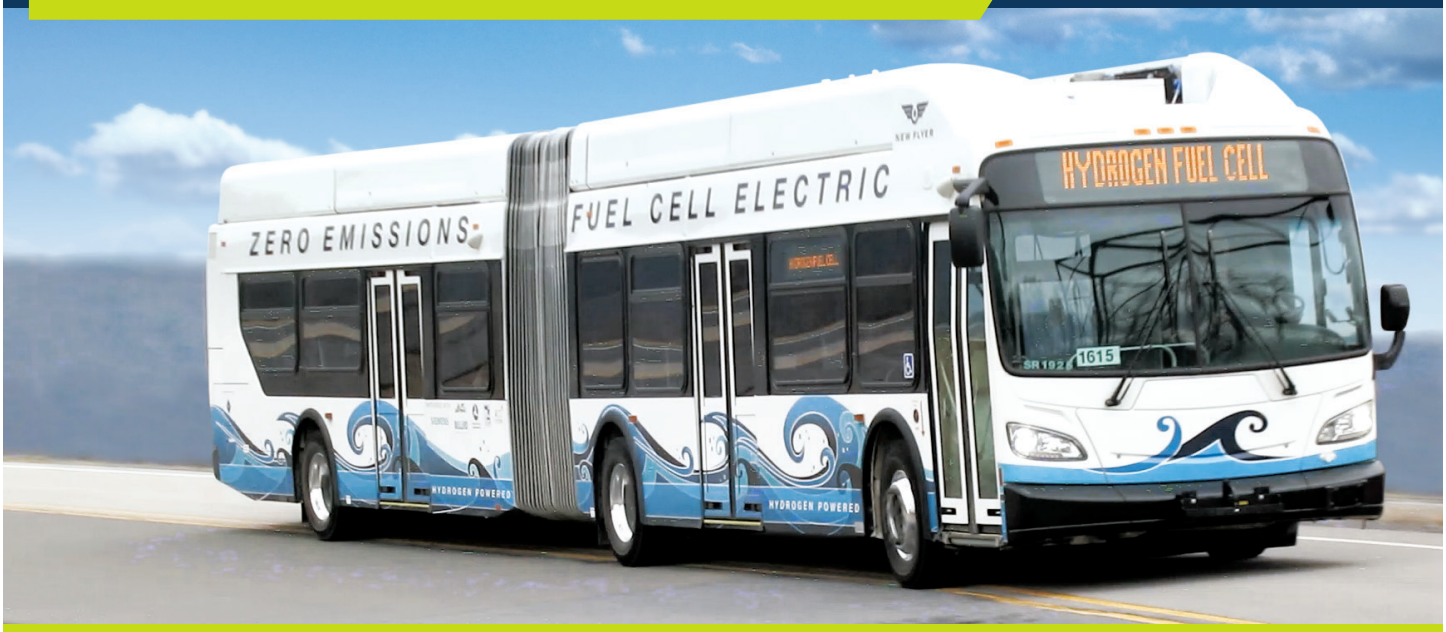
100BUS® INITIATIVE

FUEL CELL ELECTRIC

THE 100-BUS FUEL CELL ELECTRIC BUS INITIATIVE



PREPARED BY THE CENTER FOR TRANSPORTATION AND THE ENVIRONMENT

The 100-Bus Fuel Cell Electric Bus Initiative (100-Bus Initiative) is a Center for Transportation and the Environment (CTE)-led consortium including leading transit agencies from California, bus original equipment manufacturers (OEMs), technology companies, and fueling infrastructure providers focused on accelerating the commercialization of fuel cell electric buses (FCEBs) in California.

Background

FCEBs have proven out the technology in deployments all over the world, with more than **10 million miles of passenger service**. The deployments have demonstrated the performance, reliability, and durability required for commercial operation of the technology, achieving significant commercial milestones including: Buy America compliance, Federal Transit Administration (FTA) Altoona testing, and a burgeoning competitive landscape between bus OEMs and fuel cell engine suppliers, all indicators of the technology's readiness for widespread commercialization. The pace of implementation has increased dramatically over the last few years, both globally and in North America, where only a few barriers remain to the large-scale adoption of FCEBs within both public transit agencies and other adjacent markets.

FCEBs offer **four distinct advantages**, including:

300-340 miles
Proven range (300 to 340 miles, with advanced fueling technology that can extend this range by almost double)

Significant reduction in vehicle weight and vehicle axle weight to maximize passenger loads

Fast refueling speeds comparable to conventional diesel and CNG buses

1:1 replacement of conventional buses enabling full flexibility for route planning and operations

There are currently two primary FCEB fleets operating in California. SunLine Transit in the Coachella Valley operates five buses and there are 13 buses in operation at the Alameda-Contra Costa Transit District (AC Transit) in Oakland, CA. The AC Transit fleet has accumulated over three million miles of revenue service and the agency's two hydrogen fueling stations (one of which offers retail fueling for light-duty vehicles) have dispensed more than 500,000 kilograms of hydrogen[1]. The longest operating fuel cell engine in the fleet has more than 32,000 hours of accumulated service, analogous to the refurbishment period of a diesel engine at vehicle half-life. Eleven other AC Transit buses have fuel cell engines operating in excess of 25,000 to 29,000 hours, with the remaining one fast approaching the 20,000-hour threshold. SunLine Transit has been operating a variety of FCEBs in the Coachella Valley since the early 2000s, including the first Buy America compliant FCEB ever put into service. They currently have 10 FCEBs in revenue service utilizing ElDorado National and New Flyer 40-foot model transit bus. Hydrogen fuel is generated on site and dispensed by SunLine staff at a public/private fueling station.

GROWTH IN 2019

AC Transit will be adding a 14th bus to its FCEB fleet in August 2019, when it takes delivery of a New Flyer 60-foot, articulated FCEB — the first of its kind to deploy in North America.

Announced in early 2017, the Fuel cell electric Bus Commercialization Consortium (FCEBCC) is a large-scale project supporting the deployment of 20 zero-emission hydrogen fuel cell electric buses at two transit agencies in California. The project is sponsored by the California Air Resources Board (CARB) through California Climate Investments. AC Transit and the Orange County Transportation Authority (OCTA) — two of the largest bus transit agencies in California — will each deploy 10 Buy America-compliant, 40-foot New Flyer FCEBs (XHE40). In support of this project both the South Coast Air Quality Management District (SCAQMD) and Bay Area Air Quality Management District (BAAQMD) each awarded $1 million for the purchase of these buses. Additionally, CARB awarded funds to build a new hydrogen fueling station for OCTA, with a fueling capacity of 40 to 50 buses, and to modify one of AC Transit's fueling stations to support their fleet expansion.

Concurrently, SunLine Transit received grants from FTA's Low- or No-Emission Vehicle Program, the CARB's Low Carbon Transportation and Air Quality Improvement Program, and SCAQMD for five ElDorado National and five New Flyer FCEBs. In addition to the buses, CARB awarded funds for a large-scale PEM electrolyzer for onsite generation of hydrogen using wind and solar power, capable of producing 900 kilograms per day — the equivalent of 30 to 35 buses per day — making it the largest renewable hydrogen fueling facility in the United States.

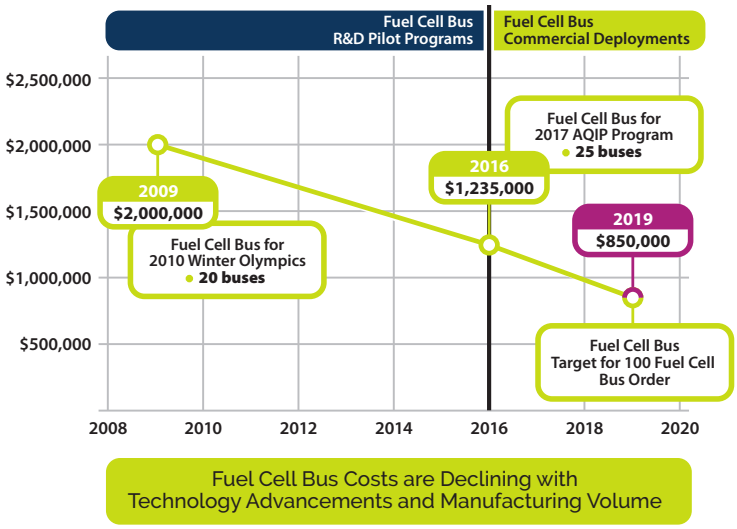
[1]One kilogram of hydrogen has an equivalent energy value to one gallon of gasoline.

Objectives of the Initiative

The primary objective of the 100-Bus Initiative is to drive down the capital cost of North American FCEBs to the point where they are commercially viable for transit properties seeking zero-emission solutions. New Flyer Industries presented the following cost-reduction curve at the 2017 North American Fuel Cell Bus Conference in Canton, OH.

CTE and its consortium partners believe that economies of scale for the bus OEMs and supply chain associated with an aggregate 100-unit order will drive the unit cost of the bus down to approximately $850,000. At this price point, FCEBs become a viable and complementary electric-drive technology for transit agencies to meet the state's Innovative Clean Transit Regulation that will transform California's public transit fleets to zero-emission by 2040.

Driving Price Down



Fuel Cell Bus Costs are Declining with Technology Advancements and Manufacturing Volume

Other consortium objectives include:

- Lowering fuel costs as a result of increased centralized production and the introduction of higher density distribution methods.
- Stimulating new hydrogen supply and service models e.g. pipeline hydrogen.
- Increased volumes to grow the fueling infrastructure beyond the three transit agencies in California that have adopted hydrogen fueling technology.
- The implementation of zero-emission technology at smaller transit agencies.
- The introduction of a mixed fleet of battery-electric and fuel cell electric buses, allowing side by side comparison, and the opportunity for each technology to "play to its strengths".
- The validation of lifecycle costs at larger scale deployments.
- The reduction of GHG and criteria emissions without performance compromise.

Initiative Scope

The scope of the 100-Bus Initiative includes the rolling stock, fueling infrastructure, maintenance upgrades, staff and first-responder training, and project management. Buses will be designed and built to operate for at least 12 years, as mandated by FTA, and will include extended warranties on the fuel cell, batteries, and hybrid propulsion systems. Data collection and project reporting to track the status and progress of vehicle and fueling infrastructure will be required by funding agencies.

BUSES

The intent of the 100-Bus Initiative is to include buses from ElDorado National and New Flyer Industries, both of which have FCEBs currently in service in California. The buses are Buy America compliant, undergoing Altoona testing, and are in the process of being certified by the State of California (a precursor to CARB's Clean Truck and Bus Voucher Program (HVIP) registration).

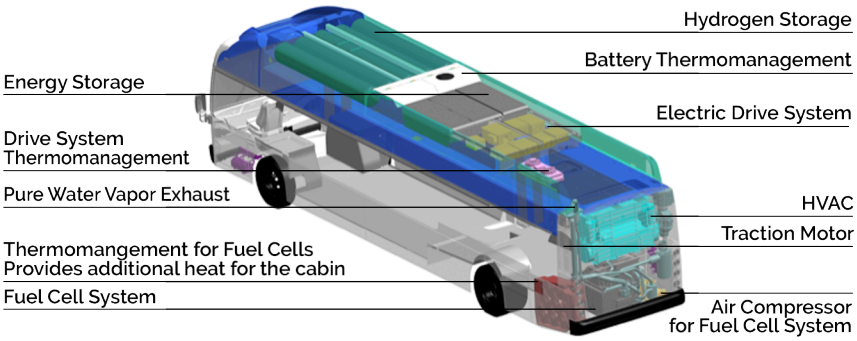


Figure 1 - New Flyer XHE-40

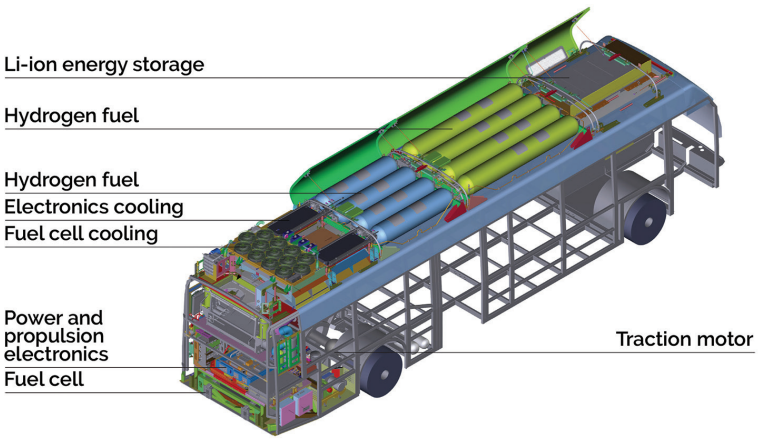


Figure 2 - ElDorado National AXXESS-40

FUELING INFRASTRUCTURE

The 100-Bus Initiative will require upgrades to both existing fueling stations and installation of new hydrogen fueling stations. A fully integrated fueling solution installed at a bus depot will typically include two primary systems:

1

A system for generating hydrogen: The system can be on-site hydrogen generation (e.g. electrolysis[2] or steam methane reforming[3]) or the centralized production of fuel which takes place off-site and is trucked in as a gas or liquid. In at least one location in California hydrogen can be supplied via a pipeline.

2

A compression, storage, and dispensing (CSD) system: The CSD delivers fuel to the vehicle, including the hydrogen compression, high-pressure storage, and dispensing systems. Hydrogen is dispensed to the vehicles at a pressure of 350-bar (5,000 psi). Typically, one or more dispensers are located on a fueling island in line with normal bus fueling operations.

Photo credits: Frank Tapia Photography

STATION UPGRADES

Some of the existing hydrogen fueling stations will require upgrades to service additional buses. For example, AC Transit would require upgrades such as additional compression hardware, storage, and dispensers to accommodate higher capacity throughput. SunLine Transit and OCTA will have relatively new systems installed capable of handling the additional load with minor or no modifications.

NEW STATIONS

One of the objectives of the 100-Bus Initiative is to develop new fueling infrastructure in California municipalities that have not yet adopted FCEB technology. It is expected that two or more new stations will be developed at greenfield sites in the state, with a focus on jurisdictions designated as non-attainment with identified disadvantaged communities.

FACILITY UPGRADES

As a turnkey solution for the participating transit agencies, it is important that the initiative include all costs related to maintaining the FCEB fleet, which will include upgrades to existing maintenance facilities. These modifications include ventilation upgrades, detection and alarm systems for hydrogen, and modifications to electrical and HVAC systems.

TRAINING AND PROJECT MANAGEMENT

No variable predicts the success or failure of the deployment more so than transit operator engagement. CTE will ensure participating transit agencies receive both operator and maintenance training in conjunction with the consortium members for both the FCEBs and the fueling station equipment. This training will include both preventative and corrective maintenance. Additional training, critical to project acceptance, will focus on first responders serving each transit agency.

CTE has proven experience organizing consortia and managing complex ZEB projects with the ability to assist consortium members in defining vehicle and infrastructure requirements and specifications, preparing RFPs and IFBs for vehicles and infrastructure, conducting vehicle inspections on behalf of transit agencies, ensuring Buy America and Quality Assurance/Control standards and processes are followed, overseeing and managing infrastructure improvements, facilitating the process of obtaining local permits, managing grants, conducting data analysis, preparing reports, and coordinating training for staff and first responders.

[2]Generating hydrogen by splitting water into hydrogen and oxygen utilizing electric power from solar, wind, or grid power.
[3]Producing hydrogen by injecting steam into methane derived from either biogas (dairy and animal waste or landfill gas) or from pipeline natural gas.

Policy & Regulation

There is no jurisdiction in North America that provides the supportive policy and regulatory framework for zero-emission transit buses that California does.

In California, SB 32 codifies a 2030 GHG emissions reduction target of 40 percent in the State of California. The Governor's Executive Order B-48-2018 requires five million zero-emission vehicles on California roads by 2035 and zero-emission vehicle infrastructure able to support these vehicles by 2025. The Governor has proposed a $2.5 billion funding plan to facilitate this transition. In addition, the state must implement SB 1275 (De León, 2014) and SB 1204 (Lara, 2014), which set targets for the deployment of one million zero- and near-zero-emission vehicles by 2023, access to these vehicles by disadvantaged and low- and moderate-income communities, and deployment of zero- and near-zero-emission medium- and heavy-duty vehicle technologies.

CARB's Innovative Clean Transit Regulation was adopted in December 2018 and will transform California's transit fleet of more than 10,500 buses to zero emission by 2040, with purchase requirements of zero-emission buses beginning in 2023.

In addition to state regulations, progressive cities are adopting zero-emission policies for their transit fleets. For example, the Los Angeles Metropolitan Transportation Authority (Metro) adopted the ZEB plan described below in their August 2017 press release:

"The Los Angeles County Metropolitan Transportation Authority (Metro) Board unanimously adopted a motion endorsing a comprehensive plan to transition the agency to a 100 percent zero-emission bus fleet by 2030. The plan is contingent upon two primary factors: continuous advancements in electric bus technology – which includes an increase in range, reduction of bus weight, reduction of charging times and extension of battery life cycles – as well as a drop in price as the technology develops. Metro is the largest American transportation agency to endorse such a goal."

Sources Of Funding

The CARB 2018/19 Investment Plan for Low Carbon Transportation funding includes adjustments to the Clean Truck and Bus Voucher program (HVIP) favorable to the deployment of FCEBs. HVIP has provided $300k or more per fuel cell electric bus and $100k per bus for infrastructure costs. The proposed 2019/20 Investment Plan assumes a possible reduction of 15% to 25% of HVIP funding, and no infrastructure funding. CTE believes that the capital cost of the bus can still be mangaged using a combination of this voucher, federal formula (FTA) funds and local match, and a consortium purchase of 100 or more buses.

THE GAP

Although HVIP funds in combination with conventional FTA funds are likely sufficient to cover the capital costs of the vehicles, incremental funding will be required to address the fueling infrastructure costs and facility upgrades. It will be necessary to secure additional funding for fueling infrastructure, maintenance facility upgrades, project management, and training.

Moving Forward

TEAMING AGREEMENT AND OUTREACH

CTE is seeking a teaming agreement that will include interested transit agencies, bus OEMs, technology providers, and fueling infrastructure providers.

CTE and its consortium partners will work with California stakeholders to communicate the vision for this Initiative to members of the state legislature, CARB, CEC, and other state agencies.

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IN SUMMARY

NEED

Transit agencies will need **both** Battery-Electric and Fuel Cell Electric Buses (FCEBs) to meet the California Air Resources Board goal of 100% zero emission buses by 2040.

OBJECTIVE

Drive down the capital cost of North American FCEBs to the point where they are **commercially viable** for transit properties seeking zero-emission solutions — **$850,000/bus**.

ACTION

Four or more transit agencies in northern and southern California, **purchasing up to 20 or 25 FCEBs** each, and installing hydrogen fueling stations and facility upgrades where needed.

Funding Needs

VEHICLE ACQUISITION

Cost share from FTA Bus Procurement formula funds and local match. These base funds combined with **VW Settlement** funds and the continuation of **CARB's HVIP** rebates are sufficient to purchase these zero-emission fuel cell electric buses. ***We urge the Legislature's continued support for appropriating Cap & Trade funds for the HVIP rebates.***

INFRASTRUCTURE

A significant funding gap remains to fully fund fueling facilities, maintenance facilities upgrades, and workforce training needs. *We urge the Legislature to **appropriate $20 million** for the 100-Bus Initiative Infrastructure Program, and **CARB and CEC** to collaborate on funding infrastructure in support of an expanded deployment of FCEBs at much larger scale.*

Fuel Cell Electric Bus Benefits

FOUR PRINCIPLE ADVANTAGES TO FCEB

300-340 miles Proven range

Significant reduction in vehicle weight (carry more passengers)

Rapid refueling speeds (6 to 10 minutes)

1:1 replacement of conventional vehicles

FUELING STATION CAPABILITIES

Scalable to support hundreds of buses

Small footprint

Renewable sources (wind, solar, biogas)

Resiliency and backup (enable operators to respond to natural disasters)

Performance

10 million miles

Over 10 million miles of proven service worldwide; 3 million miles at AC Transit and over 1 million at SunLine Transit.

32,000 hours

Fuel cell durabilty — over 32,000 hours of service and counting. Exceeds the half-life of the bus.

Global Expansion

There will be over 330 fuel cell electric buses in operation in Europe at more than 22 cities by the end of 2020 (FCH-JU, JIVE, and 3Emotion programs) and over 1,800 worldwide with large scale deployments in China.