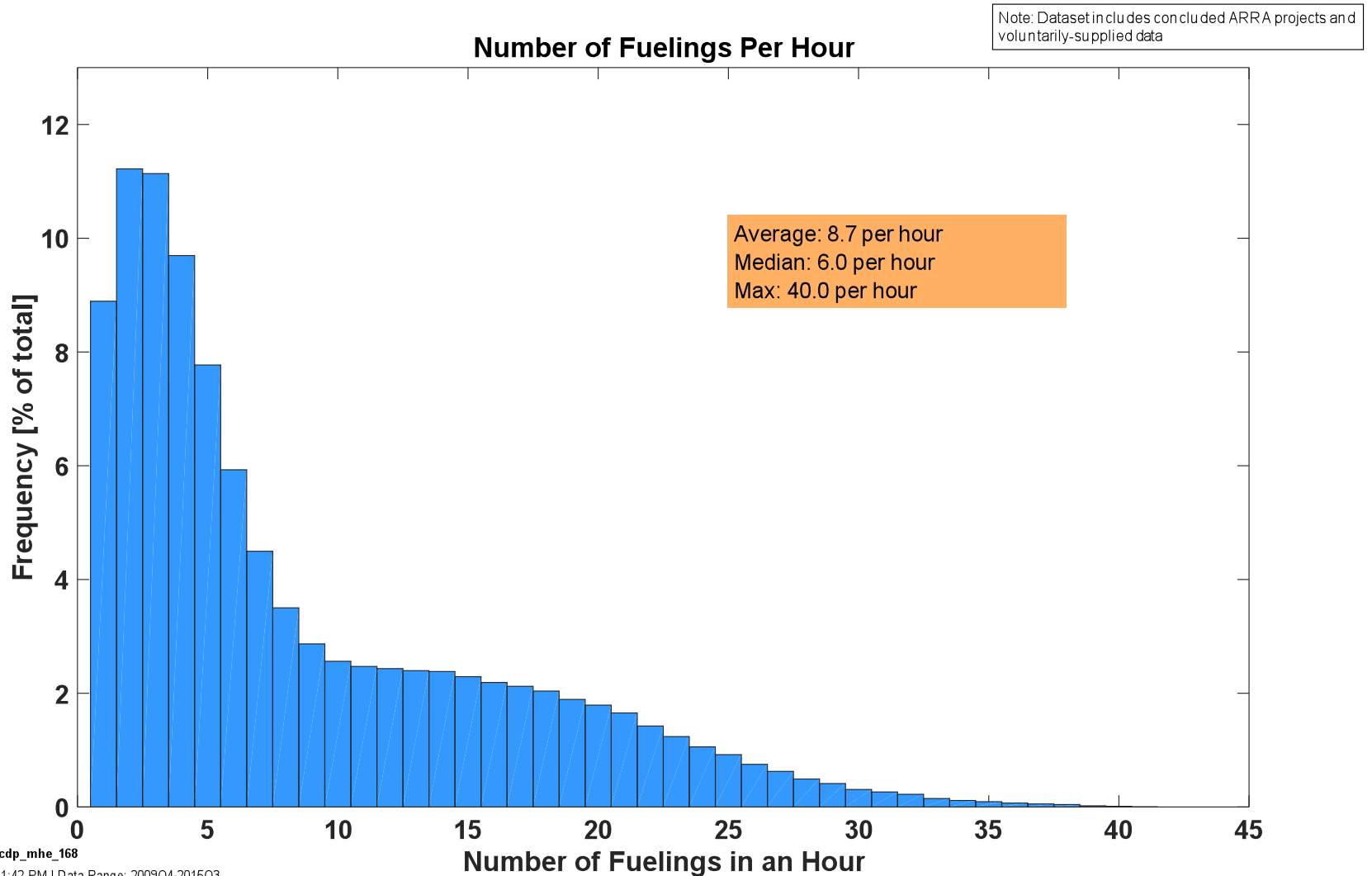
techval@nrel.gov

Chris.Ainscough@nrel.gov

Technical Back-Up Slides

CDP-MHE-168

Fill Counts per Hours

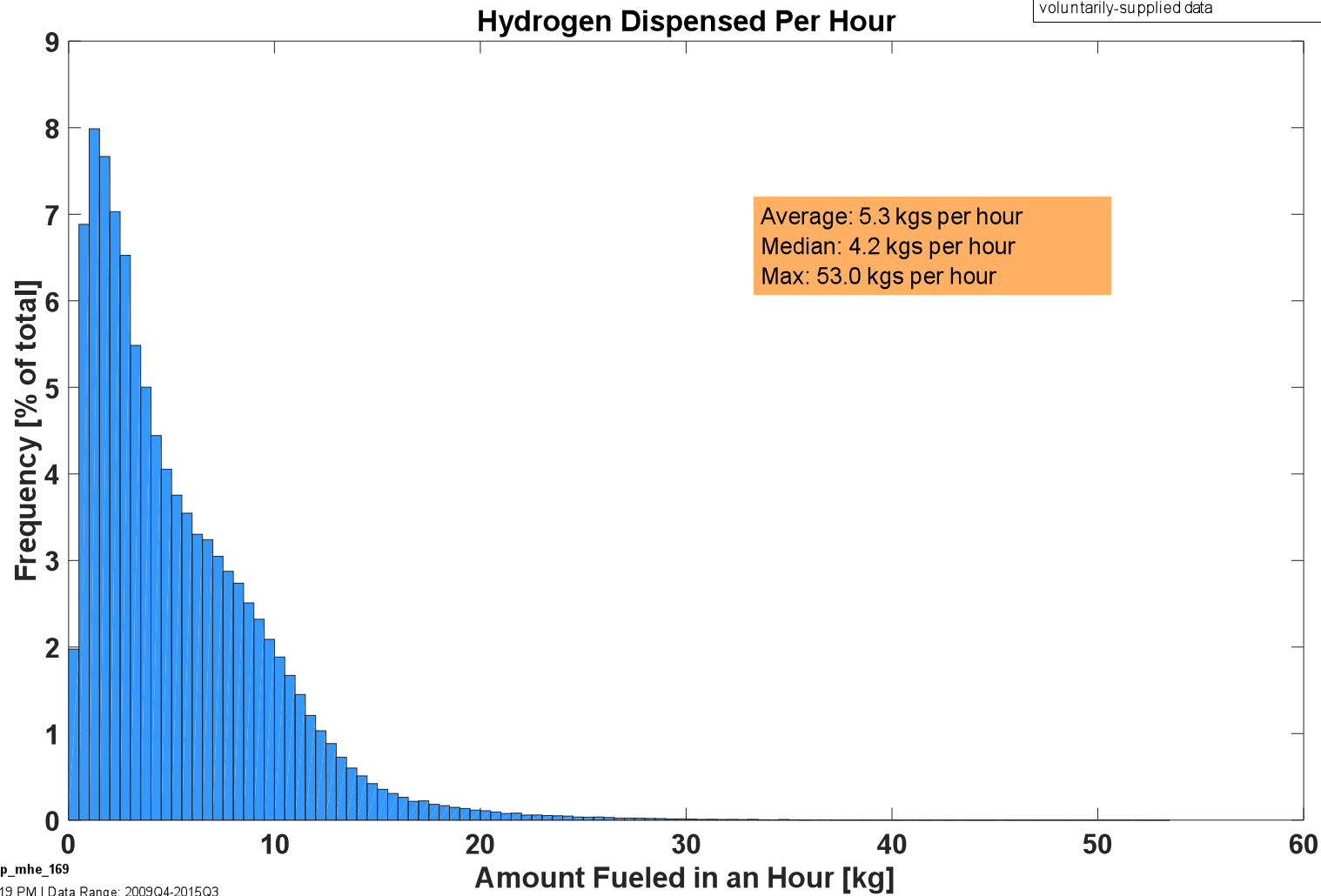


NREL cdp_mhe_168

Created: Mar-31-16 1:42 PM | Data Range: 2009Q4-2015Q3

CDP-MHE-169

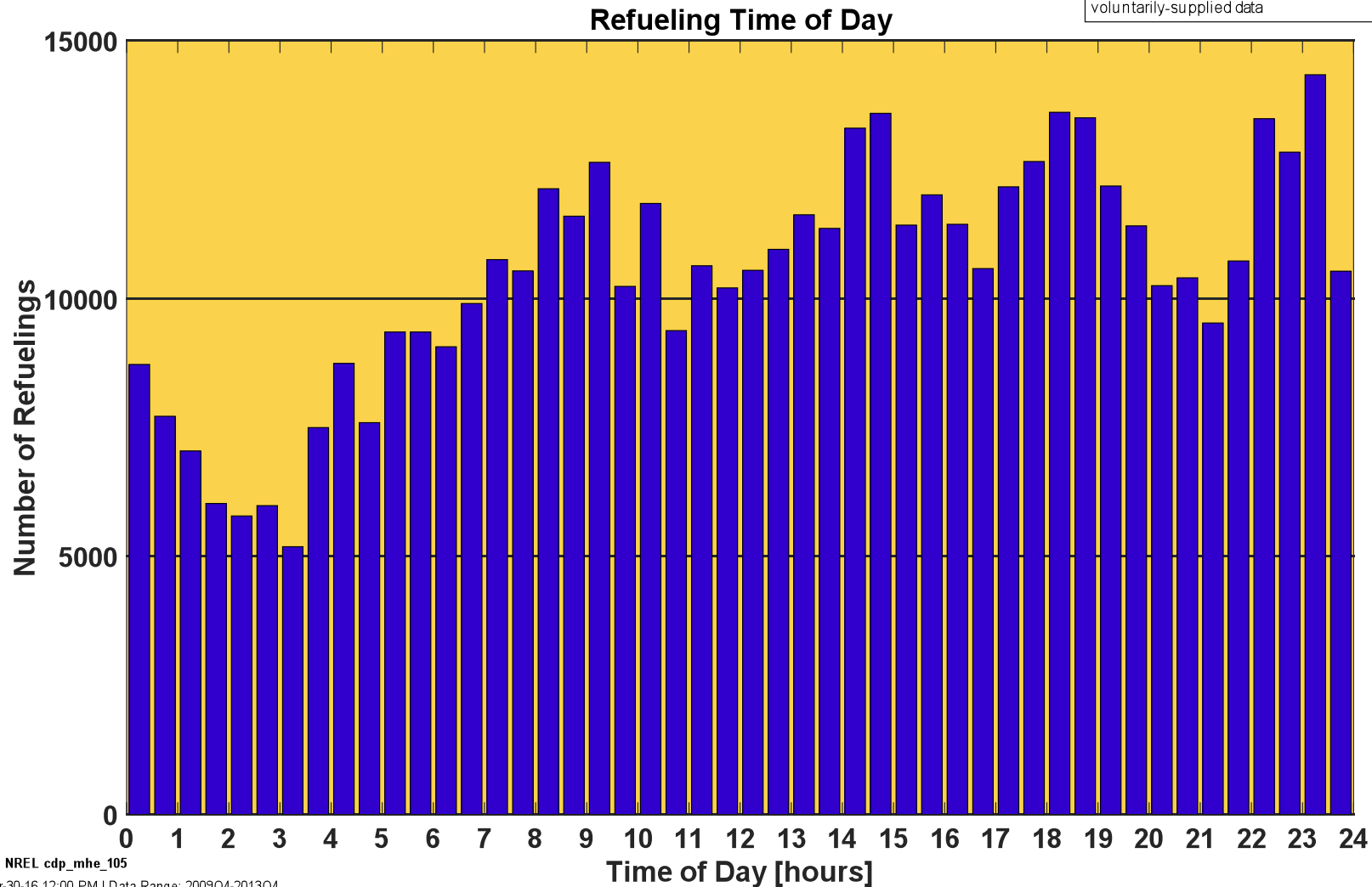
Fill Amount per Hour



NREL cdp_mhe_169

Created: Mar-31-16 5:19 PM | Data Range: 2009Q4-2015Q3

Note: Dataset includes concluded ARRA projects and voluntarily-supplied data



NREL cdp_mhe_105

Created: Mar-30-16 12:00 PM | Data Range: 2009Q4-2013Q4