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Fuel Cell Transit Bus Coordination and Evaluation Plan
California Fuel Cell Transit Evaluation Team

National Renewable Energy Laboratory

For the

United States Department of Energy
Hydrogen, Fuel Cells & Infrastructure Technologies Program

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About This Document

The purpose of this document is to describe the coordination and evaluation of the demonstration of seven full-size (40-foot) fuel cell transit buses. The descriptions in this document include the partners, fuel cell bus demonstration sites, objectives, and the actual planned data collection and evaluation. This document also includes descriptions of the U.S. Department of Energy/National Renewable Energy Laboratory evaluation program, transit agency evaluation projects, and plans for the coordination of data, analyses, reporting, and public dissemination of results.

This is a working document that is intended to be updated on a regular basis and tracked so participants in this activity have the most current plan. The report will be posted on a Web site for easy access and download. This site will have publicly accessible pages as well as a password-protected area available only to evaluation team members. The public side of the Web site will contain PDFs of the evaluation plan and finished reports as they become available. The password-protected side will contain documents in Microsoft Word and PDF formats to allow for quick information sharing between team members.

DOE/NREL Project Team

The U.S. Department of Energy (DOE) is participating in this demonstration and evaluation of fuel cell transit buses as part of the Hydrogen, Fuel Cells & Infrastructure Technologies (HFC&IT) Program. This DOE program integrates activities in hydrogen production, storage, and delivery with transportation and stationary fuel cell applications. Goals for this program are to be accomplished in partnership with other DOE programs, national laboratories, industry, and academia[1]. These goals include:

- Overcoming technical barriers through research and development of hydrogen production, delivery, and storage technologies, as well as fuel cell technologies for transportation, distributed stationary power, and portable power applications
- Addressing safety concerns and develop model codes and standards
- Validating and demonstrating hydrogen and fuel cell technologies in real-world conditions
- Educating key stakeholders whose acceptance of these technologies will determine their success in the marketplace

The National Renewable Energy Laboratory (NREL) is a DOE laboratory that supports numerous programs at DOE. This demonstration and evaluation effort is supported by the NREL Fleet Test and Evaluation (FT&E) Team[2], which was formed to accomplish the objectives of existing and emerging programs, including hydrogen and fuel cell vehicles. The FT&E Team works with commercial and government fleets and industry groups to test alternative fuel and

[1] DOE Web site – www.eere.energy.gov/hydrogenandfuelcells/about.html
[2] NREL Web site – www.nrel.gov/vehiclesandfuels/fleet_test_evaluation.html

advanced technology vehicles in service and provide unbiased information resources for people who are considering adding these types of vehicles to their fleets. Information derived from the evaluation of vehicle performance is fed back to research programs to help shape future work.

This fuel cell bus demonstration and evaluation may also include participation by NREL's Vehicle Systems Analysis Team[3] using ADVISOR™[4] software, which is an analysis (modeling) tool that helps the vehicle industries develop accurate component and vehicle simulations. Analysis and simulation are critical to increasing the life of components, improving vehicle performance, optimizing vehicle system designs, and reducing development time.

Federal Transit Administration (FTA) Fuel Cell Programs

The U.S. Departments of Energy and Transportation are collaborating on this fuel cell bus demonstration and evaluation project. The U.S. Department of Transportation (DOT) through the Federal Transit Administration (FTA) has established a Hydrogen & Fuel Cell Bus Initiative to complement the President's FreedomCAR & Hydrogen Fuel Initiatives. This Initiative is a broad-based, national effort to coordinate, consolidate, and rationalize the diverse efforts in hydrogen fuel cell buses in order to accelerate its commercial viability, and to help accelerate the successful commercialization of hydrogen fuel cells into other transportation applications. It focuses on the 40-foot, heavy-duty transit bus, the most prevalent vehicle used by U.S. transit agencies. Improvements to this 40-foot transit bus platform will benefit other transit and heavy-duty vehicle platforms as well as other applications.

FTA's Initiative includes three key elements: Transit Bus Research, Development and Demonstration; Transit Hydrogen Infrastructure; and Education, Outreach and Workforce Training. Efforts under Transit Bus RD&D include three vehicle approaches in parallel—heavy-duty fuel cell bus with a fuel cell system designed for heavy-duty use to supply all of the power requirements for this transit bus; automotive based fuel cell hybrid bus with a light-duty fuel cell system in a hybrid configuration to provide the necessary power requirements for a bus; and a hydrogen internal combustion engine hybrid electric bus to enhance the introduction of hydrogen infrastructure. It also includes development and demonstration efforts for the commercial maturation of hybrid electric vehicle technologies as a key transition pathway.

FTA supports the development, demonstration and evaluation of the seven fuel cell buses in California through funding assistance and input to the evaluation strategies. The seven buses are considered to current or Generation I of fuel cell buses. In its on-going leadership role in the RD&D of fuel cell buses, FTA is planning for the development and demonstration of future generations of fuel cell buses as well as the next generation of hybrid electric buses. Coordination of this activity is through the U.S. Fuel Cell Working Group composed of transit agencies, bus manufacturers, electric drive developers, and fuel cell suppliers as well as DOT/FTA and DOE/NREL. As part of an effort to increase international coordination and collaboration in the development of hydrogen technologies, FTA is leading an effort to estblish an International Fuel Cell Bus Working Group. This International Group would complement the efforts of the U.S. Working Group to harmonize data collection and evalution, creating a central

[3] NREL Web site – www.ctts.nrel.gov/analysis/
[4] ADVISOR is a trademark of the Midwest Research Institute

database for information sharing, and collaboration and coordination in the development and demonstrations of future generations of fuel cell buses.

Objectives and Goals

The objective of the DOE/NREL evaluation program is to provide comprehensive, unbiased evaluation results of advanced technology vehicle development and operations, evaluation of hydrogen infrastructure development and operation, and descriptions of the facility modifications required for safe operation of the fuel cell vehicles. This evaluation includes economic, technical, emissions, and safety factors. Decision makers, including transit operators, considering the use of these advanced technology vehicles are the primary audience for this information.

- Each of the transit agencies participating in the demonstration of fuel cell buses has specific objectives that generally include the demonstration of safe, reliable, efficient, and cost effective operation of fuel cell buses and fueling infrastructure in transit operations.

- The California state agencies (California Energy Commission and California Air Resources Board), the California Fuel Cell Partnership (CaFCP), FTA, and the DOE have objectives for participating in this program that include (but are not limited to) promoting the successful demonstration of fuel cell technologies for transit buses and supporting infrastructure.

The demonstration and evaluation program has two major goals for this collaborative effort as follows:

- Create and provide credible data results and evaluation to the transit bus and fuel cell industries that go beyond the "proof of concept" of fuel cell transit buses and infrastructure. These results are also intended to be useful to policy-makers and funding organizations.

- Create results that focus on performance and usage including progress over time and experience from integration of vehicle systems, operations, and facilities for the fuel cell transit buses and supporting infrastructure.

Background

Manufacturers have been working with fuel cells in transportation applications since the early 1990s. Early fuel cell systems for light-duty vehicles were bulky and often consumed most of the vehicles' available space. Rapid progress with the technology has led to light-duty fuel cell vehicles that are comparable to conventional vehicles in size and performance.

Fuel cell systems for buses have also experienced significant progress during the last several years. Heavy-duty vehicles offer the advantage of extra space for larger propulsion systems but sometimes at the cost of passenger or cargo space. Like their light-duty counterparts, fuel cell bus systems have decreased in size by an order of magnitude. Much progress has been made, but

more work is needed to prove reliability and durability. Demonstration programs, such as that of the seven fuel cell buses, are necessary to validate the performance of the current generation of fuel cell systems. Lessons learned in evaluating the buses in revenue service will help assess the status of fuel cell bus technology and determine issues that need further development.

Program Participants

In February 2000, the California Air Resources Board (ARB) approved regulations to reduce emissions from transit buses in California. The goal of the Public Transit Bus Fleet Rule and Emission Standards for New Urban Buses was to reduce overall emission of particulate matter (PM) and oxides of nitrogen (NOx) through use of advanced technologies. These technologies include alternative fuel buses, use of low sulfur diesel fuel and PM filters in conventional buses, and the demonstration and eventual purchase of zero emission bus technologies. Zero-emission technologies include battery electric, electric trolley, and fuel cell. Because of this ruling, several transit agencies in the state began developing programs to demonstrate zero emission buses, specifically fuel cell technology buses.

Transit Agency Partners
Five transit organizations are involved in this demonstration project. Their responsibilities include procurement of the buses, operation of the buses in revenue service, bus maintenance, and transmission of data to evaluation partners. The five organizations involved are briefly described below. For a more detailed description of each agency see Appendix B.

The Alameda-Contra Costa Transit District (AC Transit), is based in Oakland, California, and provides transportation services to the East Bay of the San Francisco. The 360-square-mile service area includes 13 cities and adjacent unincorporated areas in Alameda and Contra Costa counties. AC Transit's 843 vehicles (including paratransit) serve more than 69 million annual passengers. After having the opportunity to test early prototype fuel cell buses, AC Transit began plans to add these zero emission buses to their fleet. In 2003, the agency entered into an agreement with ISE Research and UTC Fuel Cells to procure four 40-foot fuel cell hybrid buses for their demonstration program (three buses to be operated by AC Transit, one to be operated by SunLine Transit Agency). (www.actransit.org)

Golden Gate Bridge, Highway and Transportation District is responsible for transportation services within the Highway 101, Golden Gate Corridor. These services include both bus and ferry routes. Golden Gate Transit (GGT) is the division responsible for bus services. GGT's 268 coaches provide commuter service between San Francisco, and Marin and Sonoma Counties, resulting in less congestion over the Golden Gate Bridge. GGT is working with AC Transit to demonstrate the three fuel cell buses. (www.goldengate.org)

Santa Clara Valley Transportation Authority (VTA) is based in San Jose, California, and provides service in and around the county of Santa Clara. As a multi-modal transportation planning organization, VTA provides bus and light rail service, as well as congestion mitigation, highway improvement projects and countywide transportation planning. VTA's 524 buses serve an annual ridership of nearly 45 million and cover an area of approximately 326 square miles. The organization adopted a Clean Fuels Strategy in December of 2000, which included a zero

emission bus program. In 2002, VTA entered into contract with Gillig Corporation and Ballard Power Systems to procure three low floor fuel cell buses. (www.vta.org)

San Mateo County Transit District (SamTrans) provides transportation services to San Mateo County, which is south of San Francisco. In addition to fixed-route bus system, the district provides daily paratransit service. SamTrans' fleet of 321 buses, vans, and sedans, covering approximately 440 square miles and serving a population of more than 707,000. SamTrans is working in partnership with VTA to demonstrate fuel cell buses. (www.samtrans.com)

SunLine Transit Agency provides public transit and community services to California's Coachella Valley. The service area is more than 1,100 square miles and includes nine member cities, as well as Riverside County. Over the years, SunLine has pursued an aggressive strategy for implementing clean technologies into its fleet. SunLine began by switching the fleet to natural gas, then began a path toward more advanced technologies including hydrogen/CNG blended fuels and fuel cells. The agency has established itself as a test bed for multiple vehicle and hydrogen production technologies. In partnership with AC Transit, SunLine is contracting to purchase one fuel cell bus for the demonstration. SunLine's fuel cell bus will be identical to those at AC Transit. (www.sunline.org)

Manufacturer Partners

The fuel cell buses in the demonstration are designed in two different configurations: a 40-foot Gillig chassis with a fuel cell system by Ballard Power Systems, and a 40-foot Van Hool chassis with a fuel cell system using a UTC Fuel Cell integrated by ISE Research.

Ballard Power Systems, based in Burnaby, British Columbia, Canada, develops and manufactures proton exchange membrane fuel cells for transportation and stationary applications. In addition to producing the fuel cells for Gillig buses, the company is responsible for designing and integrating the fuel cell system. (www.ballard.com)

Gillig Corporation, is based in Hayward, California, and produces heavy-duty buses. The company is building the chassis for three of the fuel cell buses in the demonstration and working closely with Ballard on integration of the fuel cell system. (www.gillig.com)

ISE Research (ISER), is headquartered in San Diego, California, and develops and integrates electric drive systems for transportation applications. ISER works with multiple industry and government partners to develop and demonstrate these vehicles. The company is responsible for development and integration of the fuel cell system into the Van Hool bus. (www.isecorp.com)

UTC Fuel Cells is part of the UTC Power division of United Technologies Corporation and is based in South Winsor, Connecticut. The company develops and produces fuel cells for transportation, stationary, and space applications. In addition to manufacturing fuel cells, the company is working closely with ISER to integrate the fuel cell into the propulsion system for the Van Hool bus. (www.utcfuelcells.com)

Van Hool manufacturers buses, coaches, and commercial vehicles and is headquartered in Belgium. The company is building the chassis for four of the fuel cell buses in the demonstration program. (www.vanhool.com)

Federal Government Partners
DOE's HFC&IT Program is implementing the technology development efforts needed to realize the vision of a hydrogen economy. Technology validation is an important part of this plan and will verify that complete integrated fuel cell systems can perform in real-world conditions. This evaluation is funded as a part of the Technology Validation section of the Multi-Year Research, Development and Demonstration Plan. (www.eere.energy.gov/hydrogenandfuelcells/mypp/)

FTA is a division of the U.S. Department of Transportation that is focused on leading development of efficient mass transportation systems across the United States through financial, technical, and planning assistance. In addition to providing funding for the purchase of the buses, FTA will provide guidance in the evaluation strategy. (www.fta.dot.gov)

California Partners
ARB, which is a part of the California Environmental Protection Agency, has a mission to "promote and protect public health, welfare, and ecological resources through the effective and efficient reduction of air pollutants while recognizing and considering the effects on the economy of the state." ARB established its commitment to fuel cell technology in transportation by passing several rulings for California fleets, including the Public Transit Fleet Rule. ARB is a funding partner for the development and demonstration of the fuel cell buses. (www.arb.ca.gov)

The California Energy Commission (CEC) is the primary energy policy and planning agency for California. One role of the CEC is to help advance energy related science and technology through research, development, and demonstration. The CEC's Transportation Technology Office is involved with assessing the market potential of new transportation technologies, including fuel cell transit buses. CEC provides funding for the development and demonstration of these buses as well as leadership for the Bus Team of the CaFCP. (www.energy.ca.gov/efficiency)

The California Fuel Cell Partnership (CaFCP) is a collaborative effort between auto manufacturers, energy companies, fuel cell technology companies, and government agencies. This partnership brings together a diverse group of players to accomplish common goals that include demonstrating fuel cell vehicles and the associated fueling infrastructure under real-world service. The Bus Team is focused on demonstrating fuel cell buses in transit applications. The three main transit partners involved in this demonstration are associate members of the CaFCP. (www.cafcp.org)

Evaluation Partners
NREL is a DOE laboratory focused on renewable energy and energy efficiency. NREL's hydrogen and fuel cells research includes projects on hydrogen production and storage, fuel cells, codes and standards, and technology validation. Technology validation projects, such as this bus evaluation, will test and evaluate complex integrated hydrogen and fuel cell systems under real-world conditions. NREL will lead the evaluation effort for this demonstration project. Responsibilities include coordinating the team, collecting the evaluation data, and leading the reporting effort. (www.nrel.gov)

Battelle, under subcontract to NREL, will collect and evaluate the standard data for the DOE/NREL projects, provide leadership in the data collection and evaluation effort, and take the lead in the reporting effort. (www.battelle.org)

University of California, Davis (UCD) The Institute of Transportation Studies at the University of California, Davis (ITS-Davis) is a multidisciplinary research department focusing on travel behavior, advanced environmental vehicle technology, and environmental impacts of transportation. ITS-Davis hydrogen and fuel cell research includes the Hydrogen Bus Technology Validation Program, the Toyota light duty fuel cell vehicle demonstration program, research on fuel cell APUs for trucks, research using the first DOE fuel cell bus, and research focusing on technical, economic, environmental, and policy issues related to the development of hydrogen infrastructure. ITS-Davis will assist NREL and AC Transit on the demonstration program. Responsibilities include measuring bus performance parameters, evaluating the fueling station, and cost analysis for both the buses and the fueling station. (www.ucdavis.edu)

Evaluation Approach

The objectives of this evaluation include:

- Provide credible data and evaluation results
- Provide results in context of the fact that these fuel cell buses and supporting infrastructure are prototypes
- Provide results that show progress and experience for fuel cell bus and infrastructure operation in transit service
- Provide results from multiple operating experiences and different transit agencies

This evaluation will be a snapshot in time and technology. The results will be extremely important in understanding the state of the technology and the work that still needs to be done. This information will also be important for estimating what the future technology and costs of operation may look like based on the experiences of these operations and expected advances in the systems integration and developments.

The design of this evaluation requires several levels of data collection to complete.

1. The story of implementation of the fuel cell buses and infrastructure
2. The vehicles used in the evaluation activities including the fuel cell buses and control/baseline vehicles used for comparison; these descriptions need to be as detailed as the manufacturers will allow and include system and component level information
3. The public awareness materials and public perception of the projects as available
4. Vehicle performance testing as made available from the manufacturers and transit agencies
5. The facilities built and/or used specifically for this demonstration including fueling and modifications to existing structures to accommodate the use of fuel cell buses
6. The capital costs for the vehicles, facilities, and training
7. The safety and training efforts at each site
8. Data collection for each site to describe the baseline of operations for standard buses at the site using the newest standard bus operations for diesel and/or CNG buses as appropriate
9. Operations data collection – vehicle and fueling infrastructure, duty cycle/assignment, fueling, maintenance, and configuration/design changes

The data collection and evaluation described here is planned to commence after the delivery of the fuel cell buses. Some work is planned to track the progress of facility modifications and fueling infrastructure implementation. The evaluation effort planned as part of the NREL activity is described next. The remaining evaluation effort is then described presuming that adequate funding is available.

DOE/NREL Data Collection Protocol

The NREL data collection items are shown in Table 1. For each test fleet selected for evaluation, NREL/Battelle will collect all fueling, cost, and maintenance data for a period up to 12 to 18 months and report this data to NREL and the project team. At the beginning of the data collection period, NREL/Battelle also will collect details on the fleet's operations including a description of facilities and services, capital costs, maintenance and fueling practices, and any other information needed to get a complete understanding of the fleet's experiences.

The data collection effort is intended to cause as little disruption as possible for the transit agencies. Visits to the site for information gathering, collection of costs, and facilities descriptions are planned. Telephone calls will be made to verify data, investigate some details such as problems that arise with the vehicles or fueling infrastructure, and gather information on the overall experience of using advanced technology vehicles at the site. Data collected and evaluations/analyses will be distributed for review and input as required and/or as requested by the project partners.

For the full evaluation, the fuel cell buses will be compared with similar diesel or CNG buses of a similar age and similar operation. For bus evaluation groups (fuel cell and diesel/CNG), all maintenance and fueling data will be collected. An evaluation period will be selected based on a comparison of similar vehicle lifetimes of the fuel cell and diesel/CNG buses. The full evaluation period start date will be specified by the site's determination that the fuel cell buses are ready to be compared to conventional vehicles. This requires significantly more data to be collected than is required and used for the actual evaluation.

Table 1 shows a general overview of the data to be collected. These data are separated into four categories: operating descriptions, bus operations, facility operating costs, and facility descriptions and capital costs. Each of these four categories is discussed in the following sections.

Vehicle Specifications and Performance Expectations

This group of data collection items includes vehicle system descriptions and vehicle performance expectations. The specific information that has been collected as part of the vehicle system descriptions is included in the appendices. The vehicle systems are described at the beginning of the data collection; changes may be required if major systems are altered. For these evaluations, these descriptions consist of individual specification information for the advanced technology vehicles and comparison vehicles. The specifications are intended to describe the main systems of the vehicle propulsion system as well as accessory equipment. This information documents

the requirement that the evaluation vehicles be similar in equipment, and also documents specific equipment that may affect the performance of the vehicles in regards to the fuel economy and overall reliability.

The fleet's specific performance expectations for the advanced technology vehicles are collected and evaluated in regards to how well these vehicles meet the fleet's expectations and needs. Other vehicle performance information may be available from the fleet, the vehicle manufacturer, and/or system integrator that allow for a direct assessment of how well these vehicles meet the fleet's performance expectations. The types of information that may be collected include:

- The fleet's specifications for their vehicles with an emphasis on the fleet's performance requirements such as length, weight, top speed, gradeability, acceleration, range, retardation (regenerative braking), noise, durability (vehicle life, battery pack life, etc.), emissions, fuel economy, special requirements such as low floor, and other useful available information
- Interviews to document how the fleets typically measure vehicle performance when implementing a new technology
- Available performance information (such as first article acceptance testing data, independent fleet evaluations, etc) on these vehicles
- Any other pertinent data to assist with the study

Vehicle Operation

Vehicle operation data items include the vehicle operating cycle, vehicle usage in service, fuel consumption, engine oil consumption (if an internal combustion engine is being used), maintenance, and any safety incidents. The vehicle operating cycle will be described in text format for the general expected usage of the test vehicles. Data collection will include expected route descriptions, operating hours during a typical work day, number of days per week that the vehicle is operated, the amount of fuel and range (in miles) that are expected during a given work day and between fueling, and other information useful for understanding how the vehicle is used.

The vehicle usage in service will include an analysis for each vehicle of how many miles used in service per day and month. The usage or duty cycle will be described by the average speed, route assignments, and terrain information as well as possibly GPS tracking information to understand speed and acceleration in service. These advanced technology vehicles may already electronically monitor some of the information needed to describe the in-service duty cycle of the vehicles. In those cases, the manufacturers and site will be requested to participate in collecting that onboard data, if available. Data is also to be collected for number of hours for fuel cell and vehicle operation for each fuel cell bus.

Table 1. Data Collection Items

Type of Data	Frequency Recorded	Data Items
Vehicle Specification and Performance Expectations		
Vehicle System Descriptions	Start of data collection and changes as needed	Data items shown in Appendix A
Vehicle Performance Expectations	Start of data collection and changes as needed	Criteria and testing results for performance expectations
Vehicle Operation		
Vehicle Operating Cycle	Start of data collection and changes as needed	General description of daily use of vehicles
Special Service (Press events, public education, etc.)	Each time vehicle is used for atypical service	Description of event, time out of service.
Vehicle Usage in Service	At each time usage is measured	Odometer reading; hours of vehicle and fuel cell operation
		Daily vehicle assignment
		GPS data (if needed)
Fuel Consumption	Each time a vehicle is fueled	Amount of fuel
		Odometer reading
		Date
	Each time the fuel price changes at a given site	Price per unit
Engine Oil Consumption and Changes (Baseline vehicles only)	Each time oil is added	Amount of Oil
		Odometer reading
		Date
	Each time oil is changed as recommended by the engine manufacturer	Price per quart
		Amount of oil
		Odometer reading
		Date
Maintenance	For each work order	Type of Maintenance: Scheduled, Unscheduled, Configuration Change
		Labor Hours
		Date of Repair
		Number of days out of service
		Odometer reading
		Parts replaced
		Parts cost
		Description of reported problem
		Description of repair performed
Road Call	For each occurrence	Same info as above
Safety Incidents	Each occurrence	Description of each accident or incident involving the test or control vehicles, including collisions, and maintenance and fueling incidents
Facility Operating Costs		
Fueling Infrastructure	Each maintenance activity	Type of maintenance, labor, parts, costs, problems, configuration changes
Facilities (safety systems related to hydrogen and fuel cells)	Each maintenance activity	Type of maintenance, labor, parts, costs, problems, configuration changes
Facility and Capital Cost Descriptions		
Facility Descriptions	Start of data collection and as needed if and when changes are made	Fueling site equipment description
		Maintenance area description
		Vehicle storage area description
Facility Capital Costs	Start of data collection and as needed if and when changes are made	Facility modification capital costs by area (charging, maintenance, and vehicle storage)
Vehicle Capital Costs	Start of data collection	Vehicle capital cost for test vehicles

The other in-service data needed for this category includes data collection at each fuel fill (amount of fuel, odometer reading, hour reading, and date) and fuel prices (each fuel, each time the fuel price changes – price and date). Data collection also includes engine oil consumption (if an internal combustion engine is involved) and engine oil changes. Information will be recorded from each engine oil addition (amount of oil, odometer reading, and date) and oil changes (amount of oil, odometer reading, and date all as part of a maintenance action, usually preventive maintenance). Engine oil prices are also to be collected (the oil price and date each time it changes).

In the data collection, an odometer reading is usually replaced with a hubodometer reading. Most fleets use a hubodometer to track usage in miles. A hubodometer is a device placed on the wheel hub (usually the rear wheel facing the fueling side of the vehicle) that measures the revolutions of the wheel and converts those revolutions into miles traveled. The hubodometer reading is usually the only measurement of vehicle usage in miles traveled used by the site.

Maintenance data needed includes each repair action such as preventive maintenance, unscheduled maintenance, and road calls (date of repair, labor hours, number of days out of service, odometer reading, parts replaced, parts cost, and descriptions of problem reported and actual repair performed). Engine oil changes will be included as part of preventive maintenance. The maintenance data will be used to estimate operating costs (along with fuel and engine oil consumption costs) and for reliability and durability calculations.

Data on warranty repairs will be collected in a similar manner as data on normal maintenance actions. However, the cost data will not be included in the operating cost calculation. Labor costs may be included depending on the mechanic who did the work (operator or manufacturer) and whether those hours were reimbursed under the warranty agreement. The warranty maintenance information will be collected primarily for an indication of reliability and durability.

All roadcalls will be marked in the maintenance data collected. A roadcall is defined as a maintenance call required while the bus is in service and requires that the bus be replaced on the route. In this evaluation, each maintenance call in service will also be tracked, even if a roadcall is not required.

Any safety incidents occurring with the vehicles, the fueling station, or in the maintenance facilities will be described, including the nature of the incident or action and the vehicles or facilities involved. Also, a description of any changes in procedures or hardware changes required to ensure that the incident is not repeated will be required.

Facility Operating Costs

During the evaluation, the costs of operating the hydrogen fueling infrastructure and the safety systems for facilities will be collected. For the hydrogen fueling infrastructure, the intent is to collect all maintenance activities including description of problems, labor used, parts used, costs, and any configuration changes after the initial installation. For the other facilities, the cost of maintaining the safety systems for hydrogen and fuel cells will be tracked including similar data collection items as the fueling infrastructure.

Facility and Capital Cost Descriptions

At the beginning of the data collection period, the team will collect details on the fleet's operations including a description of facilities and services, capital costs, maintenance and fueling practices, and any other information needed to get a complete understanding of the fleet's experience with the advanced technology vehicles. Descriptions of facilities will include fueling, maintenance, and vehicle storage facilities that may be associated with the vehicles in the study. These descriptions will include systems in each facility that may be affected by the use of the advanced technologies or may affect how the vehicles are used. Data on capital costs will include costs for any facility modifications that are required to conduct the operation of the advanced technology vehicles. The vehicle capital costs will include the costs for new vehicles and engines.

Implementation Experience

The fleet implementation experience information collection is designed to document the background work needed for successful implementation of advanced technology vehicles, as well as some of the potential pitfalls and lessons learned. The types of information collected in support of this activity include:

- Documentation of the history that led to the fleet's decision to purchase advanced technology vehicles, i.e., the important influences (economic, environmental, legislative); their past experience with alternative fuels; incentives for advanced technology vehicles or disincentives for the other solutions that helped form their decision
- Documentation/understanding of where these vehicles fall in terms of current technology development, i.e., how is this technology different from other advanced technology vehicles on the market; why did the fleet select this particular vehicle technology
- General information related to the manufacturers' commercialization efforts, i.e., how did they get to this point, where are they going from here etc.
- Description of the vehicles' duty service and overall fleet characteristics, what is the service application for the advanced technology vehicles and why was it chosen, what performance requirements are related to this application
- Roles of important supporting organizations such as vehicle manufacturer and supplier, fuel suppliers, federal, state or local government agencies
- Specific incentives and regulations supporting the decision to purchase advanced technology vehicles
- The driver, fleet personnel and customer perceptions of the new technology vehicles, does the fleet plan any special education activities for fleet personnel, is the fleet planning any special public relations activities related to these vehicles?
- A description of the training implementation strategy including all employee orientation, operations and maintenance personnel, and the costs of this training. There is also an interest in plans to integrate this training into standard training programs
- Special fleet needs such as mechanic, driver, or technician training requirements, special equipment, safety issues - how did the fleet address these needs and were these approaches successful
- What it took to bring these vehicles into revenue service, i.e., were there any

technical/non-technical hurdles that had to be overcome

Additional Data Collection and Evaluation

In comparing the overall data collection and evaluation plan for the fuel cell bus evaluation and the NREL data collection and evaluation protocol, there are five general areas that are currently not covered above.

1. Acceptance and awareness surveys and evaluation
2. Vehicle performance testing and evaluation
3. Additional study of the fuel cell technology, performance, and operation
4. Support to transit agencies in Start-Up Activities

Acceptance and awareness surveys and evaluation are not a standard part of the NREL evaluation protocol; however, NREL has experience collecting this information and has agreed to support these activities for this evaluation. These surveys should include drivers, maintenance, fueling, and management personnel to help understand impressions of the fuel cell bus operation implementation. The public impressions on the buses are helpful for understanding public perception and acceptance of the new technology. The transit agencies are planning significant effort to educate the public about their fuel cell bus program. These activities will be coordinated with each transit agency marketing and communications. These surveys could be used to help measure the effectiveness of this education effort.

Vehicle performance testing and evaluation is not a part of the NREL evaluation protocol. Vehicle performance testing would include standard first article testing (as required for projects with FTA funding), which includes measuring vehicle top speed, gradeability, acceleration, range, noise, fuel economy, and other performance measures. The vehicle performance testing may be collected once at the beginning of the demonstration, and may be collected again during the in-service evaluation of the buses. Testing is being considered for at least three times during the evaluation. The result of this vehicle performance testing are normally collected as part of the NREL protocol but presumes that the testing was already performed by the operating site or vehicle manufacturer. Funding for the vehicle performance testing will need to be defined and secured for this project.

Additional study of the fuel cell technology, performance, operation, and troubleshooting is planned for this program and is not a part of the NREL evaluation protocol. Additional funding for this effort is needed. The sensitivity of this information may make this study difficult. The data collection may include information from the fuel cell propulsion system control computer such as bus speed, fuel cell voltage and current, controller voltage and current, input air pressure and flow rate, input hydrogen flow rate, temperature of stack, power to fuel cell auxiliaries, and power supplied to bus hotel loads (such as air conditioning, hydraulics, and air compressor). The vehicle and fuel cell manufacturers will need to be willing to participate in this effort.

Support to Transit Agencies in Start-Up Activities will include adding procedures and working through issues with implementing the fuel cell buses. The manufacturers will cover some of the start-up activities, but the transit agencies are required to “come up to speed” as

quickly as possible. The intent of this task will be to support the transit agencies in creating new procedures, finding the proper training information needed, and general support for the start-up.

Data Analysis, Evaluation, and Dissemination

Information for a full evaluation will be collected for approximately 12 months of operation for each vehicle and will serve as the basis for the analyses. The following items will be used for the data analysis.

- Mileage
- Fuel Consumption
- Fuel Consumption Cost per Mile
- Engine Oil Consumption
- Engine Oil Consumption Cost per Mile
- In-Service Vehicle Failure Rate (road calls)/Down-Time or Up-Time
- Maintenance Cost per Mile
- Maintenance Costs per Mile Breakdown by Vehicle System
- Descriptions of Major (Vehicle and Infrastructure) Failures and Service Interruptions
- Operation costs of the hydrogen fuel station
- Vehicle duty cycle calculations and descriptions

Information will be made available to the project partners (working group) on results of the data collection and evaluation for this project. This information dissemination will be ongoing during the evaluation period.

Planned Reporting

Standard NREL reporting

There are four reports planned for this site evaluation as part of the DOE/NREL project as follows:

- A four to six-page summary of vehicles and evaluation planned – this handout is intended to give an overview of each site's program and describe the vehicle technology being evaluated.

- A two page fact sheet on each bus – this handout will provide details on the bus specifications and briefly describe the transit agency's plans for demonstrating the technology.

- An eight-page, professionally laid out report – a brief summary of the implementation experience, including descriptions of the facilities and operation at the site.

- Final Results Report – an executive summary style report based on all data evaluation and results to be completed after the data collection has been completed (after

approximately 12 months of data have been collected on all vehicles at the site). The detailed analysis results will be included in an appendix, which will be included with this report on a CD.

Specifically for this fuel cell bus evaluation, the project team plans to produce a technology development comparison of this fuel cell bus implementation with natural gas and diesel hybrid bus implementation experience in the transit industry to be included in the final results report.

Results from this project also will be reported at appropriate conferences such as the Society of Automotive Engineers (SAE) Truck and Bus conference or American Public Transportation Association (APTA) Bus conference, which will require the production of a technical paper with results from the project as well as a formal presentation.

Each report including the data will be available for review and editing by each agency and the working group before any results are published. We hope that each site will be involved with the presentation and publishing of the results. We will not publish information that is deemed sensitive by the participating site without permission from the site representatives.

Other reports for the funding and project partners may be produced as required and as project resources allow.

Timeline Of Activities And Reporting

Details for this section will be determined at a later date. Timeline for many activities will be based on the delivery date of the buses. Planned dates at the time of this document are as follows:

- VTA Fuel Cell Bus Program
  - Completion of fueling infrastructure January 2004
  - First bus scheduled to arrive May 2004
- AC Transit/SunLine Fuel Cell Bus Program
  - Completion of fueling infrastructure July 2005
  - First bus scheduled to arrive September 2005

Time frame for the evaluation is at least one year of data, over a 2-year period

Information Control And Sharing

Details for this section will be determined at a later date. Information addressed will include:

- Procedures for releasing information? Who has to approve and how?
- Protocol for data sharing
- Website for data sharing

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References

To be added at a later date.

Appendix A

Vehicle Specifications Form

NREL

ADVANCED TECHNOLOGY VEHICLE SPECIFICATION FORM

Operating Company	
Vehicle Number	
Vehicle Manufacturer	
Model	
Vehicle Identification Number (VIN)	
Date of Purchase	
Accumulated Mileage at Start of Operation	
Vehicle Dimensions	
Length, ft.	
Width, in.	
Height, in.	
Ground clearance, in.	
Wheel Base	
Front overhang (axle to vehicle front), in.	
Number of axles	
Number of driven axles	
Gross Vehicle Weight Rating, lb.	
Front Axle	
Rear Axle	
Total	
Curb Weight, lb.	
Front Axle	
Rear Axle	
Total	
Seated Load Weight	
Front Axle	
Rear Axle	
Total	

Passenger Seats	
Number of Passenger Seats with no Wheelchairs on Board	
Number of Wheelchair Positions	
Number of Passenger Seats with all Wheelchair Positions Occupied	
Maximum Number of Standees	
Fuel	
Type(s)	
Necessary Additives	
Hybrid Configuration	
Series or Parallel?	
Charge Sustaining or Charge Depleting?	
Multiple operating modes? (Yes/No)	
Number of operating modes	
Driver controlled or automatic?	
Regenerative Braking?	
Power Plant	
OEM or Retrofit?	
Power Plant Type (engine, turbine, fuel cell)	
Manufacturer	
Model Number	
Year of Manufacture	
2 Cycle or 4 Cycle?	
Compression Ratio	
Ignition Aids Used? (Yes/No)	
Type of Ignition Aid (Spark Plug, Glow Plug, Pilot Ignition, Other)	
EPA Certified? (Yes/No)	
CARB Certified? (Yes/No)	
Power Rating	
Max. bhp	

RPM of Max. bhp	
Max. Torque (ft. lbs.)	
RPM of Max. Torque	
Displacement (L)	
Engine Oil	
Type(s) Used	
Necessary Additives	
Oil Capacity (qts.)	
Blower? (Yes/No)	
Turbocharger? (Yes/No)	
Liquid Fuel Delivery Systems	
Mechanical or Electronic Fuel Injectors?	
Injector Manufacturer	
Injector Model Number	
Number of Fuel Filters	
Fuel Filter Manufacturer	
Fuel Filter Model	
Gaseous Fuel Delivery Systems	
Direct Injection or Fumigation?	
Throttle for Intake Air? (Yes/No)	
OEM or Retrofit?	
Power Plant Accessories	
Mechanical or Electric Drive Accessories?	
Generator	
Output at Normal Idle	
Maximum Rating	
Starter Type (Electrical/Air)?	
Manufacturer	
Model	
Hydraulic Pump	
Manufacturer	

Model	
Output (gpm @ psi)	
Heating	
Heating System Type	
Capacity, BTU/hr	
Air Conditioning	
Manufacturer	
Model	
Capacity, BTU/hr	
Air Compressor	
Manufacturer	
Model Number	
Capacity, Cubic Ft./Min.	
Drivetrain	
Transmission/Gearbox	
Manufacturer	
Model Number	
Model Year	
Manual or Automatic?	
Number of forward speeds	
Gear Ratios	
Torque conversion ratio	
Additional features	
Retarder	
Manufacturer	
Model Number	
Drive Axle	
Manufacturer	
Model Number	
Axle ratio(s)	
Tires	

Manufacturer	
Model Number	
Size	
Torque converter	
Manufacturer	
Model Number	
Type (hydraulic, other)	
Electric Propulsion Generator	
Manufacturer	
Model Number	
Type	
Nominal output power, kW	
Peak output power, kW	
Rated speed, rpm	
Rated torque, Nm or ft-lb	
Maximum current, amps	
Minimum voltage	
Electric Propulsion Energy Storage	
Energy Storage Device (battery, ultra-capacitor)	
Manufacturer	
Model Number	
Energy Storage Type	
Number of cells or modules	
Nominal pack voltage	
Total capacity, Ah	
Source (measured, manufacturer, etc.)	
Total energy, kWh	
Source (measured, manufacturer, etc.)	
Placement in vehicle (roof, under floor, rear engine compartment, etc.)	

Electric Propulsion Motor(s)	
Manufacturer	
Model Number	
Type	
Number of motors	
Total nominal power output, kW	
Total peak power output, kW	
Rated speed, rpm	
Rated torque, Nm or ft-lb	
Maximum current, amps	
Minimum voltage	
Location of motors (hub mounted, between torque coupler and final drive, etc.)	
Electric Propulsion Energy Storage On-Board Charger	
Manufacturer	
Model Number	
Type	
Power, kW	
Fuel Storage System	
Number of Tanks	
Maximum Working Pressure (Gaseous Fuels Only)	
Total Useful Amount of Fuel	
Tank Manufacturer	
Tank Model(s)	
Total Empty Weight of Tank(s)	
Safety Equipment	
Fire Detection (Y/N)?	
Manufacturer	
Model Number	
Year of Manufacture	
Sensor Type	

Number of Sensors	
Fire Suppression (Y/N)?	
Manufacturer	
Model Number	
Year of Manufacture	
Amount of Agent	
Type of Agent	
Number of Discharge Points	
Vapor Detection (Y/N)?	
Manufacturer	
Model Number	
Year of Manufacture	
Sensor Type	
Number of Sensors	
Alarm Threshold (% LEL)	
Other Attributes or Features (Wheelchair lifts, wheelchair position, bicycle racks, any items that make this bus different from the other test or control buses)	
Emission Control	
Catalytic Converter (Y/N)?	
Manufacturer	
Model Number	
Type	
Length of pipe from engine to catalyst	
Diesel Particulate Control Device (Y/N)?	
Manufacturer	
Model Number	
Type	
Special Requirements (Low sulfur diesel, specific regeneration temperatures, etc.)	
Power Plant Emissions Certification Data	
Additional Information	

Appendix B

Descriptions of Participating Transit Agencies

Alameda-Contra Costa Transit District Site

General Site Description – AC Transit

The Alameda-Contra Costa Transit District (AC Transit) is a public agency providing transportation services since 1960 to the East Bay of the San Francisco bay area of California as shown near the center of Figure 1 (source – Metropolitan Transportation Commission, www.mtc.ca.gov). AC Transit's mission is similar to all transit agencies and includes providing safe, convenient, courteous, and reliable transit service. AC Transit has the third largest bus fleet in California, and ranks seventeenth overall in size in the U.S. (based on unlinked passenger trips in 2000, source American Public Transportation Association, www.apta.com). The service area of 360 square miles includes 13 cities and adjacent unincorporated areas in Alameda and Contra Costa counties:

Cities	**Unincorporated Areas**
Alameda	Ashland
Albany	Castro Valley
Berkeley	Cherryland
El Cerrito	El Sobrante
Emeryville	Fairview
Fremont	Kensington
Hayward	Irvington
Newark	North Richmond
Oakland	San Lorenzo
Piedmont	
Richmond	
San Leandro	
San Pablo	

The bus fleet at AC Transit includes 843 vehicles (standard and low floor buses, luxury coaches, articulated buses, and paratransit buses) operated from four divisions – Richmond, Emeryville, East Oakland, and Hayward. The AC Transit operation also includes a Central Maintenance Facility in addition to the four operating and maintenance divisions. These buses service 141 bus lines (including 37 lines transbay to San Francisco), 6,500 bus stops, and 21 million service miles. The annual ridership includes 68.9 million passengers. AC Transit employs 2,521 including bus drivers, maintenance, clerical, support, and management personnel. Source of all data presented in this section summarized from www.actransit.org .

General Site Description – Golden Gate Transit

Golden Gate Transit (GGT) is one of three divisions operated by the Golden Gate Bridge, Highway & Transportation District. The District's original mission was to maintain and operate the Golden Gate Bridge, however, increased traffic and congestion on the bridge in the late 1960s lead to the formation of two additional divisions: GGT and Golden Gate Ferry. The current mission of the District is "to provide a safe, efficient, reliable means for the movement of people, goods, and services within the Highway 101, Golden Gate Corridor." The transit system

has grown to the extent that 11 million customers rode the transit system last year, 9 million of those were bus passengers. GGT operates 268 buses in various types of bus service including intercounty, commuter express, and local for an average of over 36,000 annual miles per vehicle. GGT operates primarily in Marin and Sonoma counties across the bay northward from San Francisco.

The District is unique among Bay Area transit operations in that it receives no support from local sales tax measures or dedicated general funds. The District does not have the authority to levy taxes and relies upon surplus Bridge toll revenue as its only local support for the District's transbay transit services. At the current time, Golden Gate Transit bus and ferry operations are funded approximately 50 percent by surplus Golden Gate Bridge tolls and 30 percent by transit fares. The remaining costs are met by federal, state and local subsidies along with advertising and property equipment rental revenues. Source of all data presented in this section summarized from www.goldengate.org in October 2003.

Fuel Cell Bus Project Description

The State of California has mandated that by the year 2003 diesel bus operators with fleets of more than 200 buses must have at least three zero-emission buses and 15 percent of new bus purchases must be zero emission by 2008. Currently, the only zero-emission buses are considered to be fuel cell powered and battery electric buses. Battery electric buses have limited range capability when using batteries as the energy storage device or require another power source such as catenary wires as in trolley bus vehicles. AC Transit has expressed their intent to do more than meet the legal requirement by planning a major demonstration of full-size transit buses (40-foot) using fuel cell powered propulsion systems in revenue service. AC Transit intends to show that fuel cell buses can be fueled and maintained efficiently and can perform consistently. In the next two years (2003-2005), AC Transit plans to build a hydrogen fueling and maintenance center and acquire three fuel cell buses. Additional fuel cell buses are being pursued for the demonstration fleet.

In April 2002, AC Transit announced the purchase of four fuel cell buses using compressed hydrogen for $12.5 million or $3.1 million per bus. Three of the buses are for AC Transit and one for SunLine Transit Agency in Thousand Palms, California. The AC Transit fuel cell buses will be built on a Van Hool (from Belgium) bus platform (model A330, 40-foot bus) in a hybrid electric configuration using UTC Fuel Cells and integrated by ISE Research. A potential option to purchase six more fuel cell buses was included in the purchase agreement. The first bus is targeted for delivery to AC Transit in September 2005. AC Transit plans to modify existing facilities at the Seminary Division in East Oakland to accommodate daily maintenance and repair functions for the fuel cell buses. Plans are in place to build a hydrogen fueling station and modify the maintenance facility at Seminary Division.

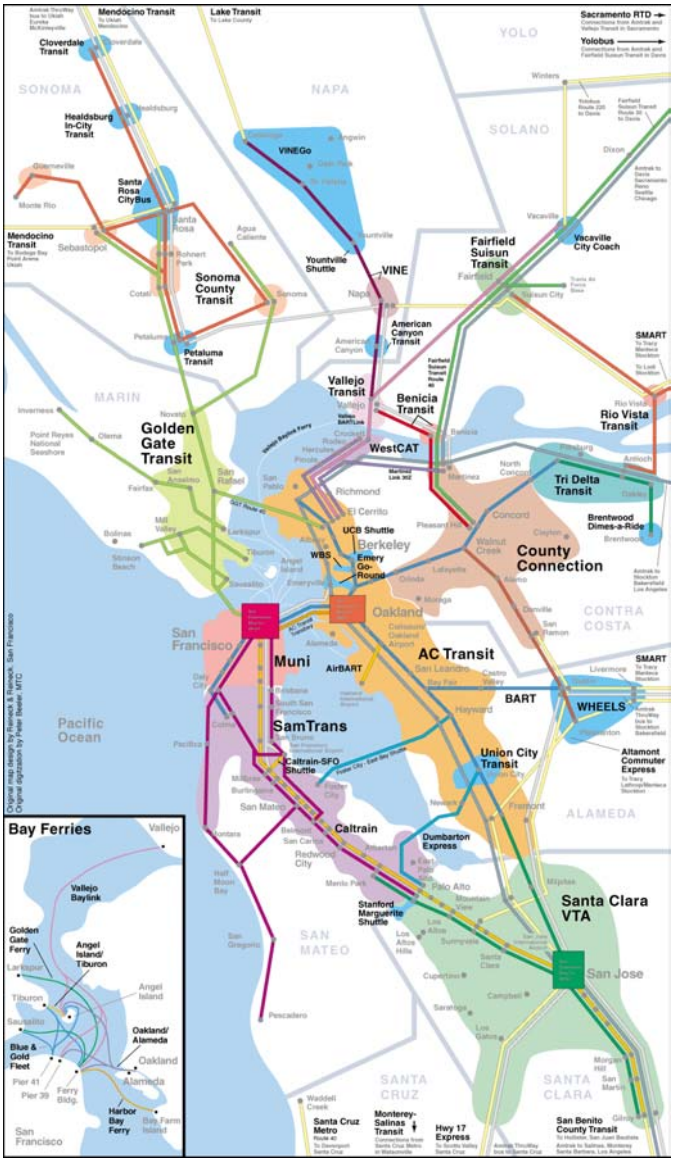

Figure 1. Transit Services in the San Francisco Bay Area

Santa Clara Valley Transportation Authority Site

General Site Description – VTA

The Santa Clara Valley Transportation Authority (VTA) was created by the Santa Clara County Board of Supervisors on June 6, 1972, as a county department charged with development, operation, and maintenance of the bus and light rail system within the county. Since this time, VTA has grown to include a bus fleet of over 500 vehicles serving a 326 square mile urbanized area and a 28.4 mile light rail system serviced by a fleet of 50 cars. VTA also employs approximately 2,650 people. The system provides bus and rail service to approximately 180,000 passengers per day in Santa Clara County which includes the area of downtown San Jose.

In January 1995, VTA separated from the County of Santa Clara and merged with the region's Congestion Management Agency. This expanded VTA's role to include managing the county's blueprint to reduce congestion and improve air quality. VTA plans to achieve this goal through highway and transit capital improvements, lessened demand on the transportation system and improved land use planning. VTA is funded by sales tax revenues, fares, federal grant programs, and other funding sources. Source of all data presented in this section summarized from www.vta.org in October 2003.

General Site Description – SamTrans

SamTrans bus service is under the San Mateo County Transit District and provides service throughout San Mateo County and into parts of San Francisco and Palo Alto. SamTrans fixed-route bus service began July 1, 1976, with the consolidation of 11 different city bus systems throughout the county. SamTrans' stated mission is "to supply the public with a high-quality, safe, and efficient transportation system that should enhance quality of life by increasing access and mobility, reducing congestion, improving the environment and promoting economic vitality." Funding sources for SamTrans $118 million budget include fares, federal funding, sales tax revenues, and other sources.

The SamTrans fixed-route bus system consists of 64 routes, 56 of which are operated by district personnel, the other eight are contracted to outside providers. The system serves a ridership of more than 17.6 million passengers, including over 700 paratransit passengers daily. The fleet consists of 321 total revenue vehicles including 69 articulated coaches, 252 standard coaches, and 60 buses, vans, and sedans for paratransit use. SamTrans has operations and maintenance facilities in South San Francisco and San Carlos as well as others operated by contract services. Source of all data presented in this section summarized from www.samtrans.com in October 2003.

Fuel Cell Bus Project Description

In December of 2000, Santa Clara Valley Transportation Authority (VTA) adopted a Clean Fuels Strategy to help meet air quality regulations in the state. As a part of the plan, VTA will transition from clean diesel to fuel cell technology buses. Their Zero Emission Bus Program will

evaluate fuel cell bus performance in revenue service beginning in mid 2004. The demonstration program is a joint project with SamTrans.

In 2002, VTA contracted with Gillig Corporation to purchase three low-floor 40-foot buses using a fuel cell power system built and integrated by Ballard Power Systems. The first bus was completed in mid 2003 and began a series of performance tests. This bus is scheduled for delivery at VTA in May 2004. The remaining buses should arrive at the agency in July. The demonstration phase is expected to begin by August 2004.

The buses will operate from VTA's Cerone Division in San Jose. Two maintenance bays at the facility will be modified to allow for safe repair of hydrogen fueled buses. The fueling infrastructure, which consists of liquid hydrogen storage and dispensing, is currently being built on the site. Plans for the fueling station include a 9000 gal liquid hydrogen tank and a dispenser capable of filling a bus in 10 to 12 minutes.

SunLine Transit Agency Site

General Site Description - SunLine

SunLine Transit Agency (www.sunline.org) is a joint powers authority that provides public transit and community services to California's Coachella Valley. SunLine's headquarters is located in Thousand Palms, California. The service area is more than 1,100 square miles and includes nine member cities (Desert Hot Springs, Palm Springs, Cathedral City, Rancho Mirage, Palm Desert, Indian Wells, La Quinta, Indio, and Coachella), as well as Riverside County. SunLine's fleet of 46 buses, vans, and shuttles cover 13 routes and serves the area's 320,000 permanent residents as well as
4 million tourists.

SunLine was an early adopter of compressed natural gas (CNG) in bus operations. In 1994 it converted its entire bus fleet to CNG. The fleet currently consists of 46 CNG and two hydrogen/CNG blend (Hythane®) heavy-duty buses, plus ongoing fuel cell bus testing. SunLine provides service for 13 fixed routes and demand response with 24 natural gas powered vans.

SunLine's headquarters include administrative offices, training/meeting rooms, and maintenance, fueling, and hydrogen fuel production facilities—all in one location. The agency operates 129 vehicles including light-, medium-, and heavy-duty vehicles. All but four of its vehicles operate on natural gas (compressed, liquefied, or Hythane®). The remaining four operate on electricity.

Fuel Cell Bus Project Description

Since the early 1990s, SunLine has pursued an aggressive course to build a fleet of clean fuel vehicles. After converting the entire fleet of buses to CNG in 1994, SunLine has continued to look for ways to further reduce or eliminate emissions. The agency has participated in many projects to evaluate the most advanced technologies including hydrogen/CNG blended fuel buses and fuel cell buses. SunLine has tested several prototype fuel cell buses over the last few years, gaining valuable experience with the technology and fuel. The most recent experience was the

demonstration of a hybrid fuel cell bus designed and developed by ISER. The ThunderPower fuel cell bus was built on an ElDorado 30-foot chassis and incorporated a fuel cell built by UTC Fuel Cells.

SunLine has been using compressed hydrogen fuel for several years. In April 2000, SunLine opened a hydrogen generation, storage, fueling, and education facility to demonstrate various approaches to hydrogen production. Hydrogen is made in two ways at SunLine. One method separates pure water into hydrogen and oxygen using electrolysis. The second method uses a reformer, which produces hydrogen by stripping it from methane molecules in natural gas. Electricity to power the electrolyzer and reformer is provided by the electric grid with some of that power being offset by SunLine's solar panels and tracking arrays.

SunLine is purchasing a fuel cell bus as a part of the AC Transit procurement. The bus will be identical to the three in service at AC Transit. The hot, dry desert climate in SunLine's service area will help further test the performance of the bus under multiple climates.