June 1, 2018

Going Electric!
Electric Bus Technology

Green Your Fleets

Jennifer Wallace-Brodeur

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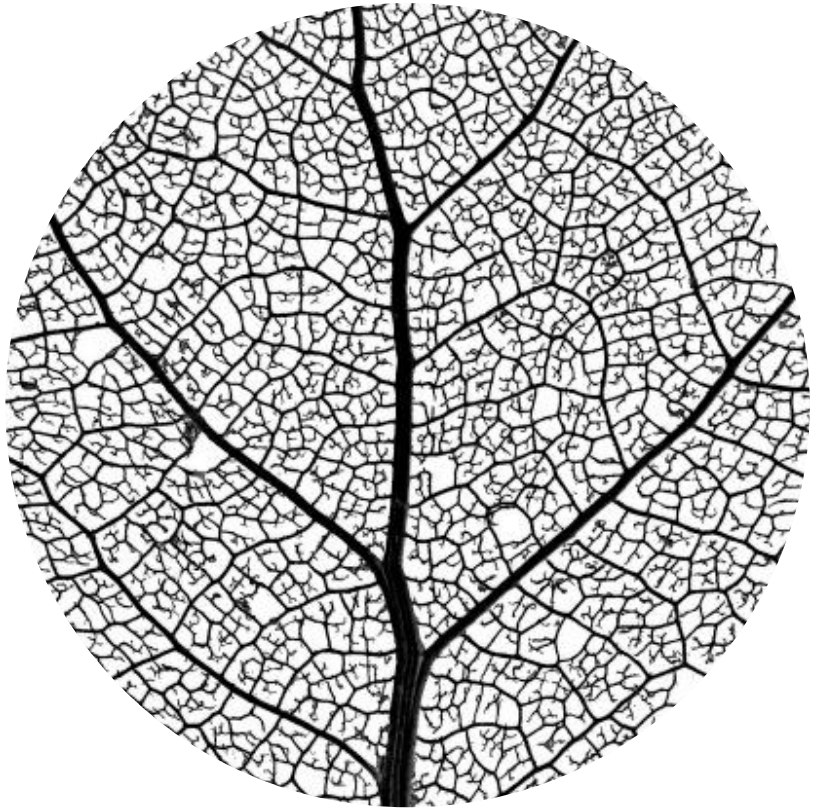
To act with urgency to enhance the economic, environmental and societal benefits of clean and efficient energy for all people.



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Agenda

- Why Go Electric?
- Electric Transit Buses
- Electric School Buses

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Why do we care?

Transportation, Climate Change, and Health Impacts

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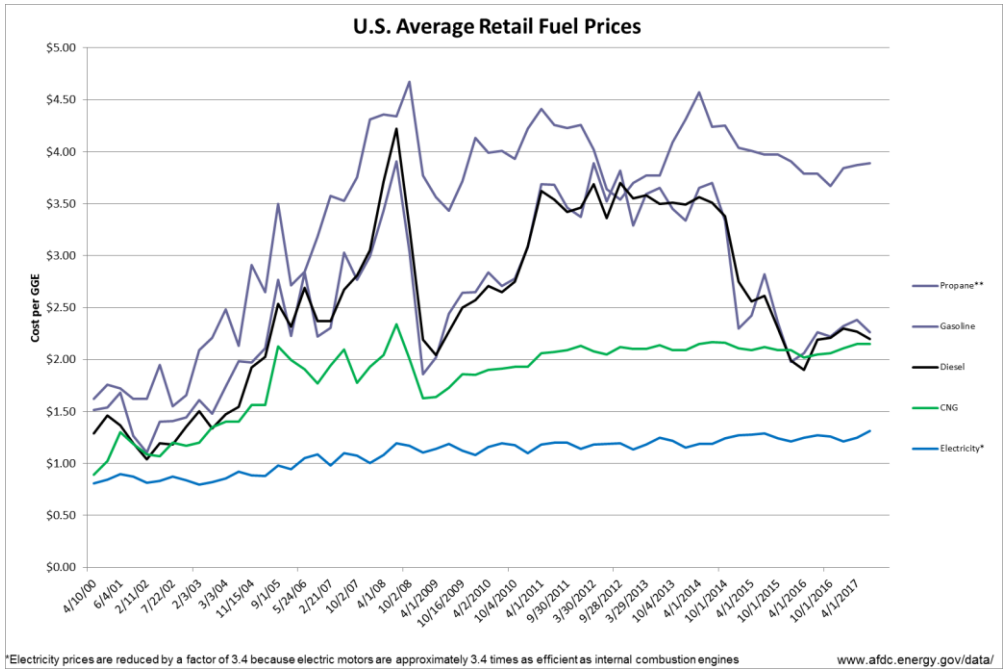
Electric Bus Benefits

- Better for the environment and public health
- Cheaper to run
  - Electric buses are less expensive to fuel and have lower maintenance cost than a diesel bus
- Energy independence
  - Keep our energy dollars here
  - Stabilize transportation costs
- Fuel price stability
- Potential value from using battery as an energy storage



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Electric Transit Bus Fundamentals

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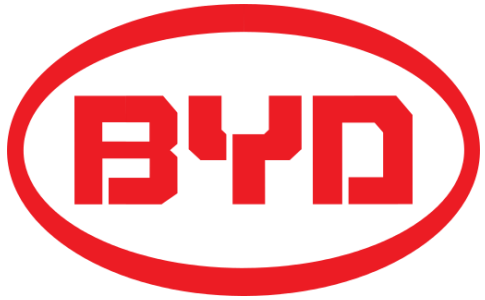
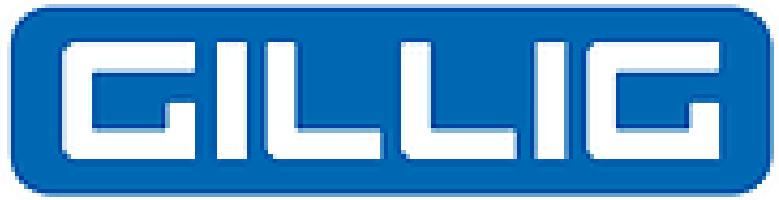
Overview: Electric Transit Buses in the US

- Electric transit buses are a relatively mature technology
  - Deployment across the Unite States
  - Multiple models and manufacturers
  - Vehicles range up to 300 miles on one charge
  - Cost has come down over the last 10 years but still considerably more expensive than a diesel vehicle

Major Manufacturers





Technology Overview

40ft or 35ft Transit Bus	Short Range	Extended Range
Range (Miles)	50-70	160-300
Battery Capacity (kWh)	94-126	324-440
Max Charging Rate (kW)	240-325	80-120
Mile Replenished in 5 min	12	5
Estimated Total Charging Time (0-100%)	<1 hour	<4.5 hours
Vehicle Costs	$780,000	$730,000-850,000
Charger Costs	$350,000	$8,000-$40,000

Technology Overview: Electric Cutaway

Electric Cutaway Estimated Vehicle Specs	
Range (Miles)	90-120
Battery Capacity (kWh)	100-135
Level 2 Estimated Total Charging time (0-100%)	8 hours
DC Fast Charger Estimated Total Charging Time (0-100%)	1.5-3 hours
Vehicle Costs	$180,000-$200,000
Level 2 Charger Costs	$4,000

Vermont Electric Transit Pilot

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Vermont Electric Transit Pilot: Project Overview

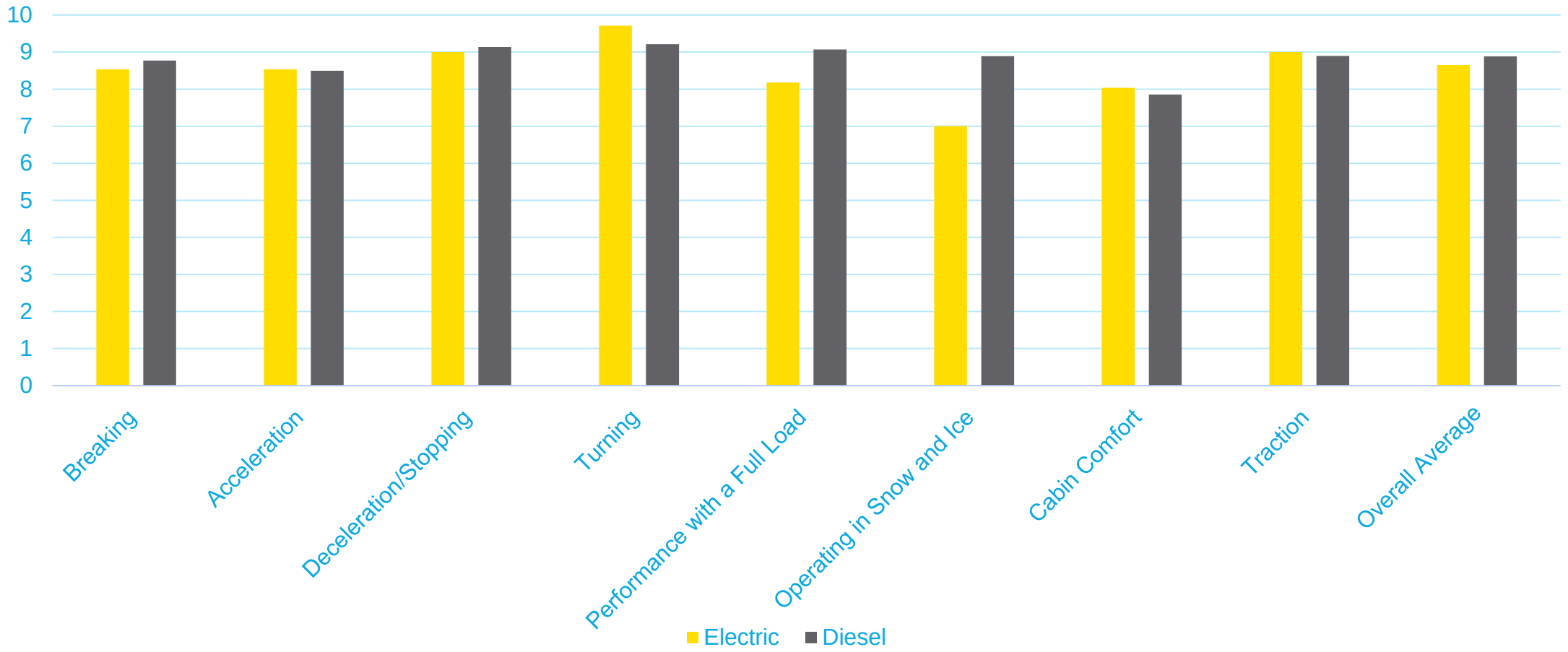
Electric Transit Bus Demonstration Deployment Schedule

Agency	Time Period
Advance Transit	February 18 – March 24, 2017
University of Vermont	March 27 – March 31, 2017
Green Mountain Transit	April 3 – April 14, 2017

Vermont Electric Transit Pilot: Energy Data

	Advance Transit	UVM	GMT	Estimated Comparable Diesel Bus
Miles Traveled	1,890	220	786	-
Fuel consumed (kWh)	3,160	729	1,719	-
Fuel Efficiency (miles/kWh or miles/gallons	0.60	0.30	0.46	4.26
Fuel Cost per Unit	$0.156/kWh	$0.10/kWh	$0.10/kWh	2.25/gallon
Fuel Cost ($ per mile)	$0.26	$0.33	$0.22	$0.53

How did the Electric Transit Bus Perform?



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Green Mountain Transit's Electric Transit Buses

- As a result of this project GMT, VTrans, VEIC, and BED collaborated to apply for additional funding.
- All funding applied for was received.
- 4 all-electric transit buses will be coming to Vermont!

Funding Awarded	
FTA Low No Award	$480,000
VLITE (BED Led)	$175,500
BED Tier 3	$262,000
Total	$917,500
Per Bus	$229, 375

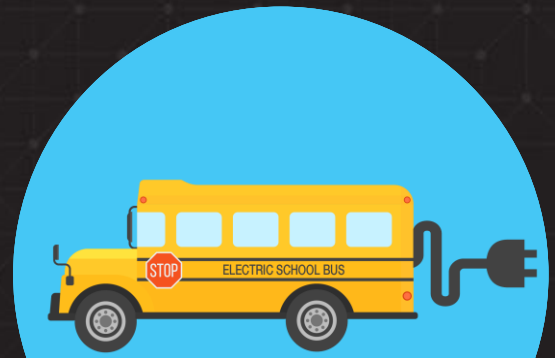
Lessons Learned

- All-electric buses are more efficient than diesel buses, but efficiency varies by operating environment.
- The electric transit bus was consistently less expensive to operate as compared with a diesel bus.
- Drivers generally liked driving the electric buses once they had a chance to experience the vehicle.
- Electric buses produce significantly fewer emissions than a new diesel bus, even when they are experiencing relatively low efficiency.

Lessons Learned, continued

- Utilities are key stakeholders in adopting electric transit technology
  - Seek utility input in procurement decisions & technical assistance for installation of EVSE
  - Engage utility to identify charging strategies to maximize fuel savings

Electric School Bus Fundamentals



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Electric School Bus Fundamentals

- Size of Opportunity
  - 400,000 school buses nationally
    - 90% – 95% of the fleet is diesel
    - Most popular alternative fuel is propane
  - About 55 electric school buses on the road (2017)
    - 3 in Massachusetts
    - 1 in New York
    - 1 in Minnesota
    - 50+ in California

– *More planned for New York and California*

Electric School Bus Barriers

- Upfront Costs
  - Electric School buses are 2 – 3 times the cost of a diesel.
- Requires new fueling practices and infrastructure
- Requires training for mechanics and drivers.

Electric School Bus Fundamentals: Models Available

TransTech- Type A

Starcraft- Type C

eLion – Type C

More Products Coming!

- 2018
  - All Electric Bluebird School Buses (Type A and D)
- 2019 – Just announced!
  - Thomas Saf-T-Liner C2 – 100 miles
  - IC chargE – 120 miles

Charging Equipment for School Buses

- Most electric school buses utilize standard AC Level 2 chargers.
- Most require higher amperage (60 amps) then standard Level 2 chargers.
- May need access to 3-phase power.

MA Electric School Bus Pilot

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Project Overview

- Goals –
  - Deploy electric school buses
  - Demonstrate V2G/V2B capabilities
  - Financial value of battery as energy storage resource
  - Outreach and Education
- Key Players
  - MA Department of Energy Resources
  - Vermont Energy Investment Corporation
  - Demonstration Sites / Participating Schools

Massachusetts Electric School Bus Pilot Project Sites

Location:	Amherst	Cambridge	Concord
School type:	Regional Small-town/rural	Urban	Suburban
Service structure:	School owns vehicles, contracts for service	Contractor owns buses and operates service	Owns/operates school bus service
Local utility:	Investor owned	Investor owned	Municipal
Unique features:	Pays demand charges	Renewables on-site Pays demand charges	Renewables on-site Pays demand charges

Lessons Learned

Easier Than We Thought	Harder Than We Thought
Public Opinion	Charging Siting and Installation
Driver Training and Adoption	Manufacture Communication
Vehicle Delivery Time	Resolving Minor Mechanical Issues
Utility Interaction	Bi-directional Charging

Project Findings

- More testing and demonstrations needed
- Managed charging needed to realize energy and fuel cost savings
- Significant GHG reductions compared to diesel
- Vehicle to grid or vehicle to building applications not currently cost effective

Questions?

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Thank you!