Issues and Challenges
Fuel Cell Related Transit Research Programs

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International Hydrail Conference
June 11, 2009 | Charlotte, NC, USA
Overview

- U.S. DOT Strategic Goals
- FTA Strategic Goals
- Transit Interest in Clean Energy
- FTA Research in Clean Fuels/Technology
- Electric Drive Strategic Plan
- FTA National Fuel Cell Bus Program
- U.S. Fuel Cell Rail Projects
- Proposed Rail Related Hydrogen Fuel Research Projects
- Lessons Learned
U.S. DOT Strategic Goals

- Safety
- Reduced Congestion
- Global Connectivity
- Environmental Stewardship
- Security, Preparedness and Response
FTA Strategic Goals

- Maximize Security and Safety of Transit Systems for Service Users
- Foster Customer Oriented Public Transportation
- Foster Industry Adaptability
- Maximize Multimodal Approach to Transportation
FTA Strategic Goals (Continued)

- Ensure a Quality Organization that Emphasizes Mutual Respect
- Ensure the Highest Level of Transit Service Assistance Delivery
- Promote Linkages Between Transit Needs and Community Needs
- Foster a Positive Image for Public Transportation and FTA
FTA Research Strategic Goals

- Provide National Transit Research Leadership
- Support Increasing Transit’s Market Share
- Support Improving the Performance of Transit Operations and Systems
Transit Interest in Clean, Energy Efficient Vehicle Technologies

- Reduce transit bus emissions
- Lower greenhouse gas transportation emissions
- Improve fuel efficiency
  - Fuel is second largest operating cost, and not eligible for FTA assistance
  - Current full size transit buses achieve only 2 to 4 mpg
- Improve vehicle performance
- Consumer Acceptance/ Public Relations
  - Smoke and odor free
  - Clean and quiet
  - Move toward “greener” technologies
Transit Industry: Platform for Advanced Technologies

**Fleet Operations**
- Centrally fueled and maintained
- Professional operators and mechanics
- Urban stop-go duty cycle and fixed route
- Start-up time

**Federal Capital Funding Support**
- Federal procurement funding
- Assistance for developing new technologies

**High Visibility & High Impact**
- Operate in densely populated areas
- Broader public exposure and acceptance
FTA Research in Clean Fuels/ Technology

❖ **U.S. Tested First Fuel Cell Public Buses**
  - Chicago, IL and Palm Springs, CA (1998 – 2001)

❖ **Alternative Fuel (e.g., Hydrogen) Research for Public Transportation Systems**
  - Development and Demonstration
  - Vehicle Testing and Evaluation
  - Outreach and Coordination

❖ **Multiple technologies including biofuels, gaseous fuels (Hydrogen ICE), electric drive, energy storage and fuel cells**

❖ **Collaboration with Industry, Universities, U.S. Government Agencies, International Outreach**
FTA Research Activities

- $25 Million for Hybrid Electric and Electric Drive Bus Testing (2000 - present)


- 11 Hydrogen Fuel Cell Public Buses In Service Today and Up to 12 More Planned
  - (3) San Jose, California (near Silicon Valley)
  - Palm Springs, California
  - Honolulu, Hawaii
  - (3) Oakland, California (near San Francisco)
  - Hartford, Connecticut
  - Newark, Delaware (near Philadelphia)

Moving Forward: Electric Drive Strategic Plan

Purpose: Plan to help guide FTA research in electric drive technologies

- Electric drive technologies have significant potential to enable cleaner, more efficient transit
- While FTA’s approach considers all power sources, electric drive technology is likely to play a strong role in future scenarios
- Given National interest in fuel cell and other electric-drive dependent solutions, FTA needs to ensure that our direction has industry support
Electric Drive Strategic Plan

- Plan defines a 5-year electric drive research plan in the context of a 20-year strategic outlook

- FTA plan that was developed in consultation with industry
  - Broad cross section of industry input sought, including:
    - Transit agencies
    - Bus manufacturers
    - System/component suppliers
    - Academia
  - Several industry/government meetings held to get individual industry perspectives
Electric Drive Strategic Plan

**Electric Drive Program Vision:**
The commercial availability of zero and near-zero emissions, high efficiency, affordable transit vehicles for transit agencies across the country by 2030 from domestic suppliers.

**Electric Drive Research Goal:**
Advance electric drive and related technologies to enable commercially-viable transit vehicles with significantly higher efficiencies, lower emissions and superior performance.
Electric Drive Strategic Plan

Benefits of Electric Drive

Increasing the use of electricity in transit vehicles improves the efficiency and reduces emissions from the national transit fleet.

These technologies have the ability to improve existing diesel buses and enable the deployment of fuel cell and other advanced technology buses.

- By 2030, electric drive could save over $500 M in fuel costs per year
- By 2030, electric drive could reduce CO$_2$ emissions by 1.6 M tons per year
**Strategic Research Approach**

Through a planning process including industry analysis and meetings with stakeholders, FTA identified five focus areas, in priority order, necessary to advance technology to the 20 year vision.

<table>
<thead>
<tr>
<th>Technical Focus Area</th>
<th>2014 Objective</th>
<th>2030 Objective</th>
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<tbody>
<tr>
<td>Vehicle Energy Management</td>
<td>Implement innovative bus energy system demonstration and evaluation program</td>
<td>Validated energy storage systems commercially available for transit</td>
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<tr>
<td>Electrification of Accessories</td>
<td>Validate all-electric 40’ bus</td>
<td>All-electric bus commercially established</td>
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<tr>
<td>Bus Design</td>
<td>Prepare advanced propulsion bus design standards and guidelines</td>
<td>Commercially established innovative bus design for advanced propulsion systems</td>
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<tr>
<td>Rail Energy Management</td>
<td>Implement innovative rail energy system demonstration and evaluation program</td>
<td>Validated energy management systems commercially available for rail transit</td>
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<tr>
<td>Locomotive Design</td>
<td>Analyze alternative locomotive designs</td>
<td>Established validation program for alternative locomotive designs</td>
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FTA typically funds applied research, which consists of three phases:

- **Develop**
  - Feasibility Analysis
  - Analyze: Innovative concepts, technology transfer from other industries and review of domestic and international research and practices
  - Prototypes and Concepts
  - New technologies and transit specific applications

- **Demonstrate**
  - Demonstrations and Validation
  - Data

- **Validate**
  - Commercial Product
  - Lessons Learned

- **Deploy**
  - Deploy: Product meets industry business case

- **Implement**
  - Standards, Guidance and Outreach

- **Deployment and Implementation**
## Analysis and Development
- Current Industry and Technology Assessment
- Electric Drive Research Program Analysis
- Compendium of Energy Storage Options for Transit
- Rail Transit Energy Saving Technology Evaluation
- Evaluation of Electrified Accessories in Transit
- Advanced Locomotive Design Applications in Transit
- Advanced Propulsion Locomotive Evaluation
- Infrastructure Support and Analysis
- Load-leveling and Smart Grid Assessment
- Rail Transit Energy Usage Analysis
- Electric Drive Bus Noise Reduction Analysis
- Emissions Requirements Impact Assessment

## Demonstrations and Validation
- Wayside Energy Storage Demonstration
- Optimized System Integration Demonstration
- Integrated Starter/Alternator Demonstration
- Fuel Cell Bus Fleet Demonstration
- Advanced Energy Storage System Rail Demonstration
- Advanced Electric Drive Bus Demonstration
- Evaluation of Electrified Accessories in Transit
- Reduced Weight Rail Vehicle Demonstration
- Optimized Electric Bus Chassis and Body Demonstration
- Evaluation of Electrified Accessories in Transit

## Deployment and Implementation
- Life Cycle Cost Assessments
- Electric Drive Research Website
- Energy Storage System Fire and Safety Analysis
- Mainstream Hybrid-Electric Buses
- Energy Storage System Standards
- Industry Standards Assessment and Development Plan
- Auxiliary Power Unit Demonstration
- Advanced Propulsion Bus Design and Procurement Guidelines
- On-board Fuel and Energy Storage Safety Analysis
- Program Assessment
- Evaluation of Electrified Accessories in Transit

## Timeline
- 2010
  - Vehicle Energy Mgmt.
  - Electrification
  - Bus Design
  - Rail Energy Mgmt.
  - Locomotive Design
  - Program Implementation
- 2011
- 2012
- 2013
- 2014
National Fuel Cell Bus Program:

- Goal is to facilitate the development of commercially-viable fuel cell buses
- Authorized under SAFETEA-LU
- $49 Million over fiscal years 2006 to 2009
- Teams and projects competitively selected
- 50-percent non-Federal cost share required
- Program consistent with FTA Electric Drive Research Objectives
National Fuel Cell Bus Program: Performance Objectives

- Achieve cost less than 5 times that of a commercial transit bus
  - Current 40’ diesel transit bus cost ~ $328,000
  - Current 40’ fuel cell transit bus cost ~ $3,000,000

- Achieve 20,000-30,000 hours (4-6 yrs) of fuel cell durability
  - Common fuel cell warranties for 4,000 hours, next generation warranties up to 12,000 hours

- Double the fuel efficiency compared to a commercial transit bus
  - Average diesel fuel efficiency 3.5 mpg
  - Current fuel cell efficiencies ~7 miles per DGE

- Achieve fuel cell bus performance equivalent to commercial transit bus
  - Acceleration, gradability, range, braking distance, etc.
National Fuel Cell Bus Program Projects

Balanced portfolio of projects selected to best advance fuel cell bus commercialization

- Development and Demo Projects (8 projects, $43M)
  - Both evolutionary and “clean sheet” approaches
  - Spectrum of cost and risk
  - Multiple drive technologies/configurations
  - Fuel cell stack size/utilization
  - Multiple energy storage technologies - NiMH, Li ion, ultracaps
  - Supporting infrastructure

- Component Technology (2 projects, $300K)

- Analysis, Outreach, Coordination (4 projects, $1.25M)
National Fuel Cell Bus Program

Each project managed by one of three non-profit consortium:

- Center for Transportation and the Environment in Atlanta, GA
- Northeast Advanced Vehicle Consortium in Boston, MA
- WestStart /CALSTART in Pasadena, CA

Projects include partners from industry, government, transit:

- Multiple fuel cell manufacturers - UTC, Ballard, Hydrogenics, Nuvera
- Multiple drive system integrators - ISE Corp, BAE Systems, GE Global Research
- Multiple bus manufacturers
- Multiple fuel suppliers
National Fuel Cell Bus Program

Demonstration sites across U.S. in diverse locations, climates

Oakland, CA
San Francisco, CA
Thousand Palms, CA
Hartford, CT
Boston, MA
Columbia, SC
Albany, NY
Austin, TX
National Fuel Cell Bus Program
Supporting Efforts

- Data collection in partnership with the Department of Energy (DOE) National Renewable Energy Lab (NREL)
- Outreach efforts to share findings and results, nationally and internationally
- Coordination with existing FTA, DOT, DOE and State research efforts in electric drive and fuel cell research
- Comprehensive safety plan assessment for each test site conducted by DOT Volpe Center
National Fuel Cell Bus Program
Status and Accomplishments

- Up to 12 new buses will begin rollout in 2009 to 2010

- Hydrogen Hybrid Bus
  - 35-foot Battery-dominant hydrogen fuel cell bus by Proterra
  - Dual 16 Kw fuel cell stacks managed through algorithms to optimize output and minimize wear
  - H2 fueling station in Columbia, SC open
  - Delivery to Columbia, SC this summer, for demonstration to begin this fall
National Fuel Cell Bus Program
Status and Accomplishments

AC Transit Fuel Cell Bus Demonstration

- Accelerated testing of current fleet of 3 fuel cell buses at AC Transit – initial evaluation complete, testing continues

National Fuel Cell Bus Program
Status and Accomplishments

Component projects completed successfully

- **Hybrid Fuel Cell Power Converter**
  - Scaled design of an existing automotive fuel cell DC-DC high power converter to heavy-duty fuel cell transit bus requirements.
  - Can replace functions now accomplished with expensive custom one-off designs
  - Will work with multiple fuel cell power system manufacturer products and multiple energy storage devices

- **Integrated Auxiliary Module for Fuel Cell Bus**
  - Fabrication and demonstration of a low-cost, compact, integrated auxiliary module (IAM).
  - Design intended to increase efficiency and reduce cost from current auxiliary systems.

- **Exploring integration and testing of components in full scale fuel cell bus demo**
National Fuel Cell Bus Program: Outreach and Coordination

Hydrogen Bus Survey Report

- Released March 2009
- Based on interviews with Hydrogen Bus operators from around the world Survey of International Fuel Cell Bus Demonstrations

International Fuel Cell Working Group

- Meeting held in Reykjavik, Iceland, May 2008
- Meeting held in Vancouver, B.C. in June 2009

International fuel cell bus website in beta testing
Transit Investment in Greenhouse Gas and Energy Reduction (TIGGER)

- New program part of the ARRA
- $100 Million in discretion grants to transit agencies
  - Reduce Energy Consumption
  - Reduce Greenhouse gas emissions
- 100-percent Federal share available
- Proposals were due to FTA May 22, 2009
- FTA Currently reviewing proposals, selections expected by September 2009
- Multiple fuel cell projects proposed
U.S. Fuel Cell Rail Projects

- Fuel Cell Switcher Locomotive
- Fuel Cell Subway Maintenance Locomotive
- Stationary Fuel Cells for Traction Power Backup
Fuel Cell Switcher Locomotive

- Dept. of Defense and BNSF Railway Co.
- Developed Quickly Using Hybrid Electric Switcher and Fuel Cell Bus Components
- Zero Emissions, Unlike Diesel Switchers
- Ideal for Stop-and-Go Cycles
- Demonstrations: Seaport and Army Base
Fuel Cell Subway Maintenance Locomotive

- **Transport Workers and Machines During Maintenance Operations (Rails Unpowered)**
- **Longer Range than Battery Powered Vehicles; No recharging**
- **Designed for Safe Operation in Tunnels**
Stationary Fuel Cell Tractive Power Generation

- Connecticut Department of Transportation

- Stationary Fuel Cells Could Provide Alternate Traction Power Source for Existing Electrified Commuter Rail Service

- Power Transmission Congestion in Connecticut Poses Risk of Service Disruption

- Study Complete; More Analysis Needed
Hydrogen Streetcar Projects

- Several Cities Are Investigating Hydrogen Fuel Cell Powered Streetcars
- New Systems Where Overhead Wires Are Not Desirable
- Can Use Many Fuel Cell Bus Components
- Concept Phase
Proposed Rail Related Hydrogen Fuel Cell Project

**FTA feasibility study to include:**

- Report of the current diesel commuter rail car market and its potential (GHG and oil consumption reduction)
- Review of fuel cell(s) best suited for commuter rail applications and required infrastructure
- Required engineering specifications for the fuel cell (retrofit and new build; clean sheet or using existing fuel cell power plant)
- Potential partners (fuel cell suppliers, transit agencies, fuel suppliers, etc) for demonstration project

**Demonstration phase will depend on the result of the feasibility study and availability of funds**
Proposed Rail Related Hydrogen Fuel Cell Project (Continued)

- FTA to work closely with FRA
- FRA reviewing the cost of designing a rail freight system to provide 100% power
- FRA considering a research grant to Norfolk Southern Railroad and UTC Power for development of a switch engine locomotive utilizing hydrogen fuel cells for power
Lessons Learned - Fuel Cell Programs

**Durability**
- More research and development needed to improve durability

**Project Management**
- Strong project team adhering to sound management principles

**Project Schedules**
- Realistic schedules a must

**Partners**
- Right partners needed to deliver the most effective product

**Funding**
- More research and development funds necessary
Lessons Learned (Continued)

- **Hydrogen Infrastructure**
  - National objective required

- **Energy Storage Technology**
  - More research and development needed

- **Fuel Cell Technology**
  - Share platform, applications, modes

- **Evaluation**
  - Evaluation and consistent data collection critical

- **Political Will Necessary**
Thank you

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