Fuel cell electric bus program for Far North transit

May 2022

Presented by Ed Krueger
KTC Biz Development Manager for Ballard Fuel Cells North America
Snapshot of Hydrogen and Fuel Cells Applications in the U.S.

Examples of Applications

- **>500MW**
  - Stationary Power

- **>35,000**
  - Forklifts

- **>60**
  - Fuel Cell Buses

- **>45**
  - H₂ Retail Stations

- **>8,700**
  - Fuel Cell Cars

Hydrogen Production Across the U.S.

- 10 million metric tons produced annually
- More than 1,600 miles of H₂ pipeline
- World’s largest H₂ storage cavern

Hydrogen Stations: Examples of Plans Across States

<table>
<thead>
<tr>
<th>California</th>
<th>Northeast</th>
<th>HI, OH, SC, NY, CT, MA, CO, UT, TX, MI</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 Stations Planned</td>
<td>12 – 20 Stations Planned</td>
<td>And Others</td>
</tr>
</tbody>
</table>

U.S. DEPARTMENT OF ENERGY
OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY
HYDROGEN AND FUEL CELL TECHNOLOGIES OFFICE
As Result of ICT Planning, there is Growing Demand for FCEBs

1. 66% of the 19 agencies surveyed in California include fuel cell electric buses (FCEB's) in their plans, with more than 50% dedicating part or 100% of their fleet to FCEB’s.

2. Report shows an opportunity for 2,800 to 6,500 fuel cell electric buses in service, or 71 to 163 tons per day of renewable hydrogen consumption
Hundreds of millions of dollars already invested to supply California with Hydrogen

Air Products plant in Sacramento, Ca $150 million benefit to the California market. In the same city!

West Coast’s largest green hydrogen plant 30 metric tons of liquid green hydrogen daily within about four years. The facility will use a new 300 megawatt zero-carbon solar farm to power 120 megawatts of Plug Power’s state-of-the-art PEM electrolyzers, which split water into hydrogen and oxygen through an electro-chemical process, the announcement stated.
Ballard by the numbers

42 years
900 employees
1,400 patented technologies
26 years Nasdaq
28 years TSX
4 strategic shareholders

1,300+ transit buses
2,200+ trucks
6 TRAIN projects on track
8 SHIPS in development

850 MW fuel cell products delivered
>6.5 million MEAs produced
>88 million kilometers in operation
>35,000 hours operation of fuel cell stack

2030 commitment to carbon neutrality
A fuel cell bus is an electric bus

- This is a ZEB POWERHOUSE
- Equivalence of 640kwh of energy through 37.5 kg of hydrogen on roof generating its own power
- Same electric drivetrain as battery electric buses
- Same maintenance and parts apart from the fuel cell power module and gas tanks
New Flyer Electric Bus Experience

- Over 50 years of experience manufacturing zero-emission buses
- New Flyer actively supports over 41,000 heavy-duty transit buses currently in service, of which 7,300 are powered by electric motors and battery propulsion and 1,600 are zero-emissions
- New Flyer offers all 4 types of electric, and all 3 types of zero-emission propulsion systems:
  - Diesel-electric hybrid (low-emission)
  - Battery Electric (zero-emission)
  - Trolley-electric (zero-emission)
  - Fuel cell-electric (zero-emission)
xcelsior CHARGE H2™
60-foot & 40-foot Layouts
Zero-Emission Options

**Battery Electric Bus (BEB)**
- Eco Friendly
- Robust Design
- Up to 200 mile Range*
- Curb Weight Heavier than FCEB
- 4 Hour typical overnight Charge
- One charger per 2-3 buses
  *40-foot on APTA BAC transit duty cycle

**Fuel Cell Electric Bus (FCEB)**
- Eco Friendly
- Robust Design
- 300+ Range*
- Curb Weight Lighter than a long range BEB
- 6-20 minutes fill time
- Fill station scalable by fleet size
- No secondary Aux heater required for cold climates
FCEB Deployment Status (March 2021)

- (20) FCEBs at AC Transit (Bay Area)
  - With 33 buses to come at Foothill transit

- (10) XHE40 FCEBs in service at OCTA (Orange County)

- (11) XHE40 FCEBs delivered to SunLine (Thousand Palms)
When grouped together by ZEB type, the decrease in average range going from a temperature interval of 50-60°F to 22-32°F was greater for BEBs (37.8% decrease) than for FCEBs (23.1% decrease) when weighting by miles traveled below base temperature for the respective agencies,
Fuel cell module preventive maintenance plan

Preventive Maintenance (PM)
- Check filters (replace as required)
- Check coolant conductivity
- Check calibration of sensors
- Check smoke detector
- Check ventilation fan
- Minimum interval of 1 month or 5,000 miles

Training
- Provided to transit technicians to be qualified for PM work

PM parts
- Source from Ballard, or
- Source directly from suppliers
- [https://www.youtube.com/watch?v=vFIE0We0gx0](https://www.youtube.com/watch?v=vFIE0We0gx0)
We continuously invest in our technology and product development

- Unit cell components
  - MEA, bipolar plates

- Fuel cell stacks
  - 14th generation

- Fuel cell modules
  - 8th generation

- Fuel cell vehicle integration
  - application engineering/after sales service

- Humidified and pressurized system
- Freeze-start from -30°C
- IP67 protection
- >30,000 hours life time
Costs are trending down

Hydrogen fuel cell transport's path to cost competitiveness with Diesel

- Fuel cell system cost will drop by 70% in 10 years
- Hydrogen distribution & refueling cost will drop by 40% in 10 years

“In less than 10 years, it will become cheaper to run a fuel cell electric vehicle (FCEV) than it is to run a battery electric vehicle (BEV) or an internal combustion engine (ICE) vehicle for certain commercial applications.”


California is Leading the Move Towards Hydrogen Mobility With Strong Regulations Now In Place

- Executive order directing that all new cars and passenger trucks sold in California be ZEV by 2035
- 8,475 fuel cell cars on the road
- 48 fuel cell buses in service, 67 on order
- More than 20 trucks in operation or in assembly for demonstration projects
- 42 hydrogen refueling stations (HRS) in service and 15 in construction & planning
The West, Midwest and Eastern USA is moving towards H2 as a fuel for Mobility

• Fort Collins has received Colorado’s first hydrogen fueling station. They will generate hydrogen on-site by splitting water molecules using renewable electricity.

• Nevada won a $3.8 million dollar Low- no grant to fully fund FCEB and a liquid station with a goal to convert 200 buses to FCEB by 2035.

• Indygo is considering 30 60’ FCEB for their BRT line. WMATA is considering hydrogen
Cost Comparison: Battery Electric Buses vs Fuel Cell Electric Buses to be performed for VTA

Foothill Transit’s study compares the cost of deploying 20 zero-emission buses on a 42-mile roundtrip route.

Due to the range limitations of BEBs, it was determined the line will require 34 BEBs vs 23 FCEB, incurring an additional cost of $4.9 million dollars in 11 BEB buses.

### Fueling Infrastructure

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel cell – 23 buses but can fuel up to 50 buses</td>
<td>$4 million</td>
</tr>
<tr>
<td>BEB – Chargers for 34 buses</td>
<td>$11 million</td>
</tr>
</tbody>
</table>

### Mid-Life Replacement Cost/Bus

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel cell</td>
<td>$30,000</td>
</tr>
<tr>
<td>Battery</td>
<td>$200,000</td>
</tr>
</tbody>
</table>

### Capital Cost

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel cell electric bus</td>
<td>$1,100,000</td>
</tr>
<tr>
<td>Battery electric bus</td>
<td>$890,000</td>
</tr>
</tbody>
</table>

### Fuel Cost/Mile/Bus

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel cell</td>
<td>$1.00</td>
</tr>
<tr>
<td>BEB/kW</td>
<td>$0.76</td>
</tr>
</tbody>
</table>

### Scheduled Maintenance per Mile

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel cell</td>
<td>$0.12</td>
</tr>
<tr>
<td>Battery</td>
<td>$0.04</td>
</tr>
</tbody>
</table>
The results of Foothill Transit’s study show the total cost of ownership of BEBs is higher than FCEBs.

### 12-year Lifecycle Cost Comparison

<table>
<thead>
<tr>
<th></th>
<th>34 BEBs</th>
<th>20 FCEBs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost- buses</td>
<td>$30,260,000</td>
<td>$25,300,000</td>
</tr>
<tr>
<td>Capital cost – fueling infrastructure</td>
<td>$10,948,000</td>
<td>$4,000,000</td>
</tr>
<tr>
<td>12 year fuel cost</td>
<td>$11,839,973</td>
<td>$15,661,340</td>
</tr>
<tr>
<td>12 year PMI cost</td>
<td>$626,454</td>
<td>$1,879,361</td>
</tr>
<tr>
<td>Mid-life maintenance cost</td>
<td>$6,800,000</td>
<td>$690,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$60,474,427</strong></td>
<td><strong>$47,530,700</strong></td>
</tr>
</tbody>
</table>

**Cost Savings with FCEB: $12,943,726**
Liquid Power Requirements for Zero Emission Bus Fleet at Scale

Fuel Cell Electric Buses

- For a 100 bus fleet, the hydrogen fueling infrastructure will require 750 kW of electricity
- For a 10-15 bus fleet, only 100 kW to 200 kW of electricity is needed

Battery Electric Buses

- For a 100 bus fleet, the charging infrastructure will require 7,000 to 12,000 kW of electricity
- That’s 10 times more power – could require investment in additional infrastructure (i.e. substation)
Cost Comparison: Hydrogen vs Charging Infrastructure

**King County Metro**
- **BEB:** Quoted $60 million per 100 bus base to bring in additional electricity
- **FCEB:** Hydrogen fueling facility was quoted at $8.3 million per 100 bus base
- **Savings of $51.7 million per 100 bus base to go with hydrogen**

**Foothill Transit**
- **BEB:** $125 million for charging infrastructure for 363 buses
- **FCEB:** $23.4 million for hydrogen fueling infrastructure for same fleet size
- **Savings of $100 million to go with hydrogen**

**La Metro**
- **BEB:** $1 billion for charging infrastructure for 2,200 buses
- **FCEB:** $206 million for hydrogen fueling infrastructure for same fleet size
- **Savings of $794 million to go with hydrogen**
ICT planning studies confirmed that as fleet size increases, cost of hydrogen infrastructure per vehicle decreases.

<table>
<thead>
<tr>
<th>Agency</th>
<th>FCEB</th>
<th>BEB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foothill Transit</td>
<td>$133k/bus, 30 buses</td>
<td>$322k/bus, 30 buses</td>
</tr>
<tr>
<td>Long Beach</td>
<td>$108k/bus, 125 buses</td>
<td>$209k/bus, 100 buses</td>
</tr>
<tr>
<td>AC Transit</td>
<td>$90k/bus, 200 buses</td>
<td>$560k/bus, 530 buses</td>
</tr>
</tbody>
</table>

Data collected from CARB published ICT roll out plans.
OCTA plans to transition 100% of its 500+ buses to fuel cell vehicles

“The 100 percent FCEBs scenario showed a slightly lower overall cost than the mixed technology fleet given current vehicle, fuel, and support infrastructure pricing. ...FCEBs offer an extended range and better match to OCTA’s current operating parameters. In comparison, the current range of BEBs may require more vehicles and drivers to meet similar service levels.”

*Orange County Transportation Authority*
GET Selected 100% FCEBs in their ZEB Rollout Plan

“The final composition of the fixed route fleet will be **100% fuel cell electric buses**. Modelling analysis found that a small percentage of the routes currently operated by GET could be satisfied by battery electric buses as a 1:1 BEB:CNG bus replacement. However, **operating one type of vehicle offers significant benefits** to the agency as all buses can be operated and maintained efficiently and economically. It also means the **buses are interchangeable and can be dispatched on any route as required.”

*Golden Empire Transit District*
Sunline Transit fleet will be zero emission by 2035 with 85% fuel cell buses

Sunline transit has been operating fuel cell buses since 2000. It now operates 16 hydrogen buses in one the hottest region of the US.

The final fleet composition – 67 fixed route fuel cell buses, 18 fixed route battery-electric buses and 39 paratransit fuel cell vehicles – was determined to maximize performance and minimize cost.

Sunline ZEB roll out plan 2020
Hydrogen can be generated from various sources.
NICE America liquid mobile hydrogen trailer

**Square Footage:** 45' by 20'

**Power requirements:** 480V 3 phase 60hz
300A requirement, primarily for our HDU (hydraulic drive unit) to drive the pump

**Price:** $3.2 million

**Lead Time:** 1 year

**Equipment:** Fully mobile on wheels. Pump in primary LH2 tank, heat exchanger, vaporizer, HDU, dispenser, power electronics/controls, HMI

**Performance**

- Transit bus filling (35 MPa):
  - 431 lbs; 10+ hrs delivered; 300+ days operation; 100% availability

- Filling demonstration
  - SARTA, Canton, OH
  - Feb 2021 to Jun 2021
  - 3,700 kg LH2 dispensed
  - 118 individual 320 lbs

- Fueling service
  - Sunkme, India, CA
  - Oct 2021 to Feb 2022
  - 6,755 kg LH2 dispensed
  - 312 individual 320 lbs

**Product offerings**

- Mobile trailer
  - 1 pump; 350 kg storage

- Permanent station
  - 2 pumps; 4500 kg storage

- Portable station
  - 1 or 2 pumps; 1100 kg storage

Linde standard hydrogen filling station with the cryopump in their containerized solution

https://www.youtube.com/watch?v=Pjh639S2dek

Equipment delivery:
https://www.youtube.com/watch?v=TRerXAnMO qb0&fbclid=IwAR28RnlSLUatAnisxRNMAATf6gwN2PW3Mh92TU1J6gc2ia2TrH2EQ6TGQ
Air Products fueling vehicles on these markets in Europe, Asia and US
Scaling Comparison and Hydrogen Supply Options

<table>
<thead>
<tr>
<th>Scale</th>
<th>Hydrogen Supply</th>
<th>Electricity Supply</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2 Buses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-50 Buses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50+ Buses</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2020 Liquid Hydrogen Fueling Station at AC Transit Emeryville Hydrogen station which we could model our Far North transit agencies station after

1. Small Liquid Hydrogen station footprint in AC transits depot

2. 15,000-gallon liquid h2 tank receives delivery 2x month of 4,000kg. They have not missed a delivery in a year

3. Two reciprocating cryogenic liquid pumps. Pumps can handle 130kg/ hour or fill 65 buses in 6 mins in a 12-hour window

4. Pressurized vaporizers transform the hydrogen from a liquid into a gas and distributes it to the dispenser Fueling line is run around 500 feet to separate fuel island with 2 redundant dispensers
Reference #2 – OCTA’s Liquid Hydrogen Fueling Station- 60x40 footprint at their depot, built to fuel 50 40’ buses. Currently fuels 10 FCEB
Option 1: Liquid Hydrogen Delivery for up to entire fleet

Hydrogen delivered via cryogenic truck and stored on site in tanks

**Estimated cost:**
- $1.7 million to fuel 10-15 buses
- $4.7 million to fuel 50 buses
- $8.3 million to fuel 100 buses station $15.1 million for 200 buses

→ Around $80,000-$100,000/bus and .78 cents per mile or $7.80-8.60/kg or

- Includes site work, liquid storage, vaporization, compression, gas storage, and dispensing

**Optimized footprint:**
- 34 ft x 41 ft for 15 bus station
- 30 ft x 60 ft for 50 bus station
- 24ft x 100ft = for 100 bus station
Options for Hydrogen Supply for Far North

1) Air Products supply from Sacramento is 146 miles

2) Plug Power supply from Fresno is 200+ miles and 100% clean h2
Hydrogen fueling stations: flexible solutions for each depot

Liquid hydrogen delivery
OCTA Station ~ 60’ x 30’ (up to 50 buses)

On Site Reformer
AC Transit – Emeryville
On site H2 production (Electrolyser)

On Site Electrolyser
Transit bus depot (Europe)
Hydrogen storage & dispensing area
Compressed H2 delivery
(55”x45” – 20 buses)
Option 2: On-Site SMR

**Hy-Gear 150**

(2) HyGen 150 SMR – 300 kg to fuel 12 40’ bus $3.64M
(2) Compressor Skids $0.7M
(3) H2 Storage Modules $0.41M
(2) Dispensers $0.7M
TOTAL = $5.45M

plus permitting, facility work

Layout: Two 40’ containers (SMR’s) plus four 20’ containers (3 storage + 1 compressor)
Option 2: On-Site SMR Layout, 20 Bus Deployment

Estimated Layout Requirements*
(2) 40’ Containers (1 per SMR)
(3) 20’ Containers (high pressure storage)
(1) 20’ Container, electrical and controls

*Rough estimates from HyGear, actual layout requires evaluation from SMR supplier. Stacking of containers may reduce footprint.
Option 2: Onsite Steam Methane Reformer

Hydrogen reformed onsite from natural gas, delivered through existing pipeline

Estimated cost:
→ around $190,000 to $210,000 /bus

Total footprint:
• 4,000ft² for reformer, 4,000ft² for compression and storage
• Dispensed at existing CNG fueling station

$0.60/therm with 50% renewable natural gas
Option 3: Centralized Electrolysis Production of Renewable Hydrogen

On-site electrolysis

Best way to get 100% renewable hydrogen today is from centralized production through electrolysis, powered by wind and solar.
Option 3: Centralized Electrolysis Production of Renewable Hydrogen

On-site electrolysis

| Quality Assurance & Inspection, Project Management & Tech. Assistance | Contractor | CTE | $523,225 |
| Facility Design & Engineering | Fiedler Group | $436,900 |
| Bus Procurement | New Flyer | $3,087,084 |
| **Hydrogen Fueling Station** | Trillium | $7,918,092 |
| **Total** | | **$11,965,301** |

| Funding Sources: | Federal | State | Local |
| $1,080,479 | $2,006,605 | $436,900 |
| **$2,771,332** | **$5,146,760** |  |
| **$3,851,811** | **$7,153,365** | **$960,125** |

32% 60% 8%
Option 3: Centralized Electrolysis Production of Renewable Hydrogen

Hydrogen for Buses in California (2019)

- SunLine Transit Agency in Thousand Palms, California.
- Turn-key solution including civil works and permitting.
- Proton® PEM electrolyser for hydrogen production – 900kg/day.
- Two H2Station® for fueling of two busses simultaneously
- Capacity for up to 24 hydrogen fuel cell busses per day.
- Nel conduct operation and maintenance of facility.
Option 3: Centralized Electrolysis Production of Renewable Hydrogen

On-site electrolysis challenging at scale in CA due to real estate, power costs

Best way to get 100% renewable hydrogen today is from centralized production through electrolysis, powered by wind and solar

Compressed hydrogen gas is delivered to the depot from production site (within 120 mi)

Can take advantage of a higher LCFS rebate

- $5.40/kg for renewable hydrogen vs $0.50/kg for hydrogen from natural gas

At scale, this option is a path to reduced cost and 100% zero-emissions well-to-wheel
World’s Largest Green Hydrogen Project to Launch in Lancaster, California

• Will produce 11,000 kilograms per day of green hydrogen

• SGH2’s patented Solena Plasma Enhanced Gasification (SPEG) technology gasifies biogenic waste materials

• Five to seven times cheaper than other green hydrogen

• Hopeful for more projects like this to come with the DOE announcement of $5 billion for hydrogen hubs across the US
Thank you

Please contact Sydney Krueger for more information

+1 510 590 0943
Sydneykrueger@gmail.com
Or Ed Krueger 510 397 8098

ballard.com