Demonstrating Electric School Buses

Lessons from the Field
To act with urgency to enhance the economic, environmental and societal benefits of clean and efficient energy for all people.
Presentation Overview

Massachusetts Electric School Bus Pilot Project

Lessons for Demonstration Projects
Massachusetts Electric School Bus Pilot
Massachusetts Electric School Bus Pilot
Project Goals

- Deploy electric school buses
  - Fuel efficiency and energy costs
  - Reliability and performance

- Vehicle to Grid/Vehicle to Building demonstrations
  - Demonstrate V2G/V2B capabilities
  - Financial value of battery as energy storage resource

- Education and outreach
Massachusetts Electric School Bus Pilot Demonstration Sites

<table>
<thead>
<tr>
<th>Amherst</th>
<th>Cambridge</th>
<th>Concord</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small, rural district</td>
<td>Small, urban district</td>
<td>Large suburban district</td>
</tr>
<tr>
<td>Operates own bus service</td>
<td>Contracts for bus service</td>
<td>Operates own bus service</td>
</tr>
<tr>
<td>Fleet of about 10 buses with one technician</td>
<td>School district had one bus (electric one) and one driver</td>
<td>Large fleet of 50-60 buses with small team of technicians</td>
</tr>
<tr>
<td>Large investor own utility</td>
<td>Large investor own utility</td>
<td>Municipal utility</td>
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Massachusetts Electric School Bus Pilot Noteworthy

- First eLion Bus in U.S.
- Cold weather operations
- Wheelchair lift
Massachusetts Electric School Bus Pilot
Summary of Findings

• Electric school buses generated a lot of interest and enthusiasm
  • Students, parents and school staff
• Drivers liked the buses
  • Lots of improvements that make it a better vehicle
• Vehicle range was not an issue
  • 104 kWh battery well sized
• Cold temperatures were not a factor
  • Fuel fired heater worked well
Massachusetts Electric School Bus Pilot
Research Questions

1. Are electric school buses reliable?
2. Are electric school buses energy efficient?
3. Do they have lower operating costs?
4. Can the battery be used as an energy storage resource?
Massachusetts Electric School Bus Pilot
Vehicle Reliability

- Bus was not as reliable as expected
  - Buses spent several days out of service
  - Buses logged fewer miles than expected
    - 4,000 – 5,000 miles as compared with 10,000 to 12,000

- Reliability issues across all systems
  - Fuel tank, head lamps and water pump
  - Charging infrastructure
  - Electric drive train / battery systems
    - Battery back failure
    - Multiple failures with DC / DC converter
Massachusetts Electric School Bus Pilot
Vehicle Reliability

- Minor problems took longer to resolve
- More training with the systems
- Need more experience with technology
Massachusetts Electric School Bus Pilot Vehicle Reliability

Finding / Lessons Learned

• Cold weather was not a factor in reliability
• Bus performance improved over time
  • Training and experience
• With more technical support and better/more training, technology is ready for wider deployment
Massachusetts Electric School Bus Pilot
Energy Efficiency

- Expected electric school buses to be more energy efficient than diesel buses

- Bus is efficient during operations (energy consumed while driving)
  - Measures efficiency in range of 1.3 to 1.4 kWh / mile
  - In line with vehicle specification

- But not efficient when charging is taken into consideration
  - Bus plugged in overnight, 2.38 kWh / mile
  - Bus plugged in over school break, 4.29 kWh / mile
Massachusetts Electric School Bus Pilot
Relationship between Temperature and Efficiency

Efficiency Increases With Temperature

Energy use (kWh/mi)

Daily Average Temperature (°F)
Massachusetts Electric School Bus Pilot
Relationship between Charging Time and Efficiency
Massachusetts Electric School Bus Pilot
Energy Efficiency

Findings / Lessons Learned

- Need to be careful with vehicle charging
- Actively monitor and manage charging systems
- Report findings and work with manufacturers to improve vehicle energy systems
Massachusetts Electric School Bus Pilot
Cost Effectiveness

• Expect electric school bus to be less expensive
  • Electricity is cheaper than diesel
  • Fuel price is more stable
  • Vehicle is more efficient

• Findings work if consider energy consumed during operations only, but charging inefficiencies erode cost savings
Massachusetts Electric School Bus Pilot
Cost Effectiveness

Electric School Bus
• Overall bus efficiency is 2.38 kWh /mile
• $0.13 per kWh and 13,902 miles
• Energy costs = $7,240
• Cost per mile $0.52

Diesel School Bus
• Fleet average 6.3 miles per gallon
• $2.00 per gallon and 13,902
• Energy costs = $4,417
• Cost per mile $0.32
Massachusetts Electric School Bus Pilot
Cost Effectiveness

Electric School Bus
• Overall bus efficiency is 2.38 kWh /mile
• $0.13 per kWh and 13,902 miles
• Energy costs = $4,632 (without demand charges)
• Cost per mile $0.33

Electric School Bus
• Overall bus efficiency is 1.4 kWh /mile
• $0.13 per kWh and 13,902 miles
• Energy costs = $2,530 (without demand charges)
• Cost per mile $0.18
Massachusetts Electric School Bus Pilot Cost Effectiveness

Comparison of Cost per Mile

- Measured
- Measured without Demand Charges
- Efficiency at 1.4
- Diesel
Massachusetts Electric School Bus Pilot
Cost Effectiveness

Findings / Lessons Learned

- Need to actively monitor and manage charging systems
- Work with manufacturers to improve energy needs while plugged in
Next Steps for Electric School Buses

- Vehicle to Grid and Vehicle to Building Strategies
  - V2G/V2B systems have been successfully deployed
  - Experience with school buses is limited
  - Tremendous opportunities, but some challenges remain
More Information:

www.veic.org/eschoolbus

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