Advanced Bus Concepts: Perspectives from FTA Programs
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Director, Office of Mobility Innovation
Federal Transit Administration
Overview

- Public Transit Bus Operations & Challenges

- FTA Bus Research Areas and Programs
  - Fuel Efficiency and Zero-Emissions
  - Innovative Bus Designs
  - Intelligent Transportation System (ITS) Technology

- The Route Ahead
Public Transit Bus Operations

- 1,100 transit systems operate buses\(^1\)
- 48,000 buses in operation\(^2\)
- Transit is a leader in adopting clean fuel and advanced technology
- About 30% of transit buses are alternatively-powered

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\(^1\) Source: Environmental Benefits of Alternative Fuels and Advanced Technology in Transit, FTA-WV-26-7003-07.2

\(^2\) Source: 2010 PUBLIC TRANSPORTATION VEHICLE DATABASE, APTA, June 2010

### Transit Bus Fuel Types (2010 Fleet)

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas-Electric</td>
<td>(216)</td>
</tr>
<tr>
<td>Gasoline</td>
<td>(381)</td>
</tr>
<tr>
<td>Propane</td>
<td>(37)</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>(49)</td>
</tr>
<tr>
<td>Battery-Electric</td>
<td>(71)</td>
</tr>
<tr>
<td>LNG</td>
<td>(2)</td>
</tr>
<tr>
<td>Bio diesel</td>
<td>(8)</td>
</tr>
<tr>
<td>Diesel - Electric</td>
<td>(71)</td>
</tr>
<tr>
<td>CNG</td>
<td>(16)</td>
</tr>
<tr>
<td>Diesel</td>
<td>(63)</td>
</tr>
</tbody>
</table>

Other 1%
Challenges in Bus Transit Operations

- Rising & Unstable Petroleum Costs
- Low Emission & Zero Emission Requirements
- Need for Rugged Dual Purpose (Transit/Paratransit) Buses
- Boosting Operational Efficiency & Reducing Cost
- Collecting and Providing Bus Operations Information
U.S. Transit Policy

DOT Strategic Goal:

Environmental Stewardship

FTA Strategic Goal:

Environmental Sustainability

- Reduced carbon and other harmful emissions
- Improved energy efficiency
- Reduced dependence on fossil fuels
- Reduced transportation-related air, water, and noise pollution and impacts on ecosystems
FTA Bus Research Areas & Programs

- Zero and Near Zero Emission Bus Propulsion
  - National Fuel Cell Bus Program (NFCBP)
  - Wireless Electric Vehicle Charging
  - Hydraulic Hybrid Propulsion

- Innovative Bus Designs
  - Altair BUSolutions LCO-140
  - Advanced Small Transit Vehicle

- Intelligent Transportation System (ITS) Technology
## Transit Bus Fuel Technology History

<table>
<thead>
<tr>
<th>PHASE</th>
<th>1980’s</th>
<th>1990’s</th>
<th>2000’s</th>
<th>2010’s</th>
<th>2020’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>Diesel Gas</td>
<td>CNG Diesel Gas</td>
<td>Hybrid CNG Diesel Gas</td>
<td>Hybrid Electric CNG Diesel Gas</td>
<td>Fuel Cell Hybrid Electric CNG Diesel Gas</td>
</tr>
</tbody>
</table>

- **CNG**
- **Diesel**
- **Gas**
Notional Electric Drive Goals

**The Vision**
Commercial availability of zero and near-zero emissions, high efficiency, affordable transit vehicles for transit agencies across the country by 2030 from domestic suppliers

**The Goal**
To advance electric drive and related technologies to enable commercially-viable transit vehicles with significantly higher efficiencies, lower emissions, and superior performance

<table>
<thead>
<tr>
<th>Specific Goal</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Quadruple fuel efficiency of 40’ transit bus</td>
<td>Fuel economy greater than 12 miles per diesel equivalent gallon</td>
</tr>
<tr>
<td>2 Decrease transit vehicle tailpipe emissions</td>
<td>&gt;50% improvement over 2010 EPA requirements for heavy-duty diesel engines</td>
</tr>
<tr>
<td>3 Achieve superior performance of new transit vehicles</td>
<td>10 % increase in MBRC 25 % reduction of interior noise Minimum 12-year vehicle lifetime Zero safety incidents</td>
</tr>
</tbody>
</table>
Projected Impact of Electrification on the Transit Bus Fleet 2010-2030

Fuel Cost Savings of $0.6B over 20 years
(assuming no fuel cost increases above 2008 level)
# National Fuel Cell Bus Program (NFCBP) Performance Targets

<table>
<thead>
<tr>
<th>Target</th>
<th>NFCBP Targets</th>
<th>Revised Draft Target</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bus Cost</strong></td>
<td>Less than 5x cost of conventional bus</td>
<td>$600,000</td>
</tr>
<tr>
<td><strong>Power plant lifetime</strong></td>
<td>Original: 10,000 to 20,000 hours/4 to 6 year; Current: 20,000 to 30,000 hours</td>
<td>6 years/ 25,000 hours</td>
</tr>
<tr>
<td><strong>Fuel Economy</strong></td>
<td>Double fuel economy compared to commercial transit bus</td>
<td>8 miles/ gallon of diesel equivalent</td>
</tr>
<tr>
<td><strong>Performance</strong></td>
<td>Bus performance equal to or greater than equivalent commercial bus</td>
<td>Range: 300 miles</td>
</tr>
<tr>
<td></td>
<td>• Acceleration</td>
<td>Road call frequency (miles between road calls)</td>
</tr>
<tr>
<td></td>
<td>• Gradability</td>
<td>All: 4,000 MBRC</td>
</tr>
<tr>
<td></td>
<td>• Range</td>
<td>Powerplant: 10,000 MBRC</td>
</tr>
<tr>
<td></td>
<td>• Braking distance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Noise</td>
<td></td>
</tr>
<tr>
<td><strong>Emissions</strong></td>
<td>Exceed current emissions standards</td>
<td>Exceeds - zero emissions</td>
</tr>
<tr>
<td><strong>Power plant cost</strong></td>
<td>$200,000</td>
<td></td>
</tr>
<tr>
<td><strong>Operating cost</strong></td>
<td>$0.38 /mile (excludes overall and fuel)</td>
<td></td>
</tr>
<tr>
<td><strong>Fuel fills</strong></td>
<td>1 per day (&lt; 5 min)</td>
<td></td>
</tr>
</tbody>
</table>

Revised draft targets from October 2011 presentation by Dimitrios Papageorgopoulos, DOE Fuel Cell Technologies Program at National Fuel Cell Bus Workshop.
NFCBP Highlights

All-American Fuel Cell Bus

- Battery-dominant hydrogen fuel cell bus
- ElDorado National Axess platform
- 90 Percent U.S. Content
- U.S. Made Ballard HD6 150kW Fuel Cell
- BAE Systems HybriDrive
- A123 Nanophosphate batteries
- Demonstration at SunLine Transit
- Electrically driven accessories
NFCBP Highlights

**Proterra Fuel Cell Bus**
- Battery-dominant hydrogen fuel cell 35-foot bus
- Dual 16 Kw Hydrogenics fuel cell stacks
- Lightweight composite structure
- Advanced Lithium-Titanate batteries
- Demonstration in South Carolina, and planned for Austin, TX
- All-electric buses with opportunity charging developed from platform

**Compound Hybrid Fuel Cell Bus**
- Blends energy from three power sources, capable of zero emissions operation
- BAE Hybrid drive system with Cummins diesel engine
- Hydrogenics fuel cell stack
- Lithium ion energy storage system
- Electrically driven accessories (AC, power steering, cooling)
- Demonstration in San Francisco, CA
- Evolutionary pathway to zero emissions, while improving hybrid efficiency
Electric Bus Innovation

• Innovation in Electric Buses has never been greater
  o Fast Charge Battery Technology and “Opportunity” Charging Concept
  o Decreases Size of Battery Pack & Vehicle Cost
  o “Opportunity” Chargers placed on Bus Route
  o Major Step Forward for Electric Bus Viability

• FTA supporting several key demonstrations
  o Proterra Fast Charge Bus
  o EBUS Fast Charge Bus
  o Wireless Battery Charging
Proterra Bus Design

- Lightweight Electric Bus
- 30 Mile Range
- 10 Minute Recharge
- Automated Conductive Charging
- Inductive (Wireless) Charging in Development

Conductive Fast Charging  Inductive Fast Charging  Proterra Battery Pack
EBUS Bus Design

- 22-Foot Bus & Trolley
- Flexible Propulsion Options
  - Hybrid Electric with MicroTurbin
    - Propane
    - Diesel
  - Fast-Charge Electric (Ni-Cd)
- 45 Mile Electric Range
- 30 Minute Recharge @ 90kW
- Lithium-Titanate Battery Bus in Demonstration
- Automated Conductive Overhead Charging in Demonstration

Fast Charge Bus

Conductive Fast Charging Trolley Concept
Wireless Electric Fast Charge

• The Next Step in “Opportunity” Charging
• Embedded Charging Stations
• Charging with Bus Stationary for Short Time (3-6 minutes)
• University of Tennessee at Chattanooga Achieved Goals of:
  • ONE MINUTE
  • ONE MILE
  • ONE DIME ($0.10/mile)
  • ONE HUNDRED MILES
  • ZERO TAILPIPE EMISSION
• Successful Research Leading to Several New FTA Demonstrations

UT Demo Bus Approaching Charging Station

Positioning of Vehicle Receiver And Roadway Transmitter
Wireless Charging Demonstrations

Demonstration Sites:
- Howard County Maryland – *Wampfler Inductive*
- CARTA – Chattanooga – *Wampfler Inductive*
- McAllen, Texas – *OLEV Technologies @ 3 bus stops*
- University of Utah Campus Shuttle – *WAVE Inductive @ 3 bus stops*

*WAVE Charging Concept (Energy Dynamics Laboratory – Utah)*

*OLEV Roadway Embedded Charging (KAIST)*

*Wampfler Inductive Charging Pad*
Hydraulic Hybrid Propulsion

- Series Hydraulic Hybrid
- Replaces Automatic Transmission
- 70% Braking Energy Recovery vs. 25% for Hybrid Electric
- Employed in Refuse Trucks
- 3X Fuel Economy Potential
- NVH and speed range improvements necessary for transit use

*ALTAIR LCO-140
Hydraulic Hybrid EPA Laboratory Results

[Bar chart showing percentage improvement over vehicle's baseline for various drive schedules and configurations, including Manhattan Bus, CBD truck, WVU City, NYC truck, FTP bag2, FTP cold start, FTP bag3, and HWFET.]

February 6, 2012
Hydraulic Hybrid Energy & Power Density

The HHV UPS truck operates here.
Innovative Bus Design – Altair LCO-140

- Lightweight Heavy-Duty Bus
- Life-Cycle Cost Design Focus
- 15% lighter than Conventional Bus
- Hydraulic Hybrid Powertrain
- Demonstrated Significant Fuel Savings
- Designed for Manufacturability
Advanced Small Transit Vehicle

❖ Need for an improved small vehicle to support rural/small urban transit markets

❖ Current small vehicles
  o Adapted Commercial Chassis
  o Harsh ride & limited to good roads
  o Crude wheel-chair lifts
  o Inflexible Seating

❖ Future Small Transit Vehicle
  o Low-floor wheelchair friendly
  o Reconfigurable seating
  o Compact powertrain
  o Traction Control
  o Adjustable Ground Clearance
Ride Solutions Brevi Bus

- Small heavy-duty low-floor bus designed by BreviBus
- Key Innovations
  - Transverse Engine/Transmission
  - H-drive translates transmission output 270 degrees into rear axle
  - 25 seated passengers in only 26-foot length
  - Seating converts to 5 wheelchair positions or 6 stretchers
  - Built-in Wheelchair Ramp
Vehicle Assist and Automation (VAA) for Transit Operations

Assists or automates movement of buses to allow precise operations in extremely narrow lanes, at stations, and potentially bus maintenance facilities

Major functions:
- Precision docking
- Vehicle guidance
- Vehicle platooning
- Automated operations
Improved Station Design & Off-Board Fare Collection
ITS Fleet Management, Signal Priority, and Real Time Traveler Information
The Route Ahead

- The evolution of bus design & technology will continue

- Revolutionary Bus design & technology changes are expected as well

- New fueling and propulsion system choices will emerge

- Application of automation, information, and communication technology will continue indefinitely
Thank You

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