



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

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November 2010

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

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

Current as of November 3, 2010

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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 | 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/EV America | Development |
| 20 | University of Georgetown | Georgetown | 1 | Ballard/Nucellsys/ EV America | 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 |

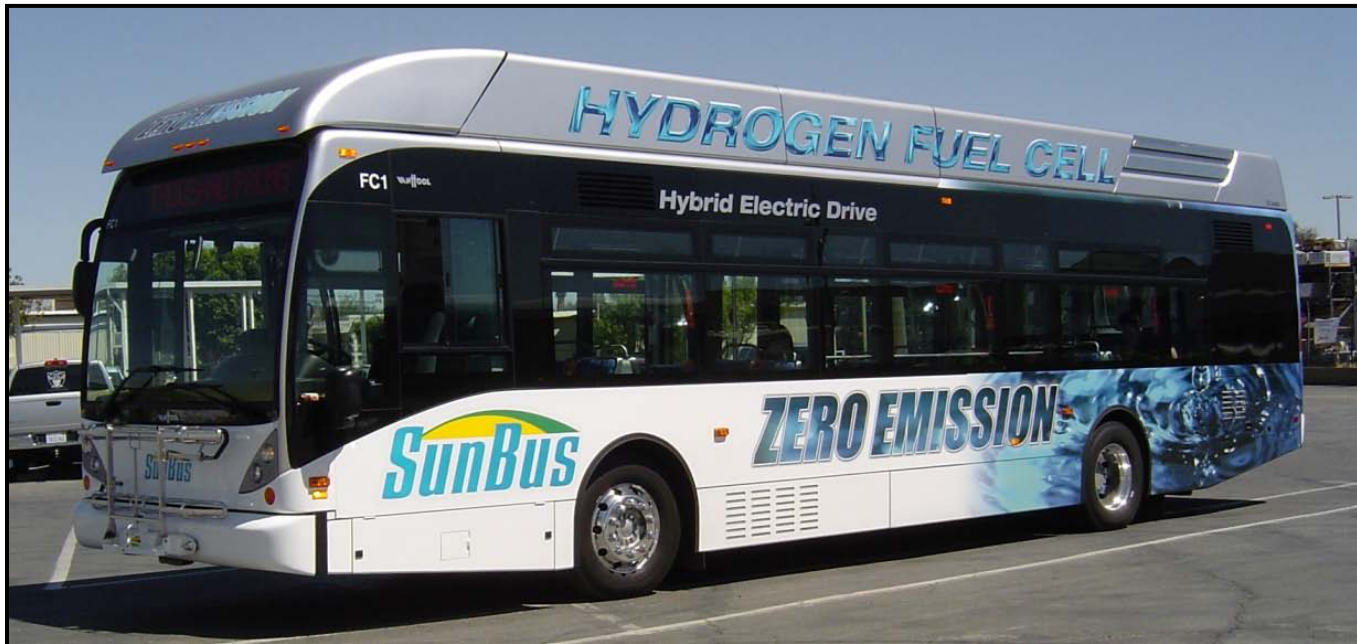


Table A18. SunLine Fuel Cell Bus – Extended Service**Evaluation Complete**

| | |
|-----------------------------|--|
| 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 |

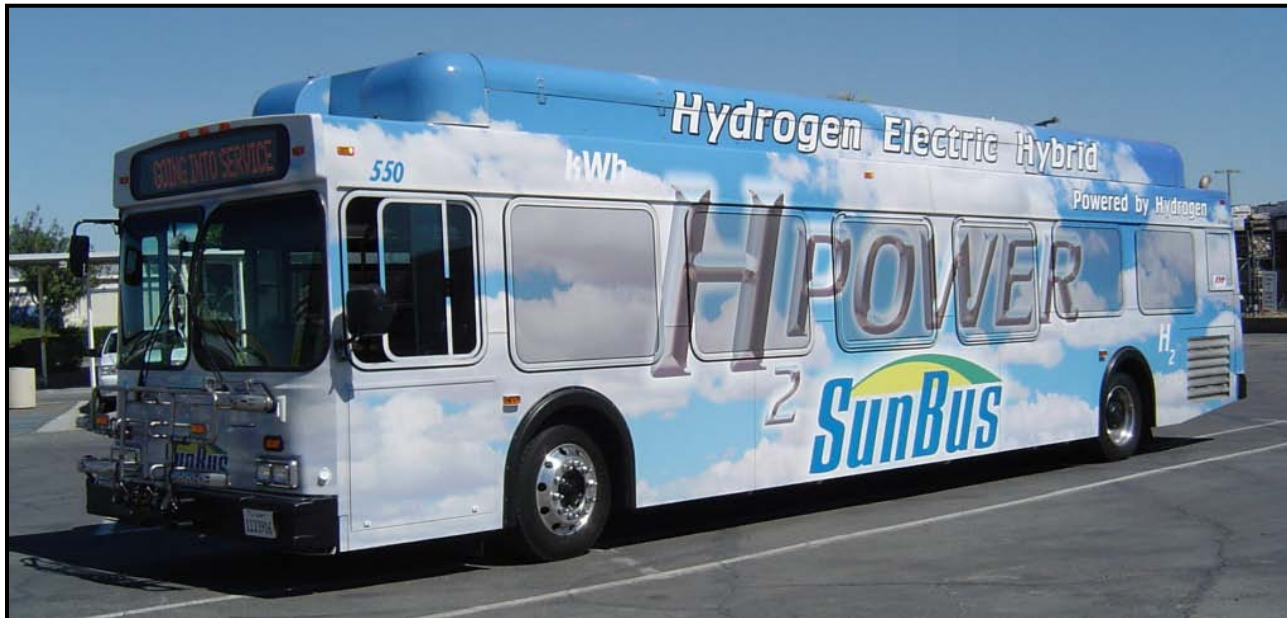


Table A20. University of Delaware

| | |
|-----------------------------|--|
| 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 |

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