



Fuel Cell Transit Bus Evaluations

**Joint Evaluation Plan for the U.S.
Department of Energy and the Federal
Transit Administration**

**Appendix: Summary of Fuel Cell Transit
Bus Demonstration Sites in North
America**

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

Technical Report

NREL/TP-5600-49342-2

November 2010

Contract No. DE-AC36-08GO28308

Fuel Cell Transit Bus Evaluations

**Joint Evaluation Plan for the U.S.
Department of Energy and the Federal
Transit Administration**

**Appendix: Summary of Fuel Cell Transit
Bus Demonstration Sites in North
America**

Prepared under Task No(s). H270.8150, WF2B.1000

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

NOTICE

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

Available electronically at <http://www.osti.gov/bridge>

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: <mailto:reports@adonis.osti.gov>

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: <http://www.ntis.gov/help/ordermethods.aspx>

Cover Photos: (left to right) PIX 16416, PIX 17423, PIX 16560, PIX 17613, PIX 17436, PIX 17721



Printed on paper containing at least 50% wastepaper, including 10% post consumer waste.

Appendix: Summary of Fuel Cell Transit Bus Demonstration Sites in North America

Current as of November 3, 2010

List of Tables

Table A1. NREL Current & Planned Evaluations for FTA & DOE	1
Table A2. Completed Evaluations	1
Table A3. Potential Evaluations	2
Table A4. AC Transit – ZEBRA Demonstration Evaluation In-Process	3
Table A5. City of Burbank Fuel Cell Bus Demo Evaluation In-Process	4
Table A6. Dual Variable Output Fuel Cell Hybrid Bus Evaluation In-Process	5
Table A7. SunLine – Advanced Fuel Cell Bus Evaluation In-Process	6
Table A8. Nutmeg Hybrid Fuel Cell Bus Evaluation In-Process.....	7
Table A9. Compound FCB Hybrid Bus for 2010	8
Table A10. Massachusetts Hydrogen Fuel Cell Powered Bus Fleet	9
Table A11. Lightweight Fuel Cell Bus Demo	10
Table A12. SunLine – American Fuel Cell Bus	11
Table A13. AC Transit: Accelerated Testing Evaluation Complete	12
Table A14. AC Transit: HyRoad Evaluation Complete.....	13
Table A15. Connecticut Transit – Fuel Cell Bus Evaluation Complete.....	14
Table A16. Santa Clara VTA – Fuel Cell Bus Evaluation Complete.....	15
Table A17. SunLine Fuel Cell Bus Evaluation Complete.....	16
Table A18. SunLine Fuel Cell Bus – Extended Service Evaluation Complete	17
Table A19. SunLine HHICE bus Evaluation Complete	18
Table A20. University of Delaware.....	19
Table A21. University of Texas (Austin)	20
Table A22. University of Alabama.....	21
Table A23. Georgetown University.....	22
Table A24. BC Transit.....	23

Credit for all photos in this Appendix: L. Eudy, NREL

Summary of Sites and Schedules

Table A1. NREL Current & Planned Evaluations for FTA & DOE

	Sites/Locations	Project/Title	Buses	Propulsion	Eval. Funding	Selected	CY 2010				CY 2011				CY 2012				
							1	2	3	4	1	2	3	4	1	2	3	4	
1	AC Transit (lead) / SF Bay Area, CA	ZEBA Demo 2009	12	UTC Power/Van Hool	DOE	Full			X	X	X	X	X	X	X	X	X		
2	City of Burbank / Burbank, CA	Burbank FCB Demo	1	Proterra/Hydrogenics	DOE	Partial				X	X	X	X						
3	USC, CMRTA / Columbia, SC UT / Austin, TX	Dual Variable Output Fuel Cell Hybrid Bus	1	Proterra/Hydrogenics	FTA	Partial	X	X	X	X	X	X	X	X					
4	SunLine / Thousand Palms, CA	Advanced Fuel Cell Bus Project	1	Ballard/ISE	DOE	Full		X	X	X	X	X	X	X	X				
5	CTTRANSIT / Hartford, CT	CT FCB Demonstration	4	UTC Power/Van Hool	FTA	Full			X	X	X	X	X	X	X	X			
6	SFMTA / San Francisco, CA	Compound Fuel Cell Hybrid Bus Demonstration	1	Hydrogenics/BAE	FTA	Full					X	X	X	X					
7	Logan Airport / Boston, MA	MA Hydrogen Fuel Cell Powered Bus Fleet	1	Nuvera/Proterra	FTA	Full						X	X	X	X	X			
8	Albany / NY	Lightweight Fuel Cell Bus Demonstration	1	GE/Hydrogenics	FTA	Full							X	X	X				
9	SunLine / Thousand Palms, CA	American Fuel Cell Bus Demonstration	1	BAE/Ballard	FTA	Full								X	X	X	X	X	

Table A2. Completed Evaluations

	Sites/Locations	Project/Title	Buses	Propulsion	Eval. Funding	Dates
10	AC Transit / Oakland, CA	Accelerated Fuel Cell Bus Testing	3	UTC Power/ISE	FTA	Nov 2007 – Feb 2010
11	AC Transit / Oakland, CA	HyRoad	3	UTC Power/ISE	DOE	Apr 2006 – Dec 2007
12	CTTRANSIT / Hartford, CT	CTTRANSIT	1	UTC Power/ISE	DOE	Apr 2007 – Oct 2009
13	Santa Clara VTA / CA	FCB Demo	3	Gillig/Ballard	DOE	Mar 2005 – July 2006
14	SunLine / Thousand Palms, CA	SunLine Fuel Cell Bus	1	UTC Power/ISE	DOE	Jan 2006 – Mar 2008
15	SunLine / Thousand Palms, CA	SunLine Extended Service	1	UTC Power/ISE	DOE	Apr 2008 – June 2009
16	SunLine / Thousand Palms, CA	HHICE Bus	1	ISE/Ford ICE	DOE	Jan 2006 – Mar 2008

Green shaded numbers denote projects that are part of the FTA's National Fuel Cell Bus Program

Table A3. Potential Evaluations

	Potential Sites/Locations	Project/Title	Buses	Propulsion	Status
17	University of Delaware / Newark, DE	University of Delaware	1	Ballard/Ebus 22-ft	In-service, Spring 2007
			1	Ballard/Ebus 22-ft	In-service, Fall 2009
			1	Ballard/Ebus 30-ft	Development
			1	Ballard/Ebus 30-ft	Development
18	University of Texas / Austin, TX	University of Texas	1	Ballard/Ebus	In-service, Oct 2007
19	University of Alabama / Birmingham	University of Alabama	1	Hydrogenics/EVAmerica	Development
20	University of Georgetown	Georgetown	1	Ballard/Nucellsys/ EVAmerica	Development
21	BC Transit / Whistler, Canada	BC Transit FCB	20	Ballard/ISE/New Flyer	In-service, Jan 2010

Table A4. AC Transit – ZEB A Demonstration **Evaluation In-Process**

Project	Zero Emission Bay Area Demo 2009
Lead organization	AC Transit
Consortia	N/A
Partners	UTC Power: fuel cell system Van Hool: bus chassis and hybrid system EnerDel: lithium ion batteries Linde: infrastructure Golden Gate Transit, Santa Clara VTA, SamTrans, SFMTA: demo
Technology description	40-ft hybrid FCB with newest fuel cell system and advanced batteries
Operating site and location	AC Transit, Oakland; Golden Gate, San Rafael; VTA, San Jose; SamTrans, San Mateo; SFMTA, San Francisco
Estimated demo start date	Fall 2010
Duration	2 years
Number of buses	12
Infrastructure description	Linde building new station at Emeryville Division and replacing the existing station at East Oakland Division. Both are liquid hydrogen delivery/storage and dispensing. Emeryville will include light-duty FCEV public access for 350 and 700 bar
Evaluation Type	Full
Funding source	DOE



Table A5. City of Burbank Fuel Cell Bus Demo **Evaluation In-Process**

Project	Burbank FCB Demonstration
Lead organization	City of Burbank
Consortia	N/A
Partners	Proterra: bus chassis and hybrid system Hydrogenics: fuel cells Altairnano: batteries CARB: funding organization
Technology description	Battery dominant fuel cell system employing a strategy using two 16-kW FC stacks packaged into a single 32-kW parallel operating system and lithium titanate batteries (this bus is the same design as the Proterra bus for NFCBP)
Operating site and location	Burbank, CA
Estimated demo start date	Sep 2010
Duration	1 year
Number of buses	1
Infrastructure description	Burbank station
Evaluation type	Partial
Funding source	DOE



Table A6. Dual Variable Output Fuel Cell Hybrid Bus

Evaluation In-Process

Project	Dual Variable Output Fuel Cell Hybrid Bus
Lead organization	CTE
Consortia	CTE
Partners	Proterra: bus chassis and hybrid system Hydrogenics: fuel cell stacks (2) Altairnano: batteries
Technology description	Battery dominant fuel cell system employing a strategy using two 16-kW FC stacks packaged into a single 32-kW parallel operating system and lithium titanate batteries
Operating site and location	USC & CMRTA, Columbia, SC, followed by University of Texas, Austin, TX
Estimated demo start date	4 th Qtr 2009
Duration	1 year at each location
Number of buses	1
Infrastructure description	GTI station in Columbia – trucked in hydrogen
Evaluation type	Partial
Funding source	FTA



Table A7. SunLine – Advanced Fuel Cell Bus **Evaluation In-Process**

Project	Advanced Hybrid Fuel Cell Bus Project
Lead organization	SunLine
Consortia	N/A
Partners	Ballard: fuel cell ISE: hybrid system and integration New Flyer: 40-ft bus chassis
Technology description	ISE hybrid system with a Ballard fuel cell on a New Flyer chassis. This is the pilot bus from the BC Transit FCB demo.
Operating site and location	SunLine, Thousand Palms, CA
Estimated demo start date	June 2010
Duration	1 year
Number of buses	1
Infrastructure description	Hyradix natural gas reformer (existing)
Evaluation type	Full
Funding source	DOE



Table A8. Nutmeg Hybrid Fuel Cell Bus **Evaluation In-Process**

Project	CT Hybrid Fuel Cell Bus Demo
Lead organization	UTC Power
Consortia	NAVC
Partners	UTC Power: fuel cell Van Hool: chassis and hybrid system EnerDel: lithium ion batteries
Technology description	Advanced version of the current 40-ft hybrid FCB incorporating the latest technology to increase durability, reliability, and performance of the bus.
Operating site and location	CTTRANSIT, Hartford, CT, & other locations TBD
Estimated demo start date	July 2010
Duration	2 years
Number of buses	4
Infrastructure description	UTC Power fueling facility to start, adding a H2 electrolysis system and dispenser at CTT facility (DOE Clean Cities funded)
Evaluation type	Full
Funding source	FTA



Table A9. Compound FCB Hybrid Bus for 2010

Project	Compound Fuel Cell Hybrid Bus for 2010
Lead organization	BAE Systems
Consortia	CALSTART
Partners	BAE: hybrid system & integration Orion: bus chassis Hydrogenics: fuel cell APU Lincoln Composites: hydrogen storage
Technology description	40-ft diesel hybrid bus with fuel cell APU to handle auxiliary loads and advanced energy storage; design includes a 15–25 kW fuel cell and integrated starter generator coupled to a diesel engine and energy storage system.
Operating site and location	SFMTA, San Francisco, CA
Estimated demo start date	3 rd Qtr 2010
Duration	8 months
Number of buses	1
Infrastructure description	TBD
Evaluation type	Full
Funding source	FTA

Table A10. Massachusetts Hydrogen Fuel Cell Powered Bus Fleet

Project	Massachusetts Hydrogen Fuel Cell Powered Bus Fleet
Lead organization	Nuvera/ISE
Consortia	NAVC
Partners	Nuvera: fuel cell A123Systems: energy storage
Technology description	40-ft bus with an 82-kW Nuvera fuel cell integrated into a hybrid system with advanced energy storage
Operating site and location	Massport: Logan Airport, Boston, MA
Estimated demo start date	2011
Duration	2 years
Number of buses	1
Infrastructure description	Nuvera's PowerTap – natural gas reformer
Evaluation type	Full
Funding source	FTA

Table A11. Lightweight Fuel Cell Bus Demo

Project	Lightweight Fuel Cell Hybrid Bus
Lead organization	GE
Consortia	NAVC
Partners	GE: hybrid system & integration Hydrogenics: fuel cell
Technology description	Lightweight FCB incorporating a fuel cell, ultracaps, and lithium ion batteries
Operating site and location	Albany, NY
Estimated demo start date	2011
Duration	1 year
Number of buses	1
Infrastructure description	TBD
Evaluation type	Full
Funding source	FTA

Table A12. SunLine – American Fuel Cell Bus

Project	American Fuel Cell Bus
Lead organization	SunLine
Consortia	CALSTART
Partners	BAE: hybrid system & integration Ballard: fuel cell EIDorado: bus chassis
Technology description	Demonstrate 40-ft FCB with design improvements in an American-made bus chassis; improvements include newest fuel cell design, lithium-ion batteries, reduced weight to hybrid system, various changes to overall bus to reduce weight and increase efficiency
Operating site and location	SunLine, Thousand Palms, CA
Estimated demo start date	4 th Qtr 2011
Duration	15 months
Number of buses	1
Infrastructure description	Hyradix natural gas reformer (existing)
Evaluation type	Full
Funding source	FTA

Table A13. AC Transit: Accelerated Testing**Evaluation Complete**

Project	Accelerated Fuel Cell Bus Testing
Lead organization	AC Transit
Consortia	CALSTART
Partners	UTC Power: fuel cell system ISE: hybrid system & integration Van Hool: bus chassis Chevron Technology Ventures: infrastructure
Technology description	Accelerated testing to failure of current generation buses with new design fuel cell power systems
Operating site and location	AC Transit, Oakland, CA
Estimated demo start date	November 2007
Duration	15 months (data period starts Dec 2008)
Number of buses	3
Infrastructure description	Natural gas reformer and two dispensers
Evaluation type	Full
Funding source	FTA



Table A14. AC Transit: HyRoad

Evaluation Complete

Project	HyRoad
Lead organization	AC Transit
Consortia	N/A
Partners	UTC Power: fuel cell system ISE: hybrid system & integration Van Hool: bus chassis Chevron Technology Ventures: infrastructure Golden Gate Transit: demo
Technology description	40-ft hybrid FCB with a 120-kW fuel cell and ZEBRA batteries
Operating site and location	AC Transit, Oakland, CA
Demo start date	March 2006
Duration	2 years (analysis period: April 2006 – Dec 2008)
Number of buses	3
Infrastructure description	Natural gas reformer with two dispensers, also fuel light duty FCVs
Evaluation type	Full
Funding source	DOE



Table A15. Connecticut Transit – Fuel Cell Bus**Evaluation Complete**

Project	CTTRANSIT Fuel Cell Bus Demo
Lead organization	CTTRANSIT
Consortia	N/A
Partners	UTC Power: fuel cell system ISE: hybrid system & integration Van Hool: bus chassis
Technology description	40-ft hybrid FCB with a 120-kW fuel cell and ZEBRA batteries (same as ACT and SunLine buses)
Operating site and location	CTTRANSIT, Hartford, CT
Demo start date	May 2007
Duration	2 years (analysis period: April 2007 – Oct 2009)
Number of buses	1
Infrastructure description	Liquid hydrogen delivery, storage, and dispensing – station located at UTC Power HQ; renewable H2 production from Niagara Falls
Evaluation type	Full
Funding source	DOE



Table A16. Santa Clara VTA – Fuel Cell Bus **Evaluation Complete**

Project	Santa Clara Valley Transportation Authority – Fuel Cell Bus Demo
Lead organization	VTA
Consortia	N/A
Partners	Ballard: fuel cell system – non-hybrid Gillig: bus chassis
Technology description	40-ft FCB with a 120-kW fuel cell
Operating site and location	VTA, San Jose, CA
Demo start date	March 2005
Duration	1 year (analysis period: Mar 2005 – July 2006)
Number of buses	3
Infrastructure description	Liquid hydrogen delivery, storage, and dispensing – station located at VTA, Air Products
Evaluation type	Full
Funding source	DOE



Table A17. SunLine Fuel Cell Bus**Evaluation Complete**

Project	SunLine Fuel Cell Bus
Lead organization	SunLine
Consortia	N/A
Partners	UTC Power: fuel cell system ISE: hybrid system & integration Van Hool: FC bus chassis HyRadix: infrastructure
Technology description	FCB: 40-ft hybrid with a 120-kW fuel cell and ZEBRA batteries
Operating site and location	SunLine, Thousand Palms, CA
Demo start date	January 2006
Duration	2 years (data period: Jan 2006 – Mar 2008)
Number of buses	1
Infrastructure description	Natural gas reformer, station open to public and also fueling light-duty FCVs
Evaluation type	Full
Funding source	DOE

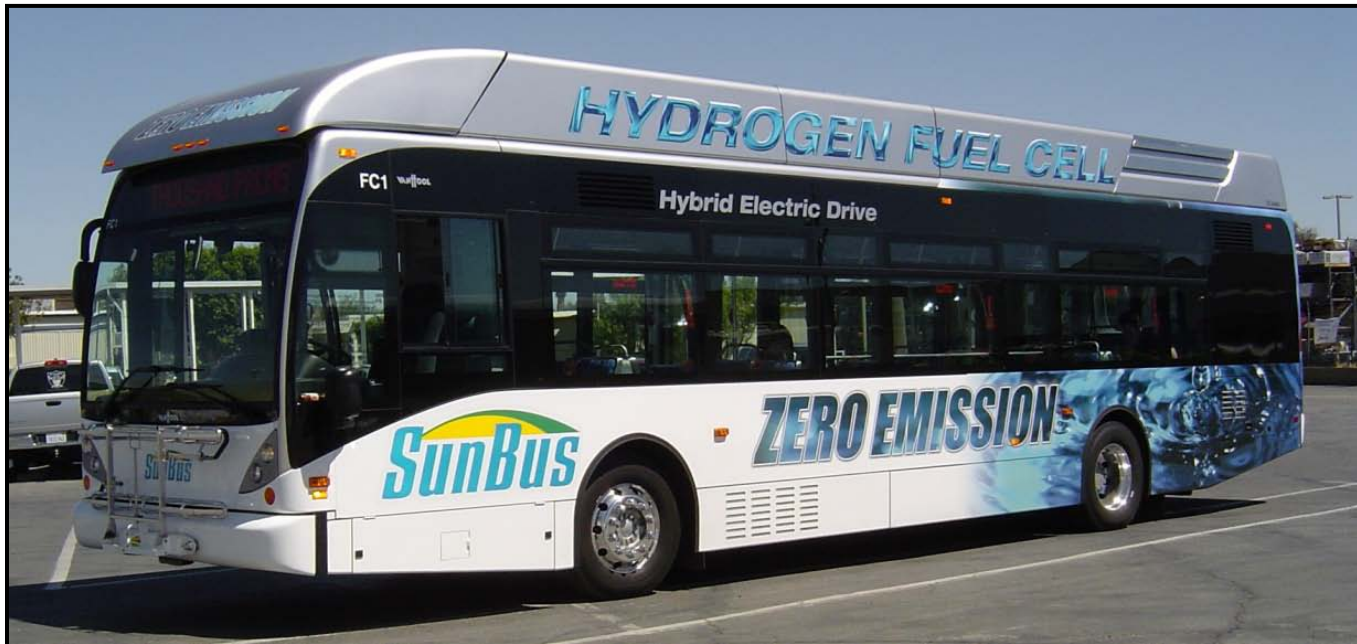


Table A18. SunLine Fuel Cell Bus – Extended Service**Evaluation Complete**

Project	Fuel Cell Bus Extended Service
Lead organization	SunLine
Consortia	N/A
Partners	UTC Power: fuel cell system ISE: hybrid system & integration Van Hool: FC bus chassis HyRadix: infrastructure
Technology description	FCB: 40-ft hybrid with an updated 120-kW fuel cell and ZEBRA batteries
Operating site and location	SunLine, Thousand Palms, CA
Estimated demo start date	April 2008
Duration	1 year (analysis period: April 2008 – June 2009)
Number of buses	1
Infrastructure description	Natural gas reformer, station open to public and also fueling light-duty FCVs
Evaluation type	Full
Funding source	DOE



Table A19. SunLine HHICE bus**Evaluation Complete**

Project	HHICE Bus
Lead organization	SunLine
Consortia	N/A
Partners	ISE: hybrid system & integration Ford: hydrogen ICE engine New Flyer: HHICE bus chassis HyRadix: infrastructure
Technology description	HHICE: 40-ft hybrid using a Ford V10 engine modified to operate on hydrogen and ultracaps
Operating site and location	SunLine, Thousand Palms, CA
Demo start date	January 2006
Duration	2 years (analysis period: Jan 2006 – Mar 2008)
Number of buses	1
Infrastructure description	Natural gas reformer, station open to public and also fueling light-duty FCVs
Evaluation type	Full
Funding source	DOE



Table A20. University of Delaware

Project	University of Delaware FCB Development/Demo
Lead organization	UD
Consortia	N/A
Partners	UD: development/demonstration, project lead Ballard: fuel cell Ebus: bus chassis and hybrid system
Technology description	22-ft, Ebus hybrid with the latest design Ballard fuel cell and NiCd batteries, also a plug-in
Operating site and location	UD Campus, Newark, DE (transit service in summer)
Estimated demo start date	First bus delivered in Spring 2007
Number of buses	2 (Phase 1 & 2: active), 2 more are planned: ~30-ft buses
Infrastructure description	Air Liquide hydrogen station in Newark, DE



Table A21. University of Texas (Austin)

Project	University of Texas FCB Demonstration
Lead organization	UT
Consortia	CTE
Partners	UT: development/demonstration, project lead Ballard: fuel cell Ebus: bus chassis and hybrid system
Technology description	22-ft, Ebus hybrid with the latest design Ballard fuel cell and NiCd batteries, also a plug-in
Operating site and location	UT campus, Austin, TX
Estimated demo start date	Bus delivered in Fall 2007
Number of buses	1
Infrastructure description	GTI station at J.J. Pickle Research Center

Table A22. University of Alabama

Project	University of Alabama FCB Demonstration
Lead organization	UAB
Consortia	N/A
Partners	UAB: development/demonstration, project lead EVAmerica: bus and hybrid system Hydrogenics: fuel cell
Technology description	30-ft bus with hybrid fuel cell system
Operating site and location	Birmingham-Jefferson County Transit Authority, Birmingham, Alabama
Estimated demo start date	TBD
Number of buses	2
Infrastructure description	TBD

Table A23. Georgetown University

Project	Georgetown University FCB Demonstration
Lead organization	GU
Consortia	CTE
Partners	Georgetown: development/demonstration, project lead Ballard: fuel cell Nucellsys: hybrid system and integration EVAmerica: bus and hybrid system
Technology description	30-ft bus methanol fueled bus with hybrid system and on-board reformer
Operating site and location	TBD
Estimated demo start date	TBD
Number of buses	1
Infrastructure description	TBD

Table A24. BC Transit

Project	BC Transit FCB Program
Lead organization	BC Transit
Consortia	N/A
Partners	Ballard: fuel cell ISE: hybrid system and integration New Flyer: chassis
Technology description	40-ft bus with hybrid fuel cell system
Operating site and location	Whistler, BC, Canada
Estimated demo start date	1 st Qtr 2010 at the 2010 Winter Olympics
Number of buses	20
Infrastructure description	Linde station; trucked in and stored hydrogen

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Executive Services and Communications Directorate (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.

1. REPORT DATE (DD-MM-YYYY) November 2010		2. REPORT TYPE Technical Paper		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE Fuel Cell Transit Bus Evaluations: Joint Evaluation Plan for the U.S. Department of Energy and the Federal Transit Administration Appendix: Summary of Fuel Cell Transit Bus Demonstration Sites in North America				5a. CONTRACT NUMBER DE-AC36-08GO28308	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Leslie Eudy and Kevin Chandler				5d. PROJECT NUMBER NREL/TP-5600-49342-2	
				5e. TASK NUMBER H270.8150, WF2B.1000	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) National Renewable Energy Laboratory 1617 Cole Blvd. Golden, CO 80401-3393				8. PERFORMING ORGANIZATION REPORT NUMBER NREL/TP-5600-49342-2	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S) NREL	
				11. SPONSORING/MONITORING AGENCY REPORT NUMBER	
12. DISTRIBUTION AVAILABILITY STATEMENT National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT (Maximum 200 Words) This document describes the fuel cell transit bus evaluations performed by the National Renewable Energy Laboratory (NREL) and funded by the U.S. Department of Energy (DOE) and the U.S. Department of Transportation's Federal Transit Administration (FTA). This document provides a description of the demonstration sites, funding sources, and data collection activities for fuel cell transit bus evaluations currently planned from FY10 through FY12.					
15. SUBJECT TERMS fuel cell; bus; buses; validation; evaluation; transit; hydrogen; fuel cell technologies					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UL	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER (Include area code)

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18