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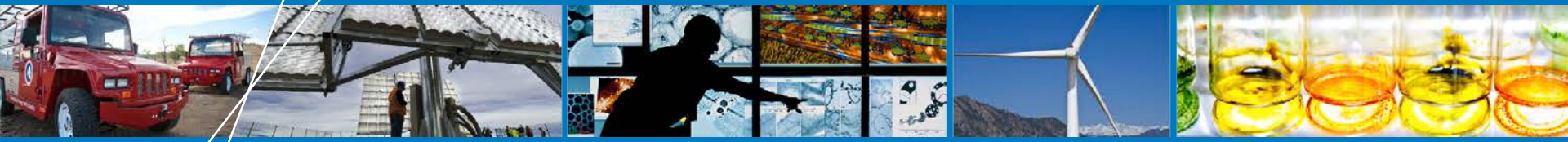
Technology Validation: Fuel Cell Bus Evaluations



2013 DOE Annual Merit Review

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May 16, 2013

Project ID# TV008

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Overview

Timeline

- Project started in FY03
- End date: 10/2013*

Budget

- Pre-FY 2012 funding
  - DOE share: $2.277 M (9 yr)
- FY 2012: $300K
- Planned FY 2013: $300K
- Additional funding from DOT/Federal Transit Admin.

*Project continuation and direction determined annually by DOE.

Tech. Val. Barriers

A. Lack of current fuel cell vehicle (bus) performance and durability data

C. Lack of current H_2 fueling infrastructure performance and availability data

Partners

- Transit Fleets: Operational data, fleet experience
- Manufacturers: Vehicle specs, data, and review
- Fuel providers: Fueling data and review

Relevance: Objectives

- Validate fuel cell electric bus (FCEB) performance and cost compared to DOE/DOT targets and conventional technologies
- Document progress and "lessons learned" on implementing fuel cell systems in transit operations to address barriers to market acceptance

Current Targets*	Units	2012 Status	2016 Target	Ultimate Target
Bus lifetime	Years / miles	5/100,000	12/500,000	12/500,000
Powerplant lifetime	Hours	12,000	18,000	25,000
Bus availability	%	60	85	90
Roadcall frequency (Bus/fuel cell system)	Miles between road call	2,500/10,000	3,500/15,000	4,000/20,000
Operation time	Hours per day/ days per week	19/7	20/7	20/7
Maintenance cost	$/mile	1.20	0.75	0.40
Fuel economy	Miles per diesel gallon equivalent	7	8	8

* Fuel Cell Technologies Program Record # 12012, Sep 2012, www.hydrogen.energy.gov/pdfs/12012_fuel_cell_bus_targets.pdf

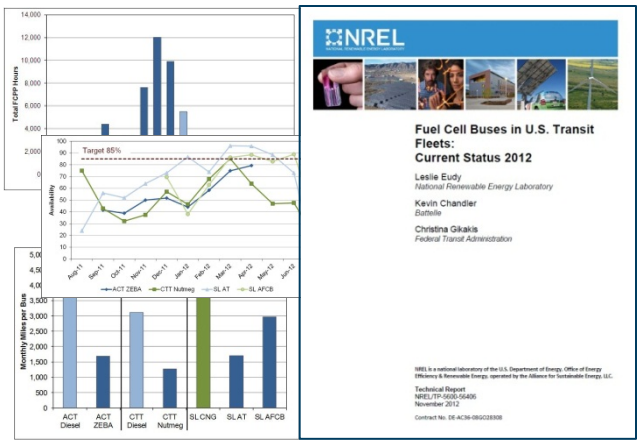
Evaluation Approach

Data Collection/Analysis

- NREL 3rd Party analysis uses standard protocol for collecting existing data from transit partners
- Includes comparisons to conventional technology buses in similar service (diesel, CNG, diesel hybrid)

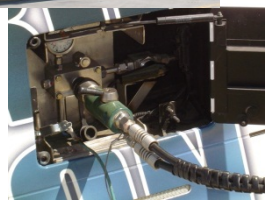
Individual Site Reports

- Documents performance results and experience for each transit agency
- Builds database of results
- Reports published and posted on NREL web site



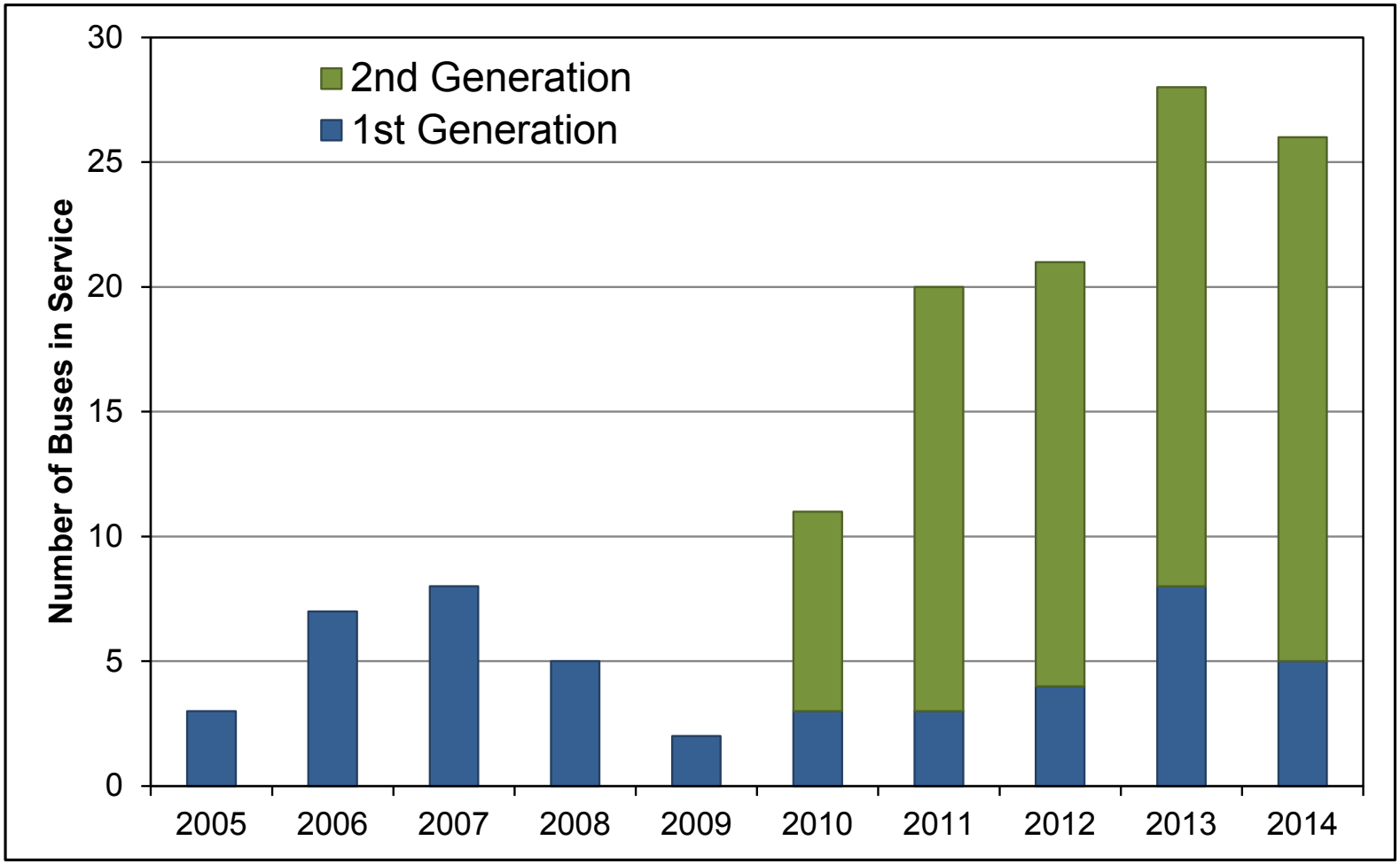
Annual FCEB status report

- Crosscutting analysis comparing results from all sites
- Assesses progress and needs for continued success
- Provides input on annual status for DOE/DOT Targets



U.S. FCEB Numbers Show Upward Trend

Data being collected on increasing number of FCEBs (includes FTA NFCBP buses)



21 active FCEBs at the end of 2012; Estimated 28 by the end of 2013; Slight drop in 2014 as several prototype demonstrations end.

Accomplishments: Progress Toward Targets

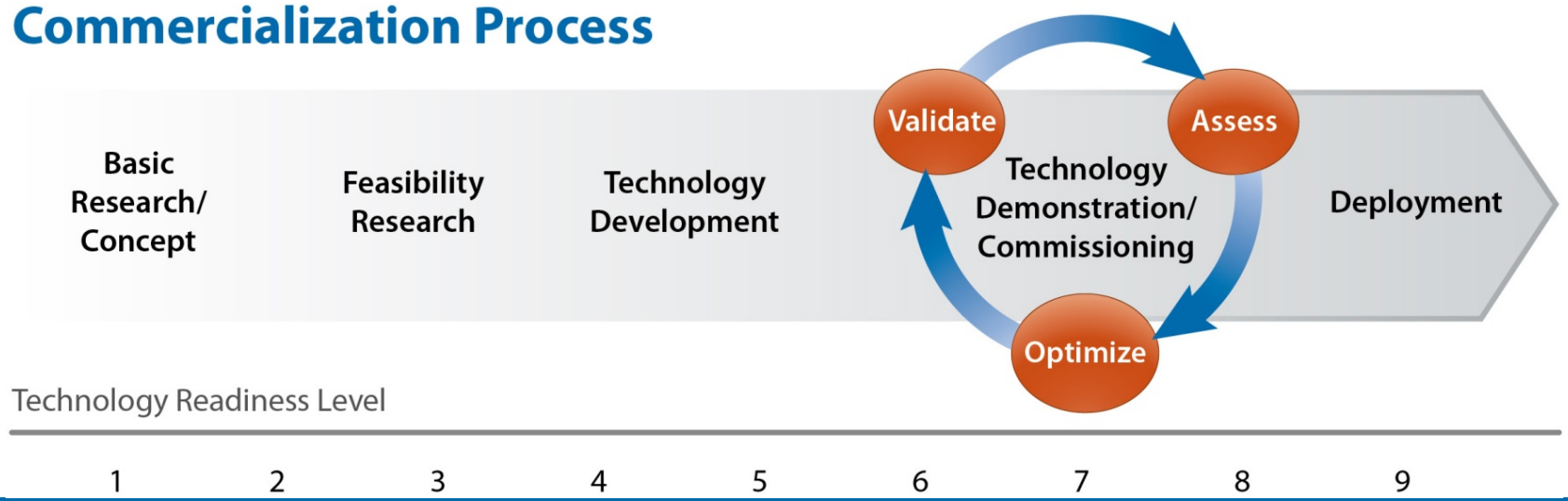
NREL Assesses Technology Readiness Levels

Manufacturer teams for FCEBs currently operating in the United States

Bus OEM	Length (ft)	Fuel Cell System	Hybrid System	Design Strategy	Energy Storage	TRL Level
Van Hool	40	ClearEdge Power	Siemens ELFA integrated by Van Hool	Fuel cell dominant	Lithium-based batteries	7 ✓
New Flyer	40	Ballard	Siemens ELFA integrated by Bluways	Fuel cell dominant	Lithium-based batteries	7 ✓
ElDorado	40	Ballard	BAE Systems	Fuel cell dominant	Lithium-based batteries	6 ✓
Proterra	35	Hydrogenics	Proterra integration	Battery dominant	Lithium-based batteries	6
Daimler (Orion)	40	Hydrogenics	BAE Systems	Diesel hybrid w/ FC	Lithium-based batteries	6 - 7
Ebus	22	Ballard	Ebus integration	Battery dominant	Nickel cadmium	6

✓ Data included in Presentation

Commercialization Process



Data Summary for 2012

Data summary includes three types of fuel cell dominant, FCEBs at three transit sites:

- AC Transit, Oakland, CA
  - 40-foot Van Hool buses with ClearEdge Power* FC (ZEBA)
- CTTRANSIT, Hartford, CT
  - 40-foot Van Hool buses with ClearEdge Power FC (Nutmeg)
- SunLine, Thousand Palms, CA
  - 40-foot New Flyer bus with Ballard FC and Bluways hybrid system (AT)
  - 40-foot ElDorado bus with Ballard FC and BAE Systems Hybrid drive (AFCB)

ACT ZEBA

CTT Nutmeg

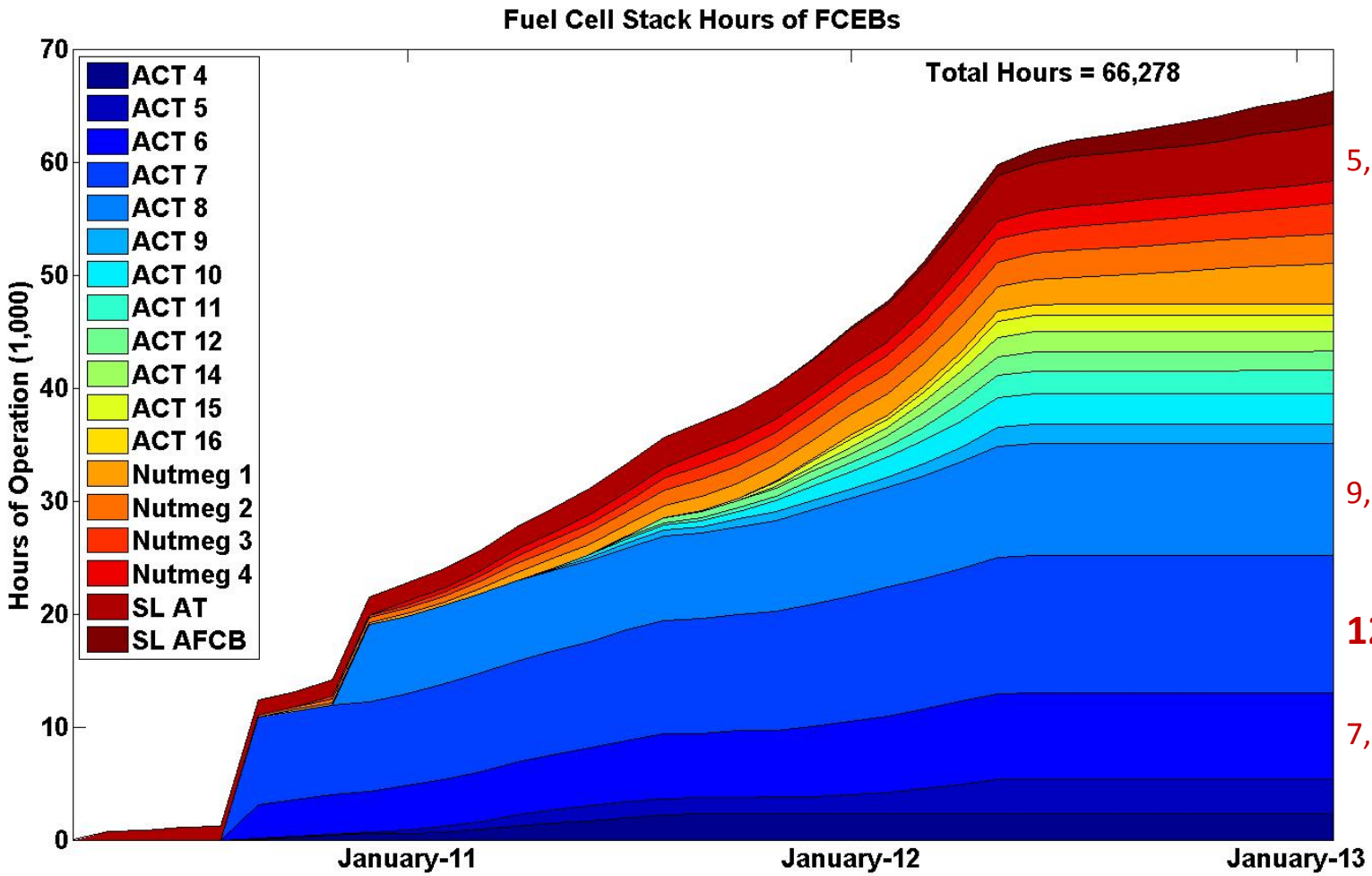
SL AT

SL AFCB

*Formerly UTC Power

Top Fuel Cell Powerplant exceeds 12,000 Hours

Total hours accumulated on each FC powerplant (FCPP) as of 1/31/13



5,087 hours

9,949 hours

12,096 hours

7,667 hours

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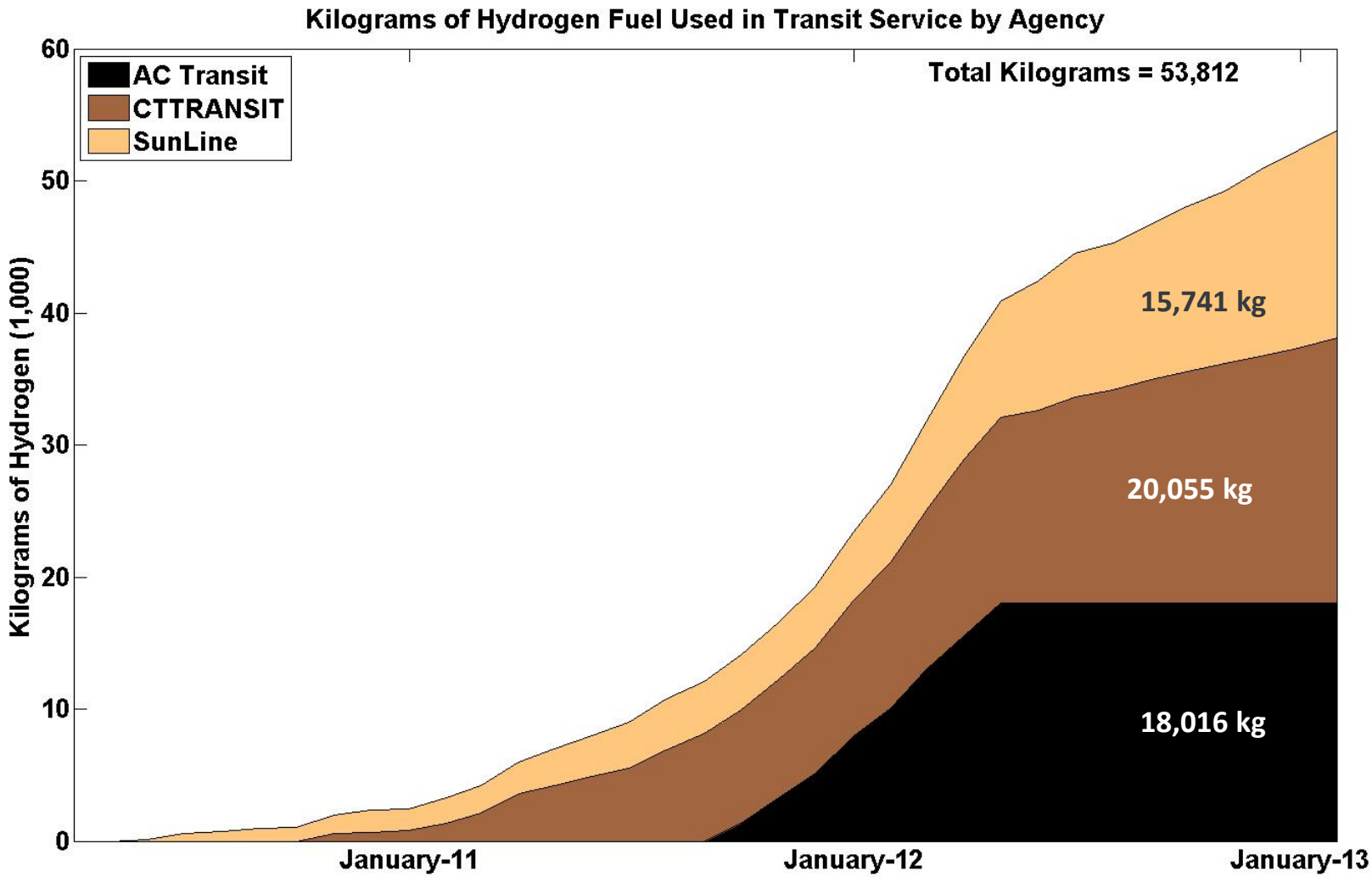
Accomplishments: Progress Toward Targets

More than 53,000 kg Hydrogen Dispensed



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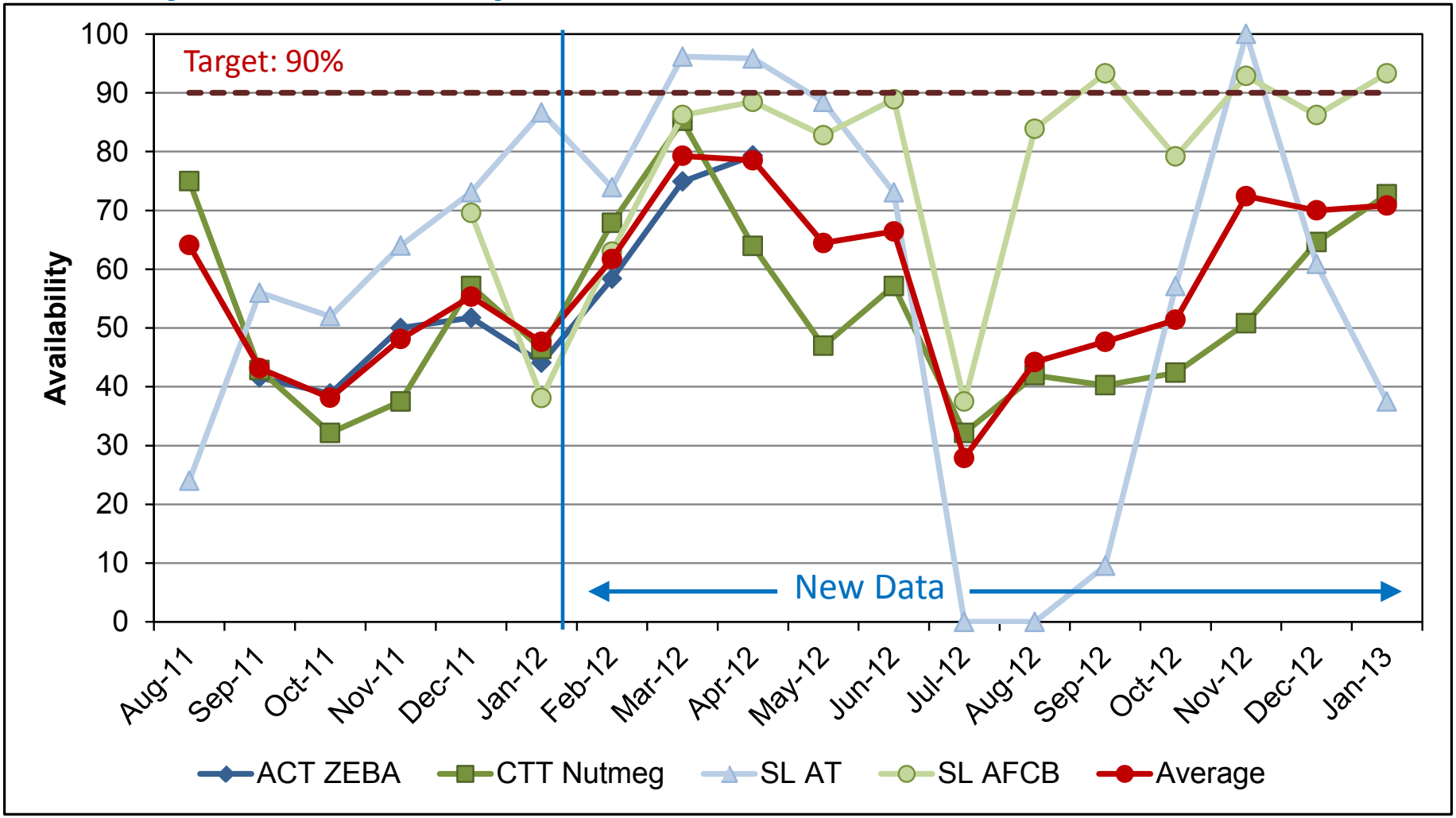
Accomplishments : Progress Toward Targets

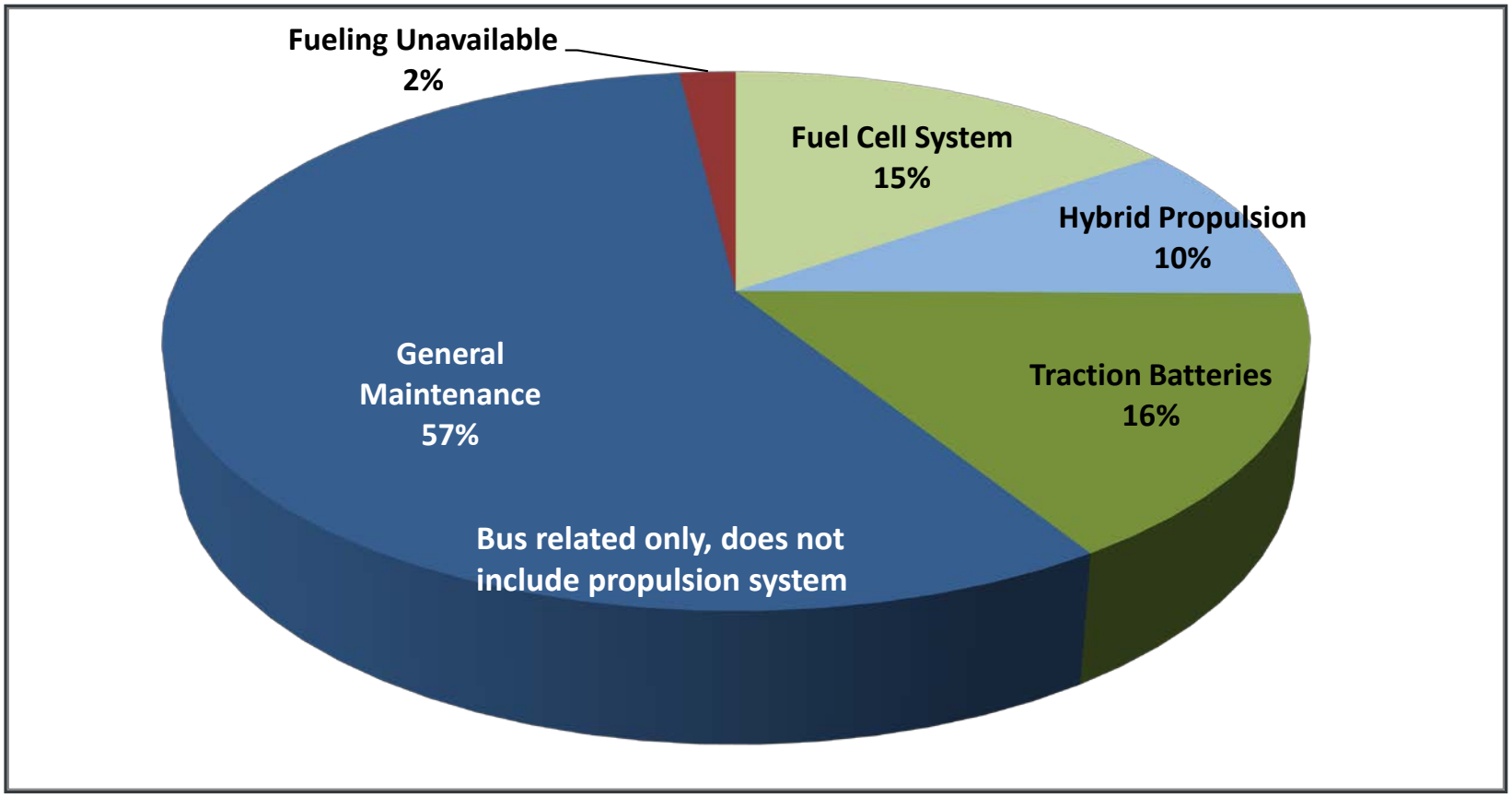
Average Bus Availability at 57%; Highest at 85%

Monthly bus availability



Availability = planned operation days compared to actual operation days

Reasons for Unavailability



Unavailability primarily due to bus related issues—Air conditioning, doors, accidents, bus preventative maintenance

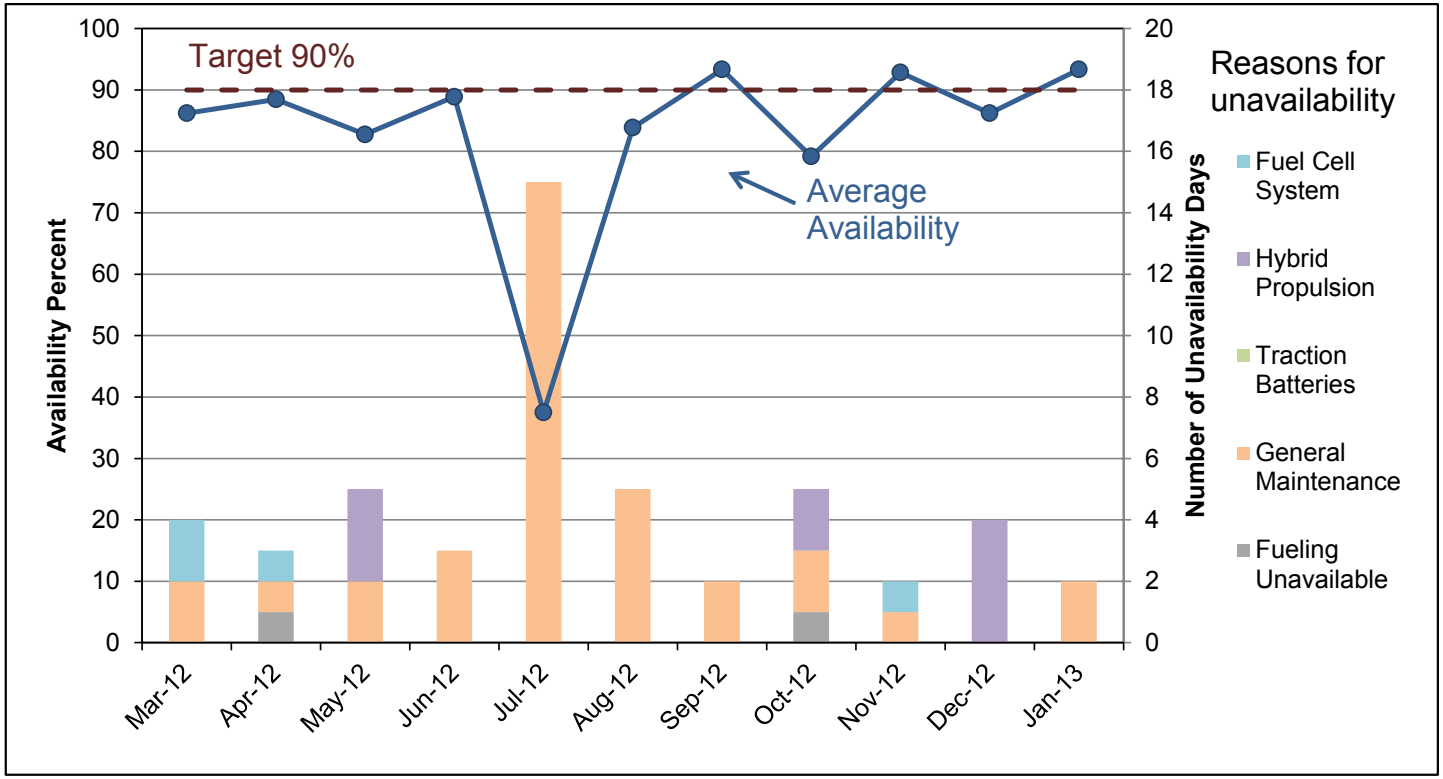
Availability = planned operation days compared to actual operation days

Accomplishments: Progress Toward Targets

Newest FCEB Bus Introduced Achieves 85% Availability

1st generation bus developed under FTA NFCBP: American Fuel Cell Bus

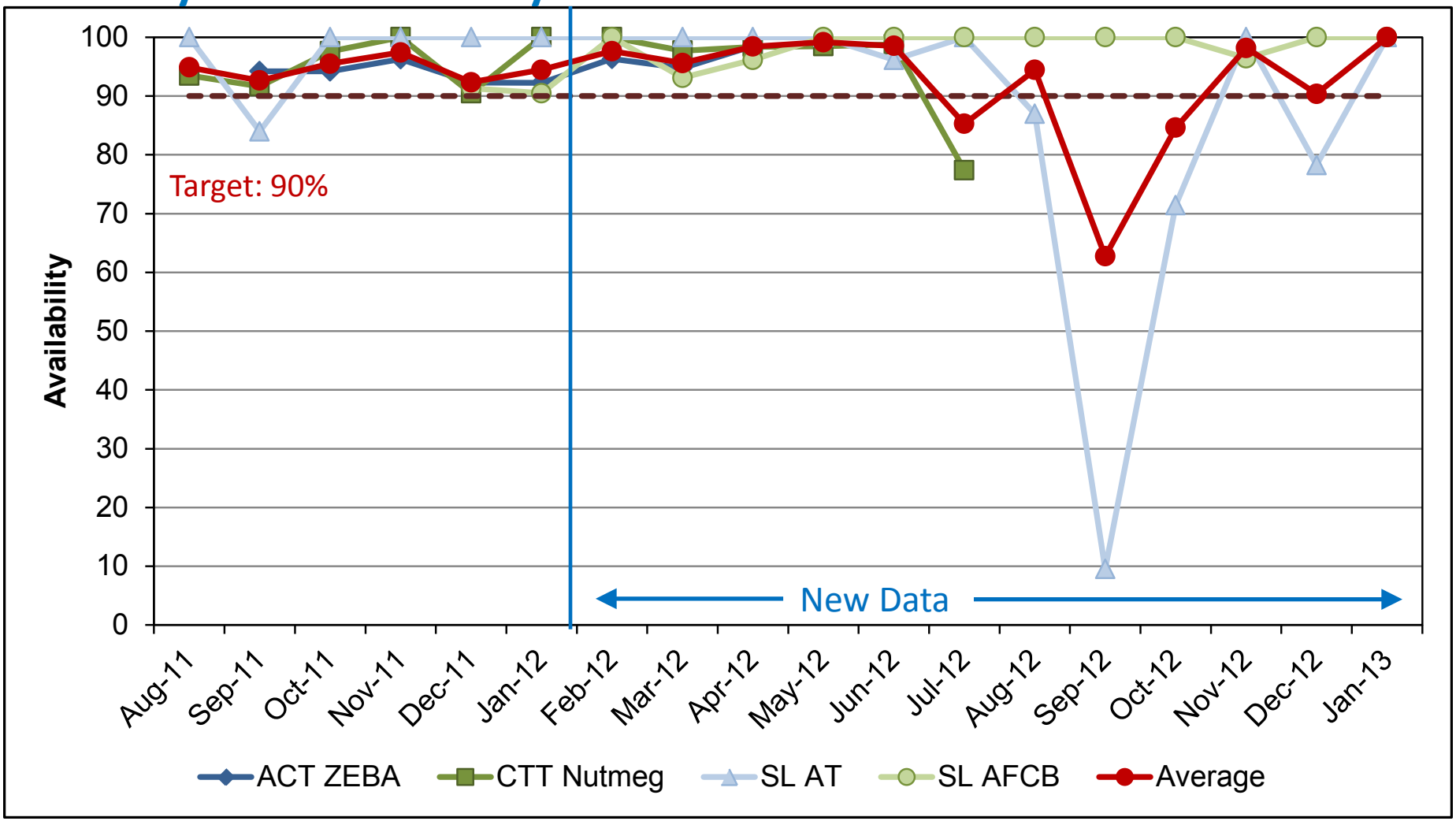
- BAE Systems hybrid drive, Ballard fuel cell, ElDorado National 40-foot bus
- Average availability: 85%
- Monthly miles: 3,445
- Fuel economy: 7.3 mpdge
- MBRC*: Bus 3,445; Propulsion system 6,316; FC System 12,632



*MBRC = miles between roadcall

Average FCPP Availability Reaches 95%

Monthly FCPP availability

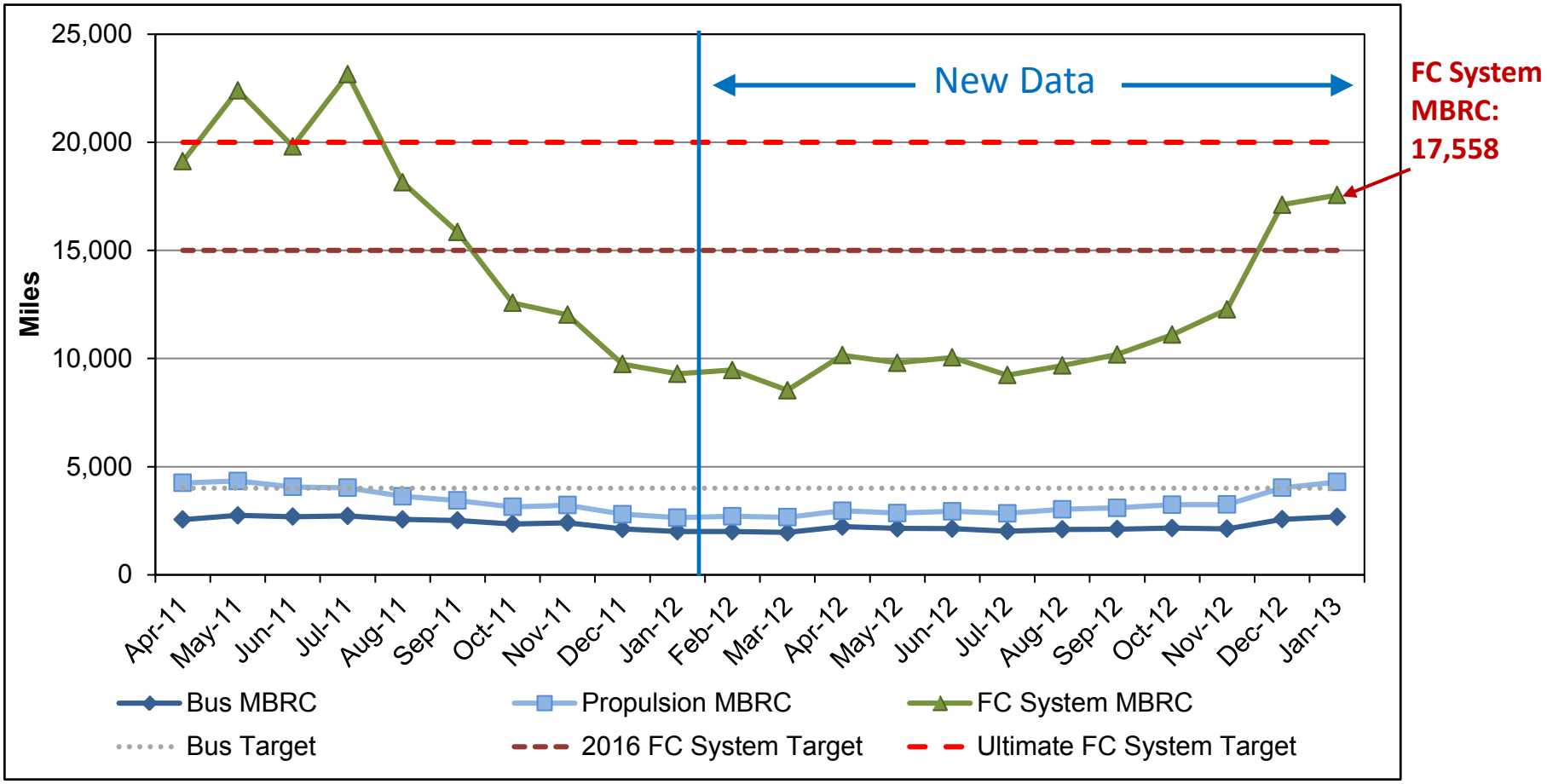


Availability = planned operation days compared to actual operation days

Accomplishments : Progress Toward Targets

FC System MBRC* Increased to 17,558 miles (56% increase)

MBRC – 12 month rolling average



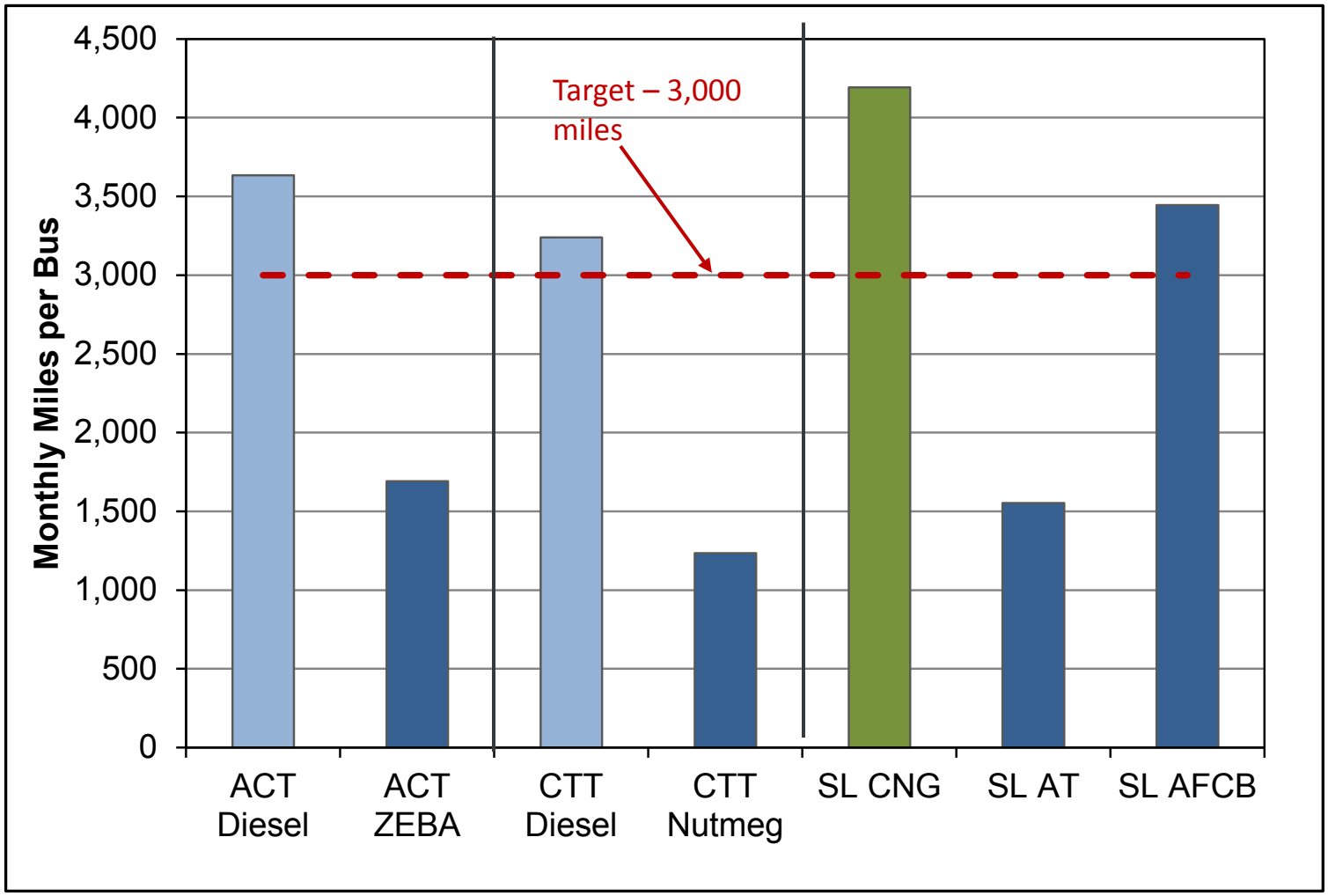
FC System MBRC 56% improvement from previous AMR

*MBRC = miles between roadcall

Average Monthly Mileage Approaching 2,000

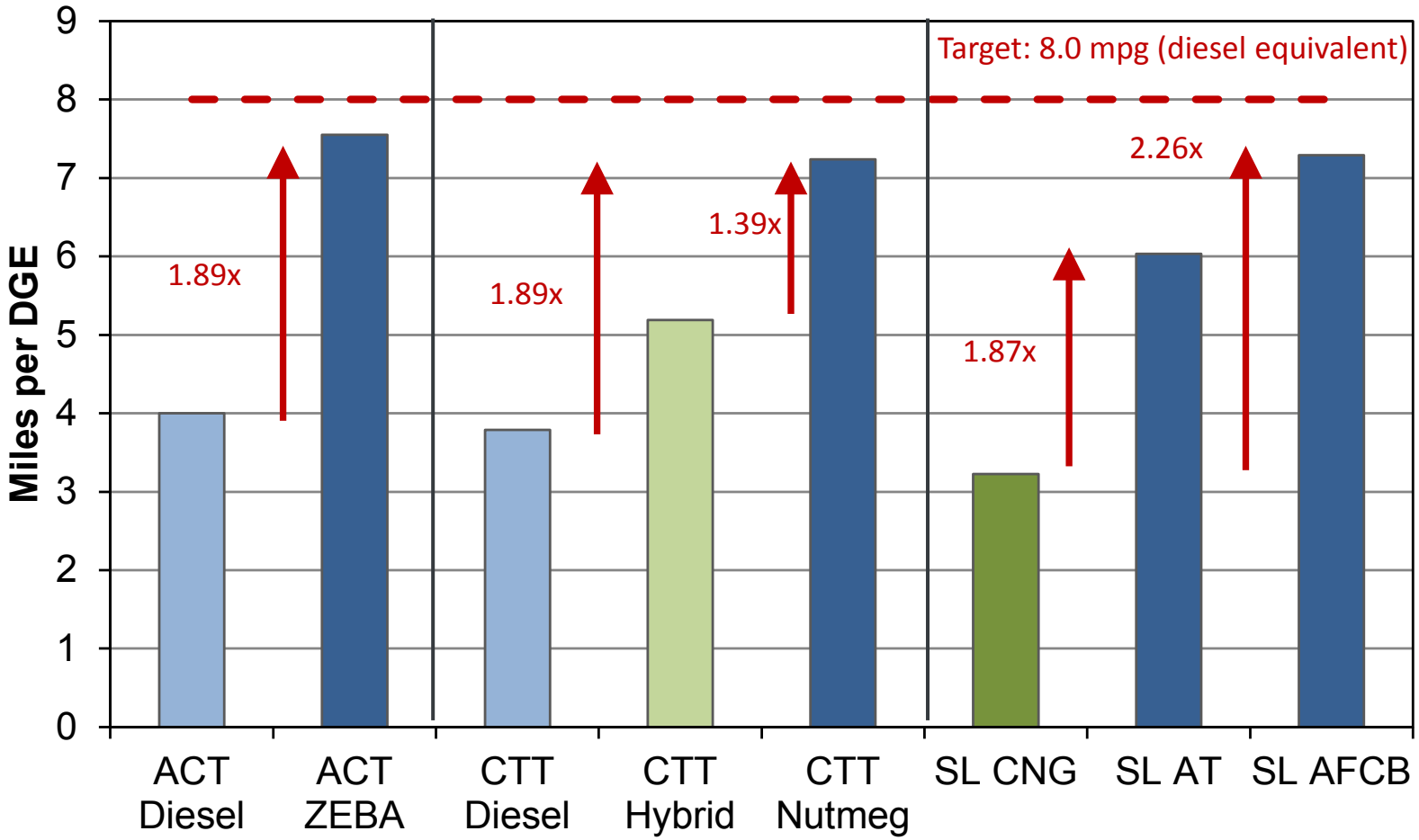
Monthly miles compared to conventional bus baseline

- Average monthly miles: 1,981
- Buses have operated as much as 20 hours in a day, 7 days per week



Accomplishments: Progress Toward Targets

FCEB Fuel Economy up to 2x over Baseline



New FC bus designs have twice the fuel economy as diesel buses

Accomplishments: Lessons Learned

ZEBA Fleet Successfully Back In Service after 9 months

- **Start-up of buses**
  - Re-wet procedure for fuel cell
  - Inspection of bus and components
  - Test drive
- **Driver training**
  - Refresher for drivers previously trained
  - Training for new drivers
- **Service start in Feb 2013**
  - Agency reports that the start-up process went extremely well
  - Buses were placed into service as soon as the start-up was completed and sufficient drivers were trained
  - Issues were minor – 24 V batteries all needed to be changed
  - No FC or traction battery issues so far

Collaborations

- **Transit agencies provide data on buses, fleet experience, and training, and review reports**
  - California: AC Transit, BurbankBus, Golden Gate Transit, Santa Clara VTA, SamTrans, SunLine, San Francisco MTA
  - Connecticut: CTTRANSIT
  - Alabama: Birmingham-Jefferson County
  - Ohio: Ohio State University
  - Illinois: Chicago Transit Authority
- **Manufacturers provide some data on buses and review reports**
  - Bus OEMs: Proterra, Van Hool, New Flyer, ElDorado National, DesignLine, EVAmerica
  - FC OEMs: Ballard, Hydrogenics, ClearEdge Power, Nuvera
  - Hybrid system OEMs: BAE Systems, Bluways, GE, Van Hool
- **Other organizations share information and data**
  - National: CARB, NAVC, CTE, CALSTART
  - International: Various organizations from Germany, Iceland, Brazil, Canada, China, Japan, England, Australia

Future Work

Fuel Cell Electric Bus Evaluations for DOE and FTA

Demonstration	State	# Buses	2012		2013				2014				2015			
			3	4	1	2	3	4	1	2	3	4	1	2	1	2
Advanced Technology FCEB	CA	1	SunLine, Thousand Palms													
Nutmeg Hybrid FCEB *	CT	2	CTTRANSIT, Hartford													
	MI	1	Flint, MTA													
	OH	1			GCRTA, Cleveland											
ZEBA Demonstration	CA	12	AC Transit, Oakland													
						GGT, San Rafael										
									VTA, San Jose; SamTrans, San Mateo							
American Fuel Cell Bus (AFCB) *	CA	1	SunLine, Thousand Palms													
	IL	1						CTA, Chicago								
AFCB (TIGGER)	CA	2										SunLine, Thousand Palms				
CT AFCB	CT	1											CTTRANSIT			
Burbank FCEB	CA	1				Burbank										
Hydrogen Hybrid FCEB *	TX	1		Cap Metro, Austin												
Compound Bus 2010 *	CA	1					SFMTA, San Francisco									
Birmingham FCEB *	AL	1					BJCTA, Birmingham									
Light weight FCEB *	NY	1				Albany										
EcoSaver IV Hybrid FCEB *	OH	1						OSU, Columbus								
Massachusetts FCEB *	MA	1						Massport, Boston								
Advanced Composite FCEB *	TX	1							Cap Metro, Austin							
	TBD												Site 2			
Advanced Generation FCEB *	CT	1							CTTRANSIT							

May 2013

* National Fuel Cell Bus Program project

National Fuel Cell Bus Program

Color coded by Design Strategy:

- Fuel cell dominant hybrid electric
- Battery dominant hybrid electric
- Diesel hybrid with fuel cell primarily for for accessories

Future Work

- **Remainder of FY 2013**
  - Complete following data analyses/reports:
    - SunLine AFCB Report, Apr 2013
    - AC Transit, ZEBA Demo Report, Aug 2013
    - City of Burbank FCEB Report, Sept 2013
    - 2013 Annual Status Report, Sep 2013
- **FY 2014**
  - Kick off new FCEB evaluations as buses go into service
  - Complete Individual Site reports as scheduled
  - Complete annual crosscutting analysis across sites

Summary

Documented progress toward targets:

	Units	2013 Status	2016 Target	Ultimate Target
Bus lifetime	Years / miles	5/100,000	12/500,000	12/500,000
Powerplant lifetime	Hours	1,000 – 12,000	18,000	25,000
Bus availability	%	53 – 84	85	90
Roadcall frequency (Bus/fuel cell system)	Miles between road call	2,000 – 3,500 / 7,000 – 20,000	3,500/15,000	4,000/20,000
Operation time	Hours per day/ days per week	19/7	20/7	20/7
Maintenance cost	$/mile	0.39 – 1.30	0.75	0.40
Fuel economy	Miles per diesel gallon equivalent	6 – 7.5	8	8
Range	miles	220 – 325	300	300