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<td><strong>Docket Number:</strong></td>
<td>19-TRAN-02</td>
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<tr>
<td><strong>Project Title:</strong></td>
<td>Medium- and Heavy-Duty Zero-Emission Vehicles and Infrastructure</td>
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<td><strong>TN #:</strong></td>
<td>230381</td>
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<td><strong>Document Title:</strong></td>
<td>CTE Prsentation for CEC workshop</td>
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<tr>
<td><strong>Description:</strong></td>
<td>N/A</td>
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<tr>
<td><strong>Filer:</strong></td>
<td>Christina Cordero</td>
</tr>
<tr>
<td><strong>Organization:</strong></td>
<td>California Energy Commission</td>
</tr>
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<td><strong>Submitter Role:</strong></td>
<td>Commission Staff</td>
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<td><strong>Submission Date:</strong></td>
<td>10/28/2019 10:38:46 AM</td>
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<td><strong>Docketed Date:</strong></td>
<td>10/28/2019</td>
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Fuel Cell Electric Buses – Building Infrastructure

Workshop on Medium- and Heavy-Duty Zero-Emission Vehicles and Infrastructure Deployment
CEC – Sacramento
October 25, 2019
About CTE

- **Mission:** To advance clean, sustainable, innovative transportation and energy technologies
- **501(3)(c) non-profit** engineering and planning firm
- **Portfolio** - ->$500 million
  - Research, demonstration, transition planning, deployment
  - **86 Active Projects** Totaling over **$300 million**
- **Focused on Zero-Emission Technologies**
- **National Presence**
  Atlanta, Berkeley, Los Angeles, Minneapolis/St. Paul
Zero-Emission Projects

- ZEB Planning Projects
- ZEB Deployment Projects

Map showing locations of ZEB planning and deployment projects across the United States.
Fuel Cell Electric and H₂ Projects

- Class 6 Trucks
- Class 8 Drayage Trucks
- Marine Cargo Top Loader
- 40’ and 60’ Transit Buses
- HD and LD H₂ Stations
Worldwide Acceptance: 2,000 by 2020

FUEL CELL BUSES WORLDWIDE

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

THE KISS PRINCIPLE

KEEP IT SIMPLE, STUPID
FCEB Advantages

300-350 miles

Proven range

Significant reduction in vehicle weight
(carry more passengers)

Rapid refueling speeds
(6 to 10 minutes)

1:1 replacement of conventional vehicles
Durability: >32,000 Hours/2.98 Million Miles

<table>
<thead>
<tr>
<th>Bus</th>
<th>Fuel Cell Hours Life to Date</th>
<th>Vehicle Miles Life to Date</th>
</tr>
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<tbody>
<tr>
<td>FC4</td>
<td>25,950</td>
<td>244,893</td>
</tr>
<tr>
<td>FC5</td>
<td>26,090</td>
<td>247,302</td>
</tr>
<tr>
<td>FC6</td>
<td>26,689</td>
<td>218,522</td>
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<tr>
<td>FC7</td>
<td>11,258</td>
<td>229,171</td>
</tr>
<tr>
<td>FC8</td>
<td>25,043</td>
<td>180,648</td>
</tr>
<tr>
<td>FC9</td>
<td>25,840</td>
<td>223,868</td>
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<tr>
<td>FC10</td>
<td>28,506</td>
<td>258,762</td>
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<tr>
<td>FC11</td>
<td>29,066</td>
<td>255,762</td>
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<tr>
<td>FC12</td>
<td>5,428</td>
<td>246,248</td>
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<tr>
<td>FC13</td>
<td>18,368</td>
<td>177,104</td>
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<tr>
<td>FC14</td>
<td>29,828</td>
<td>250,144</td>
</tr>
<tr>
<td>FC15</td>
<td>25,025</td>
<td>207,222</td>
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<tr>
<td>FC16</td>
<td>29,630</td>
<td>234,562</td>
</tr>
<tr>
<td>TOTALS</td>
<td>306,721</td>
<td>2,974,208</td>
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<tr>
<td>Average</td>
<td>25,592</td>
<td>228,785</td>
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</table>

NOTE: FC7 and FC12 fuel cells were manufactured by UTC in 2003, 14 years ago with an expected EOL of 5,000 hours. The other 11 fuel cells were manufactured by UTC in 2008 and 2009.

* LDV Station converted to Messer commercial station as of September 2018. AC Transit stopped recording fuel dispensed as of May 2018.

1) Fuel Cell on FC7 retired on 5/14/18 with 32,134 hrs.
2) Fuel Cell on FC12 retired 11/21/18 with 25,969 hrs.
New Flyer XHE40 Performance

<table>
<thead>
<tr>
<th>Date</th>
<th>Run</th>
<th>Time Out</th>
<th>Time In</th>
<th>Odometer</th>
<th>Run Time</th>
<th>Miles Run</th>
<th>Total Fuel (kg)</th>
<th>Miles per kg</th>
<th>Miles per DGE (1.13)</th>
<th>Projected Range Based on 36 kg of Useable H2</th>
<th>Approximate Battery-Only Range</th>
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<tbody>
<tr>
<td>4/10/19</td>
<td>54-0002</td>
<td>7:04 AM</td>
<td>10:42 PM</td>
<td>1697.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>300.9</td>
<td>10 to 20</td>
</tr>
<tr>
<td>4/11/19</td>
<td>54-0002</td>
<td>7:04 AM</td>
<td>10:42 PM</td>
<td>1896.3</td>
<td>15:46 hrs</td>
<td>198.9</td>
<td>23.8</td>
<td>8.36</td>
<td>9.44</td>
<td>300.9</td>
<td>10 to 20</td>
</tr>
<tr>
<td>4/12/19</td>
<td>54-2002</td>
<td>7:04 AM</td>
<td>10:42 PM</td>
<td>2098.3</td>
<td>15:46 hrs</td>
<td>202</td>
<td>22.4</td>
<td>9.02</td>
<td>10.19</td>
<td>324.6</td>
<td>10 to 20</td>
</tr>
<tr>
<td>4/13/19</td>
<td>54-2002</td>
<td>7:04 AM</td>
<td>10:42 PM</td>
<td>2298.5</td>
<td>15:46 hrs</td>
<td>200.2</td>
<td>20.9</td>
<td>9.58</td>
<td>10.82</td>
<td>344.8</td>
<td>10 to 20</td>
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</table>

Footnotes

* Three different drivers. Variation in fuel consumption based on how different drivers drive and ambient temperature.

AC Transit
- Load = 17 Average; 34 Max
- 300 to 344 miles on H2
- 20 miles on battery

OCTA
- Seated Load (40)
- 330 miles on H₂
- 20 miles on battery
100-Bus Initiative

**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 25 FCEBs each, and installing hydrogen fueling stations and facility upgrades where needed.

---

**Driving Price Down**

- **2009**
  - Fuel Cell Bus for 2010 Winter Olympics
  - $2,000,000
- **2016**
  - Fuel Cell Bus for 2017 AQIP Program
  - 25 buses
  - $1,235,000
- **2019**
  - Fuel Cell Bus Target for 100 Fuel Cell Bus Order
  - $850,000

**Source:** New Flyer Industries
# 100-Bus Initiative: Timeline

## 100-Bus Initiative Timeline

<table>
<thead>
<tr>
<th>Task</th>
<th>Task Summary</th>
<th>Responsibility</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1Q</td>
<td>2Q</td>
<td>3Q</td>
<td>4Q</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>J</td>
<td>F</td>
<td>M</td>
<td>A</td>
</tr>
<tr>
<td>1</td>
<td>GGRF FY 19-20 Budget Adoption</td>
<td>CARB/CEC</td>
<td></td>
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<tr>
<td>2</td>
<td>Setup Consortium Partners</td>
<td>CTE/Transit</td>
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<tr>
<td>3</td>
<td>Secure CARB and CEC Grant Funding</td>
<td>CTE/CARB/CEC Consortium</td>
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<tr>
<td>4</td>
<td>Select Bus OEM(s) and Fuel Suppliers</td>
<td>OEMs/Suppliers</td>
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<tr>
<td>5</td>
<td>Bus Build and Station Construction</td>
<td>Suppliers</td>
<td></td>
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<tr>
<td>6</td>
<td>Station Openings and Facility Upgrades</td>
<td>OEM (s)</td>
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<td></td>
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<tr>
<td>7</td>
<td>Bus Deliveries</td>
<td></td>
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</tr>
</tbody>
</table>

### 2019
- 1Q: 1st Quarter
- 2Q: 2nd Quarter
- 3Q: 3rd Quarter
- 4Q: 4th Quarter

### 2020
- 1Q: 1st Quarter
- 2Q: 2nd Quarter
- 3Q: 3rd Quarter
- 4Q: 4th Quarter

### 2021
- 1Q: 1st Quarter
- 2Q: 2nd Quarter
- 3Q: 3rd Quarter
- 4Q: 4th Quarter

### 2022
- 1Q: 1st Quarter
- 2Q: 2nd Quarter
- 3Q: 3rd Quarter
- 4Q: 4th Quarter

**Responsibilities:**
- **I.D. Grant Funds**
- **Transit Agencies**
- **CARB/CEC Funding**
- **Select Vendors**
- **Manufacturing/Construction/Commissioning**
- **Station Openings and Facility Upgrades**
- **Bus Deliveries**
Infrastructure Challenges

**PARSE**

**P** Price and delivery of H2 on parity with conventional fuels. Also equipment maintenance cost reduction.

**A** Area of fueling footprint to refuel 50, 100, or 200 buses.

**R** Renewables for hydrogen production; Resiliency - Natural Disasters; Also Redundancy to ensure near 100% service reliability.

**S** Speed of refueling in the normal 8- to 10-hour night window; Also Scalability for future expansion.

**E** Entry-Level Startup and Equity (CapEX) needed to build at an affordable price, utilizing baseline components for future scale up.
The Challenge for 100% ZEB Deployment

Infrastructure and Scalability

Effort and Cost

Fleet Size

FCEB

BEB
Fueling Station Evolution

40’ x 60’ (50-Bus Capacity)

Future: Underground LH2 Tanks and Pumps

Parallel Fueling

12- to 15-Bus Capacity; Expand to 30+ Buses