Alameda-Contra Costa Transit District

S T A F F R E P O R T

TO: AC Transit Board of Directors  
FROM: David J. Armijo, General Manager  
SUBJECT: Update on the Status of AC Transit’s Fuel Cell Program and Discussion of Path Forward for Zero Emission Bus Procurements

BRIEFING ITEM

RECOMMENDED ACTION(S):


EXECUTIVE SUMMARY:

The District currently operates a fleet of twelve fuel cell buses in accordance with the 2008 CARB Advanced Demonstration Program mandate. Golden Gate Transit, SamTrans, and Santa Clara Valley Transportation Authority are part of a consortium of regional transit agencies participating in the program that provides funding and operation of the buses.

The program has been primarily grant funded, with about $89.2 million from Federal, State, and regional sources. The District is currently obligated to operate the fuel cell bus fleet through December 2016, the Emeryville public hydrogen fueling station through September 30, 2015, and the Seminary hydrogen fueling station three years after commissioning, which is currently planned for the spring of 2014.

Zero emission bus technologies have advanced dramatically since inception of the fuel cell bus programs, with the primary obstacle for fuel cell bus commercial viability being the initial procurement and on-going maintenance costs. Zero emission bus technology has seen the highest level of advancement in the area of battery technology. Bus manufacturers have initiated the marketing of several models of electric buses as being a viable, less expensive alternative to fuel cell buses.

CARB is considering the adoption of further zero and near-zero regulatory bus requirements as early as December 2014. The CARB Board may consider expansion of the CARB Zbus demonstration, including a 40 fuel cell bus demonstration and/or multiple 6 - 8 battery electric vehicle demonstrations. The new NoLo Federal grant and proposed CARB regulations are for 12-year replacement buses; therefore, the District needs to consider the full life-cycle costs for all future zero emission bus procurements, including fuel cell engine rebuild costs, lithium
propulsion battery replacement costs, and infrastructure costs. A life-cycle cost analysis of the different zero emission bus technologies would allow the Board to consider the long-term financial impact of expanding the fleet of zero emission buses.

**BUDGETARY/FISCAL IMPACT:**

There are no specific budget impacts related to this briefing report; however, the District could experience significant increases in capital and operating budget expenses with expansion of zero emission bus programs, as discussed later in this report, since the Federal NoLo grant and CARB regulatory efforts are considering 12 year replacement buses rather than prototype zero emission buses.

**BACKGROUND/RATIONALE:**

In 2000, the California Air Resources Board (CARB) directed that all transit agencies with bus fleets of 200 or more vehicles choose either an Alternative Fuel or Diesel path for future bus procurements, with a requirement that agencies choosing the diesel path initiate a three-bus fuel cell demonstration program. CARB extended their mandate in 2008 for agencies on the diesel path with their Advanced Demonstration Program, including the following:

- Allowance for a jointly funded demonstration project with multiple transit agencies utilizing a minimum of 12 zero emission buses in revenue service.
- Requirement that demonstration buses be placed in revenue service for a minimum duration of 12 calendar months after delivery of all buses.
- Requirement to provide appropriate maintenance and storage facilities.
- Requirement to train bus operators and maintenance personnel from each participating transit agency in the Advanced Demonstration Program.

AC Transit serves the region as the owner and responsible party for the maintenance, servicing, and training for the twelve fuel cell buses in the CARB Advanced Demonstration Program, which is also referred to as the Zero-Emission Bay Area Program (ZEBA). The Van Hool fuel cell buses were received in the 2010/2011 timeframe and were originally fueled using a mobile fueling station until completion of the Emeryville hydrogen fueling station. A second hydrogen fueling station is planned for construction in 2014, along with modifications for an additional maintenance service bay for gaseous fuels.

Golden Gate Transit, SamTrans, and Santa Clara Valley Transportation Authority are part of a consortium of regional transit agencies that participate with AC Transit in the program. The participation in the program by these Bay Area transit agencies includes financial obligations and limited requirements for the operation of the fuel cell buses. To date, Golden Gate Transit
has been the only agency to operate one of the fuel cell buses in revenue service. The fleet distribution for the consortium partner agencies are shown in the following table:

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The Federal Transit Administration (FTA) established the National Fuel Cell Bus Program (NFCBP) in 2006 with an overall goal of developing and demonstrating commercially viable fuel cell technology for transit buses. In September 2013, FTA announced the awards for an additional $13.5 million appropriated for the NFCBP. Current efforts focus on improving the energy efficiency, emissions, performance, and cost-effectiveness of the 40-ft heavy-duty transit bus, which is the most prevalent vehicle used by U.S. transit agencies.

The National Renewable Energy Laboratory (NREL) was funded as a third-party evaluator to assess the viability of the buses demonstrated under the program. The table below was developed by NREL to summarize both current and planned DOE- and FTA-funded projects. The table shows the estimated timing for NREL’s evaluations.

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**OVERVIEW OF BUS OPERATION AND PERFORMANCE** - The AC Transit fuel cell bus fleet exceeded 526,000 total miles and 69,500 total hours at the end of 2013. The miles between road calls for the fleet averaged about 5,600 from March to October 2013, but the average
monthly mileage for each fuel cell bus was only about 2,700 miles, which was about one-half the mileage of the diesel buses in the control group. The average cost per mile for the fuel cell buses is $1.40; however, this amount only includes the cost to maintain the bus components and not the fuel cell or battery technology costs since these systems remain under warranty or service agreements. For comparative purposes, the Van Hool buses that make up the control fleet are no longer under warranty and have a cost per mile of $0.78.

The fuel cell bus fleet is currently maintained by three dedicated District maintenance employees for general system components. U.S. Hybrid has a full time maintenance technician on site that maintains the fuel cell specific components. EnerDell has a service agreement for the maintenance of the fuel cell bus battery systems. The maintenance of standard bus components and systems, such as doors, seats, and air conditioning systems, are accomplished by the regular mechanics at the bus division.

The Emeryville hydrogen fueling station has been in operation since August 2011 and provides hydrogen fuel for the twelve fuel cell buses and dispenses hydrogen fuel for sale to private vehicles at a public station located directly outside of the bus division. The fuel station is designed to dispense up to 2,000 kg of hydrogen on a monthly basis for the buses and private vehicle fueling operations.

Since August 2011, two incidents have occurred with the hydrogen fueling station. The first incident on May 4, 2012 occurred due to a relief valve failure that caused the evacuation of the liquid hydrogen from the storage tank. Hydrogen fueling was suspended for about nine months until completion of an exhaustive investigation of the root cause of the incident, implementation of design enhancements, and completion of an independent outside assessment of the fueling station and operational procedures.

The second incident occurred on January 27, 2014 when a pressure regulator valve froze in the fully open position during fuel delivery causing increased tank pressures and the venting of hydrogen through the relief valves in the emergency evacuation system. The operation of the fuel cell bus fleet was suspended for approximately two weeks after the incident until a full investigation and corrective actions were completed on February 11, 2014.

**FUNDING OBLIGATIONS** – Currently, the costs for the Advanced Demonstration Program have been primarily grant funded, which has allowed AC Transit to obtain valuable insight into the procurement, operation, and maintenance of a hydrogen fuel cell bus fleet. With future regulatory purchase requirements at the Federal or State levels, the amount of grant funding may be reduced for future procurements and may not be available for future maintenance activities.
The District has secured $89.2 million from Federal, State, and regional sources to support the existing programs, including $21 million for Phase I (2005 to 2010); $66.6 million for Phase II (2010 to present), and $1.6 million in Federal funds that the District was recently awarded for continued maintenance of the fuel cell bus fleet through December 2016. The $66.6 million includes the cost for the fuel cell buses, fueling stations, stationary fuel cell, and solar projects.

Based upon current funding obligations, the District must continue to operate the fuel cell buses and hydrogen fueling stations as follows:

- Twelve fuel cell buses – the District has fulfilled the original grant obligation to operate the fuel cell buses for one year in revenue service, but has agreed to extend the operation of the fuel cell buses through December 2016 as part of the latest $1.6 million grant.

- Emeryville hydrogen fueling station – the District is obligated to operate the Emeryville public hydrogen fueling station through September 30, 2015.

- Seminary hydrogen fueling station – the District is obligated to operate the Seminary hydrogen fueling station for a three-year period after commissioning, which is currently planned for the spring of 2014.

FUTURE PROGRAM COSTS - The procurement cost for the current fleet of fuel cell buses was about $2.5 million per bus. The California Fuel Cell Partnership has suggested that the price of fuel cell buses could be as low as $1.2 million with high volume production; however, there have been no high volume procurements to validate this claim. The procurement cost for electric buses have been about $800,000 for buses produced for Southern California.

The two AC Transit hydrogen fueling stations are capable of fueling 24 fuel cell buses, and the existing maintenance bays can accommodate the current 12 bus fleet. If the fleet is expanded, the additional cost to install ventilation systems, alarms, and non-ignition electrical systems would be about $750,000 per maintenance bay. The facility infrastructure cost for battery electric buses would be about $25,000 for each BYD bus charger to about $600,000 for Proterra quick charging stations that can recharge multiple electric buses.

The operating cost for most of the current demonstration program is funded with Federal, State, and local grants. The District recently received a $1.6 million Federal grant to support most high cost maintenance activities on the fuel cell bus fleet through December 2016. The annual service and maintenance agreement cost for the Emeryville hydrogen fueling station is about $250,000, which is expected to increase to about $500,000 with the opening of the Seminary hydrogen fueling station. As existing grant funds for fueling station maintenance is fully expended, the District will either need to seek additional grants or fund the maintenance using operating funds.
The program operating budget is currently subsidized by annual payments from partner transit agencies - Golden Gate Transit, SamTrans, and VTA; however, the agreements with these agencies expire with the implementation of any new CARB zero emission bus regulation. As funding from grant programs and agreements with partner agencies expire, the District will need to absorb the additional operating cost for the current fleet of fuel cell buses to keep the buses operational.

The Federal NoLo grants and future CARB regulations are indicating a transition from demonstration programs to procurement of 12-year replacement buses. With future zero emission replacement buses, the District will need to absorb the cost of maintaining the buses. ClearEdge power indicated that the replacement fuel cell engine for our current fleet of buses was $750,000, while Proterra has indicated that the fuel cell engine on their fuel cell bus may be as low as $300,000 to $350,000 for a high volume procurement. Fuel cell engine replacements may be required two to three times during the 12 year life of the bus. In either case, the cost is significantly higher than the $40,000 cost for a diesel engine replacement package, which is normally replaced once during the life of a bus.

Traction battery replacement costs vary based upon the type of bus, with our fuel cell bus battery replacements estimated at $50,000 per bus. BYD batteries are replaced in modules at $6,000 per module, which could cost $306,000 to replace all batteries during the 12 year life of the bus. Proterra is currently offering an option for a 12 year battery replacement warranty in the purchase price of their battery electric bus.

TECHNOLOGY ADVANCEMENTS – Zero emission bus technologies have shown significant advancement since the inception of the fuel cell bus programs at the District, with considerable improvement in performance and reliability. The primary remaining obstacle for fuel cell bus commercial viability is the initial procurement cost and on-going maintenance costs for parts and labor.

Zero emission bus technology has seen the highest level of advancement in recent years in the area of battery technology. Bus manufacturers have begun marketing several models of electric buses and near-zero emission buses as being a viable, less expensive alternative to fuel cell buses. Proterra originally paved the way for electric buses with small volume sales to transit agencies, which have expanded to fleets of up to 15 electric buses at Foothill Transit in Southern California. The BYD procurement agreements with Long Beach and Los Angeles could result in the production of up to 35 additional electric buses. New Flyer has also entered the market with their new Xcelsior electric bus. Electric bus manufacturer marketing has included the following:

- Full-size 40' battery buses that charge overnight with a range of about 155 miles per charge.
• Quick-charge technology that charges propulsion batteries in about 10 minutes at the end of every trip for a solution to the range issue and potential 24/7 operability.
• Induction quick-charge technology to charge bus batteries during normal service at strategic points to extend the range of the bus.
• Electricity costs that are generally lower than other fuels to improve efficiency, especially during off-peak charging in the evening hours.

**CARB REGULATORY EFFORTS** – The Zero Emission Bus (ZBus) regulation was designed by CARB to encourage the operation and use of zero emission buses in California urban bus fleets. CARB held workshops in September and December 2013 to focus on the current state of the technology. The workshops focused on potential regulatory concepts and options under consideration for zero and near-zero bus deployment and included a discussion of a planned broader look at the transit fleet emissions rule that will occur in 2014.

CARB staff provided an anticipated timeline for the new regulations, as follows:

• January – March 2014 - continued site visits and conference calls with stakeholders,
• April / May 2014 – planning for third workshop,
• May 2014 – briefing report to be presented to the CARB Board,
• Summer 2014 – planning for additional workshops,
• December 2014 – CARB Board to hold hearing on Fleet Rule and/or expansion of Zbus fuel cell demonstrations and/or battery electric bus demonstrations.

**NEXT STEPS** – The District is submitting a grant request to support the purchase of additional Zero Emission buses. Upon grant award, the District would be able to initiate a procurement for additional zero emission buses and supporting infrastructure. In addition, CARB is expected to issue new ZBus regulations in December 2014 that may require a percentage of future bus procurements to include zero emission buses.

It is important to note that the new NoLo Federal grant and proposed CARB regulations are for full 12-year replacement buses; therefore, the District needs to consider the full life-cycle costs for all future zero emission bus procurements. The current demonstration program only requires the District to operate the fuel cell buses for one-year; therefore, if there is a major fuel cell engine failure, the District could discontinue the operation of the bus.

The life-cycle cost for zero emission buses needs to include the following high-cost replacement components:

• Fuel cell engine rebuild and/or replacement costs
• Lithium propulsion battery replacement costs
• Electric inverter replacement costs
• Hydrogen fuel cell station maintenance costs
• Facility modifications for expanded fleets of gaseous fuel buses
• Electric charging station maintenance costs
• Hydrogen fuel cost
• Electricity cost

While there are some projections of reduced cost for production buses for a large production run, the cost of the replacement components are likely to remain much higher than the high volume production run components due to the unpredictable failure rate for these specialized components. If batteries, fuel cell engines, or other specialized components for zero emissions buses fail on a 12-year replacement bus, the District will either need to fund the replacement of the high cost components or consider repowering the bus to a lower cost propulsion system.

A life-cycle cost analysis of the different zero emission bus technologies would allow the Board to consider the long-term financial impact of expanding the fleet of zero emission buses.

**ADVANTAGES/DISADVANTAGES:**

The hydrogen fuel cell program provides several advantages to AC Transit, including gaining insight into the operating characteristics and cost of the hydrogen bus fleet, fueling station, and facility requirements. In addition, the program has allowed for a significant amount of grant funding for fueling stations and facility modifications.

The disadvantages include the future capital and operating cost for maintaining the existing program and any expansion of the program. In addition, the staff time required to support this specialized fleet detracts from the primary mission of the agency to provide high quality and efficient transit service to the East Bay service area.

A significant disadvantage is that there are currently no Original Equipment Manufacturers (OEM’s) of production model fuel cell buses, even though hydrogen buses are in the third decade of demonstration programs. While other technologies, such as natural gas and hybrid transit bus technologies, have moved into standard production, hydrogen bus technology has been slow to mature.

**ALTERNATIVE ACTIONS:**

This report is informational and no action is required from the Board at this time.

**PRIOR RELEVANT BOARD ACTIONS/POLICIES:**

There are no prior relevant Board Actions associated with this report.
ATTACHMENTS:

None

Department Head Approval: James D. Pachan, Chief Operating Officer
Reviewed by: Lewis Clinton, Chief Financial Officer
             Denise Standridge, Interim General Counsel
Prepared by: Salvador Llamas, Director of Maintenance
AC Transit’s Fuel Cell Program and Path Forward for Zero Emission Buses

Salvador Llamas, Director of Maintenance
March 12, 2014

Zero-Emission Bay Area (ZEBA) Advance Demonstration Program

- CARB Fuel Path Mandate
  - Three bus demonstration program
  - Twelve bus advanced demonstration program
- Consortium Agencies in ZEBA Program
  - Funding support for AC Transit program
  - Requirement to operate buses in revenue service
- Fleet Distribution of Consortium
  - Diesel and diesel / electric hybrid buses

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National Fuel Cell Bus Program

- Goal of Demonstrating Commercial Viability
- Demonstrations at Various Transit Agencies
  - Fuel cell dominant hybrid electric buses
  - Battery dominant hybrid electric buses
- Largest Demonstration Program at AC Transit

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Operation and Performance

- Twelve Fuel Cell Buses
  - Total miles – 526,000
  - Miles between roadcalls – 5,600
  - Monthly mileage – 2,700 (1/2 of control fleet)
  - Average cost per mile - $1.40 (verses $0.78)

- Bus Maintenance
  - Three dedicated maintenance employees
  - U.S. Hybrid maintains fuel cells with full time technician
  - EnerDell maintains battery systems under service agreement

- Hydrogen Fueling Stations
  - Emeryville - fuels twelve buses and public vehicles
  - Two valve issues resulting in H2 venting incidents
  - Seminary H2 station schedule to open in Spring 2014

- Maintenance Bays Modified for Gaseous Fuel
Funding Obligations

- Programs Primarily Grant Funded
  - $89.2M – buses, H2 stations, energy production
- Twelve Fuel Cell Buses
  - Fulfilled the original one-year requirement
  - Maintenance grant extends to December 2016
- Emeryville H2 Fueling Station
  - Operate through September 2015
- Seminary H2 Fueling Station
  - Operate for 3 years after commissioning
  - Construction completion in spring 2014
  - Obligation through spring of 2017

Future Program Costs

- Bus Procurement Cost
  - Current fuel cell buses cost $2.5M
  - Battery electric buses selling for about $800,000 to $1,000,000
- Hydrogen Fuel Station Maintenance Cost
  - Maintenance costs are currently grant funded
  - Operating cost of $250,000 per station after grants expire
- Maintenance Bay Retrofit Cost
  - Ventilation, alarm, and non-ignition electrical systems
  - Estimated cost at Emeryville is about $750,000
  - Additional bays required if fuel cell fleet is expanded
- Battery Recharging Stations
  - BYD rechargers cost about $25,000 per bus (overnight charging)
  - Proterra quick charge stations cost $600,000 (multiple buses)
Future Program Costs (cont.)

- **Operating Cost – 12 Year Replacement Buses**
  - Federal NoLo grant is for 12 year replacement buses
  - CARB indicated that new regulation will be for 12 year buses

- **Fuel Cell Engine**
  - Current buses were $750,000, but may reduced to $300,000
  - Two fuel cell engine replacements could exceed $600,000 per bus

- **Traction Battery**
  - Fuel cell bus batteries cost about $50,000 per bus
  - BYD
    - Batteries are $6,000 per module with 7 year warranty
    - Could cost $306,000 if all batteries failed outside of warranty
  - Proterra
    - Offering 12-year battery replacement warranty
    - Extended warranty would increase the bus procurement cost

Zero Emission Bus Technology Advancements

- **Proterra**

- **BYD**

- **New Flyer Xcelsior**

- **Quick-Charge Technology**
  - Overhead Automated Charging
  - Inductive Charging
CARB Regulatory Efforts

- Zero Emission Bus (Zbus) Regulation
- CARB Workshops
  - September 2013 in Southern California
  - December 2014 in Northern California
- CARB Timeline
  - January – March 2014 – stakeholder site visits and conference calls
  - April / May 2014 – planning for third workshop
  - May 2014 – briefing report to be presented to the CARB Board
  - Summer 2014 – planning for additional workshops
  - December 2014 – CARB Board hearing
  - January 2015 – Tentative date for new CARB regulation, including:
    - Possible 40 fuel cell bus demonstration program
    - Possibility of multiple 6 – 8 bus electric bus demonstrations
    - Possibility of zero-emission bus purchase requirement
      - 15% purchase requirement in original regulation

Next Steps

- Review Path Forward for ZEB Procurements
  - NoLo Federal Grant
  - CARB Regulations
- Zero Emission Bus Life-Cycle Cost
  - Fuel cell engine rebuild and/or replacement costs
  - Lithium propulsion battery replacement costs
  - Electric inverter replacement costs
  - Hydrogen fuel cell station maintenance costs
  - Facility modifications for gaseous fuel buses
  - Electric charging station maintenance costs
  - Hydrogen fuel cost
  - Electricity cost
- Consideration of Long-Term Financial Impact
- Sustainable Zbus Operation Goal
THANK YOU

ANY QUESTIONS?