

**NREL**  
NATIONAL RENEWABLE ENERGY LABORATORY

# Technology Validation of Zero-Emission Buses



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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

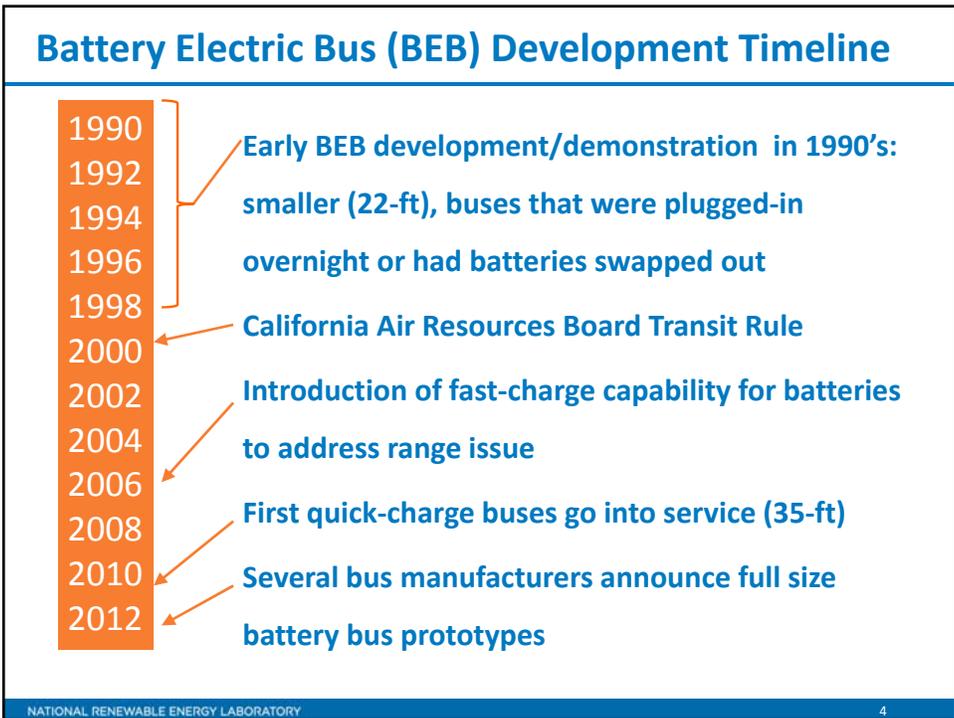
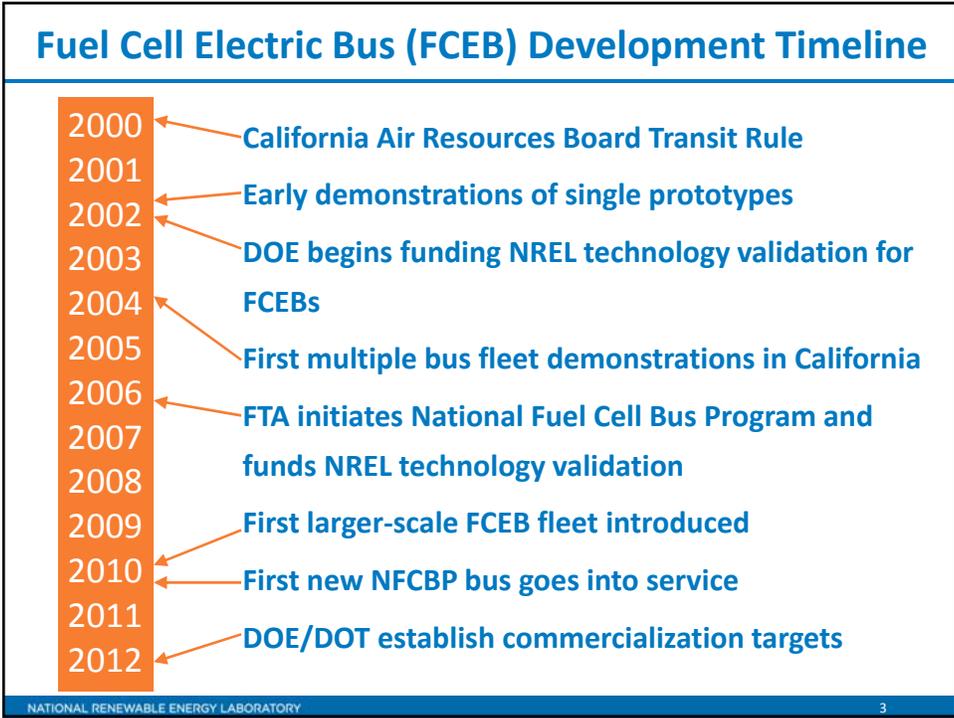
## Why Advanced Technology for Transit Buses?

- Reduce transit bus emissions
- Improve fuel efficiency
- Improve vehicle performance
- Consumer acceptance
- Transit industry is excellent test-bed for new technologies
  - Centrally fueled and maintained
  - Fixed routes with urban stop-go duty cycle
  - Professional operators and mechanics
  - Federal capital funding support
  - High visibility & high impact



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## Programs Promoting Development of ZBuses

### California Air Resources Board Transit Rule

- Set more stringent emission standards for new urban bus engines
- Set fleet emission averages
- Promoted advances in the cleanest technologies: required demonstrations of zero-emission buses
  - Fuel cell electric, battery electric, or trolley buses
  - Early demos focused on FCEBs because of range issue with early BEBs
  - Early demonstrations of 8 FCEBs at 3 agencies
  - Advanced demonstration: 12 FCEBs for SF Bay area



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## Programs Promoting Development of ZBuses

### FTA's National Fuel Cell Bus Program (NFCBP)

- Cooperative research, development and demonstration program to advance FCEB commercialization
- Program authorized by Congress in SAFETEA-LU
- Nearly \$90 Million Federal authorized to date
- 50-50 cost share with industry
- Teams and projects competitively selected
- *Balanced portfolio of projects:*
  - FCEB demonstrations
  - Component development projects
  - Outreach/education projects



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## Programs Promoting Development of ZBuses

### FTA's National Fuel Cell Bus Program (NFCBP)

2012 Awards announced September 5<sup>th</sup>



Project	Consortia	Location	Partners
FCEB Fleet Extended Operation	CTE	Oakland, CA	AC Transit (ZEBA)
American Fuel Cell Bus	CALSTART	Cleveland, OH	Greater Cleveland RTA, EIDorado National, BAE Systems, Ballard Power Systems
Battery Dominant FCEB	CALSTART	Palm Springs, CA	SunLine, EIDorado National, BAE Systems
Central NY Fuel Cell Transportation Program	CTE	Ithaca, NY	Tompkins Consolidated Transit Authority, EIDorado National, BAE Systems, Ballard Power Systems
Birmingham FCEB Operational Support	CTE	Birmingham, AL	Birmingham Jefferson County Transit
FCEB Altoona Testing	CALSTART	Altoona, PA	National Bus Testing Facility
Best Practices in H2 fueling and maintenance	CALSTART	Pasadena, CA	CALSTART
NFCBP Education & Outreach	CTE	Atlanta, GA	CTE

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## Programs Promoting Development of ZBuses

### FTA's Transit Investments for Greenhouse Gas and Energy Reduction (TIGGER)

- Initiated in 2009
- Three rounds of funding totaling ~\$225 M
- Variety of technologies to reduce energy or GHG emissions, including zero-emission buses

OEM	Charge source	Number
Proterra	Fast-charge	26
Ebus	Fast-charge	8
BYD	Plug-in, & inductive	10
TBD	Inductive	10
TBD	Fast-charge	1



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## Funding Awards Competitively Selected

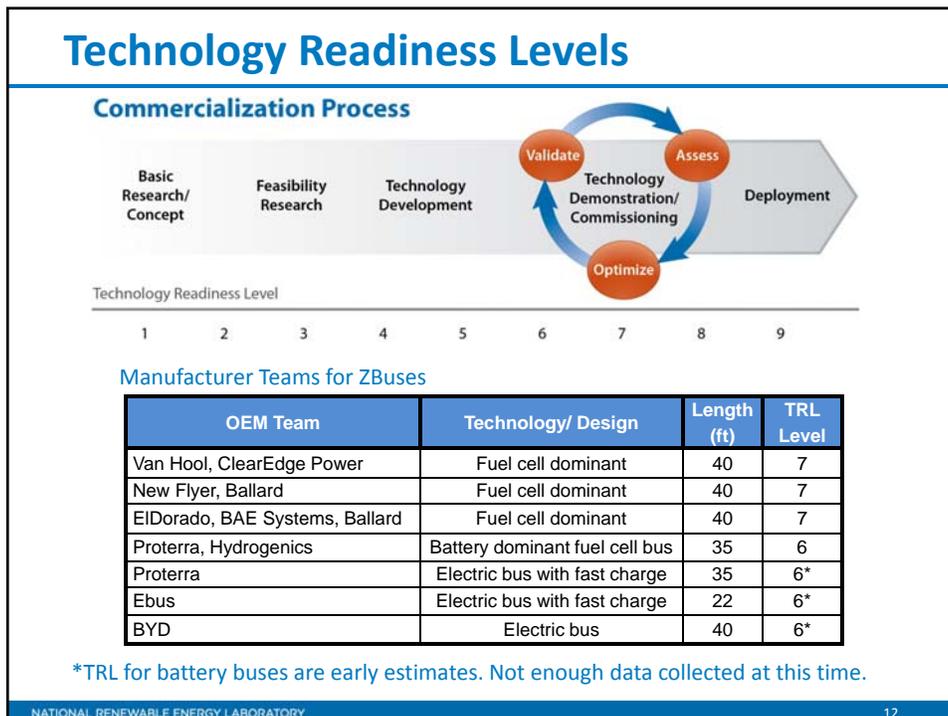
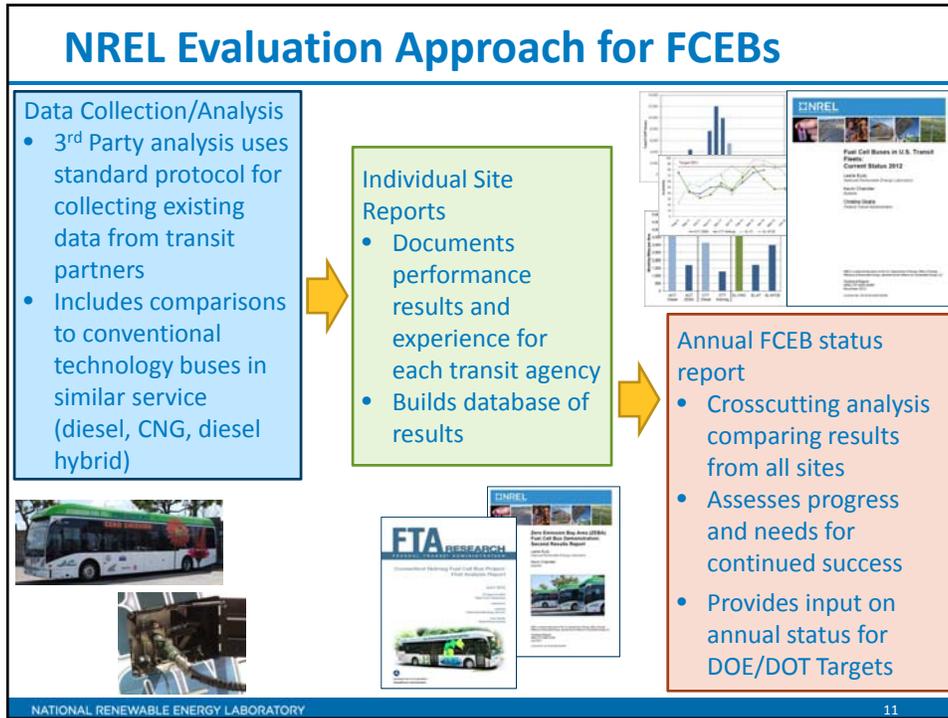
- Proposers develop project plans to meet program goals
- Evaluation criteria established for each program
- Proposals evaluated by a team of reviewers and scored compared to criteria
- Upcoming solicitations for new FTA program will provide opportunity for funding
- **3<sup>rd</sup> party assessment extremely important to measure progress**

## NREL Third-Party Assessment Objectives

- Validate ZBus 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 (from project data)	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
Road call 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](http://www.hydrogen.energy.gov/pdfs/12012_fuel_cell_bus_targets.pdf)



## NREL Technology Assessment: Next Steps

- **Current work has been focused on FCEBs (funded by DOE and FTA)**
- **Collecting selected performance results for BEBs under FTA's TIGGER program**
  - Will allow some comparisons to FCEB technology
  - Data collection is not as detailed as that of the FCEBs. Roadcall and availability are not included.
- **Collecting data on BC Transit fleet (CARB funded) to expand the database of performance results**

## Remaining Challenges for ZBuses

- Performance needs to match baseline buses
- Increase durability of FC to >20,000 hours
- Assess status of battery/fast-charge technologies
- Optimization of hybrid system & reliability of components (batteries, converters, software)
- Prepare for Market introduction:
  - Training/transition of all maintenance to transit staff
  - Develop training materials
  - Transition build process to bus OEM
- Ramp up of H2 fueling to supply larger fleets
- Address electricity demand-charge for fast-charge
- Cost reduction: capital and operating



## For more information

NREL Hydrogen Technology Validation web page:  
[www.nrel.gov/hydrogen/proj\\_tech\\_validation.html](http://www.nrel.gov/hydrogen/proj_tech_validation.html)

**Hydrogen & Fuel Cells Research**

**Hydrogen Technology Validation**

Technology validation is defined as confirmation that component and system technical targets have been met under realistic operating conditions. NREL's technology validation team is working to validate hydrogen fuel cell vehicles and refueling infrastructure as part of DOE's hydrogen technology validation activity.

Technology validation projects involve gathering extensive data from the systems and components under real-world conditions, analyzing the detailed data, and then comparing results to technical targets. While the raw data is protected by NREL, analysis results are aggregated into public results called composite data products. These public results show the status and progress of the technology, but don't identify individual companies.

Three major hydrogen technology validation efforts are underway at NREL:

- [Hydrogen Fuel Cell Vehicle and Infrastructure Learning Demonstration](#)  
Access the latest analysis results, papers, and presentations from NREL's work on DOE's Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project.
- [Hydrogen Fuel Cell Bus Evaluations](#)  
Access detailed reports and analysis results from all of NREL's fuel cell vehicle bus evaluations.
- [Early Fuel Cell Market Demonstrations](#)

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