NREL
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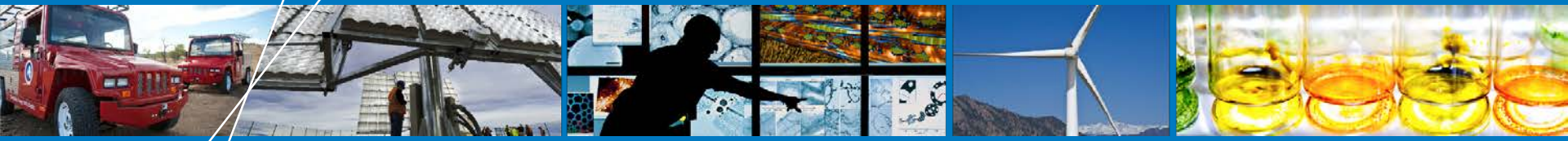
Hydrogen Station Data Collection and Analysis



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National Renewable Energy Laboratory
June 11, 2015
2015 DOE Annual Merit Review
Washington, DC

Project ID TV017

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

Overview

Timeline and Budget

- Project start date: 10/2011*
- Total DOE funds received to date: $785k
- FY14 DOE funding: $200k
- FY15 planned DOE funding: $300k

*project continuation and direction determined annually by DOE

Barriers

- Lack of current hydrogen refueling infrastructure performance and availability data

Partners

- California Air Resources Board (CARB)
- California Energy Commission (CEC)
- California State University, Los Angeles (CSULA)
- Gas Technology Institute (GTI)
- Hydrogen Frontier
- Linde
- Shell
- Proton OnSite

Relevance:
Project Objectives--Hydrogen Infrastructure Evaluation

FY15 Objectives

Analysis and reporting on infrastructure performance, cost, utilization, maintenance, and safety.

CSULA station, Los Angeles, CA. Photo: NREL

Linde Station, West Sacramento, CA. Photo: NREL

Overall Objectives

- Validate hydrogen infrastructure
- Identify status and technological improvements
- Provide feedback to hydrogen research
- Publish results for stakeholder use

Relevance: Metrics to Evaluate Infrastructure

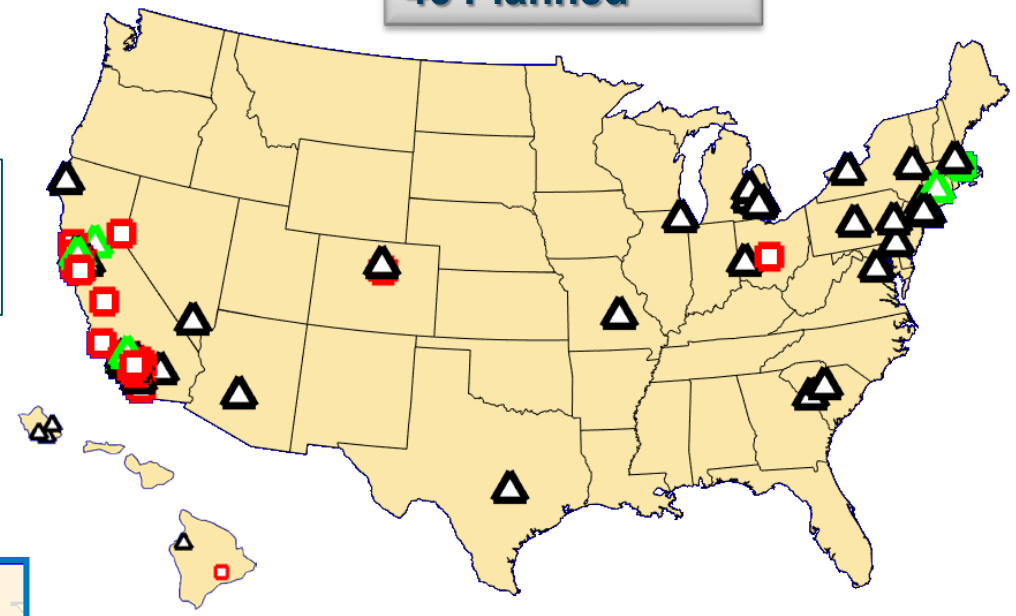
Use metrics to clearly evaluate progress toward challenges

- **Location/Capacity/Utilization**
  - ***Challenge:*** Station coverage, hydrogen availability, minimal wait time.
  - ***Metrics:*** Station usage patterns and geographic locations
- **Fueling**
  - ***Challenge:*** Vehicles fueled in an acceptable amount of time
  - ***Metrics:*** Fueling rates, times, amounts, back-to-back fills, communication
- **Maintenance/Availability**
  - ***Challenge:*** Maintenance and downtime increase cost and impact customers
  - ***Metrics:*** Maintenance patterns, reliability and availability of stations
- **Cost**
  - ***Challenge:*** Hydrogen cost is dependent on several factors including where produced, how delivered, efficiencies, and maintenance requirements
  - ***Metrics:*** Energy cost, maintenance cost, station cost
- **Station Timing**
  - ***Challenge:*** Lead time to build out infrastructure to meet vehicle demand
  - ***Metrics:*** Permitting time, building time, commissioning time

Approach: Station Locations

Legend
- Operational
- Future
- Current Project

51 Operational
46 Planned



- Maintain database of hydrogen stations in the U.S.
- Sync location data with:
  - Alternative Fuels Data Center (AFDC)
  - Pacific Northwest National Laboratory (PNNL)
  - FCHEA

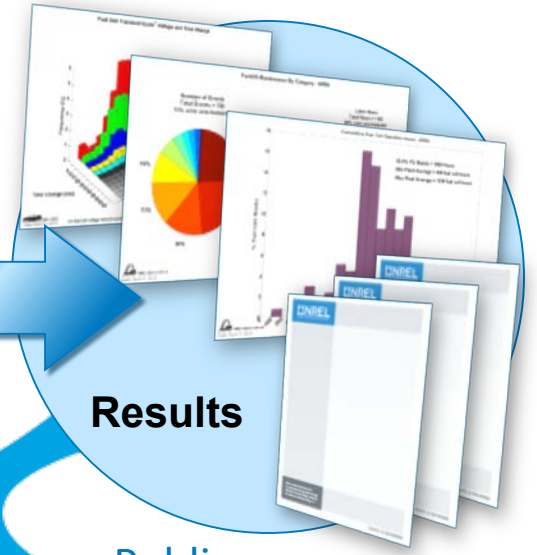
Approach: National Fuel Cell Technology Evaluation Center (NFCTEC)

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

DDPs

Internal analysis completed quarterly

NREL's National Fuel Cell Technology Evaluation Center



Results

Confidential

Public

CDPs

Detailed Data Products (DDPs)
- Individual data analyses
- Identify individual contribution to CDPs
- Only shared with partner who supplied data every 6 months[1]

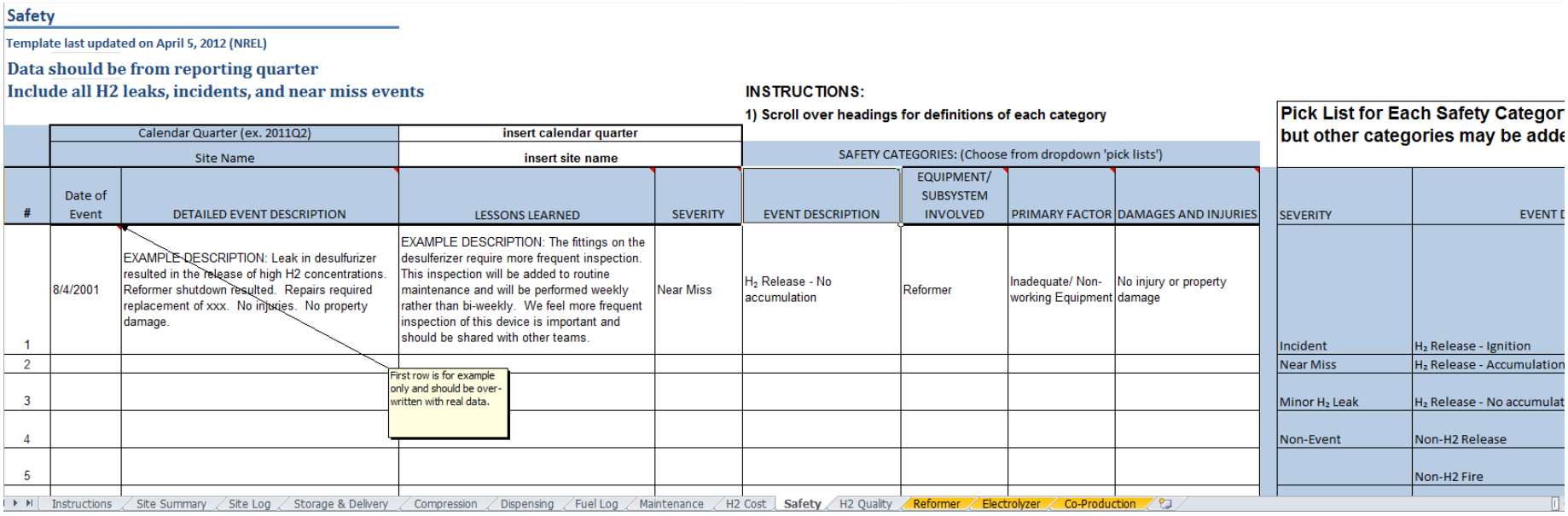
Composite Data Products (CDPs)
- Aggregated data across multiple systems, sites, and teams
- Publish analysis results without revealing proprietary data every 6 months[2]

1) Data exchange may happen more frequently based on data, analysis, and collaboration
2) Results published via NREL Tech Val website, conferences, and reports

Approach: Data and Templates

Data templates developed to collect similar data from multiple projects

- **Updated as new topics develop**
  - Future updates needed for items such as station downtime and validating J2601 fills.
- **Shared with others**
  - California Air Resources Board projects
  - California Energy Commission for inclusion in Program Opportunity Notices (PONs) and awards
  - Safety and Maintenance templates/data discussed with International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) to coordinate international data sharing



Safety

Template last updated on April 5, 2012 (NREL)

Data should be from reporting quarter
Include all H2 leaks, incidents, and near miss events

INSTRUCTIONS:
1) Scroll over headings for definitions of each category

	Calendar Quarter (ex. 2011Q2)	insert calendar quarter		SAFETY CATEGORIES: (Choose from dropdown 'pick lists')			
	Site Name	insert site name					
#	Date of Event	DETAILED EVENT DESCRIPTION	LESSONS LEARNED	SEVERITY	EVENT DESCRIPTION	EQUIPMENT/ SUBSYSTEM INVOLVED	PRIMARY FACTOR	DAMAGES AND INJURIES
1	8/4/2001	EXAMPLE DESCRIPTION: Leak in desulfurizer resulted in the release of high H2 concentrations. Reformer shutdown resulted. Repairs required replacement of xxx. No injuries. No property damage.	EXAMPLE DESCRIPTION: The fittings on the desulferizer require more frequent inspection. This inspection will be added to routine maintenance and will be performed weekly rather than bi-weekly. We feel more frequent inspection of this device is important and should be shared with other teams.	Near Miss	H_2 Release - No accumulation	Reformer	Inadequate/ Non-working Equipment	No injury or property damage
2								
3								
4								
5								

First row is for example only and should be over-written with real data.

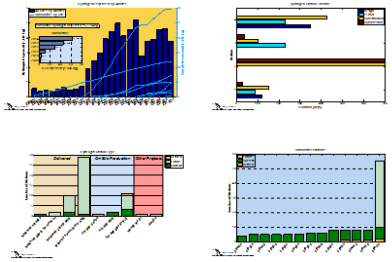
Pick List for Each Safety Categor
but other categories may be adde

SEVERITY	EVENT D
Incident	H_2 Release - Ignition
Near Miss	H_2 Release - Accumulation
Minor H_2 Leak	H_2 Release - No accumulat
Non-Event	Non-H2 Release
	Non-H2 Fire

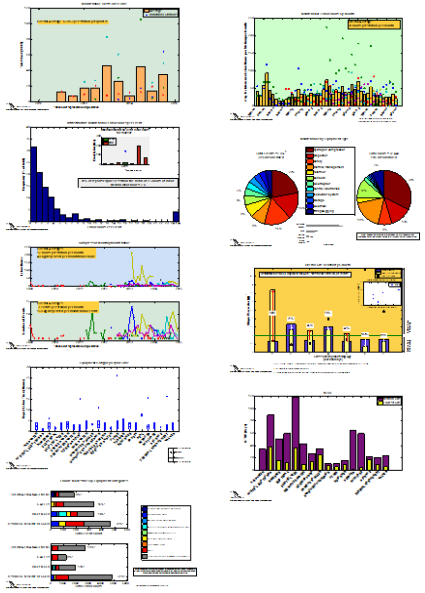
Instructions | Site Summary | Site Log | Storage & Delivery | Compression | Dispensing | Fuel Log | Maintenance | H2 Cost | Safety | H2 Quality | Reformer | Electrolyzer | Co-Production

Accomplishment: 43 Infrastructure CDPs – 9 Categories

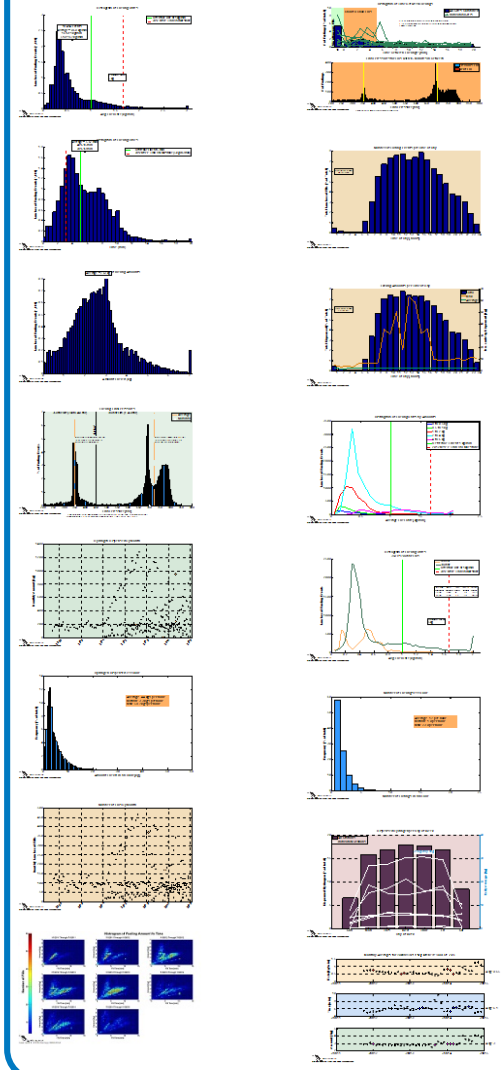
Deployment and Overview *(1,10,11,27)*



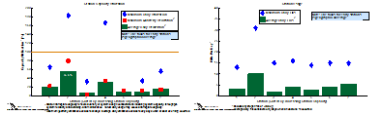
Maintenance, Reliability, Availability *(21,22,23,24,26,28,30,37,38)*



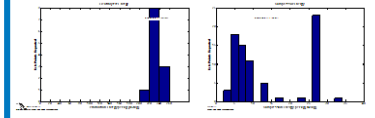
Refueling *(2,3,4,5,8,9,12,13,14,15,16,17, 18,19,20)*



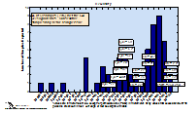
Utilization *(6,7)*



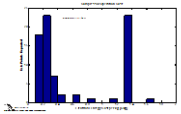
Efficiency *(35,36)*



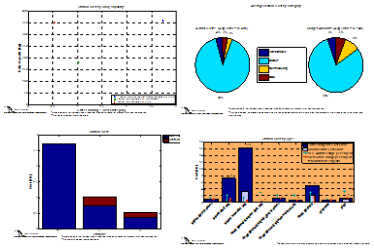
H2 Quality *(25)*



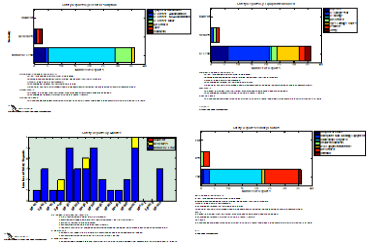
Operation Cost *(39)*



Station Cost *(40,41,42,43)*



Safety *(31,32,33,34)*

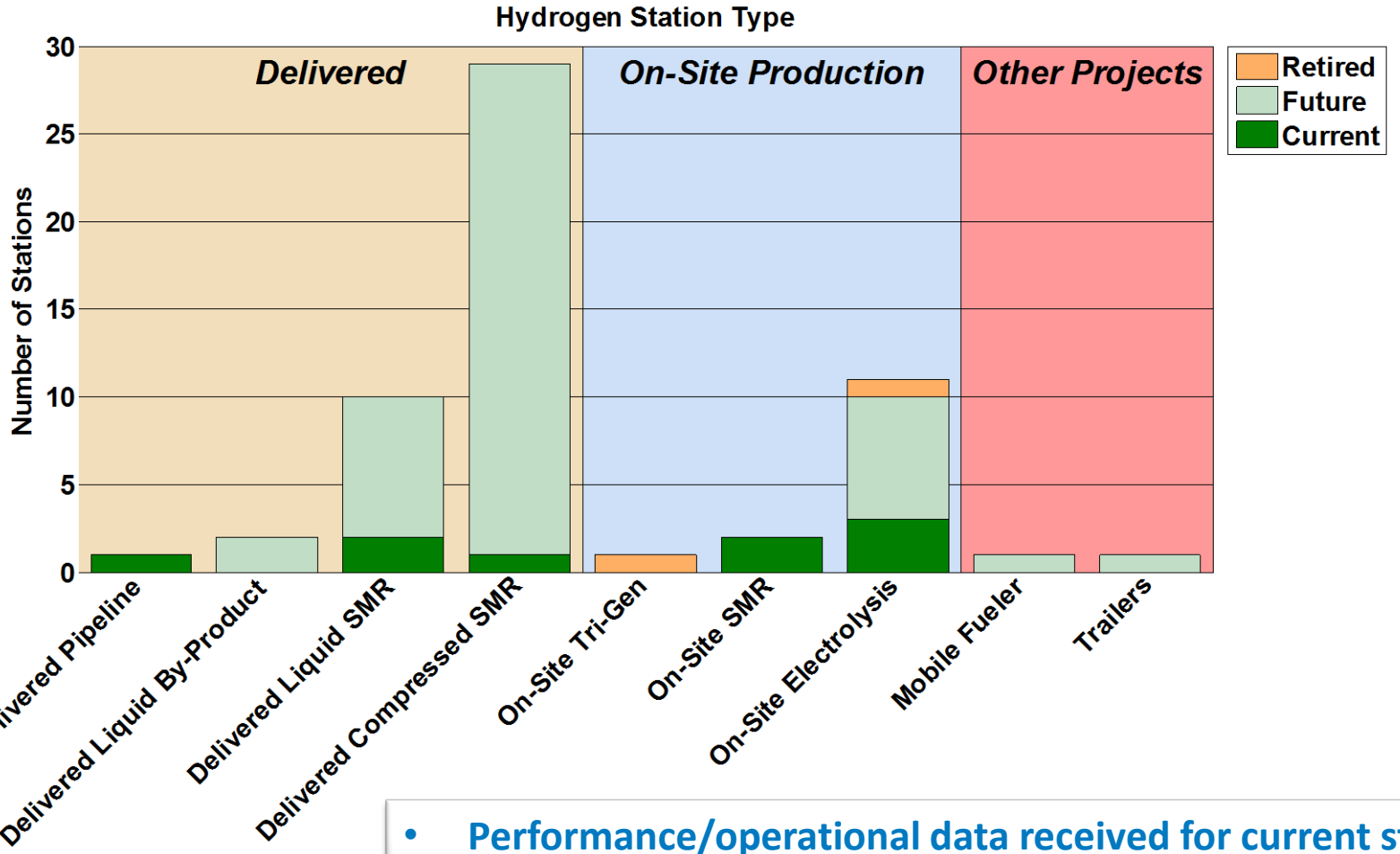


CDPs created from infrastructure data through 12/2014

Hydrogen Infrastructure Composite Data Products (CDPs)

A subset of the infrastructure CDPs presented here. All CDPs, including other projects, available at www.nrel.gov/hydrogen/proj_tech_validation

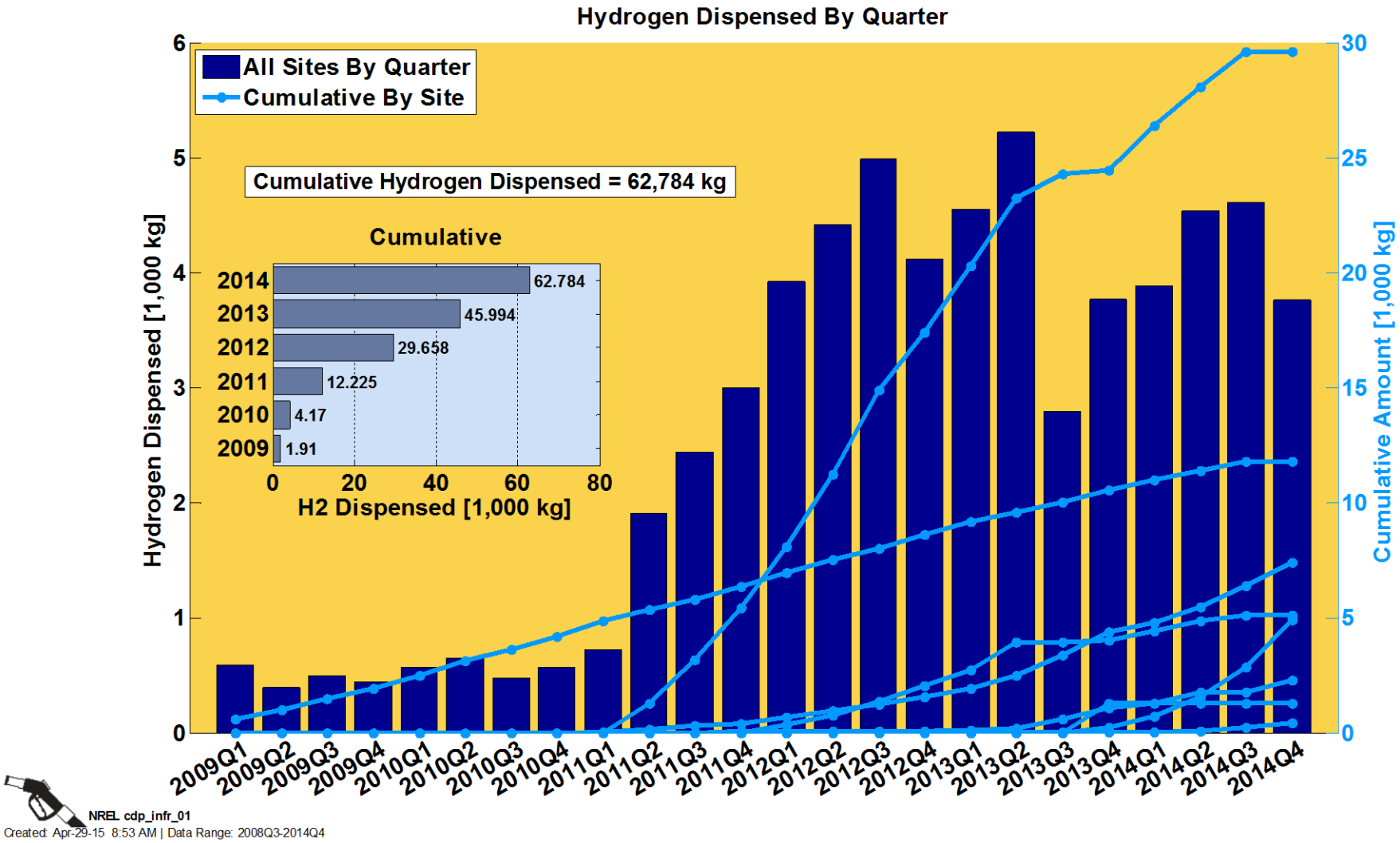
Accomplishments and Progress:
Hydrogen Stations by Type



NREL cdp_infr_11
Created: Apr-24-15 10:29 AM | Data Range: 2009Q1-2014Q4

- Performance/operational data received for current stations (except those recently operational)
- Award data received for future stations

Accomplishments and Progress:
Hydrogen Dispensed by Quarter



NREL cdp_infr_01

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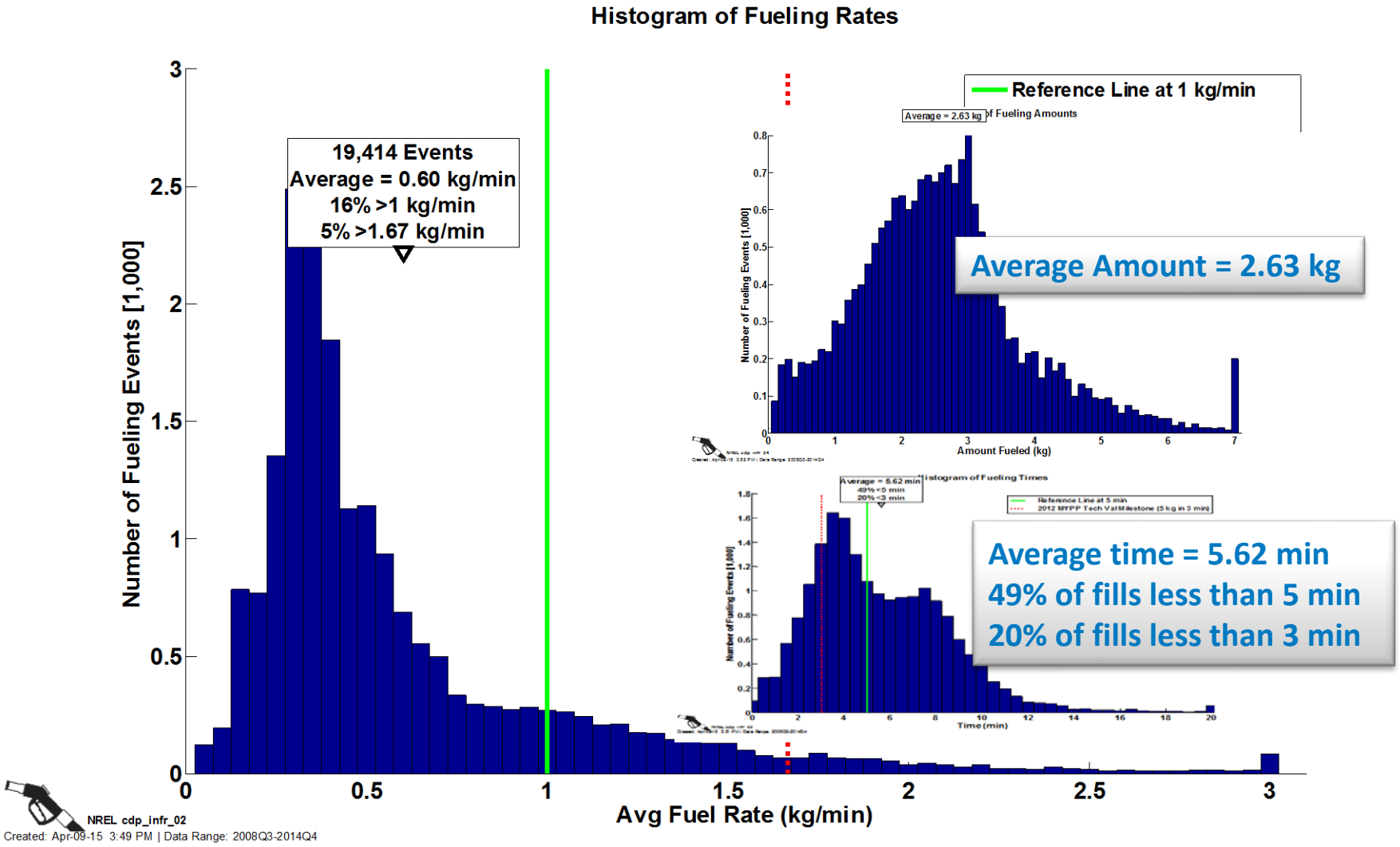
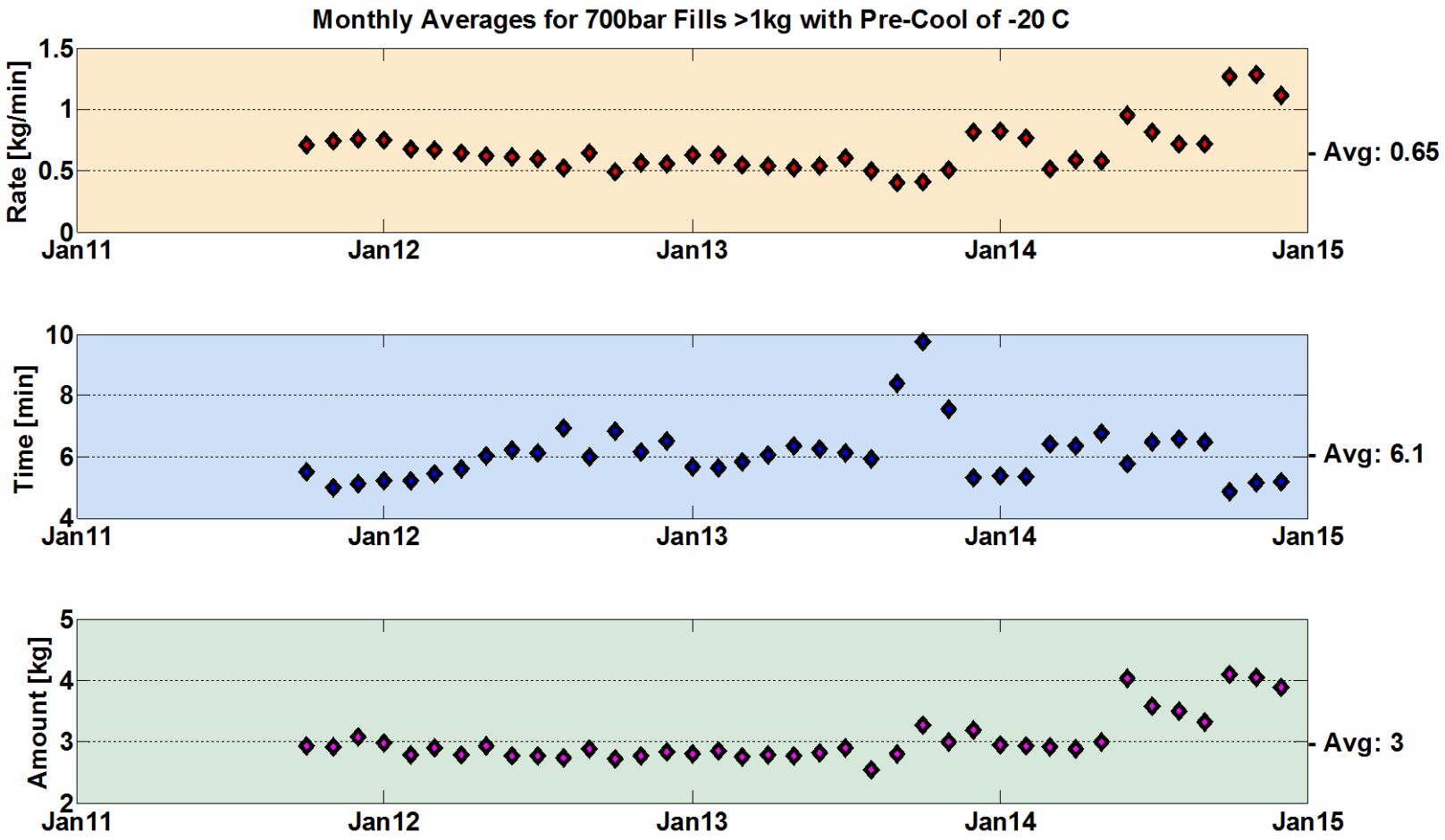
Accomplishments and Progress:
Histogram of Fueling Rates, Times, Amounts



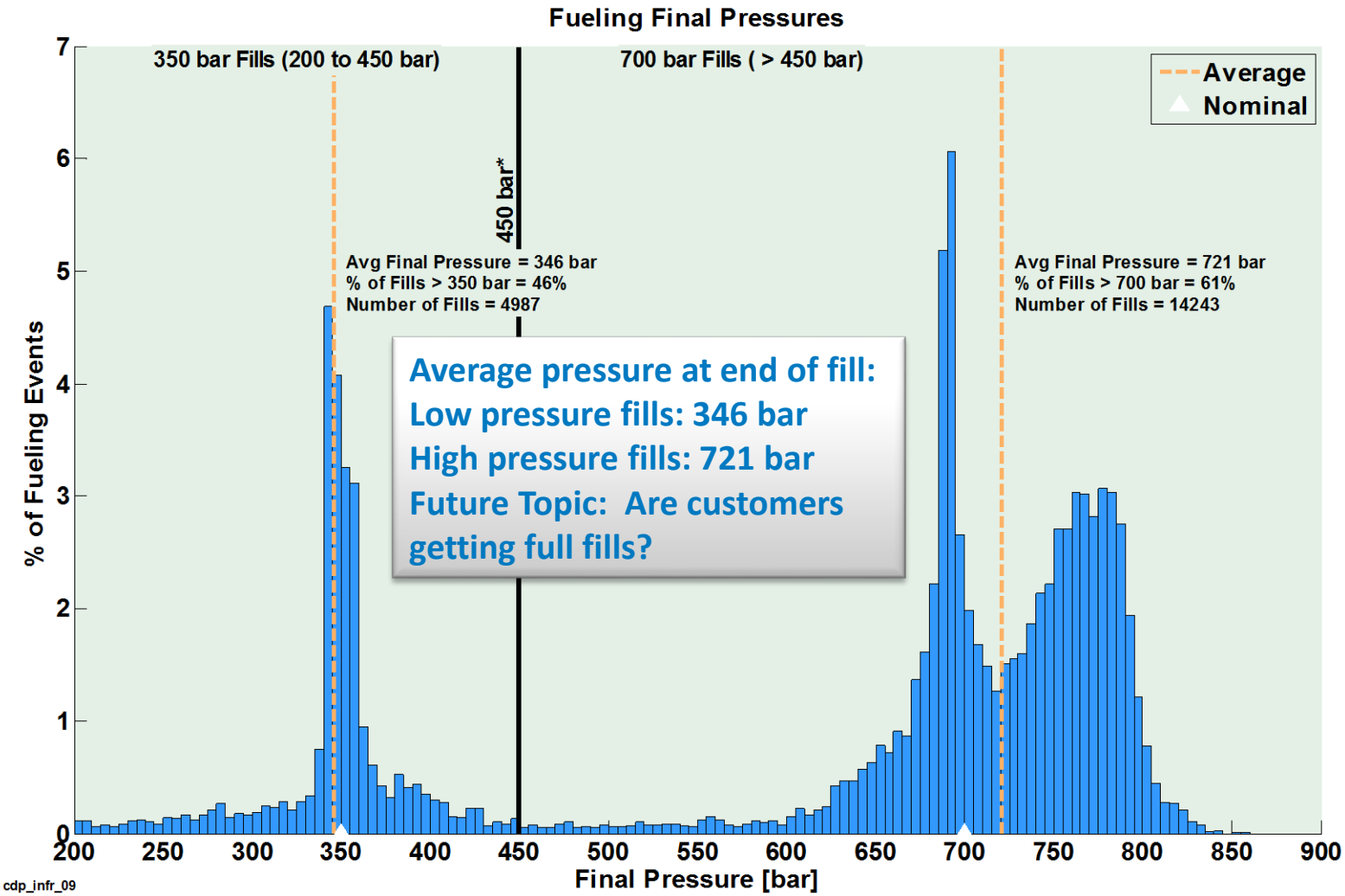
Accomplishments and Progress:
Monthly Averages for 700bar Fills >1kg with Pre-Cool of -20C



NREL cdp_infr_29
Created: Apr-09-15 4:11 PM | Data Range: 2009Q1-2014Q4

Averages for this subset:
Rate = 0.65 kg/min, Time = 6.1 min, Amount = 3 kg

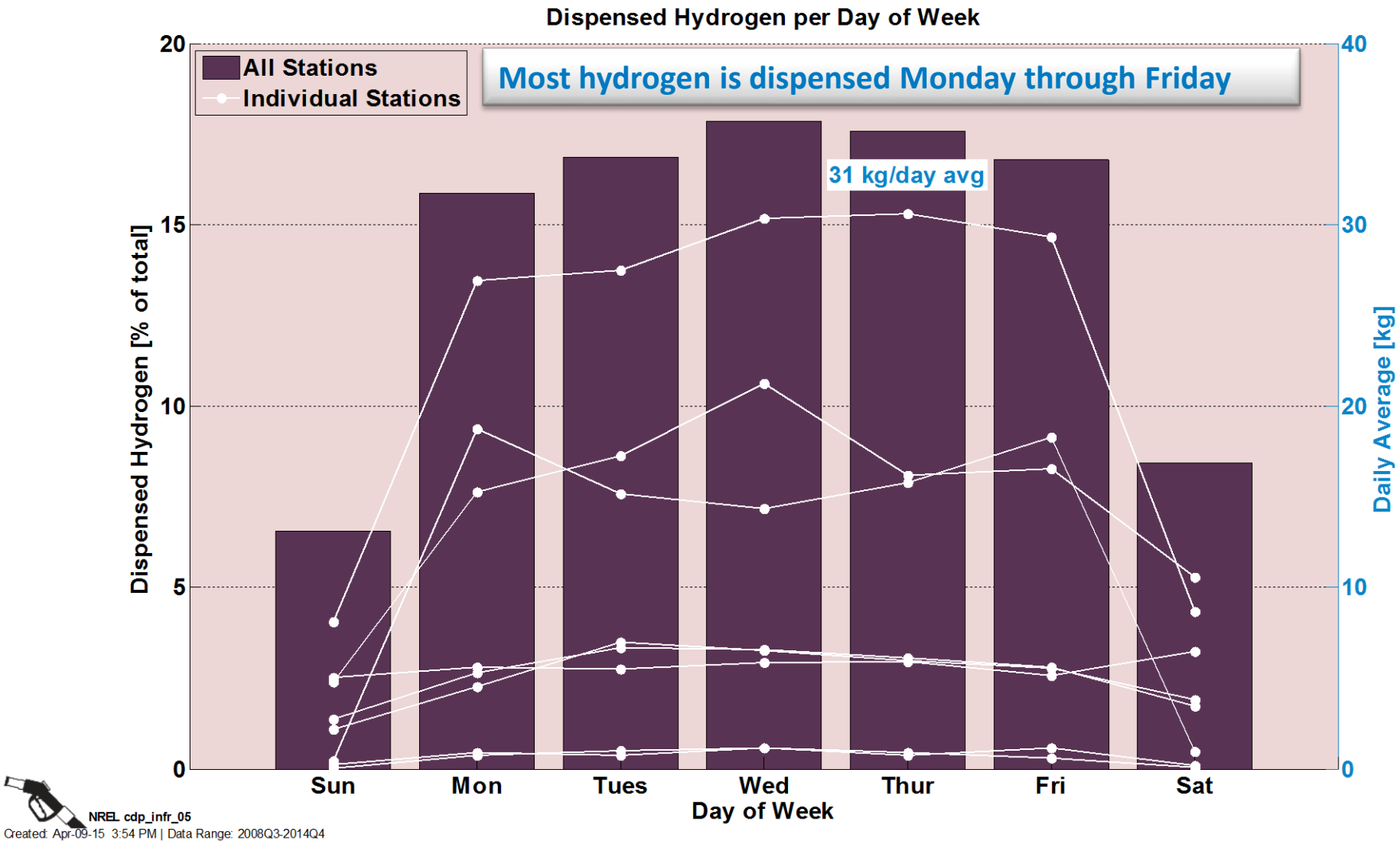
Accomplishments and Progress: Fueling Final Pressures



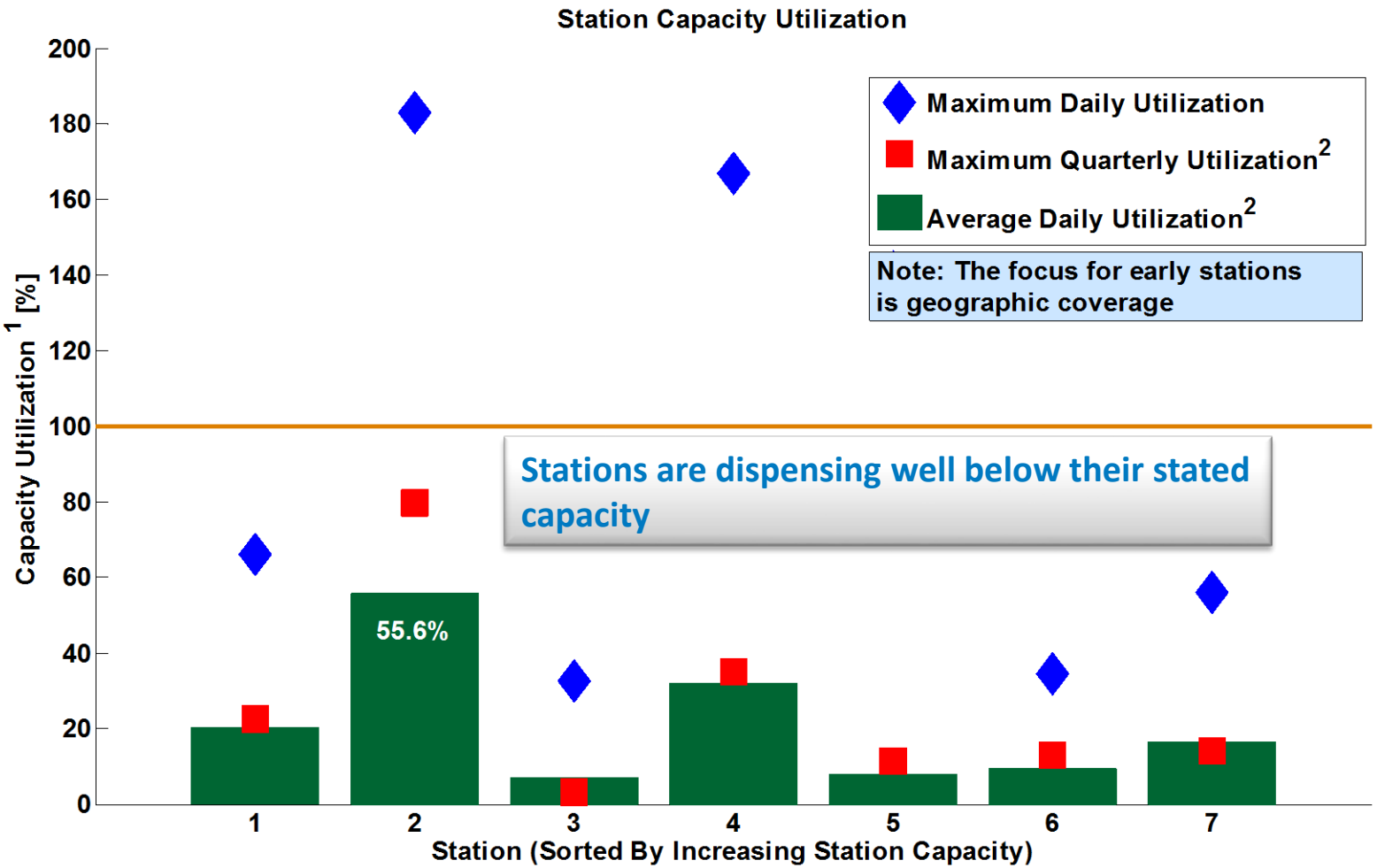
NREL cdp_infr_09
Created: Apr-09-15 3:58 PM | Data Range: 2008Q3-2014Q4

*The line at 450 bar separates 350 bar fills from 700 bar fills. It is slightly over the allowable 125% of nominal pressure (437.5 bar) from SAE J2601.

Accomplishments and Progress:
Dispensed Hydrogen per Day of Week



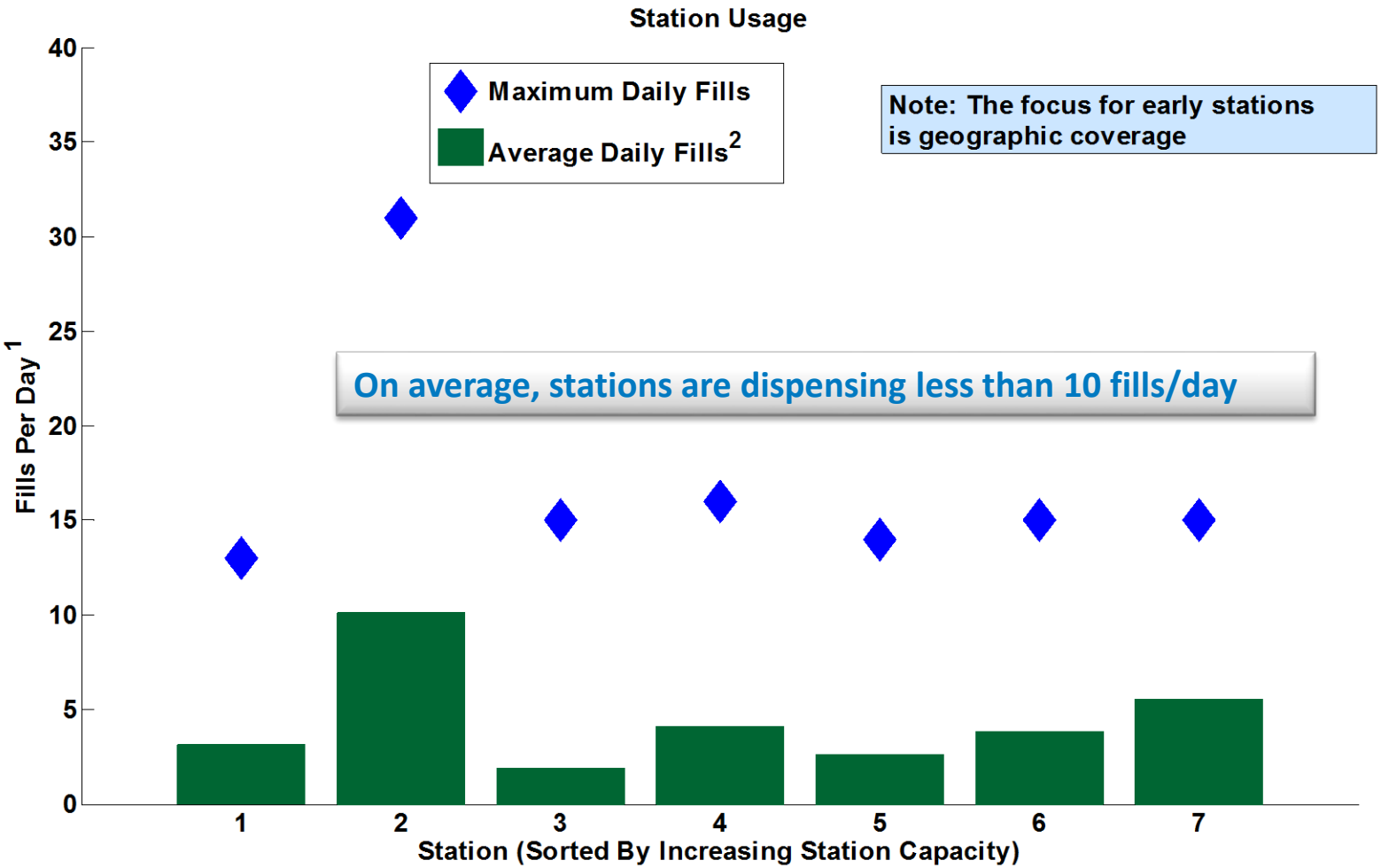
Accomplishments and Progress:
Station Capacity Utilization



NREL cdp_infr_06
Created: Apr-09-15 3:55 PM | Data Range: 2008Q3-2014Q4

[1] Station nameplate capacity reflects a variety of system design consderations including system capacity, throughput, system reliability and durability, and maintenance. Actual daily usage may exceed nameplate capacity.
[2] Maximum quarterly utilization considers all days; average daily utilization considers only days when at least one filling occurred

Accomplishments and Progress: Station Usage

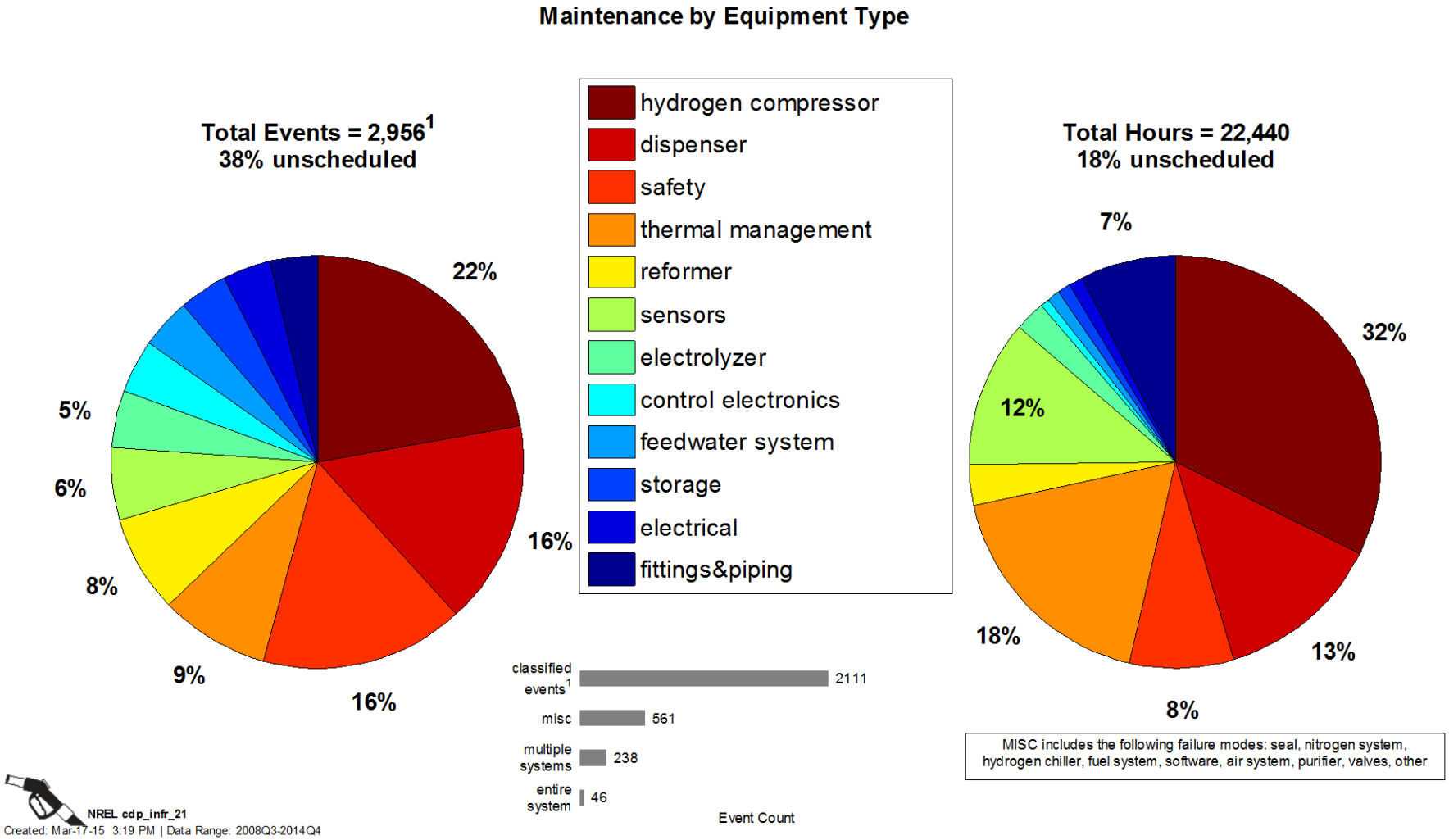


NREL cdp_infr_07
Created: Apr-09-15 3:56 PM | Data Range: 2008Q3-2014Q4

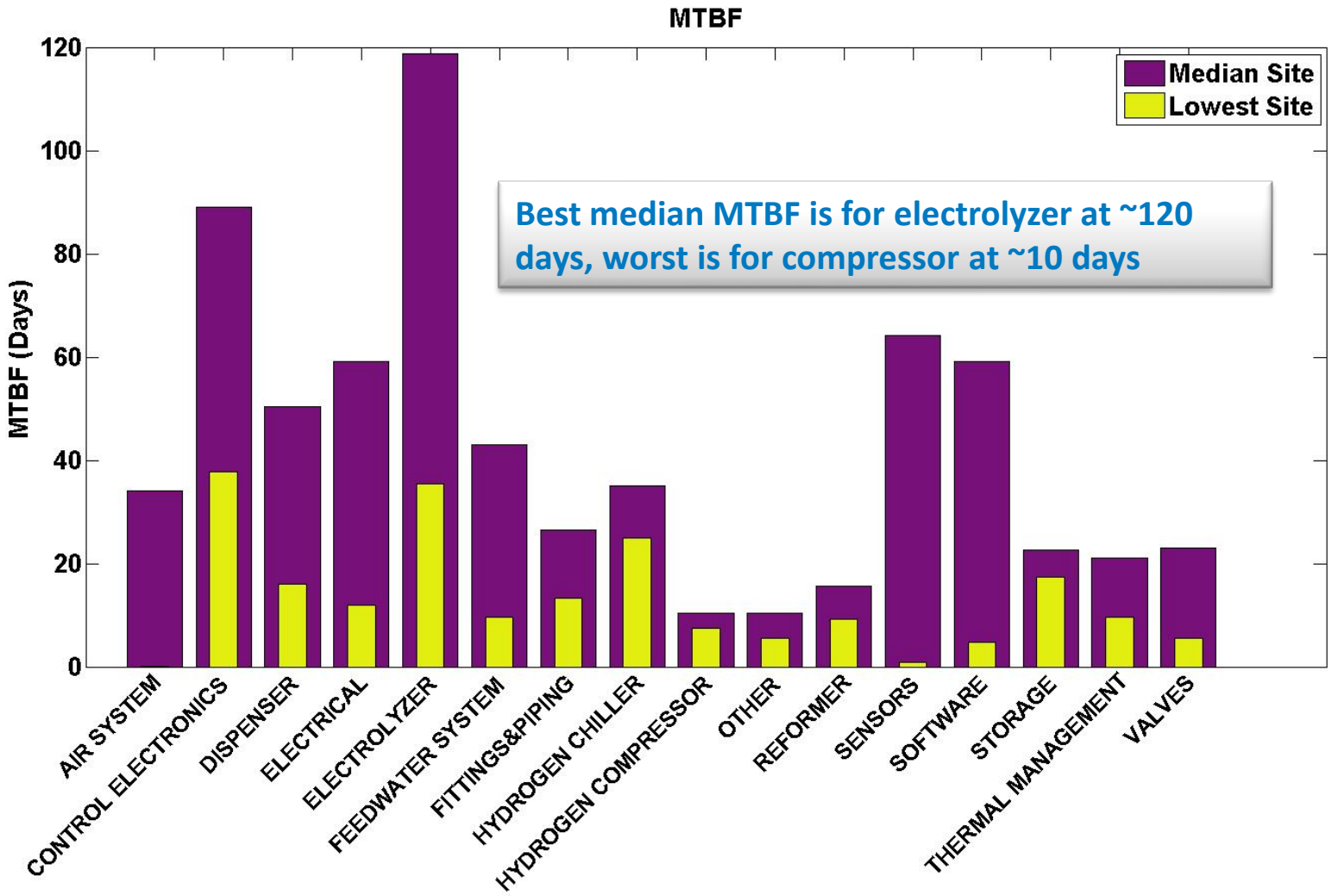
[1] Excludes hydrogen fills of < 0.5 kg
[2] Average daily fills considers only days when at least one fill occurred

Accomplishments and Progress:
Maintenance by Equipment Type

Most maintenance related to compressors and dispensers



Accomplishments and Progress: Maintenance MTBF



NREL cdp_infr_38
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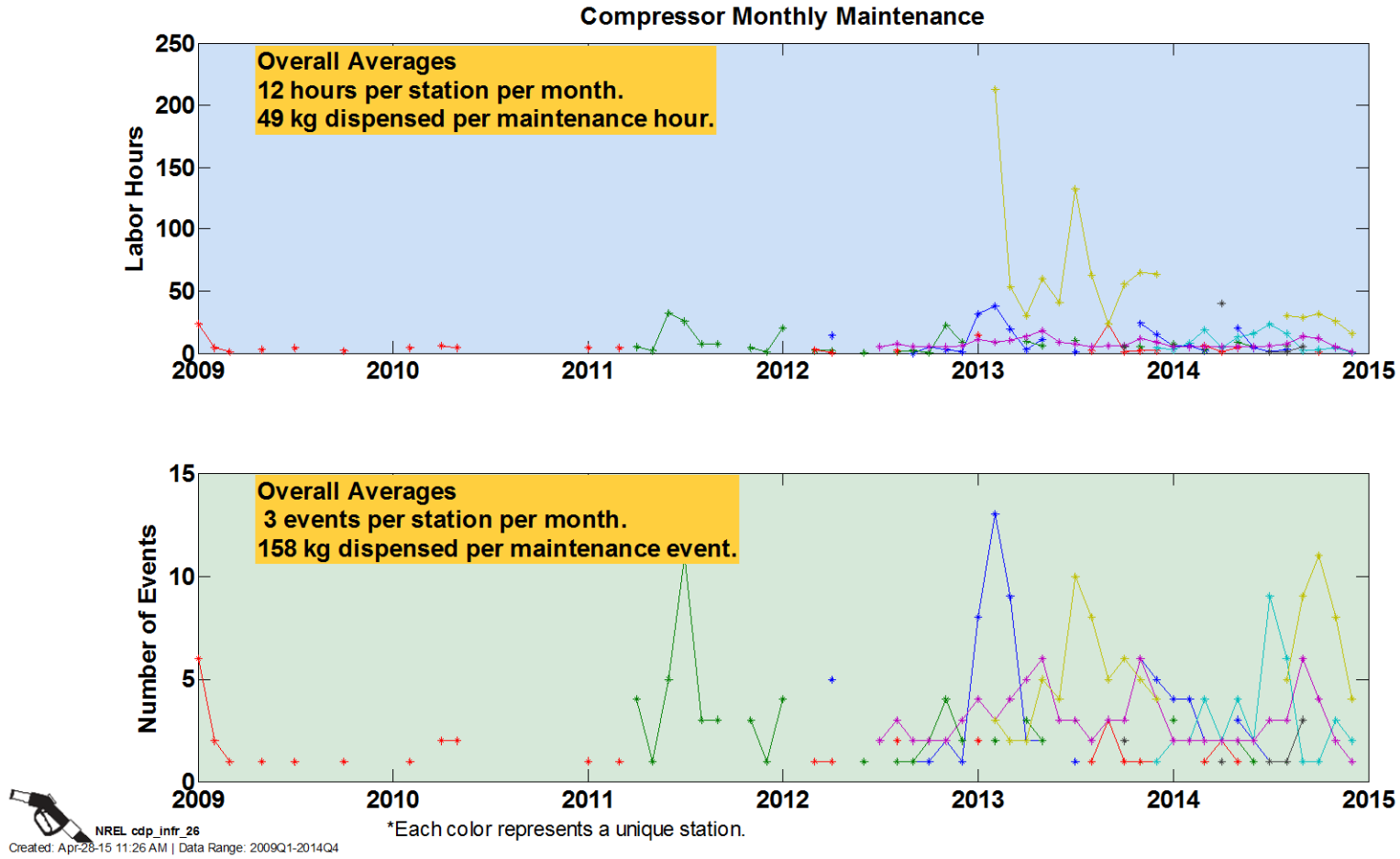
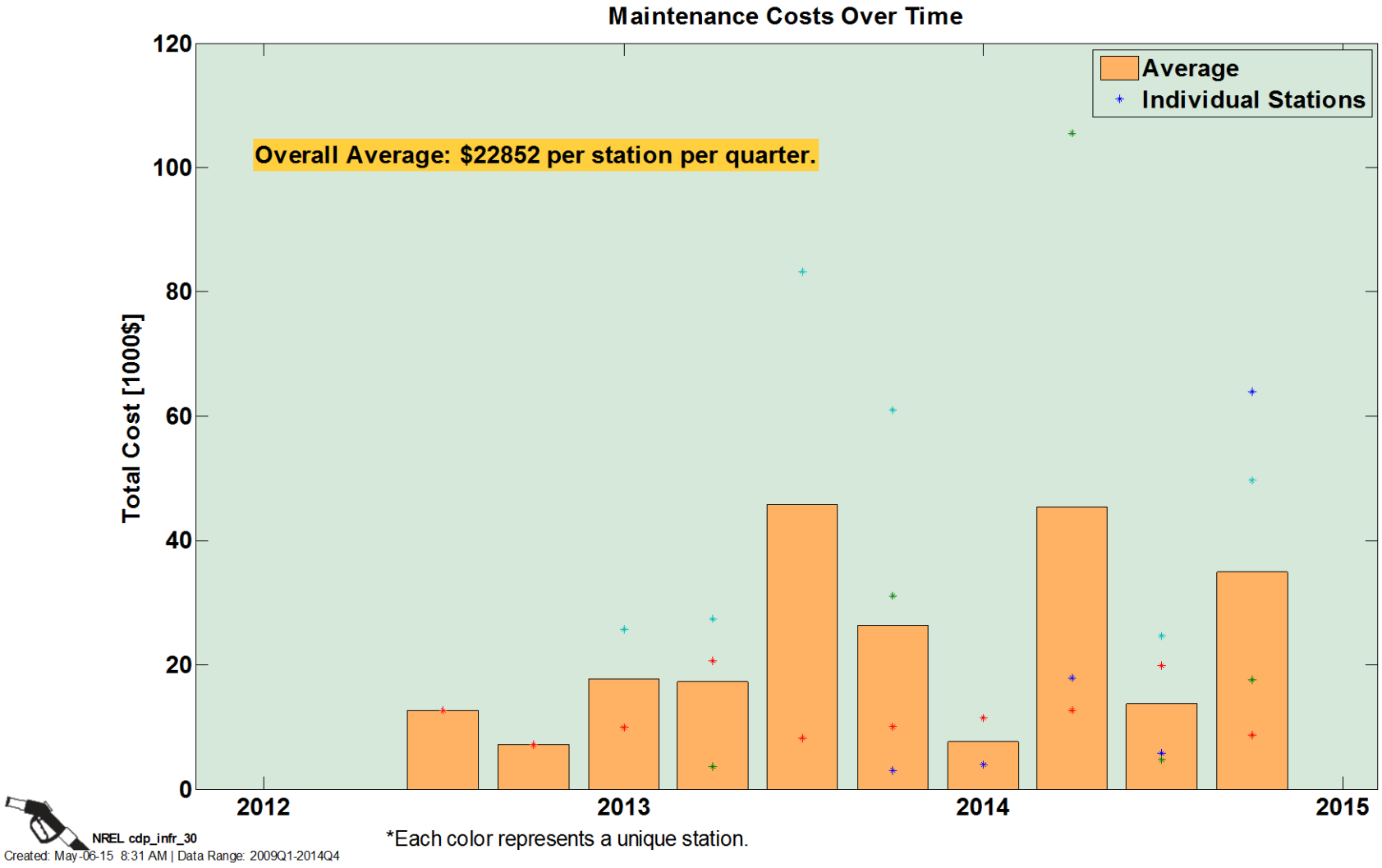
Accomplishments and Progress:
Compressor Monthly Maintenance

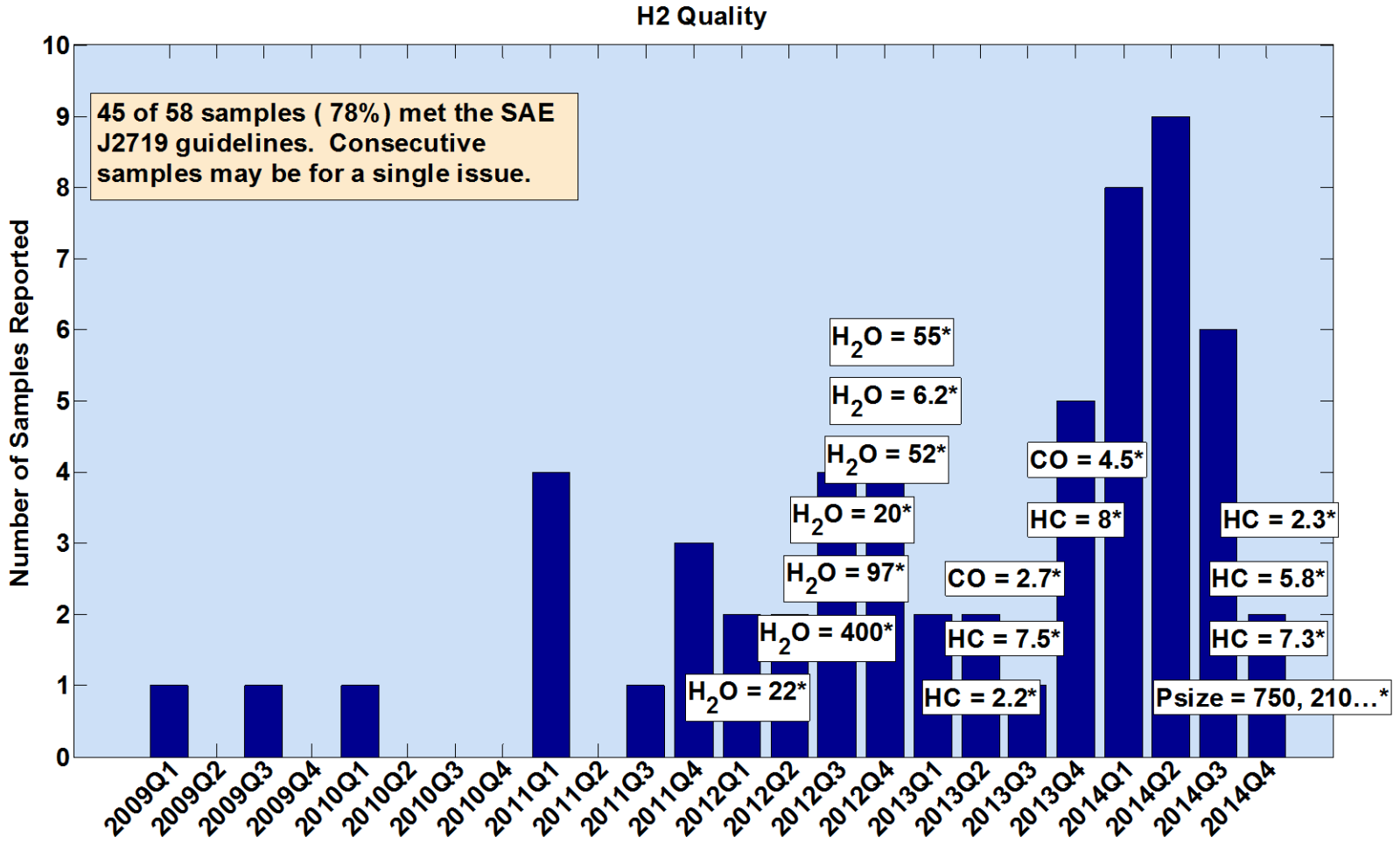
For compressors, the average per station is 3 maintenance events and 12 labor hours per month with 158 kg dispensed per maintenance event. For all maintenance items, the station average is 38 labor hours per month.



CDP-INFR-30
Maintenance Costs Over Time



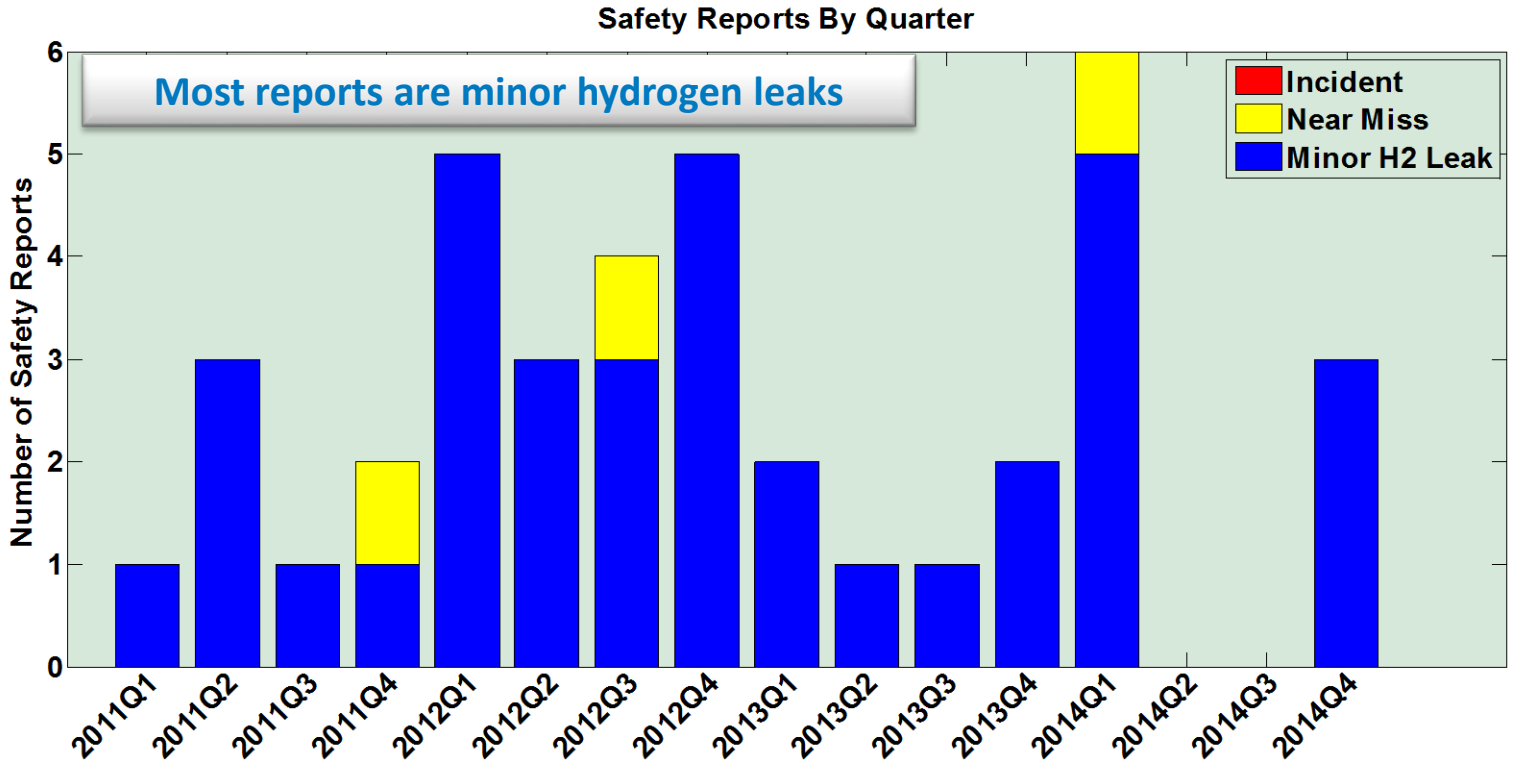
Accomplishments and Progress:
H2 Quality



NREL cdp_infr_25
Created: Mar-18-15 4:45 PM | Data Range: 2008Q3-2014Q4

*Values are in micromole/mole, except for particulate size (Psize) in micrometer. Only values that exceed SAE J2719 guideline are shown in text. Left edge of text box aligns with date

Accomplishments and Progress:
Safety Reports by Quarter



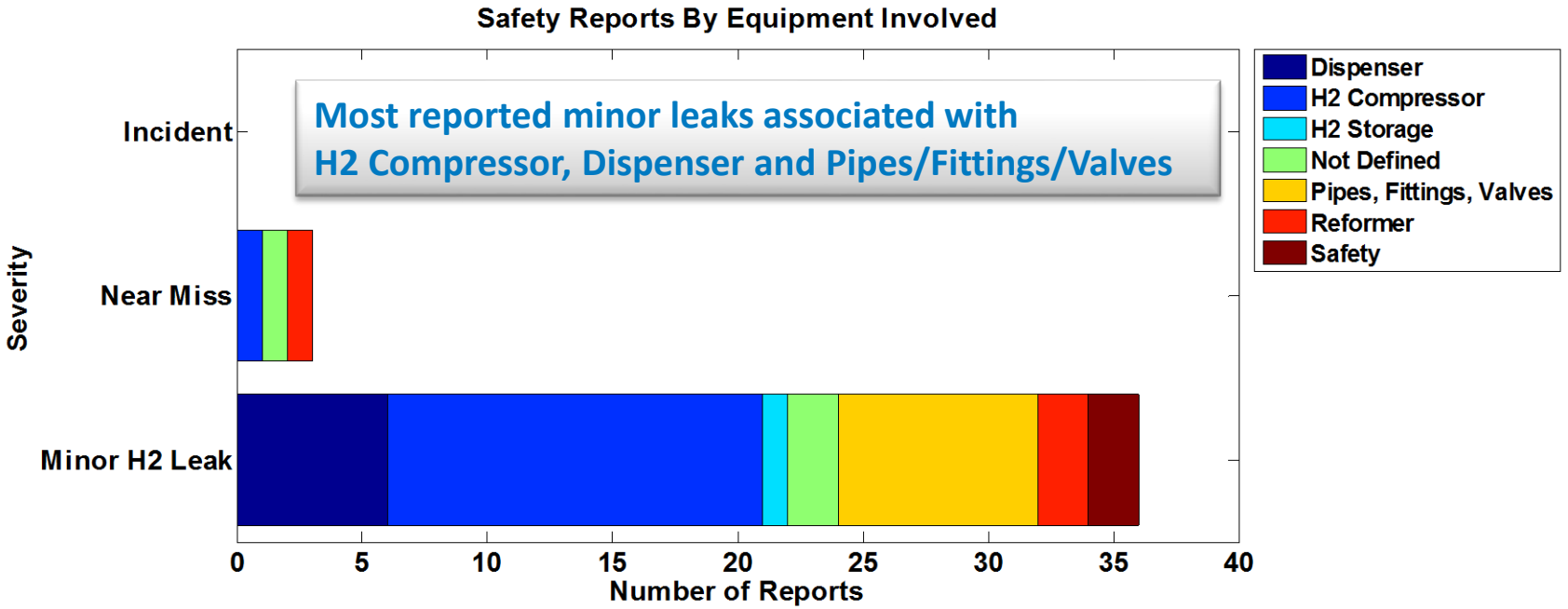
An Incident is an event that results in:
- a lost time accident and/or injury to personnel
- damage/unplanned downtime for project equipment, facilities or property
- impact to the public or environment
- any hydrogen release that unintentionally ignites
- release of any volatile, hydrogen containing compound (including the hydrocarbons used as common fuels)

A Near Miss is:
- an event that under slightly different circumstances could have become an incident
- any hydrogen release sufficient to sustain a flame if ignited

A Minor H2 Leak is:
- an unplanned hydrogen release insufficient to sustain a flame, and does not accumulate in sufficient quantity to ignite

NREL cdp_infr_33
Created: May-04-15 11:39 AM | Data Range: 2009Q1-2014Q4

Accomplishments and Progress:
Safety Reports by Equipment Involved



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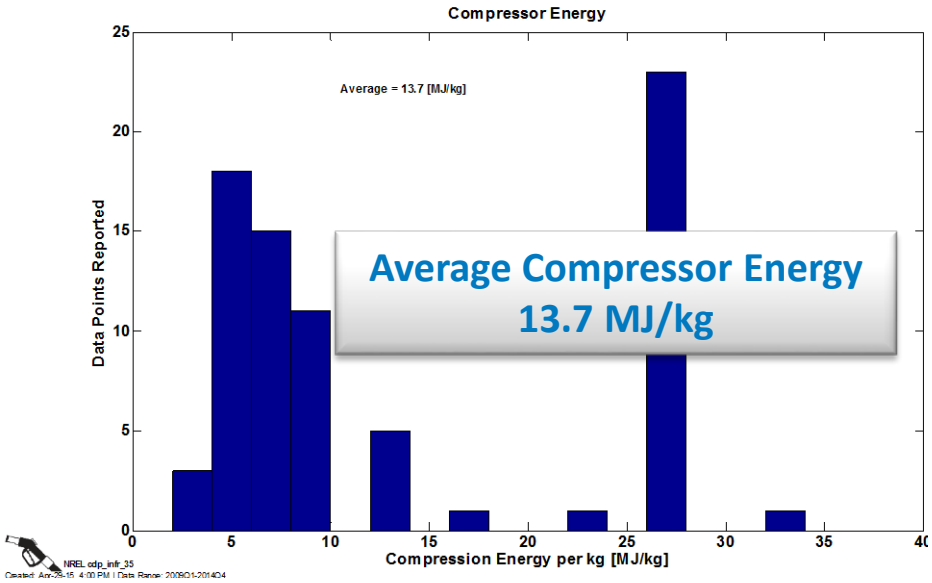
A Minor H2 Leak is:
- an unplanned hydrogen release insufficient to sustain a flame, and does not accumulate in sufficient quantity to ignite

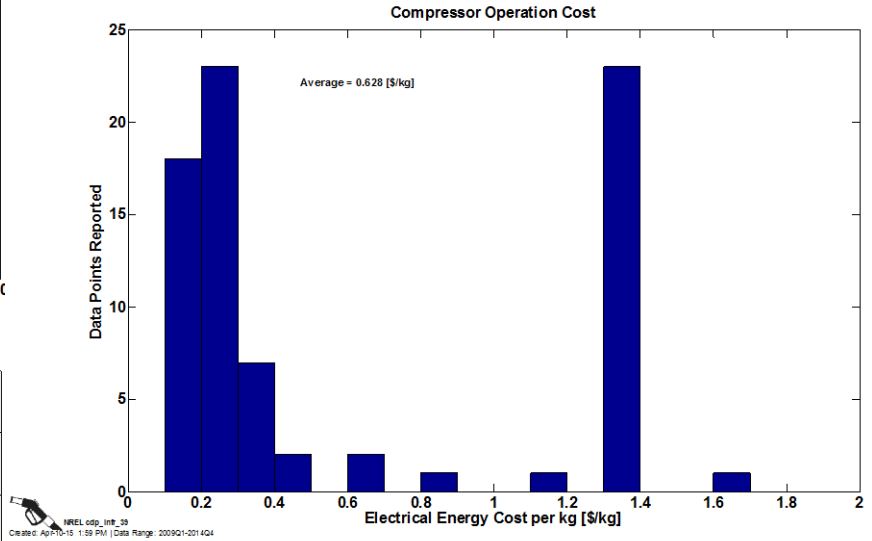
NREL cdp_infr_32
Created: May-04-15 11:39 AM | Data Range: 2009Q1-2014Q4

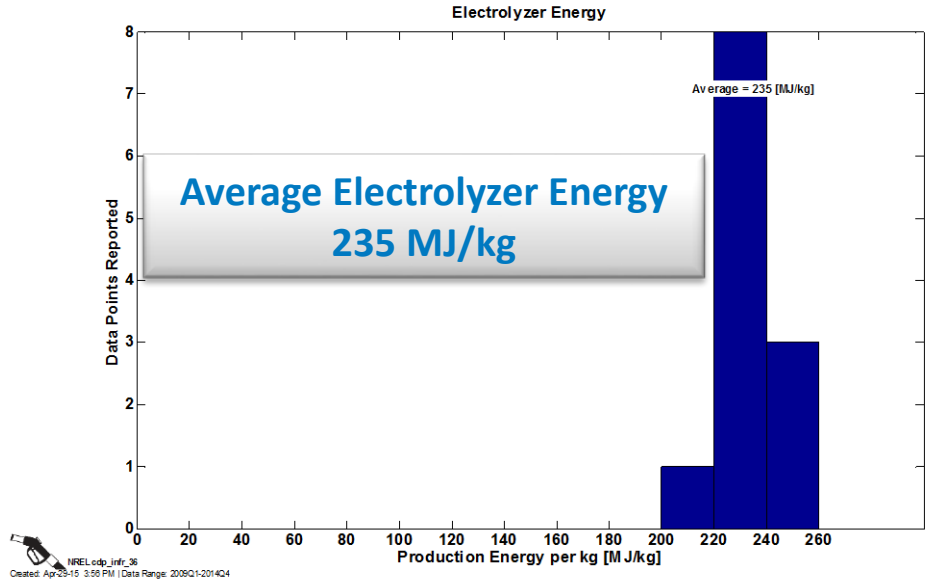
Accomplishments and Progress:
Energy and Cost per kg of Hydrogen



Average Compressor Energy
13.7 MJ/kg

Average Compressor Energy Cost
$0.628/kg



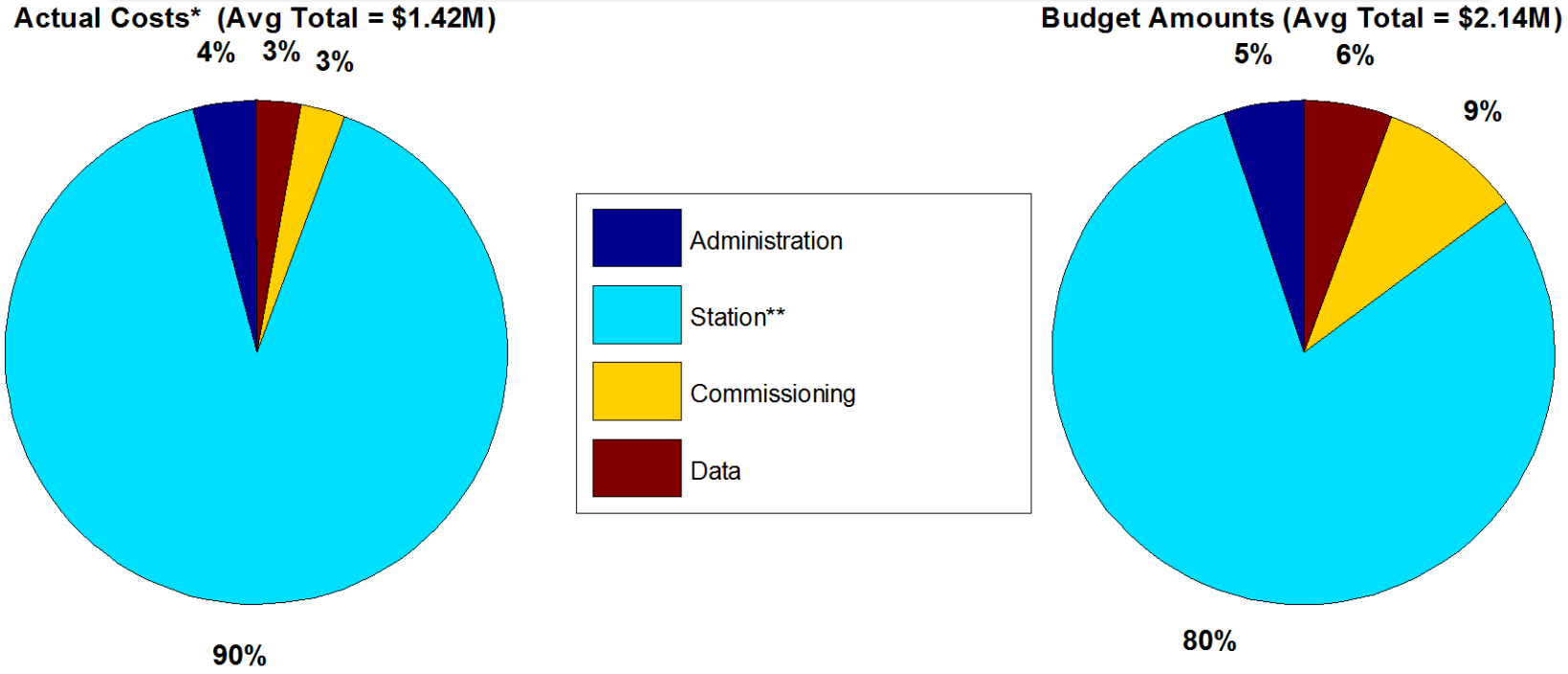


Average Electrolyzer Energy
235 MJ/kg

Accomplishments and Progress: Station Costs

Average Station Cost by Category

Based on award data, the stations that are near operational are expected to cost $2.14M on average (including cost share). This includes different station types and will be updated by type as more stations come online.

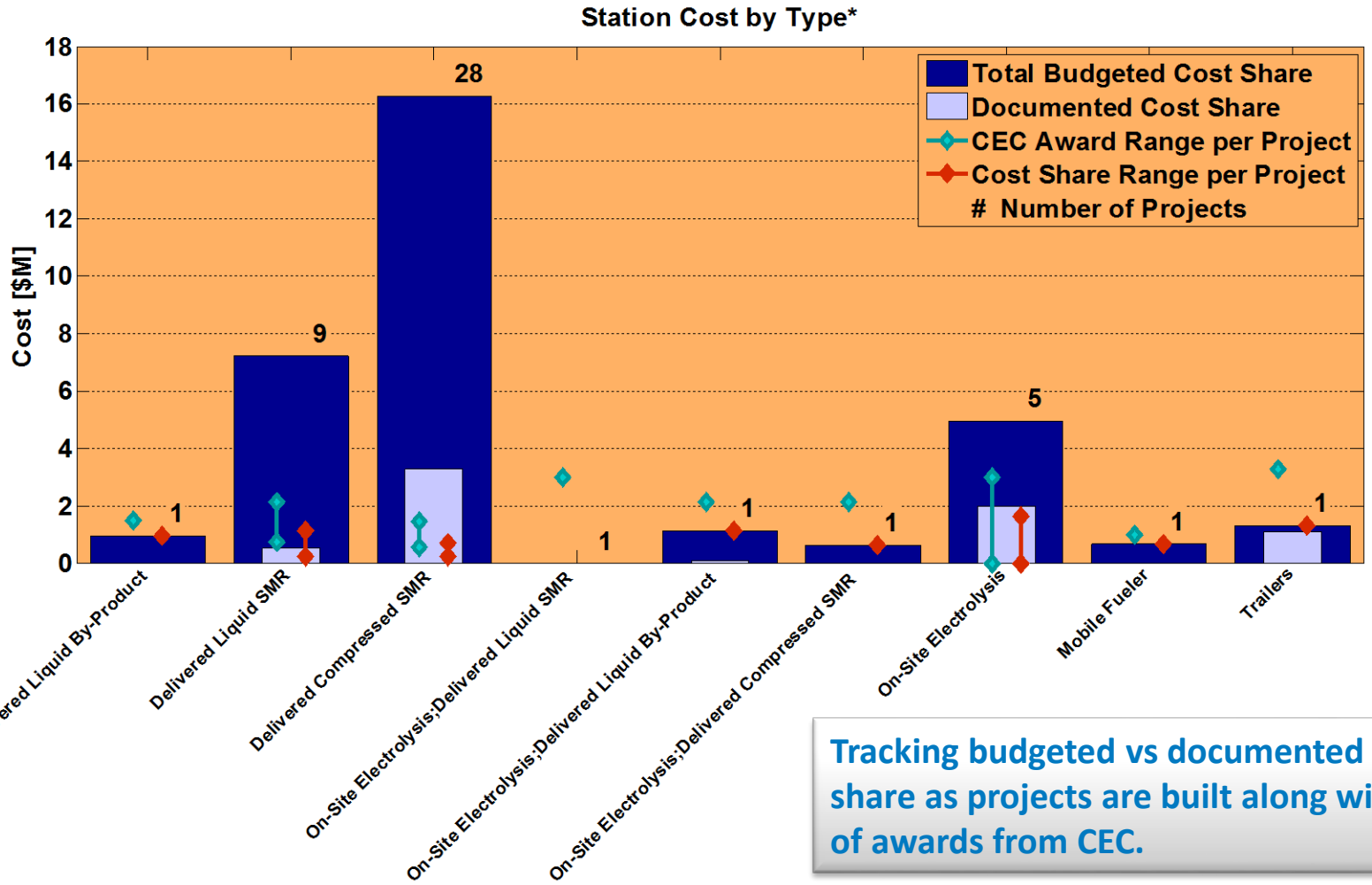


NREL cdp_infr_41
Created: Apr-29-15 9:07 AM | Data Range: 2009Q1-2014Q4

*Based on data that includes costs reported through 2014Q4 for projects at or near completion.

**Station includes: Hydrogen Equipment and Station Engineering, Design, Fabrication, Procurement, Site Preparation, Installation, and Construction

Accomplishments and Progress: Station Cost by Type



Tracking budgeted vs documented cost share as projects are built along with range of awards from CEC.

NREL cdp_infr_43
Created: May-05-15 3:58 PM | Data Range: 2009Q1-2014Q4

*Based on California Energy Commission data that includes costs reported through 2014Q4.

Accomplishments and Progress:
Responses to Previous Year Reviewers' Comments

- **This project was not reviewed last year.**

Collaborations

Data, feedback, and interactions with infrastructure partners makes this project work

- **Memorandum of Understanding between CEC/NREL**
  - Data templates included in Program Opportunity Notices/Awards
  - Will provide cost data as well as performance/operation data on latest infrastructure projects
- **Partners providing data through DOE funding or voluntarily:**
  - California Air Resources Board, California State University Los Angeles, Gas Technologies Institute, Hydrogen Frontier, Linde, Shell, Proton OnSite
- **Organizations**
  - California Fuel Cell Partnership Working Group
  - H2USA Hydrogen Fueling Station Working Group
  - IPHE for international data sharing

Proposed Future Work

- **Fall 2015**
  - Complete quarterly analysis of CY15 Q1 and Q2 data
  - Publish analysis results (10/2015)
- **Spring 2016**
  - Complete quarterly analysis of CY15 Q3 and Q4 data
  - Publish analysis results (4/2016)
- **Update data collection and analysis to address:**
  - Availability of stations
  - Performance compared to fueling standards
  - Usage of data results by others (cost analysis, safety, network health, customer satisfaction)
  - How metrics are changing over time

Summary

- **Relevance**
  - Independent validation of hydrogen infrastructure
- **Approach**
  - Collaborate with industry partners
  - Continue to develop core NFCTEC and analysis capability and tools
  - Leverage 7+ years of analysis and experience from the Learning Demonstration
- **Technical Accomplishments and Progress**
  - Analyzed performance data from 8 stations and cost data from planned stations
  - Performed detailed reviews of individual data results
  - Published results via CDPs that cover topics of station daily utilization compared to maximum demonstrated capacity, maintenance, fueling performance, operation costs, and efficiencies
- **Collaborations**
  - Working closely with industry and government partners to validate methodology and with key stakeholders to ensure relevance and accuracy of results
- **Future Work**
  - Complete analysis of hydrogen infrastructure and update results in Fall 2015; add new analysis topics
  - Identify new opportunities to document hydrogen infrastructure progress

NREL
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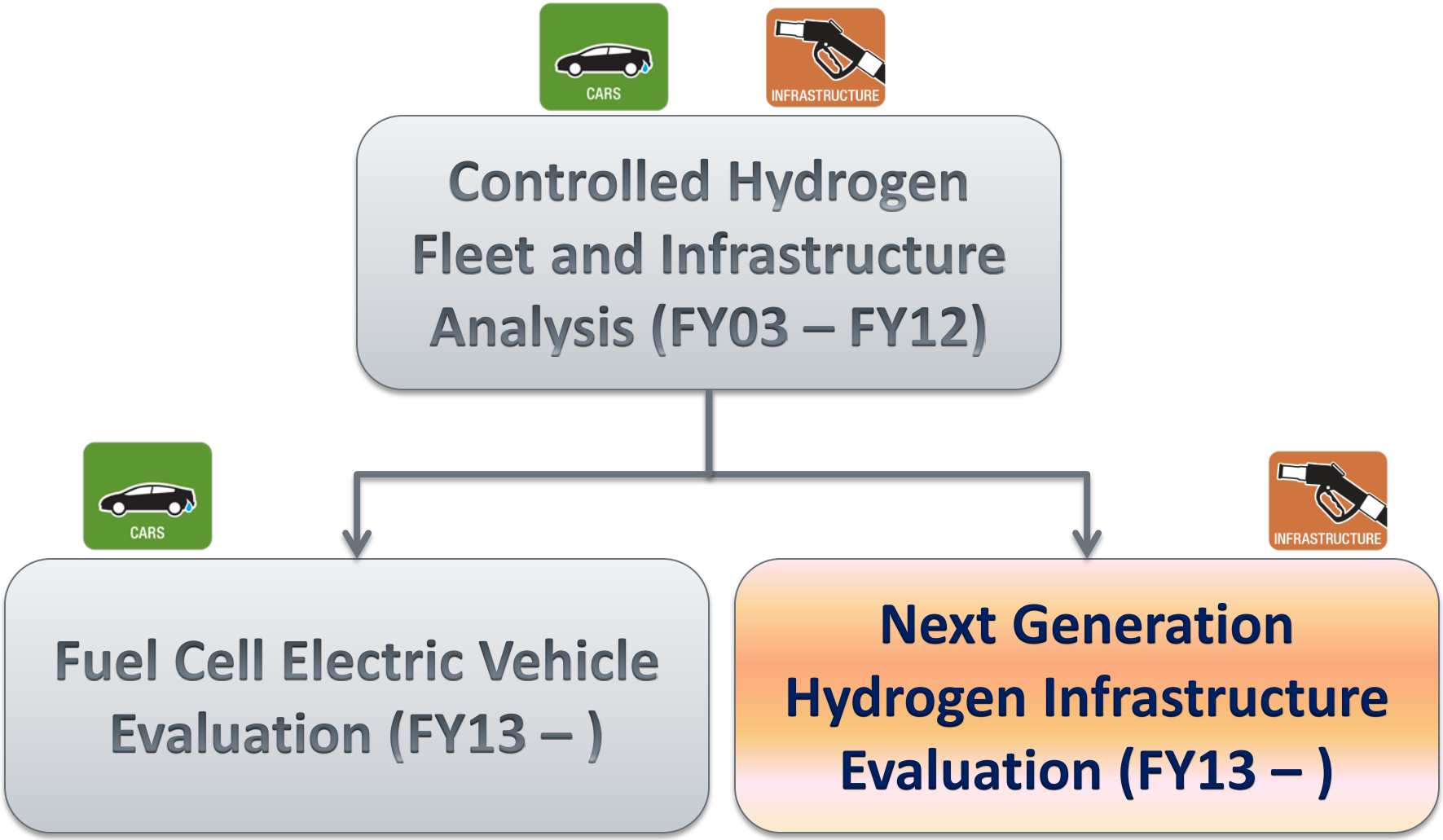
Technical Back-Up Slides

Approach: Relationship to Other Tech Val Projects



Accomplishments and Progress:
Maintenance Labor Hours by Month