

Compound Fuel Cell Hybrid Bus Hits the Streets of San Francisco



San Francisco Hosts National Fuel Cell Bus Program Demonstration

The Federal Transit Administration's (FTA) National Fuel Cell Bus Program (NFCBP) focuses on developing commercially viable fuel cell bus technologies. CALSTART is one of three non-profit consortia chosen to manage projects competitively selected under the program. BAE Systems is leading a project to develop a new concept combining a diesel hybrid propulsion system with a fuel cell to increase efficiency and reduce emissions. The Compound Fuel Cell Hybrid Bus for 2010, or **Bus 2010**, will be demonstrated in the San Francisco Municipal Transportation Agency fleet.

The San Francisco Municipal Transportation Agency (SFMTA) manages and operates the surface transportation network in San Francisco including: pedestrian, bicycle, transit, traffic, parking, and taxi regulation. The San Francisco Municipal Railway (Muni), the largest division within the SFMTA, handles transit operation and maintenance for the city's bus, light rail, trolley, historic street cars, and cable car fleets, as well as facility maintenance. Muni is the oldest public transportation agency in the United States, serving more than 200 million customers per year with the country's most diverse fleet of vehicles.

The SFMTA is committed to reducing overall carbon emissions, especially for its vehicle fleet. Although more than half of the Muni fleet is zero-emission, the agency

is actively working to further reduce fossil fuel use and emissions. The SFMTA Clean Air Plan – Zero Emissions 2020 sets a goal of an all-electric fleet by 2020.

The three-pronged strategy to reach that goal is:

- Maximizing the use of zero-emission vehicles
- Replacing conventional diesel buses with hybrids as a bridge technology to fuel cells
- Cleaning up the remaining fleet with the best available retrofit technologies and alternative fuels

Since setting those goals, the agency has switched all of its diesel-fueled buses to a 20 percent biodiesel blend (B20) and has added 86 low-emission hybrid buses to its fleet. Demonstration of Bus 2010 provides an opportunity for the SFMTA to begin learning about hydrogen fuel cell technology for the future.

Muni Bus Fleet Facts

Vehicle Type	Number
Diesel buses	420
Diesel hybrid buses	86
Electric trolley	313
Metro streetcars	151
Historic streetcars	40
Cable cars	40
Compound hybrid-fuel cell bus	1

An Evolutionary Approach

The Bus 2010 project targets FTA's NFCBP objectives of facilitating commercially viable fuel cell bus technologies. BAE Systems has teamed with CALSTART and the SFMTA to develop and demonstrate the bus in a challenging transit service. Bus 2010 is considered an evolutionary approach because it combines a smaller, low-cost fuel cell system with a commercial diesel-hybrid propulsion system. There are several potential advantages to this approach:

Bus 2010 Facts

Bus Chassis/ Model	Daimler Buses North America, Orion VII
Length/Width/ Height	40 ft./102 in./139 in.
GVWR	42,540 lb.
Seats	36 (without wheelchairs)
Hybrid System	BAE Systems series hybrid-electric propulsion and power system
Powerplant	Engine: Cummins ISB07, 6.7L, 260 HP engine powering a 200 kW PM integrated starter/generator Fuel Cell: 2 Hydrogenics HyPM HD 12, 12 kW each
Energy Storage	Lithium-ion energy storage system, 200 kW peak
Accessories	Electrically driven engine cooling, air conditioner, power steering, air compressor, and 24 V DC supply
Fuel/Storage	Gaseous hydrogen: 32 kg at 5,000 psig, 4 SCI Type III tanks Diesel: 120 gallon tank

- The primary fuel is diesel so that the bus can operate in areas where hydrogen supply is limited.
- The SFMTA has a fleet of BAE Systems hybrid buses, so the staff is already familiar with the majority of the system.
- Using a small fuel cell reduces the overall cost of the advanced technology bus, which could enable more transit agencies to adopt the technology and to begin the learning curve to full hydrogen fuel cell buses in the future.

Based on its commercial hybrid drive technology, BAE Systems' Bus 2010 blends energy from the diesel engine and the fuel cell to provide a partial zero-emission bus with improved fuel economy. Bus 2010 also incorporates a fully electric accessory package that eliminates engine belt driven components allowing operation with the diesel engine off. Like a conventional BAE Systems hybrid bus, the design utilizes nano-phosphate lithium-ion battery technology to capture and reuse braking energy. Primary power is provided by a diesel engine and two Hydrogenics fuel cells connected in series. A DC/DC converter boosts the output voltage to allow the fuel cells to provide the first 24 kW of power for both propulsion and accessory operation. Under the right conditions, the bus can operate in full zero-emission mode with the engine off. When the power demand exceeds the maximum available fuel cell power, the diesel engine starts and provides additional power. The system can also operate on the diesel engine only.

To evaluate the technology, the FTA has enlisted the help of the National Renewable Energy Laboratory (NREL). NREL will collect and analyze performance and operations data from the new bus and from a selection of the BAE Systems diesel hybrid buses in similar service. Consistent data collection and analysis will ensure fair and accurate information and comparisons, document the status and progress of fuel cell buses toward commercialization, and provide information to the transit industry to aid in purchasing decisions. The results will also be fed back into the research and development process to appropriately focus future resources.

More Information

FTA: www.fta.dot.gov **CALSTART:** www.calstart.org
SFMTA: www.sfmta.com **NREL FCB Publications:** www.nrel.gov/hydrogen/proj_fc_bus_eval.html
BAE: www.hybridrive.com

CALSTART is a non-profit organization that works with public and private partners to accelerate the growth of advanced transportation technologies. CALSTART manages several National Fuel Cell Bus Program projects. CALSTART has developed a strategy for accelerating fuel cell bus technology along three development paths:

- 1) A near-term, direct path focused on pushing the current generation fuel cell technology to its limits to maximize the learning curve;
- 2) an evolutionary path that combines smaller, less-expensive fuel cells with other supporting technologies, and;
- 3) a component path to develop specific subsystems needed to support fuel cell systems in multiple platforms. AC Transit's accelerated testing falls within the direct path strategy.

For more information on CALSTART's advanced vehicle projects, go to www.calstart.org.



FTA's National Fuel Cell Bus Program (NFCBP) is a cooperative research, development, and demonstration program, established in 2006, to advance the commercialization of fuel cell electric buses. The program is part of a broader FTA research effort designed to improve transit efficiency and deliver environmentally sustainable transportation solutions. Conducted in close partnership with the industry, the program has secured over \$62 million in local and private commitments, matching the Federal contribution. The teams and projects are competitively selected and managed by three non profit consortia. The project portfolio includes development and demonstration projects, component projects, and analysis and coordination efforts.