

Date: March 5, 2008  
Committee Meeting Date: March 20, 2008  
Board Meeting Date: April 3, 2008  
INFORMATION ITEM

## BOARD MEMORANDUM

**TO:** Transit Planning and Operations Committee  
Santa Clara Valley Transportation Authority  
Board of Directors

**THROUGH:** Michael T. Burns  
General Manager

**FROM:** Donald A. Smith, Jr.  
Chief Operating Officer

**SUBJECT:** Zero Emissions Bus (ZEB) Program Update

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### FOR INFORMATION ONLY

#### **BACKGROUND:**

On February 20, 2008 the Transit Planning and Operations (TP&O) Committee heard a presentation from staff giving the status of the current Zero Emission Bus Demonstration Program, as it is in its final stages. The Committee also received information about the California Air Resources Board (CARB) requirements for ZEBs beyond this first demonstration program. As a result of this discussion, the Committee requested additional details about the current and future ZEB demonstration program. The Committee also requested information on other emission reduction strategies that VTA is considering.

#### **CARB Requirements for Zero Emission Buses**

In February 2000, CARB enacted new regulations to reduce transit bus emissions. Transit agencies with 200 or more buses had to choose to immediately implement compressed natural gas (CNG) technology (i.e., “the alternative fuel path”) or chose the “diesel path.” Agencies on the diesel path were required to implement a Zero Emission Bus (ZEB) demonstration program. CARB mandated that beginning in 2008, 15% of the new buses purchased by diesel path transit agencies were required to be ZEBs. Transit agencies on the alternative fuel path had the ZEB purchase requirement starting in 2010.

The fuel cell bus demonstration program illustrated that ZEBs with fuel cells are not commercially ready. Based on this, CARB delayed the 15% ZEB purchase requirement and implemented the following:

- An advanced demonstration program requiring new zero emission buses to start January 2009;

- Transit agencies with 200 or more buses and on the Diesel Path – Starting 2011, 15% of new buses purchased are to be ZEB;
- Transit agencies with 200 or more buses and on the Alt Fuel Path – Starting 2012, 15% of new buses purchased are to be ZEB.

## **DISCUSSION:**

### **INITIAL ZEB DEMONSTRATION PROGRAM**

#### **Fuel Cell Cost and Performance**

The first VTA/SamTrans ZEB demonstration provided significant knowledge regarding the requirements to operate fuel cell buses in transit service. The VTA/SamTrans ZEBs are first-generation fuel cell transit buses operating on fuel cells manufactured by Ballard Power Systems. Since the purchase of the VTA/SamTrans buses, manufacturers have developed a second-generation “hybrid ZEB design” utilizing hydrogen fuel cell systems and batteries to store excess energy.

Where diesel buses average 45,000 miles per year, the three VTA ZEB fuel cell buses averaged 8,350 miles per year. The three VTA ZEB buses combined have accumulated more than 75,000 miles in revenue service since February 2005. The initial demonstration project has shown us that the fuel cell is a major cost for the ZEBs:

- Fuel cell life averaged just over 17,000 miles, or approximately 1,200 hours.
- Every one of the 36 fuel cell rows on each bus have been replaced at least once and 14 cell rows have either been replaced a second time or are in need of replacement now. A number of the cell rows were replaced under warranty.
- Ballard, the fuel cell provider, charged nearly \$35,000 plus tax and shipping per fuel cell row after warranty expired.
- Ballard has offered to sell VTA 12 fuel cell rows for a price of \$24,000 each, \$288,000 per bus; these cell rows are from the European fuel cell demonstration program and are being offered without warranty.

#### **Fuel and Fueling Facility**

Hydrogen fuel and the fueling facility are a major cost associated with hydrogen fuel cell bus operation. The present hydrogen fueling facility is leased from Air Products and Chemicals Inc. (Air Products) and is designed to handle fast fueling of transit buses. After some initial glitches, the system has operated successfully and supplied fuel as necessary to operate the fuel cell buses. Although the main compressor has been a problem, Air Products has responded quickly when problems occur and operation with the backup compressor has been acceptable.

Air Products delivers the hydrogen in liquid form to the facility using tanker trucks. The cost of the fuel and fueling facility to-date is as follows:

- Fueling facility pad and utilities - \$275,000, a one-time fee
- Initial set up and training - \$166,000
- Up-front lease payment for hydrogen compressor - \$300,000

- Taxes, Property - \$12,540 based on one invoice, although expected to be an annual expense
- Monthly lease, first three years - \$4,543/month; \$54,516/year; \$163,554/3 years
- Fuel – Cost and amount supplied \$553,264 for 55,314 Diesel Gallon Equivalent (DGE) of Hydrogen. VTA has supplied both Air Products and San Mateo C/CAG with Hydrogen fuel from the fueling facility; VTA has been reimbursed just over \$18,000.
- Monthly lease, subsequent – \$6,854 /month; \$82,250/year
- The total amount expended for the fuel and fueling facility to-date is approximately \$1,534,600.

There are several major factors related to the cost of the fuel and fueling system. First, the present system has an approximate efficiency of 50%. That is, for every two gallons of hydrogen delivered; only one gallon is dispensed to the bus, the other gallon is lost to venting. This is, in part, due to cryogenic storage of liquid hydrogen as well as the (liquid) pumping system and the process for delivering liquid hydrogen. Considering the present cost of fuel at approximately \$10.00 per DGE and the 50% efficiency, the cost of usable hydrogen, excluding lease and other charges, is \$20.00 per DGE. Second, the lease for the fueling facility is now \$11,750 per month. With associated property tax, this is equivalent to an annual cost of approximately \$154,000 excluding the cost of fuel.

Average Cost per Mile		
Avg Cost Per Mile	Diesel	Fuel Cell
Parts Cost	\$ 0.21	\$ 34.40
Labor Cost	\$ 0.84	\$ 7.87
Fuel Cost	<u>\$ 0.56</u>	<u>\$ 2.86</u>
Total Maint Cost	\$ 1.61	\$ 45.13
Fuel Loss Cost	NA	\$ 2.86
Fuel Facility Lease Cost	<u>NA</u>	<u>\$ 3.67</u>
<b>Total Cost</b>	<b>\$ 1.61</b>	<b>\$ 51.66</b>

### **Hydrogen Cleanliness**

Hydrogen gas is not a naturally available resource. Most often, the hydrogen operated in motor vehicles today is created by a reforming process using natural gas and steam, which is currently the cheapest and most common way to produce hydrogen. In this process, steam is fed methane gas at a temperature of 700-1000°C in a reactor with a metal-based catalyst. The steam reacts with methane to yield carbon monoxide and hydrogen. This process requires an additional 10-30% natural gas that is used as energy to power the reaction. The net (negative) energy used to produce hydrogen significantly reduces the environmental cleanliness of hydrogen.

### **ADVANCED DEMONSTRATION PROGRAM**

The requirement for the advanced demonstration program is regional, supported by MTC, and will have 12 advanced ZEBs in operation by January 2009. The region includes AC Transit, Golden Gate Transit, SamTrans and VTA. The proposal is for AC Transit to operate eight of the advanced fuel buses, partnering with Golden Gate Transit. VTA will operate the remaining four, partnering with SamTrans.

The goal of the advanced demonstration program is to show that, with the experience gained during the initial demonstration program and the manufacturer's improvements made as a result, zero emission fuel cell buses will be more reliable and thus ready for transit bus service. These buses are expected to have a 12-year life, with fuel cell replacements as necessary. During that time, the commercial viability of the technology will continue to be evaluated.

The estimated capital cost split for the advanced fuel cell bus demonstration is \$23,889,000 for AC Transit and \$16,411,000 for VTA, for an estimated total of \$40,300,000:

- \$28,800,000 to purchase 12 new advanced fuel cell buses
- \$10,000,000 for 2 new fueling facilities
- \$ 1,500,000 for project contingencies.

This does not include the cost to maintain or operate the buses, including fuel. A spreadsheet detailing various funding scenarios is attached.

While future buses are expected to have improved performance and lower operating costs, the actual cost is difficult to determine at this time.

### **Fueling Facility**

The current lease with Air Products for the fueling facility is \$11,750 per month, providing VTA with a facility capable of fueling buses at a very fast rate and with the ability to handle fueling for a fleet of 20 to 24 fuel cell buses. Air Products also performs all maintenance and repairs at the facility without any additional cost to VTA. For a fleet of four buses, as anticipated in the advanced demonstration program, the lease and tax cost is calculated at \$1.28 per mile and, considering vent losses at 50%, the total cost per mile is estimated between \$3.50 and \$4.50.

VTA could purchase the fueling facility from Air Products. The liquid compression pumps are proprietary and are not readily available for this type of application. This will cause VTA to lease these pumps from Air Products in addition to taking on the burden of facility maintenance and repair. With this comes the responsibility of inspection, component replacement, facility monitoring, related certifications, etc. The annual \$154,000 lease and tax charge is estimated to be reduced significantly. VTA will also be responsible for purchasing the liquid hydrogen and any vent losses.

### **Reformation**

Installing a natural gas reformation system has benefits and drawbacks. This system eliminates vent loss, making fuel cheaper and more environmentally friendly. Large storage tanks are required to accommodate this system and can fuel a limited number of vehicles. For example, AC Transit has worked with Chevron to install a reformer system with the capacity to produce approximately 300 DGE hydrogen. This will accommodate a fuel cell fleet of 8 to 10 buses. The actual cost to operate this system is not available, but their experience to date estimates the cost to produce hydrogen at \$8.00 per Kg or \$9.00 per DGE. The reformers can handle producing hydrogen, yet storage becomes the limiting factor. AC Transit has 27 hydrogen storage tanks to accommodate a fleet of 3 buses; additional storage will be necessary for fleet expansion. The estimated cost to purchase and install a natural gas hydrogen reformation system is approximately \$5,000,000.

## **ADVANCED DEMONSTRATION OPTIONS**

There are options to consider for the advanced ZEB demonstration program:

### 1. Partnerships

- AC Transit and Golden Gate as partners to procure and operate 8 ZEBs
- SamTrans and VTA as partners to procure and operate 4 ZEBs
- MTC would take the lead to obtain funding and subsequent fund distribution.

### 2. Single lead operating agency with funding arrangements

- AC Transit to purchase all 12 ZEBs and be considered the major operator
- Golden Gate, SamTrans and VTA would be partners and provide appropriate share of funding
- Golden Gate, SamTrans and VTA would be partners and operate buses for short durations in accordance with requirements
- MTC would take the lead to obtain funding and subsequent fund distribution.

### 3. Not Participate

This could lead to issues related to possible future funding from the state of California as well as significant fines from CARB. The Advanced Demonstration is a CARB-mandated project.

## **VTA BUS PROCUREMENT PLAN**

The FY2008-2017 Short Range Transit Plan indicates the bus replacement plan for full-size buses based on a 12-to-15-year replacement cycle. Typically, VTA does not replace full-size buses until they have reached their 14-year life. The replacement plan also includes the required zero emissions buses to meet CARB requirements.

2010	104 buses to replace 1997 and 1998 buses
2011	44 buses (37 diesel, 7 ZEB) to replace 1998 and 1999 buses
2012	0 buses
2013	38 buses (32 diesel, 6 ZEB) to replace 2001 buses
2014	10 buses (10 diesel, 2 ZEB) to replace 2002 articulated buses

## **ADVANCED ZEB DEMONSTRATION BUS PURCHASE**

There are options to the purchase of the ZEBs for the advanced demonstration:

1. AC Transit is presently negotiating an order for ZEBs with Van Hool of Belgium. The preliminary indication is that the price for these buses is \$2,250,000 each, as compared to a standard equivalent diesel bus at \$400,000 to \$600,000. AC Transit has indicated that purchasing these buses would not require payment of a significant portion of sales tax. Preliminary information also indicates that AC Transit would buy the fuel cells directly from UTC, a U.S. company, for installation by Van Hool.
2. BC Transit in Canada is ordering up to 20 fuel cell buses. The bus manufacturer is New Flyer Industries of Canada and the fuel cell manufacturer is Ballard Power Systems of Vancouver. Integration of the fuel cell system, hybrid drive and bus will be done by ISE of San Diego.

3. The last option would be for VTA to prepare the specifications for fuel cell buses and establish a request for proposal or bid. It would likely be 12-18 months before bids are received.

## **ALTERNATIVE EMISSION REDUCTIONS**

### Biodiesel

There have been a number of advances since the introduction of biodiesel, including established refining standards; an understanding of the effects of biodiesel source on the final product; and the effects of temperature, bacterial growth, and gelling. Engine manufacturers have made the transition to accept biodiesel as a potential fuel up to a B20 level (20% bio product). This acceptance is still with reservation, particularly with older engines.

Considering this information, VTA will gradually introduce Biodiesel in late Summer 2008, with the use of B5 (5% bio product) on a select group of newer buses. This gradual deployment assures that biodiesel will not present maintenance problems with the engines. Staff will also have an opportunity to establish acceptable maintenance programs relating to the use of biodiesel.

### Hybrid Technology

Hybrid technology has been very successful in automotive and transit bus applications. All major car manufacturers have hybrid cars in production and hybrid drive systems are now also available for bus and truck applications. Hybrid drive technology has been shown to increase fuel economy and thus reduce vehicle emissions. Although such systems are available for transit bus application, CARB has not established certification for them yet. VTA is working with the various other transit agencies to have CARB certify hybrid transit buses, given that a number of California transit agencies have been able to purchase hybrid buses under a special limited program. Additionally, VTA will be closely monitoring the development of hybrid drive systems for future Community Bus purchases.

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