The State of Zero Emissions Technology

Prepared for the
AC Transit Board of Directors

March 29, 2017
Agenda

- Zero Emission Economical and Environmental Benefits
- Overview of New Flyer and Zero Emissions Experience
- Zero Emissions Market Forces
- Battery-Electric Bus – State of the Technology
- Fuel Cell Electric Bus – State of the Technology
- Summary Comments
Environmental and Economic Benefits of Zero-Emissions

- Reduced Greenhouse Gases
- Reduced Dependence on Carbon Based Fuel
- Opportunities for Renewable Energy Sources
- Energy savings projections up to $400,000 over the life of bus
- Lower maintenance costs
- Reduced Urban Noise (< Powertrain Noise, < Brake Noise)
- Enhanced Rider Experience = Greater Transit Ridership (< Noise, < Vibration)
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- Zero Emission Economical and Environmental Benefits
- Overview of New Flyer and Zero Emissions Experience
New Flyer Industries Inc.

- Provides leading position in North American transit bus and coach platforms
- Both private and public markets
- Combined entity employ approx. 4,800 people with a like-minded commitment to excellence in bus and coach manufacturing
- Combined teams support installed base of over 42,000 transit buses (New Flyer, Orion and NABI) and 28,000 motor coaches (MCI) across North America
New Flyer is the Only Manufacturer in the Transit Industry Manufacturing All Three-Types of Zero-Emission Buses

**Low Emissions**

- **Clean Diesel**
- **Natural Gas**
- **Hybrid-Electric**

**Zero Emissions**

- **Electric-Trolley**
- **Battery-Electric**
- **Hydrogen Fuel-Cell**
New Flyer Battery-Electric Bus
Customers with Deliveries/Scheduled Orders

- Massachusetts Bay Transportation Authority (Boston)
- TRIMET (Portland)
- UTA (Salt Lake City)
- Washington Metropolitan Area Transit Authority
- SunLine Transit Agency (Thousand Palms)
- Alameda County
- OCTA (Orange County)
- Chicago
- Los Angeles
- Winnipeg
- Albany

Built to RELY ON.
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Zero-Emission Growth Drivers and Market Restraints

- FTA LoNo and California eBus Funding
- Battery Leasing Extended Warranties
- Legislative and Executive Branch Pressure
- Maintenance Cost of Diesel and CNG Low-Emission Engines
- Favorable eBus Early Adopter Experiences

Market Restraints

- Limited eBus Funding Available to offset Higher Acquisition costs
- Charging Standards Under Development
- Battery-Electric Range Limited (Currently <50% of CNG / Diesel)
- Utility Infrastructure Complexity for Large Fleet deployments
- Plentiful Domestic Supply of Natural Gas
North American ZEBs –
The Market is Moving Fast

Annual ZEB Bus Deliveries - Forecasted

825/5800 = 14% market share by 2022
### Battery Electric

<table>
<thead>
<tr>
<th>Calendar Year</th>
<th>Awards &amp; Sales</th>
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<tr>
<td>2009 - 2014</td>
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<tr>
<td>2015</td>
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### Fuel Cell Electric

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<td>10</td>
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- Battery-Electric Bus – State of the Technology
The Xcelsior XE40 completed Altoona durability track testing with no Class 1 or Class 2 Failures.

- Structure – No failures disabling the vehicle
- Propulsion System (Siemens' ELFA PEM Motor) – No failures
- Energy Storage System (ESS) and Lithium-Ion Batteries – No failures
- ESS Thermal Management and Control Systems – No failures
- Electric-Drive High Voltage System (Invertors and Other High-Voltage Components) – No failures
- Axles, Brakes and Wheels – No failures
- Drive Shaft – No failures
- Doors, Ramps, Air Systems, and Wipers – No failures

The Xcelsior bus is well proven in-service throughout North America.

The XE40’s high-quality electric propulsion system and complementary energy storage system were systematically integrated into the Xcelsior platform.

XHE60 Altoona Test – Underway (2016 – 2017)
Battery Technology and Integration – Driving Costs Down

Battery Cost - $/kWh

Advancements

1. Better chemistry = higher energy density
2. Higher manufacturing volumes = reduced costs
3. Competition between Battery Manufacturers
4. Better Packaging (density and fewer redundancies in enclosures)
5. Optimized battery heating and cooling
There are two types of electric bus charging stations and equipment infrastructure –

1) Depot Plug-in Charging, and
2) On-Route Charging (either overhead or in-ground wireless).

The type considered directly depends on range, passenger loads and energy costs.

If carrying the highest number of passengers is the top priority and the route chosen is conducive for on an on-route charger, this strategy would allow the bus to operate around the clock and carry as little as 25 percent of the batteries of an extended range bus.

If energy cost is the primary consideration, an extended range bus, potentially carrying fewer passengers and charged overnight with plug-in charging may be the most economical alternative.
Charging Standards

- Charging Standards are Under Development
  - SAE J3105 (Overhead Fast Charge)
  - SAE J2954 (Inductive)
  - SAE J3068 (Plug-In)

- Stakeholders are aiming to have key interface standards decisions made by Q3 2017
- Based on forthcoming standards, New Flyer will supply chargers to industry standards using a DC Depot Charger from companies such as Siemens and ABB.

- Depot charger will utilize a CCS 1 or CC2 Plug Connector (similar to automotive), capable of charging up to 150 kW.

- In the future, New Flyer expects transit agencies will purchase chargers directly from equipment suppliers.
- 650V DC nominal voltage output (750V max)
- Up to 400A continuous charge current
  - Future option will allow for up to 600A
  - 6 min charge per hr of driving/4 min charge per hr of driving (XE40)
- Wireless communications bus to charger
- Ground fault and high voltage isolation monitoring
- Nema Type 3R (Outdoor) enclosures
- Multiple redundant fail safes and fault checks
- Easy alignment of vehicle to charger
  - 2’ x 2’ alignment tolerance
- >91% efficiency in power transfer
- Ambient temperature operating range -40C to 50C
- Full UL and CSA certification
- Suppliers
  - Siemens
  - ABB
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Auto Fuel Cells are Driving Costs Lower Growing the H₂ Infrastructure
Much of the bus is the same as a Battery-Electric Bus regardless of Fuel Cell Type

- Same Xcelsior® Platform
- Same Siemens Electric Motor
- Same Electric Accessories
- Same Battery Technology

Hydrogen Storage on the Roof Has High Similarity to CNG

Ballard HD-7 Fuel Cell (On-Board Battery Charger)
Fuel Cell Bus Cost are Declining - Advancements and Manufacturing Order Volume

- 2010: $800,000
- 2016: $1,000,000
- 2020: $1,200,000
Feasibility of a FCEB Under $1 Million – New Flyer is Committed

Requires Cooperation, Coordination and Partnerships with Governmental Agencies, Fuel Cell Suppliers, High Pressure Fuel Tank Suppliers, and other Electric propulsion system suppliers

“We believe a 40’ Foot Fuel Cell Bus price of approximately $900,000, with a standard warranty, Including a 5-year/15,000 fuel cell Warranty is achievable given several assumptions…”
New Flyer XHE60 at the FTA Altoona Proving Grounds

North America’s First Zero-Emission Fuel Cell Electric Articulated Bus

Electric Motors Driving 2-Axles for Enhanced Traction and Safety
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Battery-Electric buses are here to stay
They work well!
- Key challenges are cost (improving), range (improving), peak demand power cost, and charging infrastructure/standards

Fuel Cell buses are close behind
They work well too!
- Key challenges are cost (volume related), developing hydrogen infrastructure, and the current cost of hydrogen
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