NREL
NATIONAL RENEWABLE ENERGY LABORATORY





Fuel Cell Buses in Public Transit

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Evaluation Objectives and DOE/FTA Targets

- 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	2016 Target	Ultimate Target
Bus lifetime	Years/miles	12/500,000	12/500,000
Powerplant lifetime	Hours	18,000	25,000
Bus availability	%	85	90
Roadcall frequency (bus/fuel cell system)	Miles between roadcall	3,500/15,000	4,000/20,000
Operation time	Hours per day/ days per week	20/7	20/7
Maintenance cost	$/mile	0.75	0.40
Fuel economy	Miles per diesel gallon equivalent	8	8

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

Specifications for FCEBs included in data summary

FCEB Identifier	ACT ZEBA	SL AFCB	UCI AFCB
Transit agency	AC Transit	SunLine	UCI
Location	Oakland, CA	Thousand Palms, CA	Irvine, CA
Number of buses	13	4	1
Bus OEM	Van Hool	ElDorado National	
Bus length/height	40 ft / 136 in.	40 ft / 140 in.	
Fuel cell OEM	UTC Power	Ballard	
Model	PureMotion 120	Fcvelocity–HD6	
Power (kW)	120	150	
Hybrid system	Siemens ELFA, Van Hool integration	BAE Systems HybriDrive	
Design strategy	Fuel cell dominant	Fuel cell dominant	
Energy storage – OEM	EnerDel	A123	
Type	Li-ion	Nanophosphate Li-ion	
Capacity	17.4 kWh	11 kWh	
Number of cylinders	8	8	
Capacity (kg)/pressure (bar)	40 / 350	50 / 350	
Technology readiness level	7	7	

OEM = original equipment manufacturer
ACT ZEBA = AC Transit Zero Emission Bay Area
SL AFCB = SunLine American Fuel Cell Bus
UCI = University of California at Irvine

ACT ZEBA

SL AFCB

UCI AFCB

Current Status of FCEBs

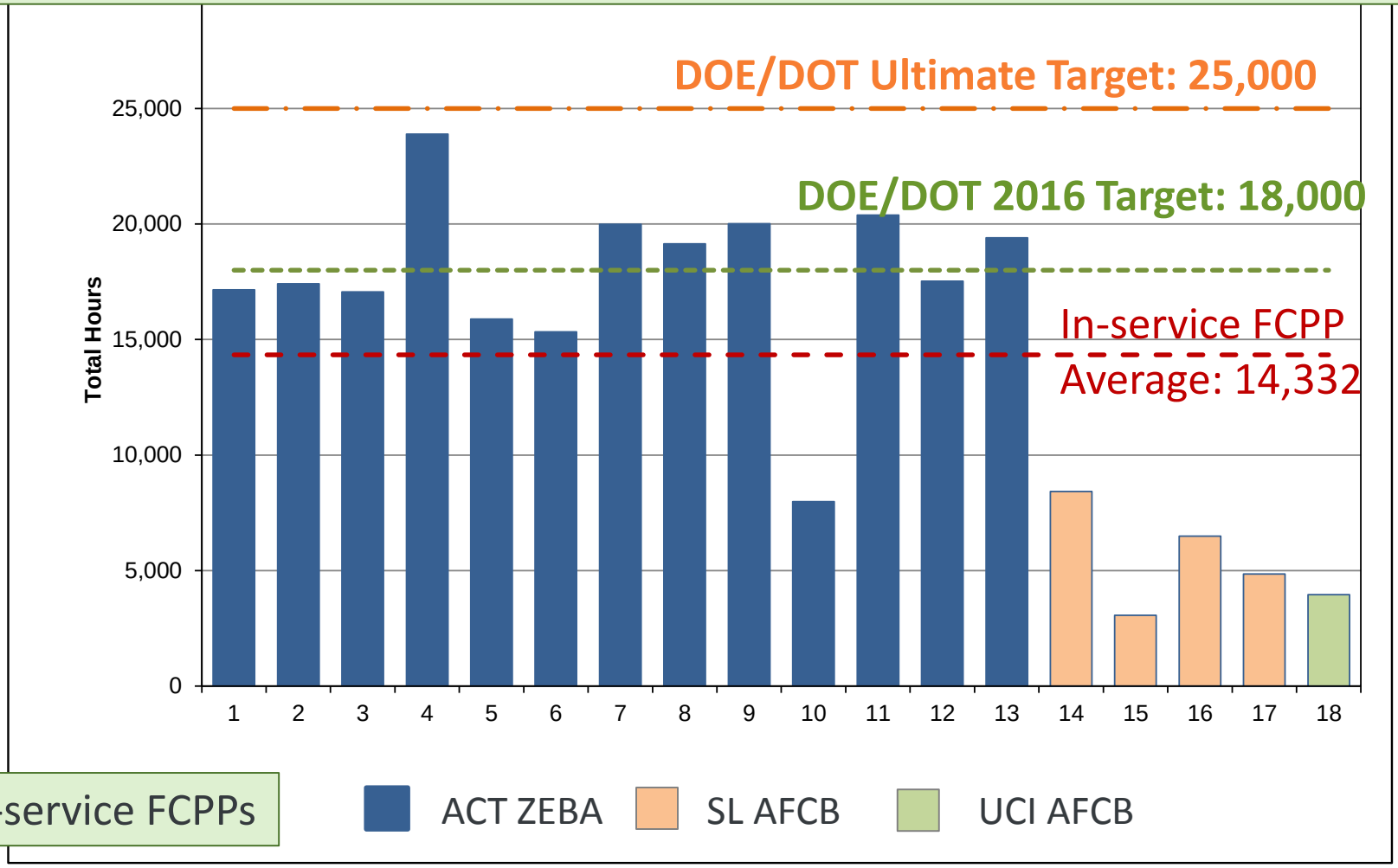
	Fleet Minimum	Fleet Maximum	Fleet Average
Bus lifetime (years)	1.3	6.4	4.7
Bus lifetime (miles)	32,485	167,352	118,989
Power plant lifetime (hours)	3,589	23,423	13,801
Bus availability (%)	44	93	76
Fuel fills (number per day)	1	1	1
Roadcall frequency – bus (MBRC)			4,710
Roadcall frequency – propulsion			8,146
Roadcall frequency – fuel cell system			20,705
Operation time (average hours per day)	7.4	13.7	11.8
Scheduled and unscheduled maintenance cost ($/mile)[1]	0.46	1.61	1.03
Range (miles)	215	274	247
Fuel economy (miles per DGE)	5.66	7.22	6.51

Data Summary from 3 fleets – 18 total buses.

[1] Buses from two fleets are still under warranty, although most of the maintenance is handled by transit staff

FC Powerplant Life

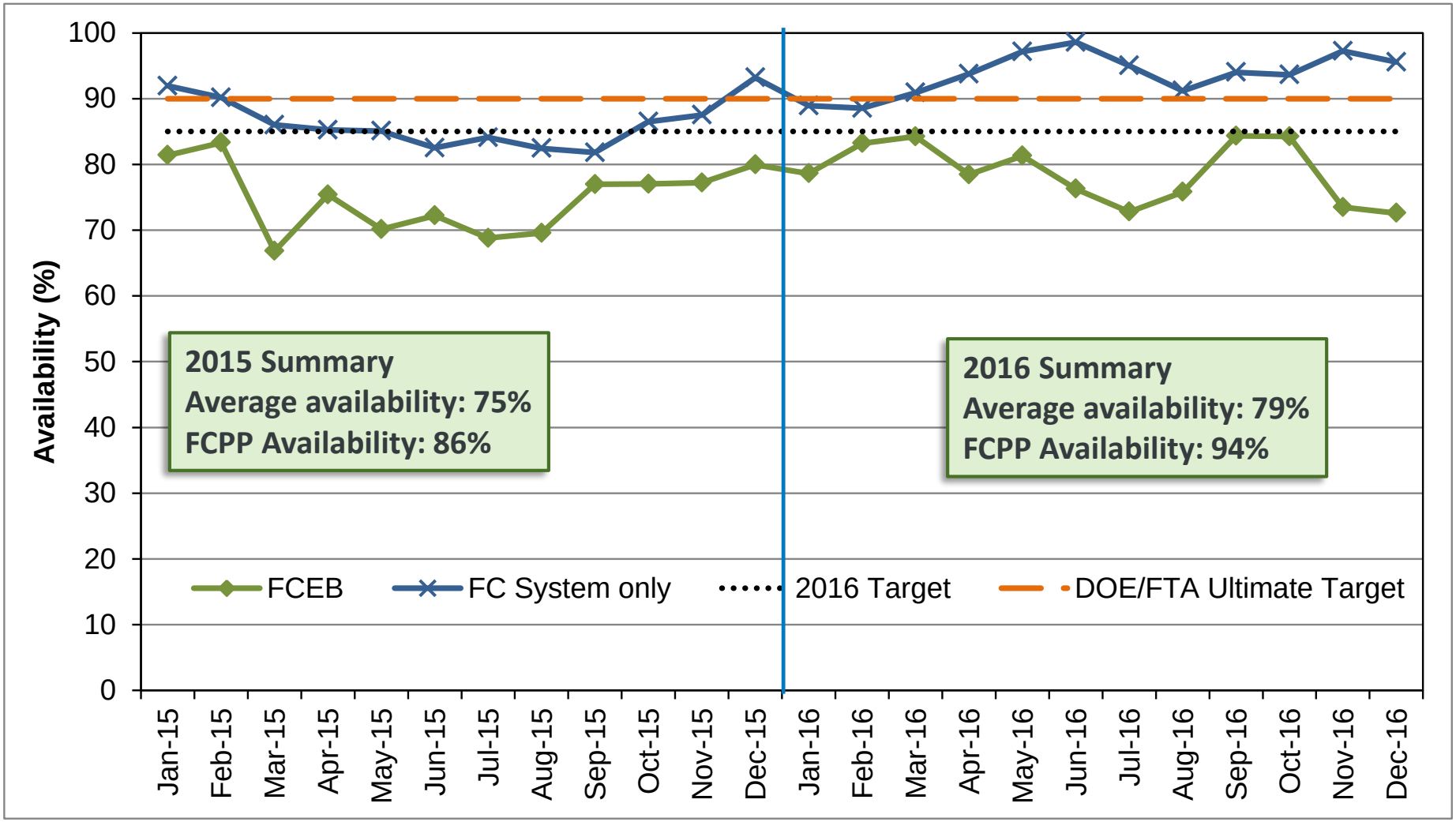
Top fuel cell powerplant (FCPP) >23,800 hours, surpassing DOE/DOT 2016 target; 67% of FCPPs (12) more than 15,000 hours



Total hours accumulated on each FCPP as of 2/28/17

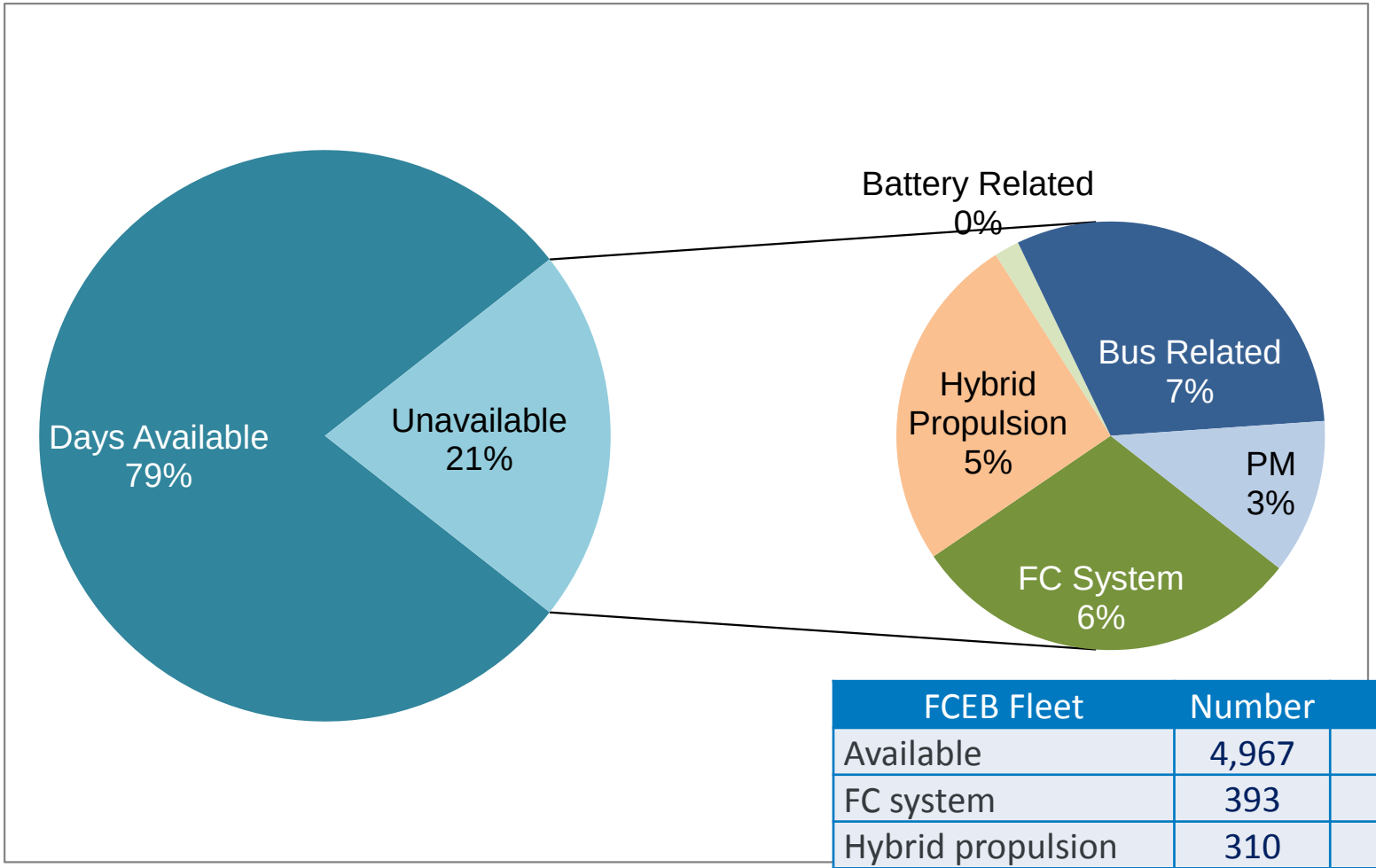
Availability

Monthly bus availability



Availability = planned operation days compared to actual operation days

Availability Summary: 2016 Data

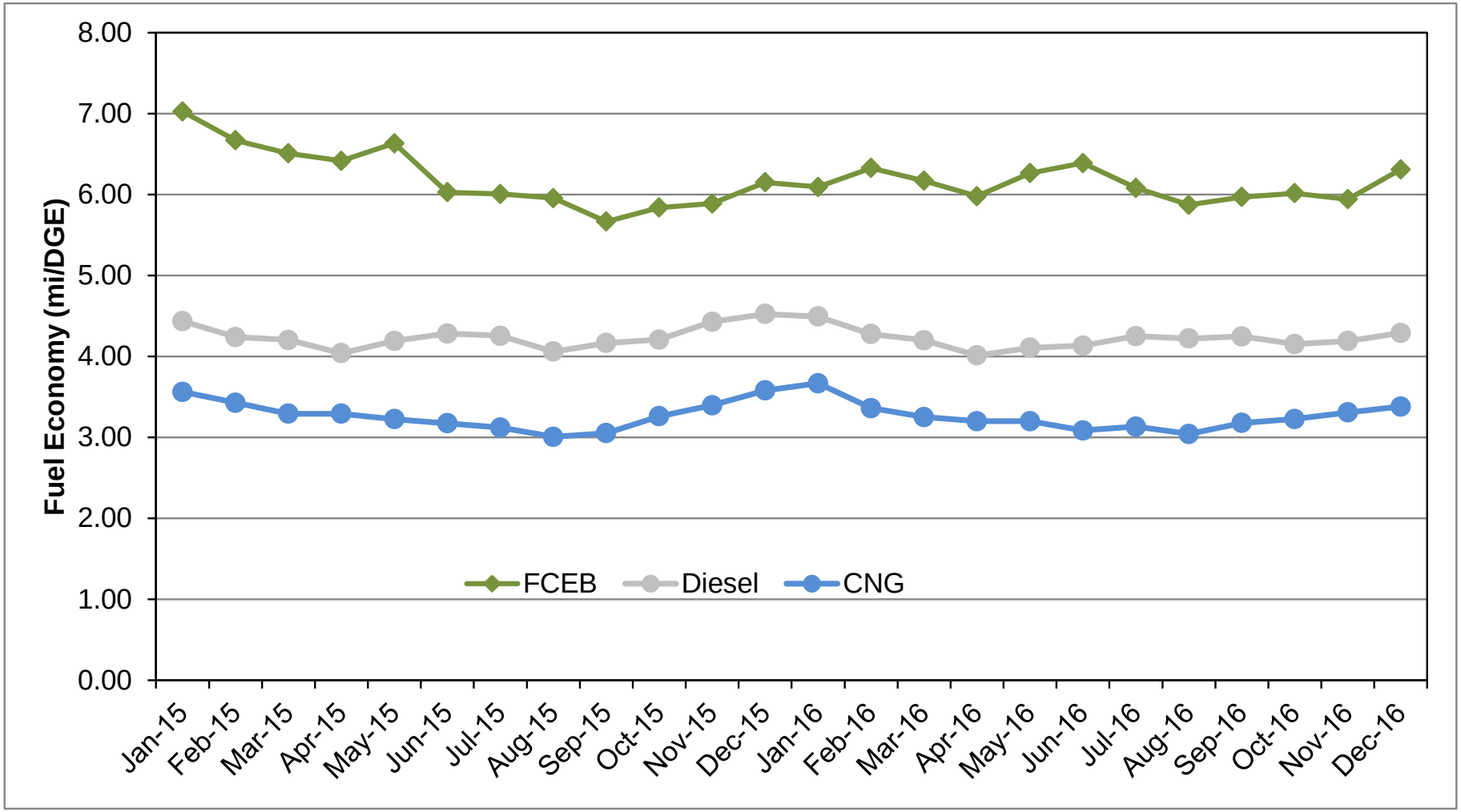


FC = fuel cell
PM = preventive maintenance

FCEB Fleet	Number	%
Available	4,967	79
FC system	393	6
Hybrid propulsion	310	5
Traction batteries	25	<1
Bus maintenance	411	7
PM	157	3
Total days	6,263	100

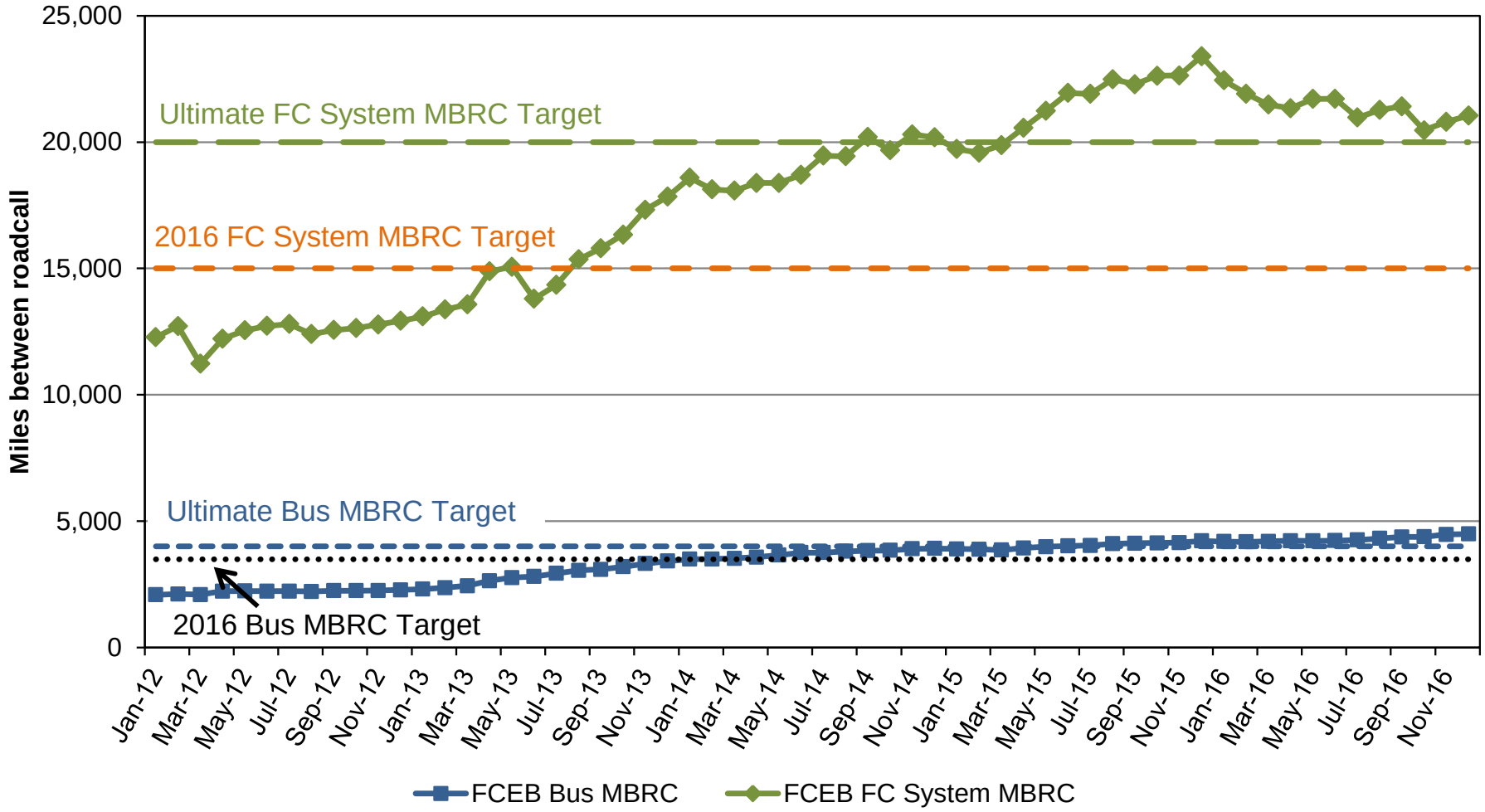
Monthly Fuel Economy Compared to Baseline

mpDGE = miles per diesel gallon equivalent



Drop in fuel economy over time could be due to several factors: degradation of fuel cells, changes in routes used, changes in hybrid system calibration

FCEB Reliability



- FCEB reliability **surpassed ultimate targets in 2015**
- Maintenance staff becoming more familiar with system, applying new tools to anticipate and fix issues before they fail in service

FCEB Fueling

Fueling Experience

- Dispenser can be located in the fueling aisle with other services
- Average fueling time: 18 minutes
- Average fill amount: 20 kilograms

Remaining Challenges and Barriers for FCEBs

Specific to FCEBs

- Increase durability and reliability of components
- Continue transition of build process to OEM
- Addition of fueling infrastructure
- Develop robust supply chain for components and parts to lower cost and downtime
  - Multiple component suppliers to stabilize supply
  - Standardized with conventional bus components to lower cost
- Establish support centers for advanced technology components
- Increase learning curve for maintenance staff
  - Develop training specific to FCEBs and incorporate in traditional classes
  - Provide tools to agencies for monitoring and troubleshooting issues
- Reduce cost, both capital and operating

Web site:

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

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