LITERATURE REVIEW AND INDUSTRY SCAN OF ELECTRIC SCHOOL BUSES

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Project Scope

**Sponsor:** The Texas Department of Transportation (TxDOT)

**Researcher:** Texas A&M Transportation Institute (TTI)

**Tasks:**
- Literature review and industry scan of electric school buses
- Proactively assist school districts with efforts in researching and making decisions on electric school bus programs

**Funding:** State Planning and Research (SP&R) funds managed by the USDOT’s FHWA

**Collaboration:** Staff from TTI and TxDOT’s RTI Program and Environmental Affairs Division
Background

School-aged children’s respiratory systems are still developing, making them more susceptible to the dangers of diesel emissions.
Fuel Types

- DIESEL
- PROPANE (LPG)
- CNG: Compressed Natural Gas
- ELECTRIC
## School Bus Comparisons

<table>
<thead>
<tr>
<th>Bus</th>
<th>Availability</th>
<th>Cost</th>
<th>Fuel Economy (MPDGE)</th>
<th>National Average Fuel Price</th>
<th>Lifetime NOx Emission Output (lb)</th>
<th>TCO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>1950s</td>
<td>$90,000</td>
<td>7.7</td>
<td>$3.05/gal</td>
<td>967</td>
<td>$429,247</td>
</tr>
<tr>
<td>Propane</td>
<td>1970s</td>
<td>$98,000</td>
<td>6.4</td>
<td>$2.79/gal</td>
<td>52</td>
<td>$389,310</td>
</tr>
<tr>
<td>CNG</td>
<td>1980s</td>
<td>$120,000</td>
<td>6.5</td>
<td>$2.18/GGE</td>
<td>121</td>
<td>$441,570</td>
</tr>
<tr>
<td>Electric</td>
<td>2015</td>
<td>$290,000</td>
<td>22.6</td>
<td>$0.13/kWh</td>
<td>0</td>
<td>$571,700</td>
</tr>
</tbody>
</table>
Fuel Price Volatility

Average Retail Fuel Prices in the United States

*Electricity prices are reduced by a factor of 3.4 because electric motors are approximately 3.4 times as efficient as internal combustion engines.

afdc.energy.gov/data
Fuel Price Volatility

Electricity and CNG fuel prices — stable

Diesel and propane — more volatile
# Electric School Bus Availability

<table>
<thead>
<tr>
<th>Bus Manufacturer</th>
<th>Bus Type</th>
<th>Bus Model</th>
<th>Seating Capacity</th>
<th>Battery Capacity</th>
<th>Battery Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue Bird</td>
<td>Type A</td>
<td>Micro Bird 5G Electric</td>
<td>30</td>
<td>88 kWh</td>
<td>Up to 100 mi</td>
</tr>
<tr>
<td>Blue Bird</td>
<td>Type C</td>
<td>Vision Electric</td>
<td>77</td>
<td>160 kWh</td>
<td>Up to 120 mi</td>
</tr>
<tr>
<td>Blue Bird</td>
<td>Type D</td>
<td>All American RE Electric</td>
<td>84</td>
<td>160 kWh</td>
<td>Up to 120 mi</td>
</tr>
<tr>
<td>GreenPower Bus</td>
<td>Type D</td>
<td>Synapse 72 School</td>
<td>72</td>
<td>194.5 kWh</td>
<td>Up to 150 mi</td>
</tr>
<tr>
<td>Lion</td>
<td>Type A</td>
<td>e-Lion A</td>
<td>26</td>
<td>80 kWh or 160 kWh</td>
<td>Up to 150 mi</td>
</tr>
<tr>
<td>Lion</td>
<td>Type C</td>
<td>e-Lion C</td>
<td>72</td>
<td>220 kWh</td>
<td>Up to 155 mi</td>
</tr>
<tr>
<td>Lion</td>
<td>Type D</td>
<td>e-Lion D</td>
<td>84</td>
<td>220 kWh</td>
<td>Up to 150 mi</td>
</tr>
<tr>
<td>Thomas Built</td>
<td>Type C</td>
<td>Saf-T-Liner C2 Jouley</td>
<td>81</td>
<td>155 kWh</td>
<td>Up to 120 mi</td>
</tr>
</tbody>
</table>
Charging Infrastructure

All buses equipped with SAE J1772 plug

AC Level 2
- Supply 19.2 kW of power
- Charging Time = 4-5 hours
- Cost = $3,000 - $10,000

DC Fast Chargers
- Supply 90 kW of power
- Charging Time = 20-30 minutes
- Cost = $25,000 - $35,000 (not including installation)
Demand Charges

Schools should be aware of demand charges – charging during peak periods

Reduce costs by charging at night
## V2G and V2B Technology Incentives

<table>
<thead>
<tr>
<th>Utilize bi-directional chargers</th>
<th>Costs not yet known</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Vehicle-to-Grid (V2G) – supply power back to grid</td>
<td>- Expensive</td>
</tr>
<tr>
<td>- Vehicle-to-Building (V2B) – supply power to building</td>
<td>- Opportunities to collaborate with utility providers</td>
</tr>
</tbody>
</table>
Electric School Bus Opportunities

V2G

- School buses sit idle the majority of the day, so could be a unique source of power during peak periods of high demand.
  - Potential savings of up to $230,000 over 14 years
  - Schools with V2G Plans
    - Nuuve - California
    - Duke Energy - North Carolina
    - Dominion Energy - Virginia
    - DTE Energy - Michigan
Electric School Bus Opportunities

V2B

- School buses sit idle the majority of the day, so could be a unique source of power during peak periods of high demand.
  - Potential savings of $1,700-$2,000 within 2 years
  - Infrastructure costs unknown
  - School would need to reduce demand during each 15 minute period of peak demand
  - Charging Management and strong partnership with utility company needed
  - Most benefit would come with large number of buses and utilizing V2B in summer months
Electric School Bus Opportunities

- **Regenerative Braking**
  - Brakes use creates kinetic energy which sends energy back to the motor.
  - This energy is then used when the bus accelerates.
  - Longer periods of braking are better, bus driver training can reinforce the benefits of gradual braking.
Alternative Fuel School Bus Opportunities

- Financing Opportunities
  - Volkswagen Settlement Funds
  - Texas Clean School Bus Program
School Buses in Texas

- 30,541 school buses in Texas traveled 280,894,699 miles
- 70 school districts operating
- Over 3,000 propane school buses
- 0 Electric school buses operating
- $6,070,000 grant funding awarded
- 125 buses replaced through TCSB Program
# Current Electric School Bus Deployments in the U.S.

<table>
<thead>
<tr>
<th>School District</th>
<th>State</th>
<th>Number of Buses</th>
<th>Bus Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amherst Regional Public School District</td>
<td>MA</td>
<td>1</td>
<td>Lion</td>
</tr>
<tr>
<td>Bay Shore Union Free School District</td>
<td>NY</td>
<td>4</td>
<td>Blue Bird</td>
</tr>
<tr>
<td>Calaveras Unified School District</td>
<td>CA</td>
<td>3</td>
<td>Blue Bird</td>
</tr>
<tr>
<td>Cambridge Public School District</td>
<td>MA</td>
<td>1</td>
<td>Lion</td>
</tr>
<tr>
<td>Concord Public School District</td>
<td>MA</td>
<td>1</td>
<td>Lion</td>
</tr>
<tr>
<td>Franklin Pierce School District</td>
<td>WA</td>
<td>1</td>
<td>Blue Bird</td>
</tr>
<tr>
<td>Kalamazoo Public Schools</td>
<td>MI</td>
<td>1</td>
<td>Lion</td>
</tr>
<tr>
<td>Lakeville School District</td>
<td>MN</td>
<td>1</td>
<td>Lion</td>
</tr>
<tr>
<td>Los Angeles Unified School District</td>
<td>CA</td>
<td>1</td>
<td>GreenPower</td>
</tr>
<tr>
<td>Phoenix Union High School District</td>
<td>AZ</td>
<td>1</td>
<td>Blue Bird</td>
</tr>
<tr>
<td>Rialto Unified School District</td>
<td>CA</td>
<td>2</td>
<td>GreenPower</td>
</tr>
<tr>
<td>Three Rivers Community Schools</td>
<td>MI</td>
<td>2</td>
<td>Lion</td>
</tr>
<tr>
<td>Torrance Unified School Districts and San Diego Unified School District</td>
<td>CA</td>
<td>6</td>
<td>Blue Bird</td>
</tr>
<tr>
<td>Twin Rivers Unified School District</td>
<td>CA</td>
<td>30</td>
<td>Lion</td>
</tr>
<tr>
<td>West Fargo Public Schools</td>
<td>ND</td>
<td>1</td>
<td>Blue Bird</td>
</tr>
<tr>
<td>White Plains School District</td>
<td>NY</td>
<td>5</td>
<td>Lion</td>
</tr>
</tbody>
</table>
Current Electric School Bus Deployments in the U.S.

- 61 deployments
- 8 states

Map showing deployments across the U.S.: 42 in California (CA), 1 in Arizona (AZ), 1 in North Dakota (ND), 1 in Minnesota (MN), 3 in Michigan (MI), 9 in New York (NY), and 3 in Maryland (MD).
Lessons Learned from Current Deployments

1. Amherst Regional Public School District,
2. Concord Public School District,
3. Cambridge Public School District

- Operating efficiency less than expected, 2.38 kWh per mile.
- Charging strategies are needed, as operating efficiency decreased if buses were plugged in for more than 10 hours.
- The three schools paid $7,240 in 12 months, $2,608 of that was a result of demand charges.

Massachusetts
Lessons Learned from Current Deployments

Twin Rivers Unified School District

- Up to $15,000 saved each year on fuel and maintenance costs.
- Challenges with charging infrastructure and batteries unable to sync.
- Collaborated with local community college to implement courses aimed at electric vehicle maintenance.
Lessons Learned from Current Deployments

New York

White Plains City School District

- School bus operations are contracted out.
- Well received by community.
- Local utility contributed $100,000 for each bus in exchange for V2G utilization.
Lessons Learned from Current Deployments

- All of the schools have continued to use the electric school buses.
- Twin Rivers Unified School District has continued to add electric buses to its fleet, now boasting a fleet of 30 electric school buses.
Planned Electric School Bus Deployments

- 192 buses
- 17 states
Considerations for School Districts

- Utilize funding opportunities.
- Be proactive in route planning and deployment.
- Build strong relationships with the school bus manufacturer and utility company.
- Inquire about current price quotes.
- Be proactive with driver and technician training.
- Ensure that chargers are in proper locations that will not block access points.
- Investigate V2G and V2B technologies for potential implementation benefits.
- Utilize the AFLEET Tool to estimate total cost of ownership and emission differences compared to diesel buses.