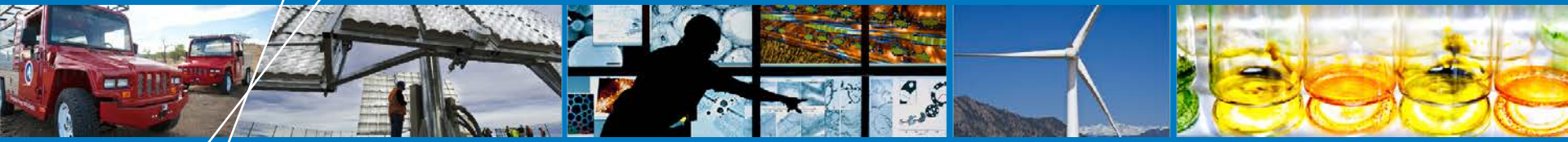
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Fuel Cell Backup Power Technology Validation



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Intelec 2012: 34th International Telecommunications Energy Conference
Scottsdale, Arizona

October 1, 2012

NREL/PR-5600-56785

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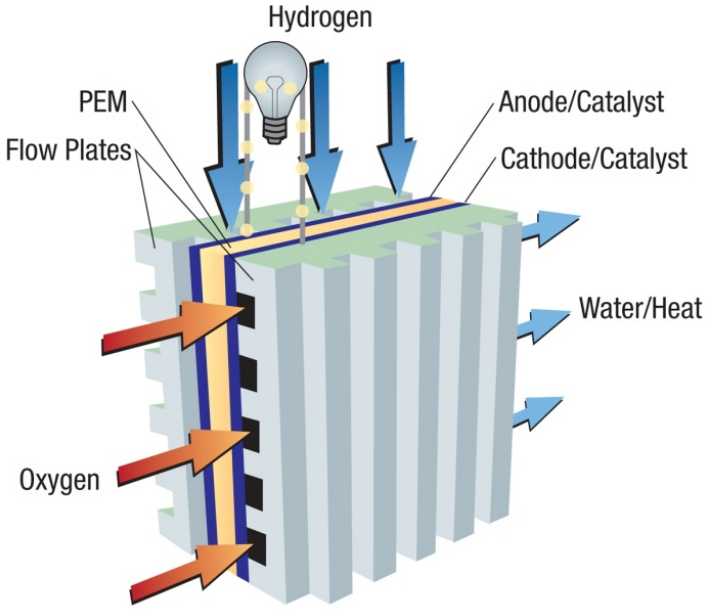
What is a Fuel Cell?

H_2 PEM Fuel Cell



- Fuel cells efficiently convert chemical energy into electricity through an electrochemical process without burning
- Represent an alternative to batteries, generators, internal combustion engines to provide power for portable electronics, stationary, transportation & other applications

- Advantage
  - High efficiencies for energy conversion
    - 40%-50% electrical efficiency (LHV of H_2)
    - ≥80% including utilization of waste heat
  - High energy density
  - Indefinite operating time as long as fuel is provided (refuel vs. recharge)
  - Scalable from mW to MW
  - Emission-free for H_2 PEMFC
  - Quiet operation

- Disadvantage
  - Cost
  - Lack of fuel infrastructure
    - Production
    - Storage
    - Distribution

Objectives – Relevance

BACKUP POWER

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**
  - Independent technology assessment in real world operation conditions
  - Focused on fuel cell system and hydrogen infrastructure: performance, operation, and safety
  - Leverage data processing and analysis capabilities developed under the fuel cell vehicle Learning Demonstration project
  - Material handling equipment, backup power, portable power, and stationary power.
- **Support Market Growth**
  - Analyses and results relevant to the markets' value proposition
  - Reporting on technology status to fuel cell and hydrogen communities and other key stakeholders like end users

Hydrogen Secure Data Center – Approach

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

Internal analysis completed quarterly

HSDC

NREL's Hydrogen Secure Data Center

DDPs

Confidential

Public

CDPs

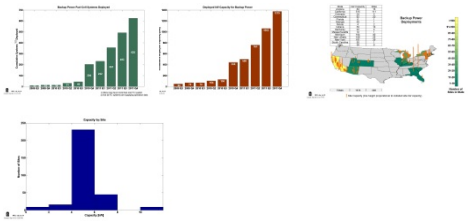
Detailed Data Products (DDPs)
- Individual data analyses
- Identify individual contribution to CDPs
- Only shared with partner who supplied data every 6 months[1]

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

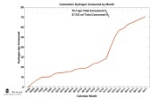
1) Data exchange may happen more frequently based on data, analysis, and collaboration
2) Results published via NREL Tech Val website, conferences, and reports

Backup power CDP count and category

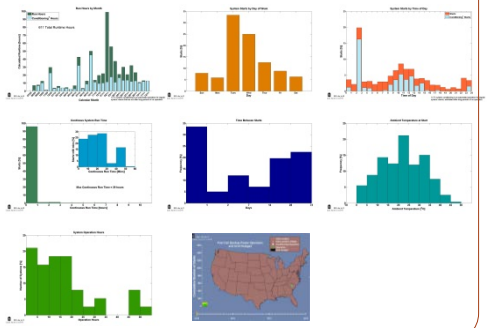
Deployment
(1, 2, 3, 14)



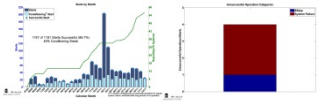
Infra. Operation
(6)



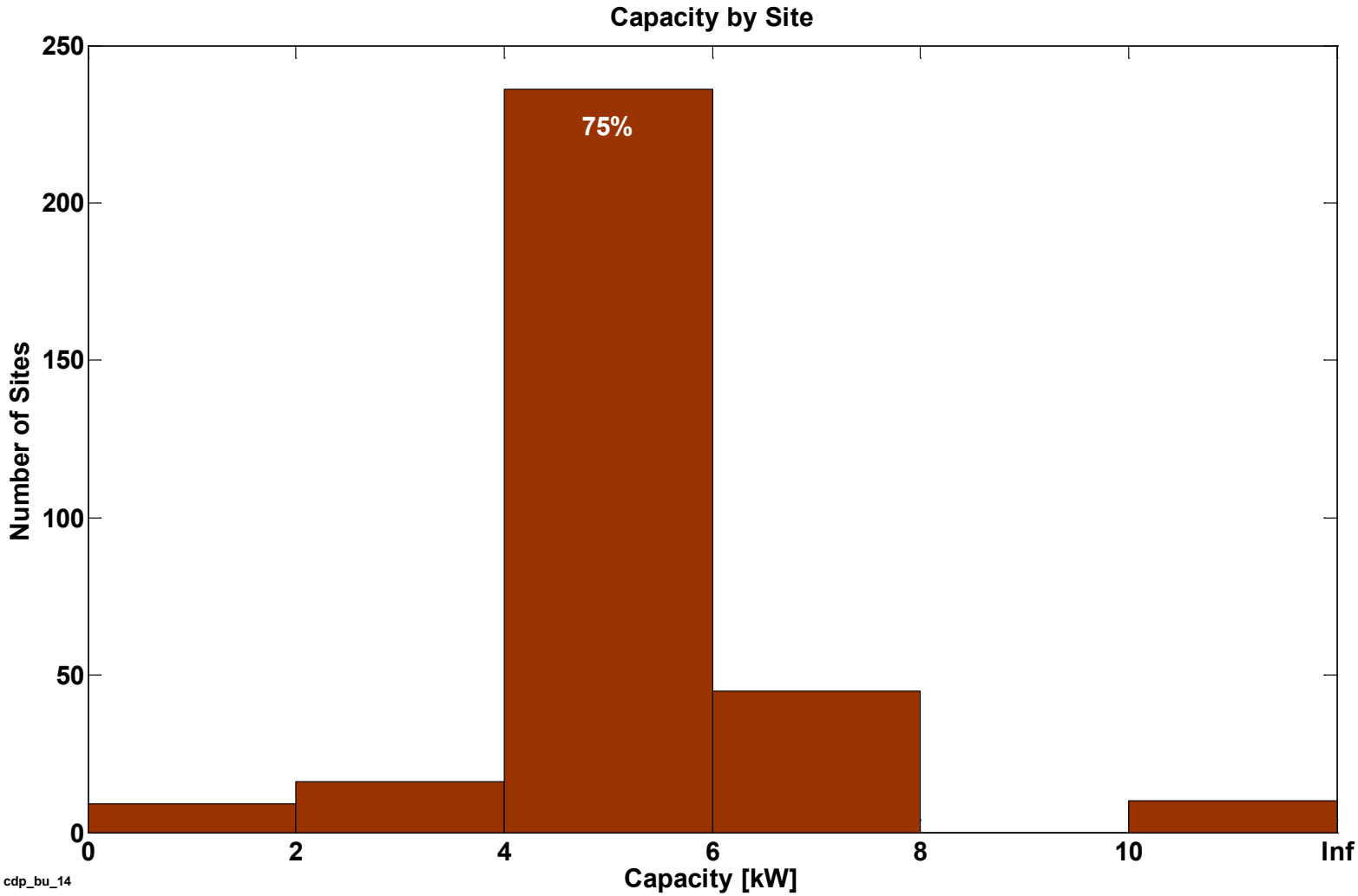
Fuel Cell Operation
(5, 7, 8, 9, 11, 12, 13, 15)



Fuel Cell Reliability
(4, 10)



Deployment: 75% sites are between 4 – 6 kW



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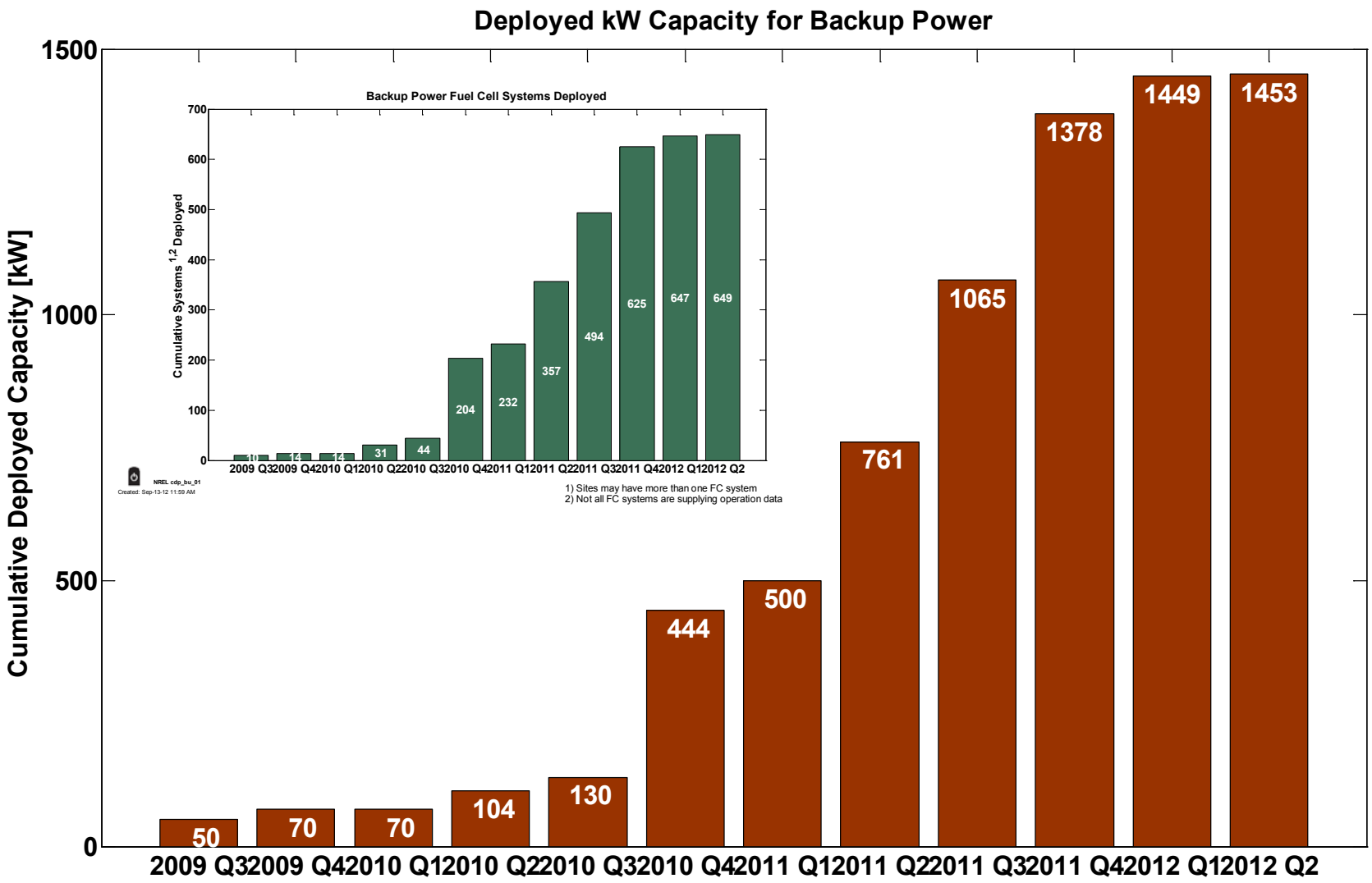
Deployment: Over 1.45 MW capacity is deployed with 649 systems



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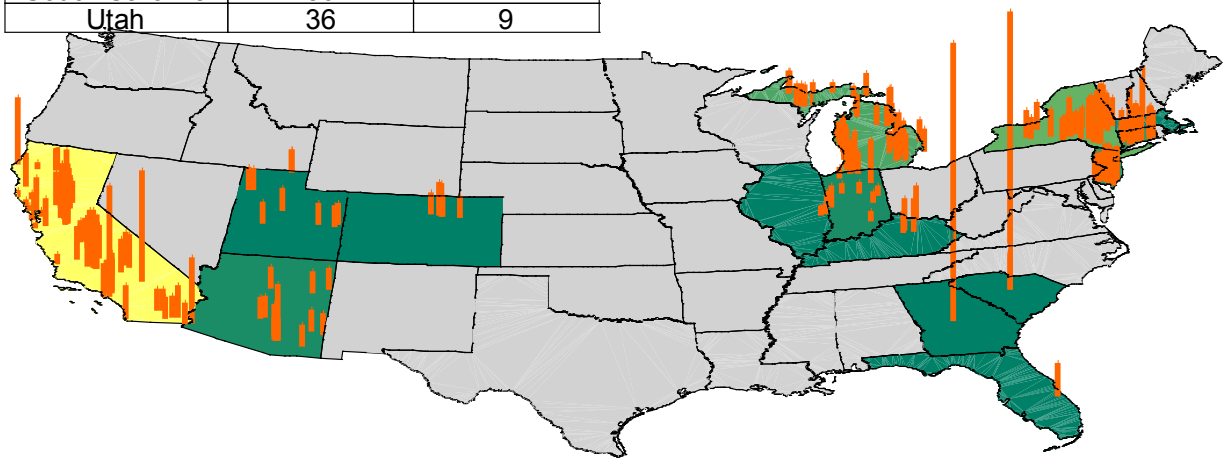
Deployment: Sites in 15 states

State	kW Capacity	Sites
Arizona	84	16
California	567	122
Colorado	24	5
Connecticut	121	26
Florida	6	1
Georgia	50	1
Illinois	4	2
Indiana	50	16
Kentucky	22	4
Massachusetts	10	1
Michigan	164	40
New Jersey	110	27
New York	186	44
South Carolina	50	1
Utah	36	9



Backup Power Deployments

>100
91-100
81-90
71-80
61-70
51-60
41-50
31-40
21-30
11-20
1-10

Number of Sites in State

Totals	1484	315

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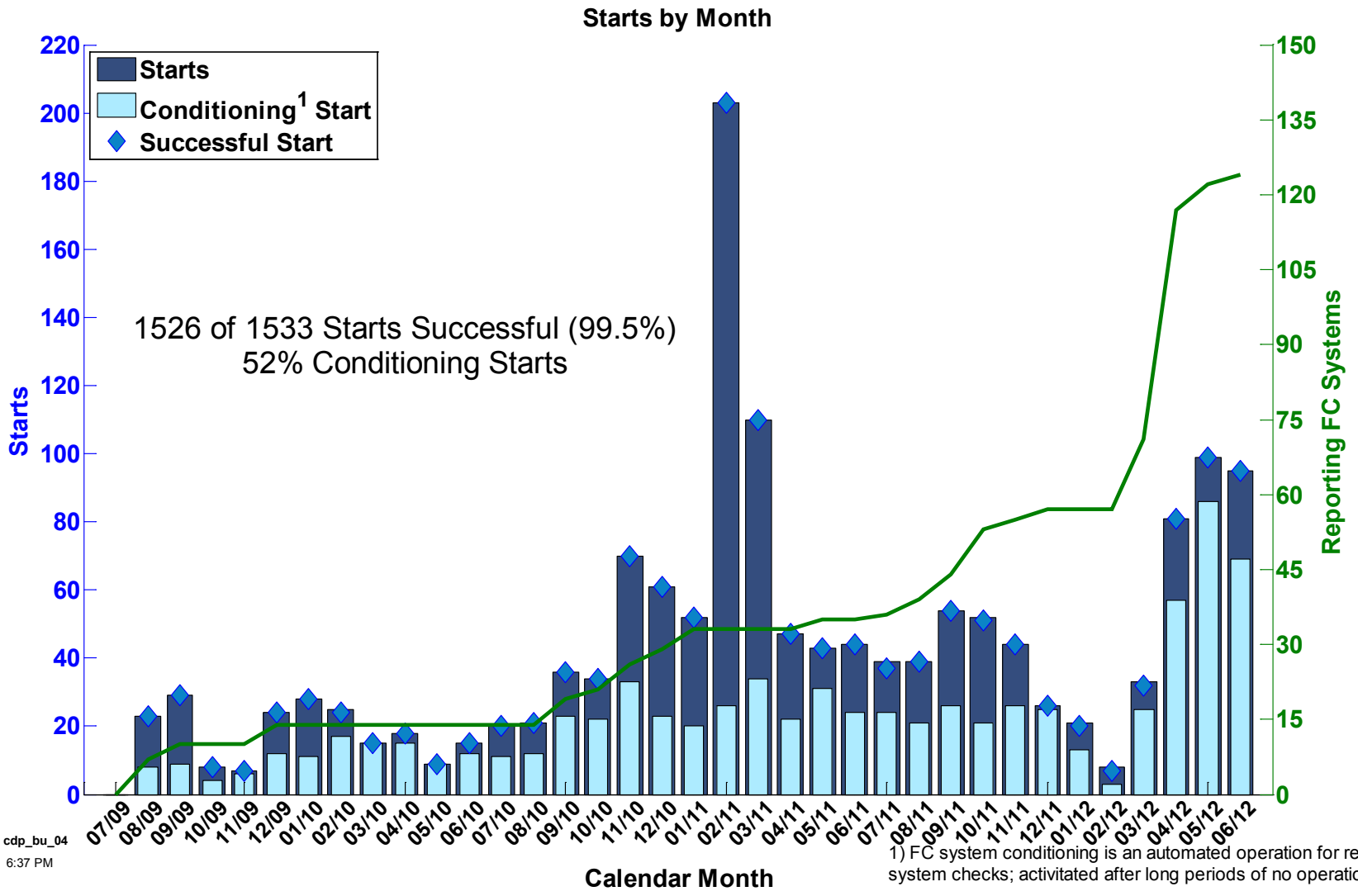
Site Capacity (line height proportional to installed site kW capacity)

Reliability: 99.5% successful starts



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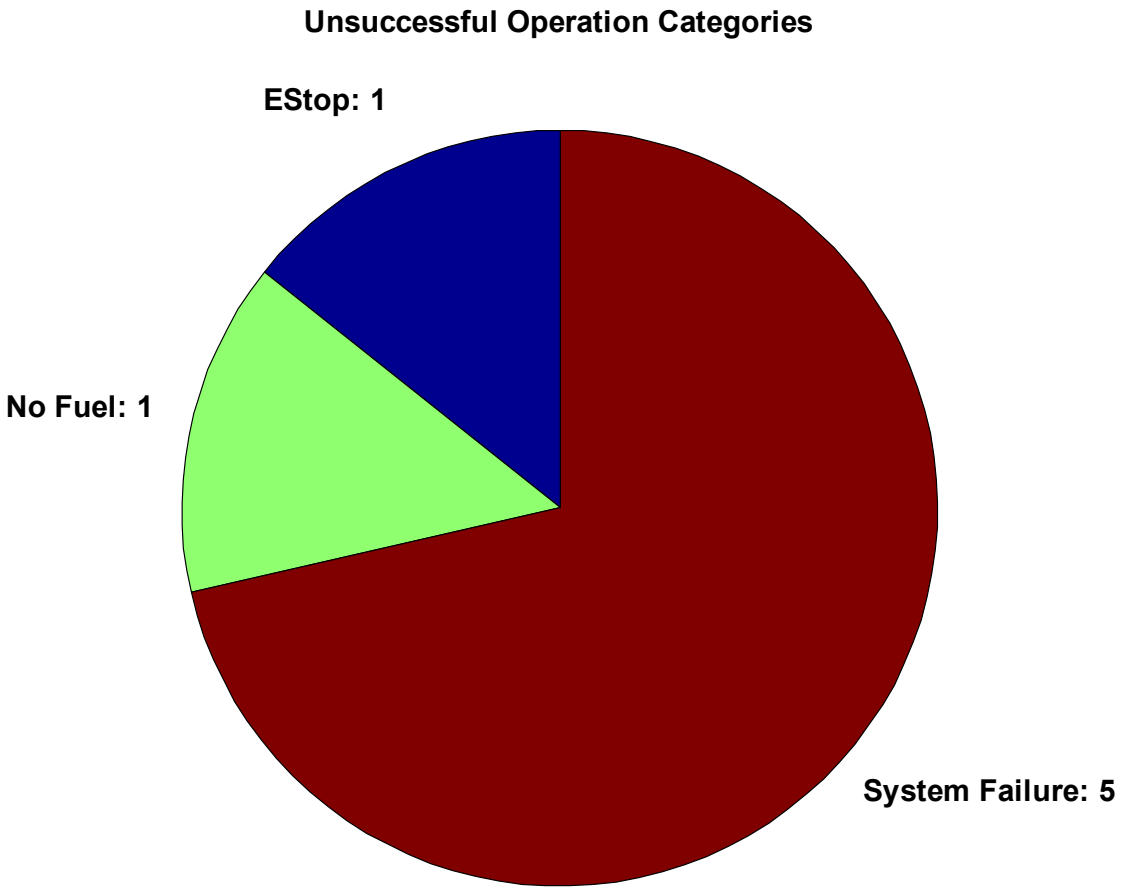
1) FC system conditioning is an automated operation for regular system checks; activitated after long periods of no operation.

Reliability: Only 7 unsuccessful starts out of 1,533 attempted starts



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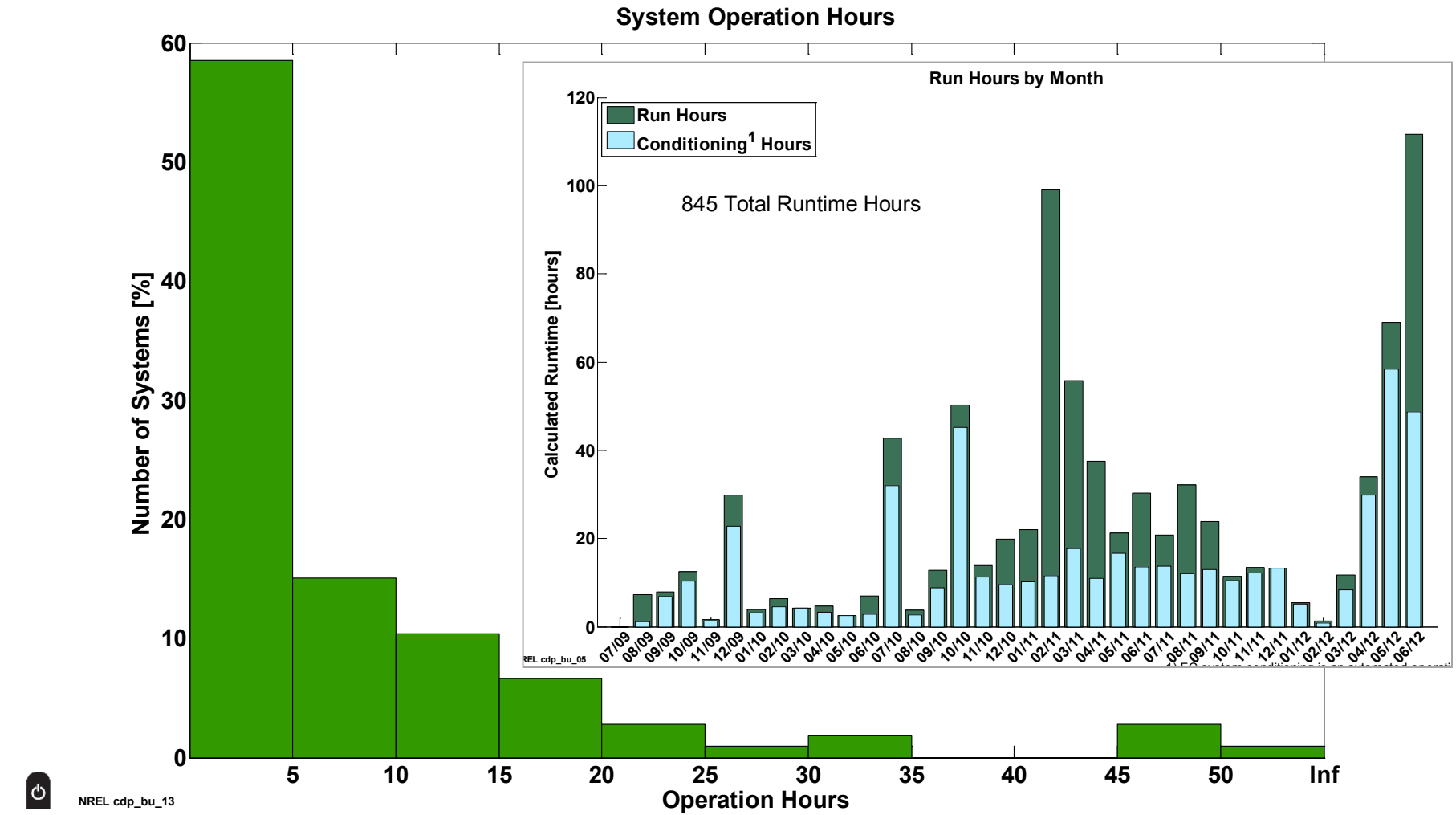
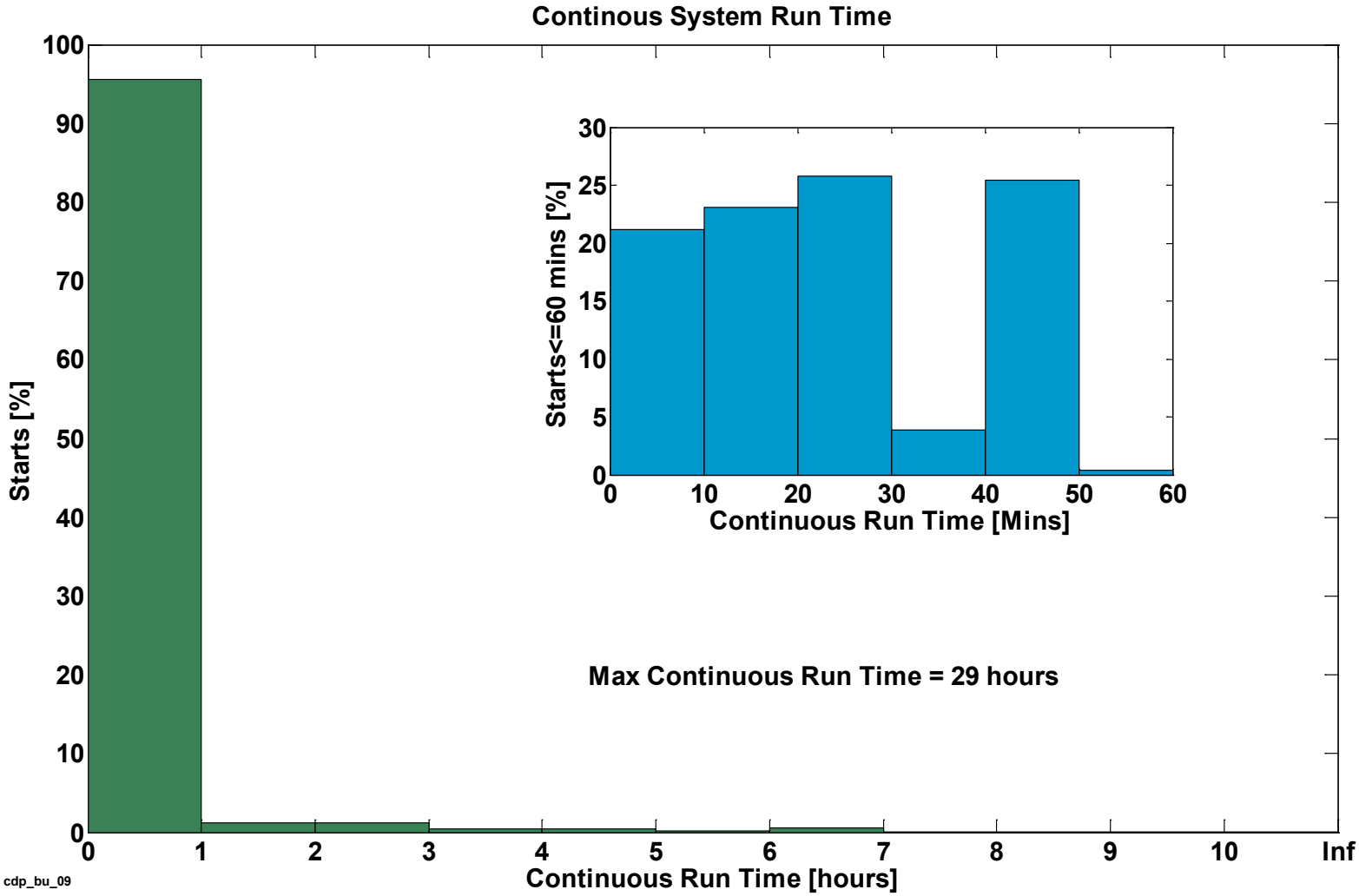
Operation: Runtime hours tend to be low due to low required operation but some months and systems see high operation time



Operation: Systems are capable of extended runtimes (72-hour capacity)



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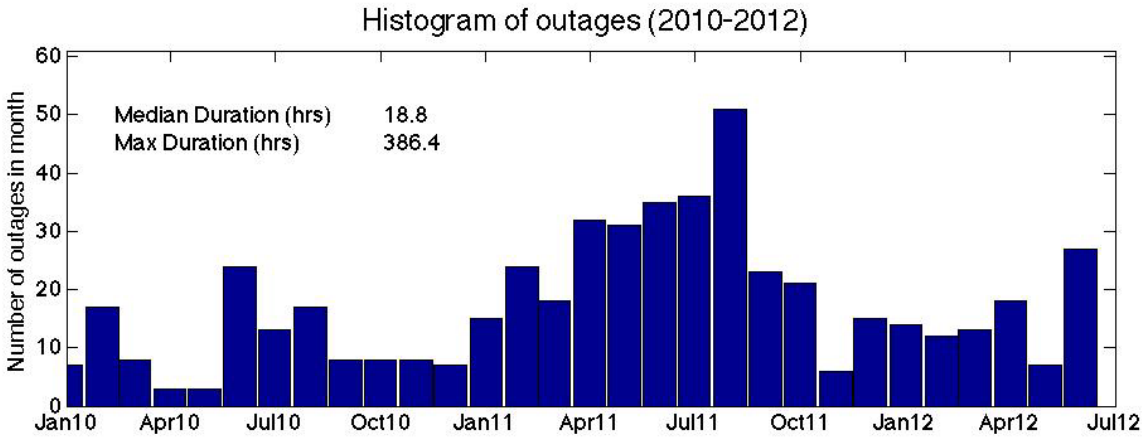
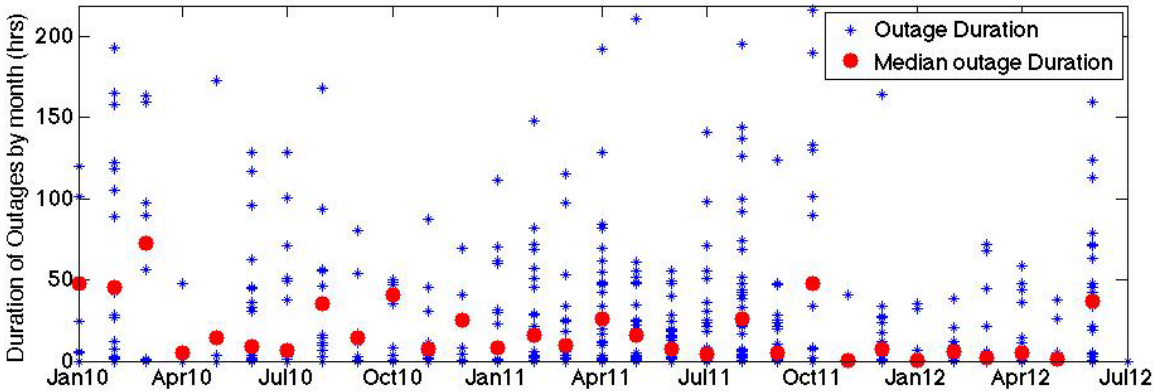
Grid outages: Association of system starts and grid outages

Some states see double digit grid outages a year with a few hours per outage

Often an outage has had extended down time

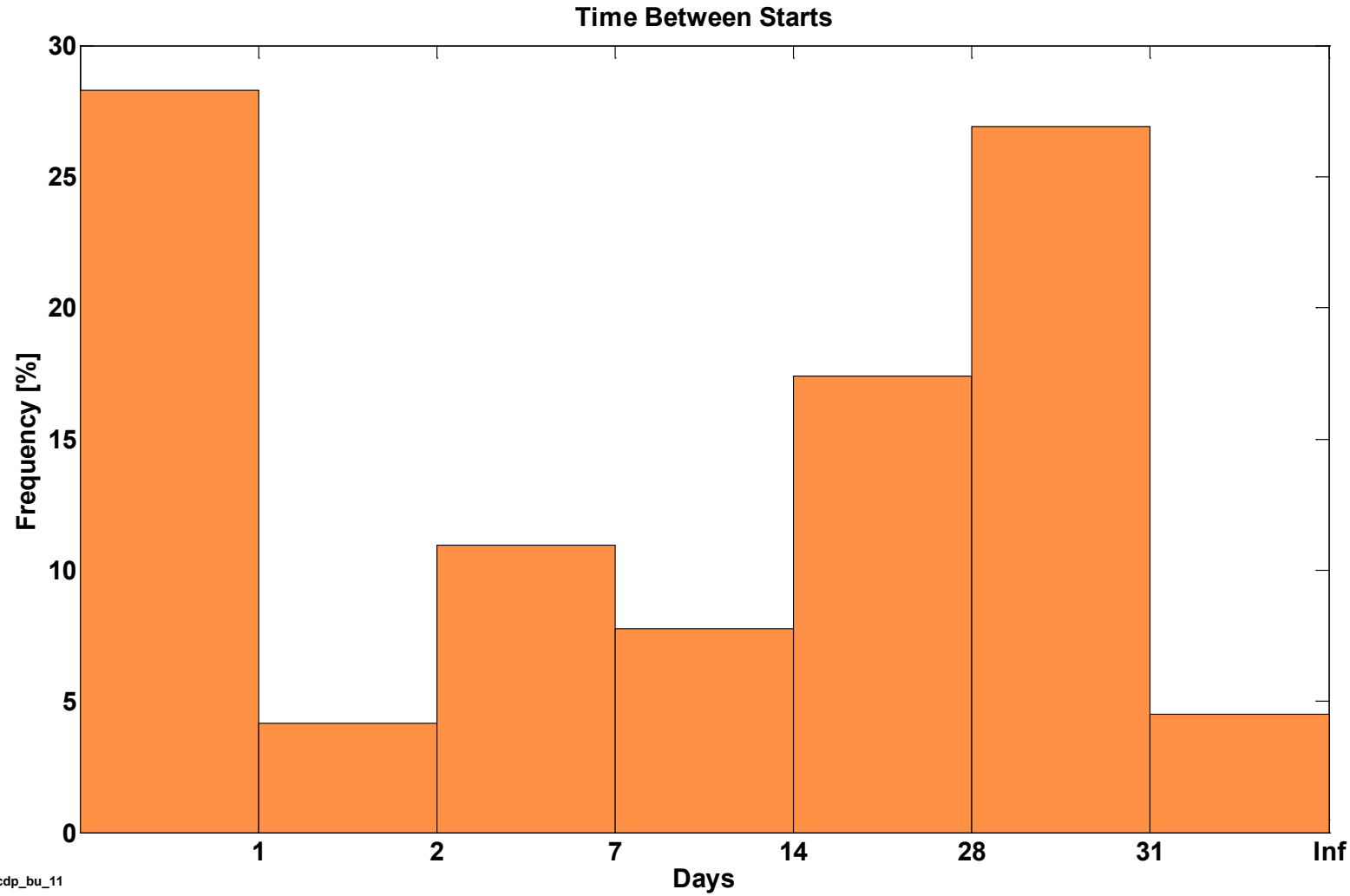
Couple fuel cell system operation data with OE-417 Electric Emergency and Disturbance (OE-417) Events, 2010-2012*





Submissions of all Electric Emergency Incident and Disturbance Reports (OE-417), *http://www.oe.netl.doe.gov/oe417.aspx*

Operation: Automatic system operation is capable of rapid restarts as well as long durations between starts



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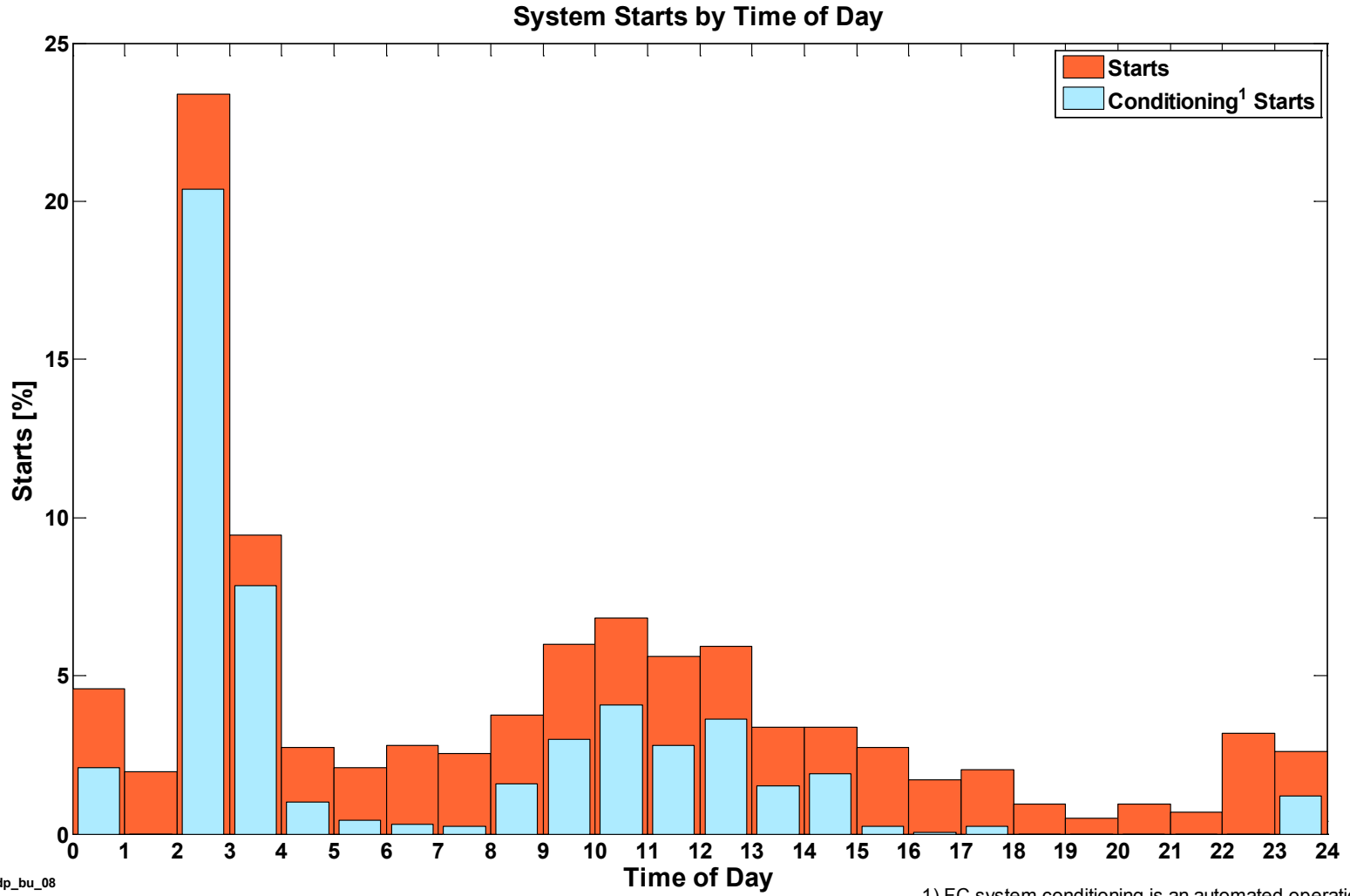
Operation: 42% of starts occur off-peak between midnight and 5 a.m.



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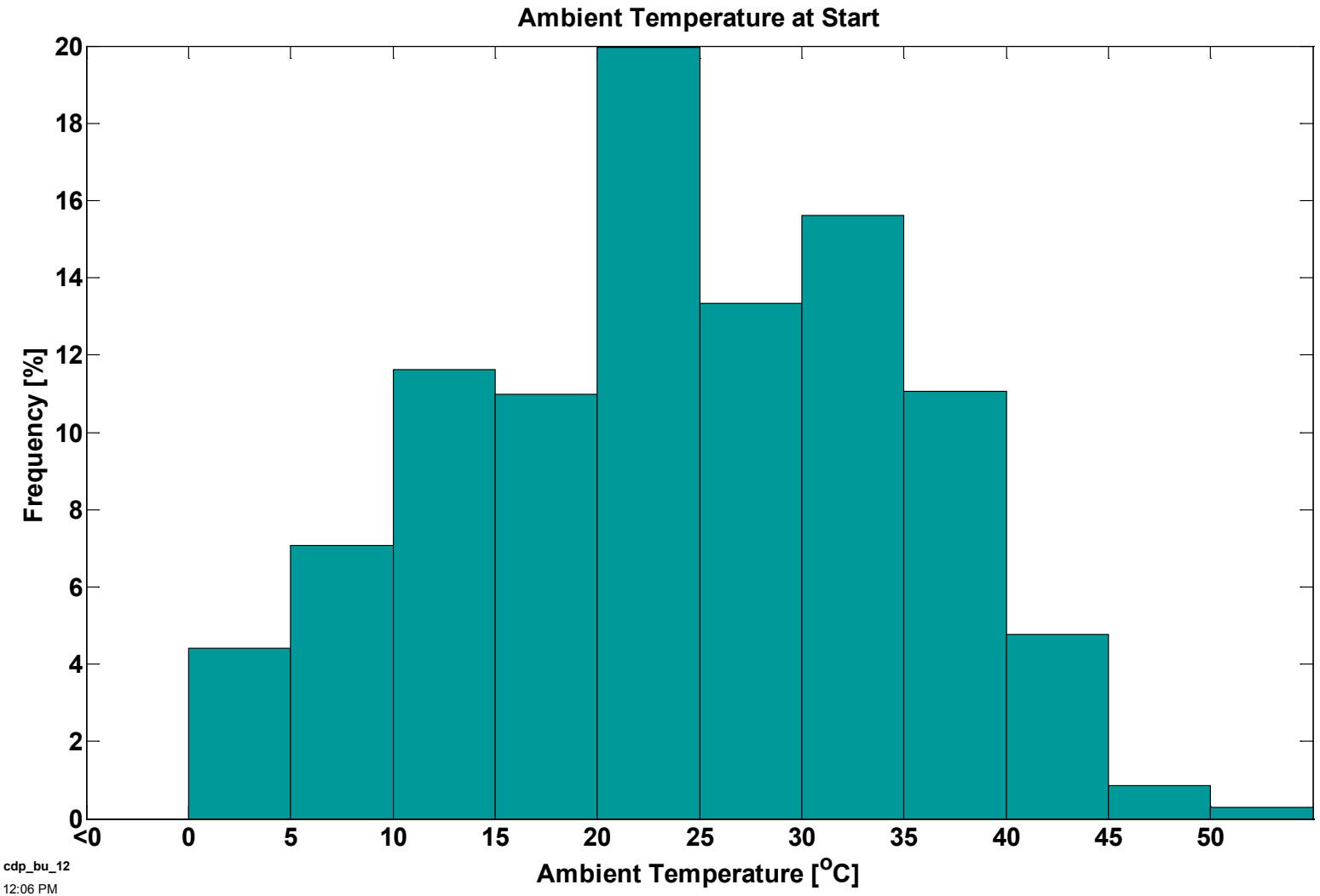
1) FC system conditioning is an automated operation for regular system checks; activitated after long periods of no operation.

Operation: Systems demonstrated operation in a wide range of ambient temperature with a keep warm strategy in ambient conditions below freezing



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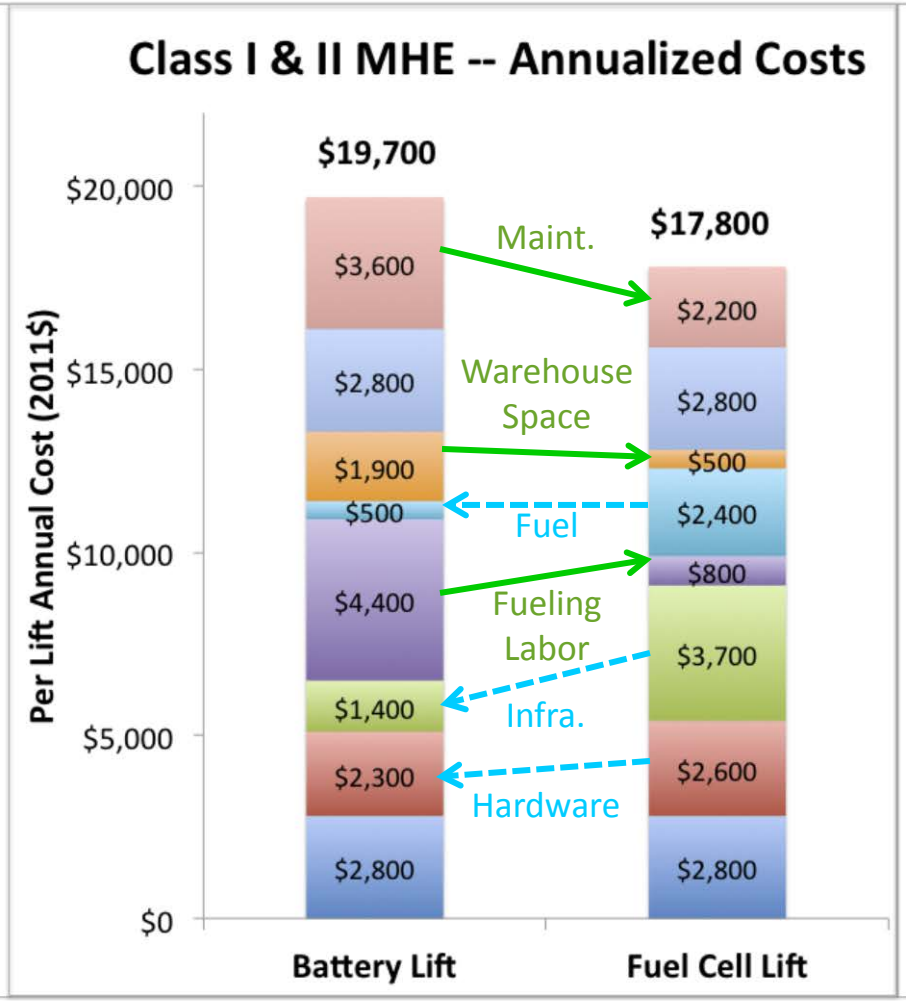
Cost of ownership: Example of annualized cost analysis for material handling that will be applied to backup power systems

FORKLIFTS

- Battery / Fuel Cell Maintenance
- Lift Truck Maintenance
- Cost of Infrastructure Warehouse Space
- Cost of Electricity / Hydrogen
- Labor Cost for Battery Charging & H2 Fueling
- Per Lift Cost of Charge/Fuel Infrastructure
- Amortized Cost of Battery / Fuel Cell Packs
- Amortized Cost of Lift

CDP Ref #: 58



Cost of ownership: Backup power

Gathering data on:

- Site Description
- System Description
- System Requirements
- Capital Cost
- Operating & Maintenance Cost
- Operating Lifetime

for fuel cells, batteries, and generators

	Fuel Cell*	Diesel	Battery
Reliability	+	o	+
Capital Cost ($/kW)	-	+	++
Extended Run Time	++	++	--
Emissions	++	-	++
Noise	+	+	++
Environmental	~	-	~
Weight	+	-	-
Efficiency	+	-	++
Annual Fuel Cost	+	-	++
Annual Maintenance Cost	+	-	++
Maintenance Frequency	++	-	?
Refurbishment	+	+	--
Conditioning Tests	+	-	~
Operation Lifetime	+	++	--

*Tax credit $3,000/kW or 30% total

Fuel Cell Backup Power

- Operating reliability in 15 states with 99.5% successful starts
- Maximum continuous run time of 29 hours due to an unplanned grid outage
- Aggregated data showcases growth over the last two years

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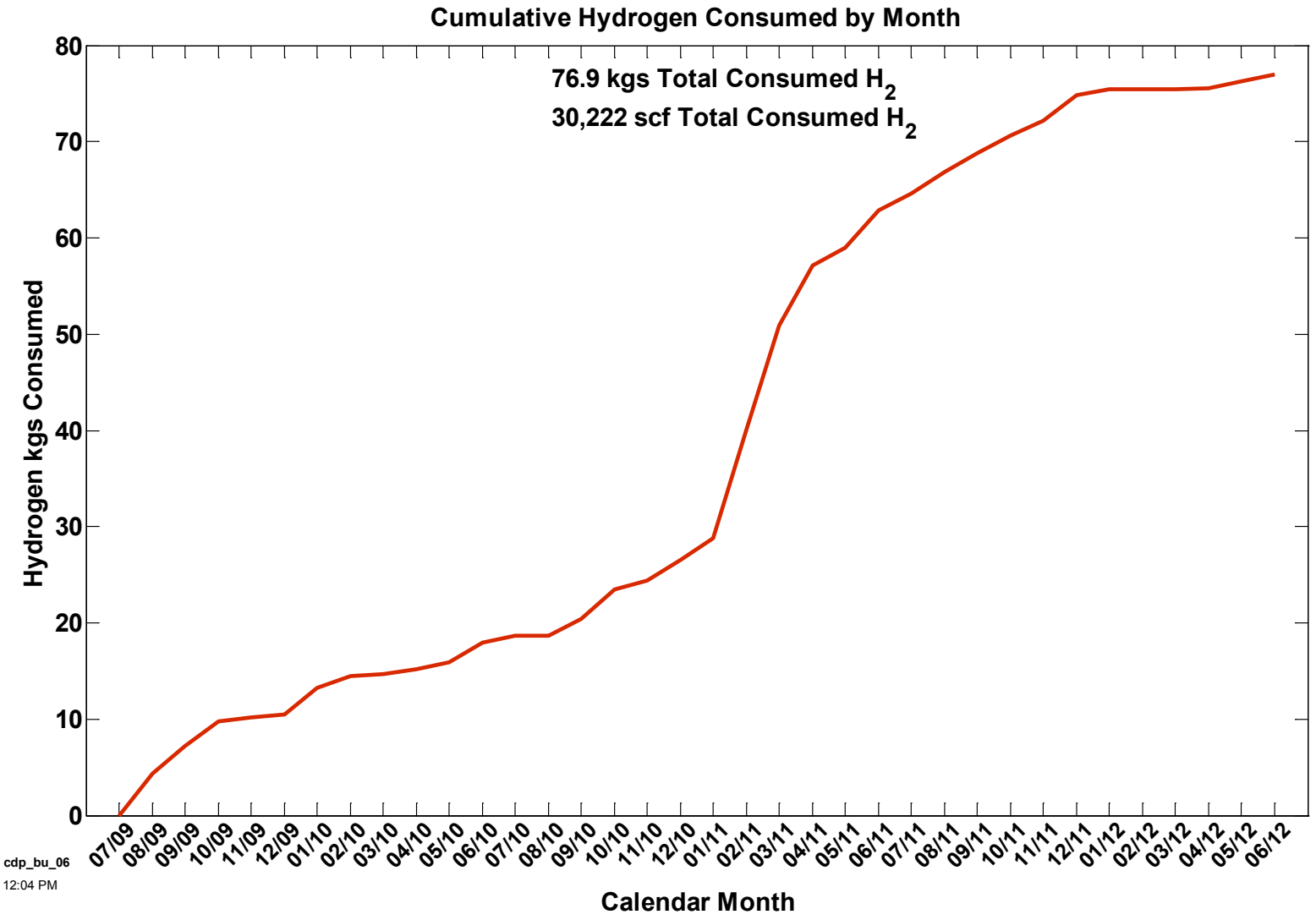
All published results can be found at

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

Backup Slides

CDP-BU-06
Cumulative Hydrogen Consumed by Month



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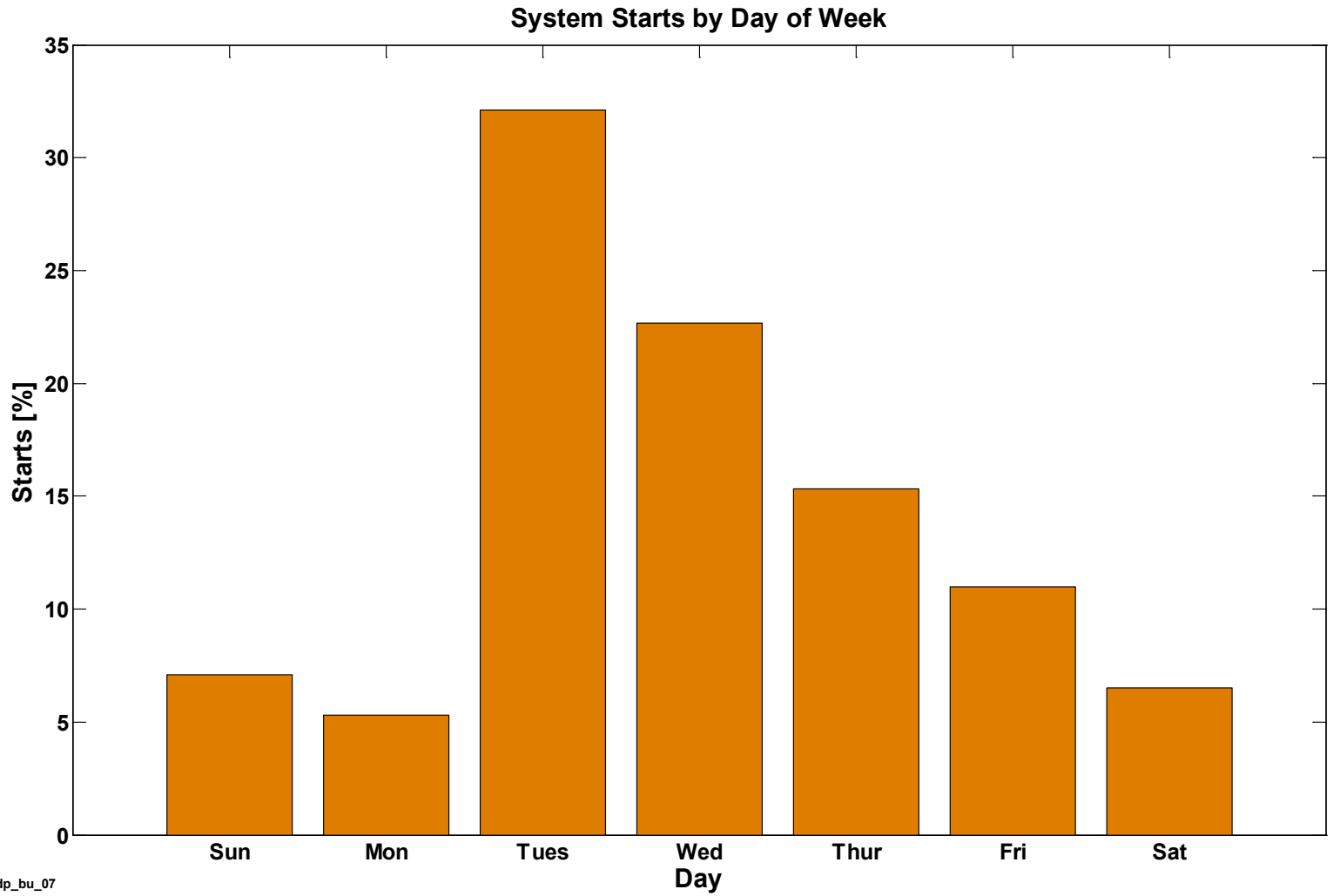
CDP-BU-07
Fuel Cell System Starts by Day of Week



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