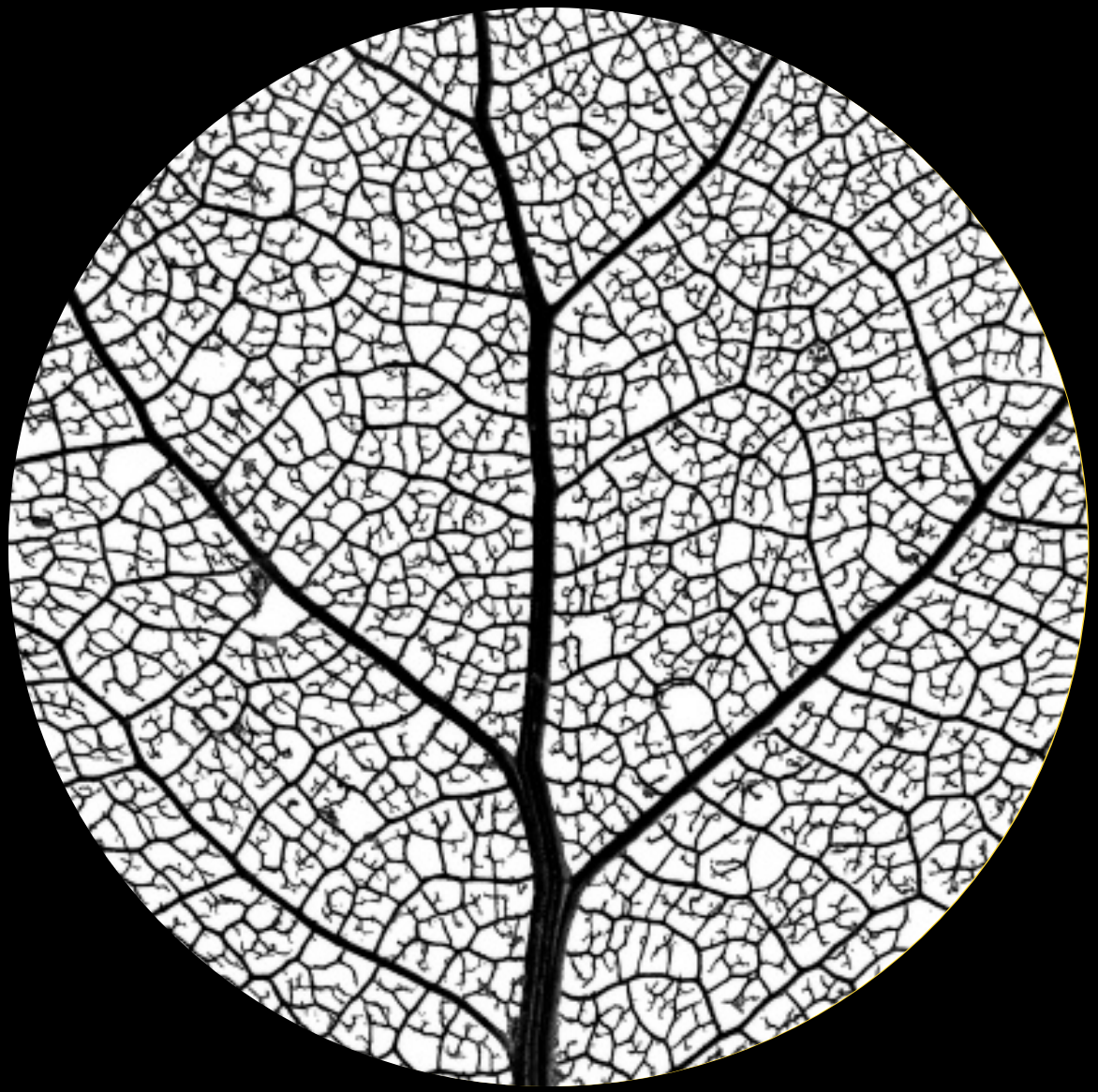
Demonstrating Electric School Buses

Lessons from the Field

Vermont Energy Investment Corporation



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

Vermont Energy Investment Corporation

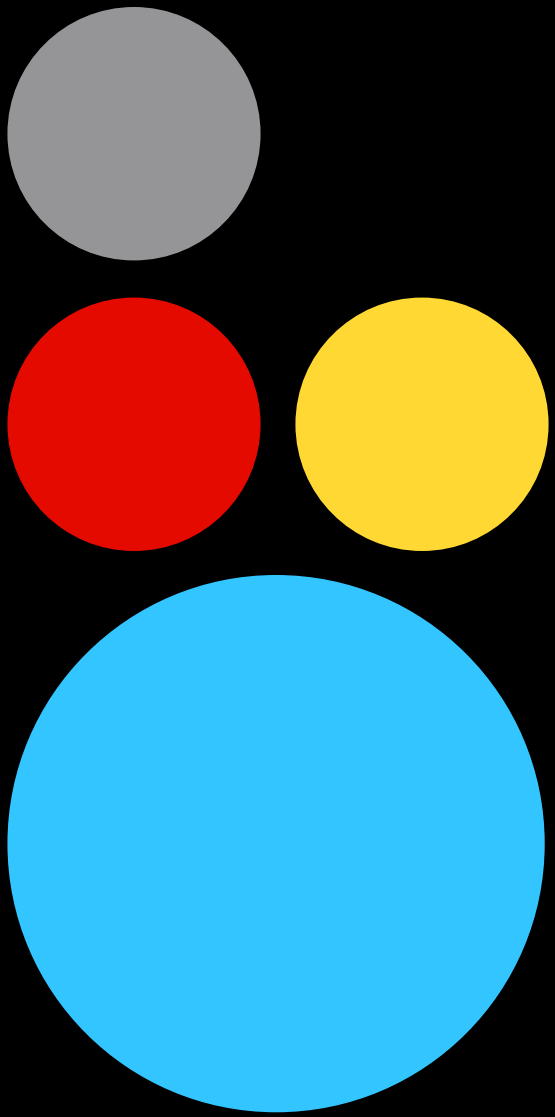
Advanced Energy Conference 2018

Presentation Overview

Massachusetts Electric School Bus Pilot Project

Lessons for Demonstration Projects

Massachusetts
Electric School Bus Pilot



Vermont Energy Investment Corporation

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

Amherst	Cambridge	Concord
Small, rural district	Small, urban district	Large suburban district
Operates own bus service	Contracts for bus service	Operates own bus service
Fleet of about 10 buses with one technician	School district had one bus (electric one) and one driver	Large fleet of 50-60 buses with small team of technicians
Large investor own utility	Large investor own utility	Municipal utility

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?

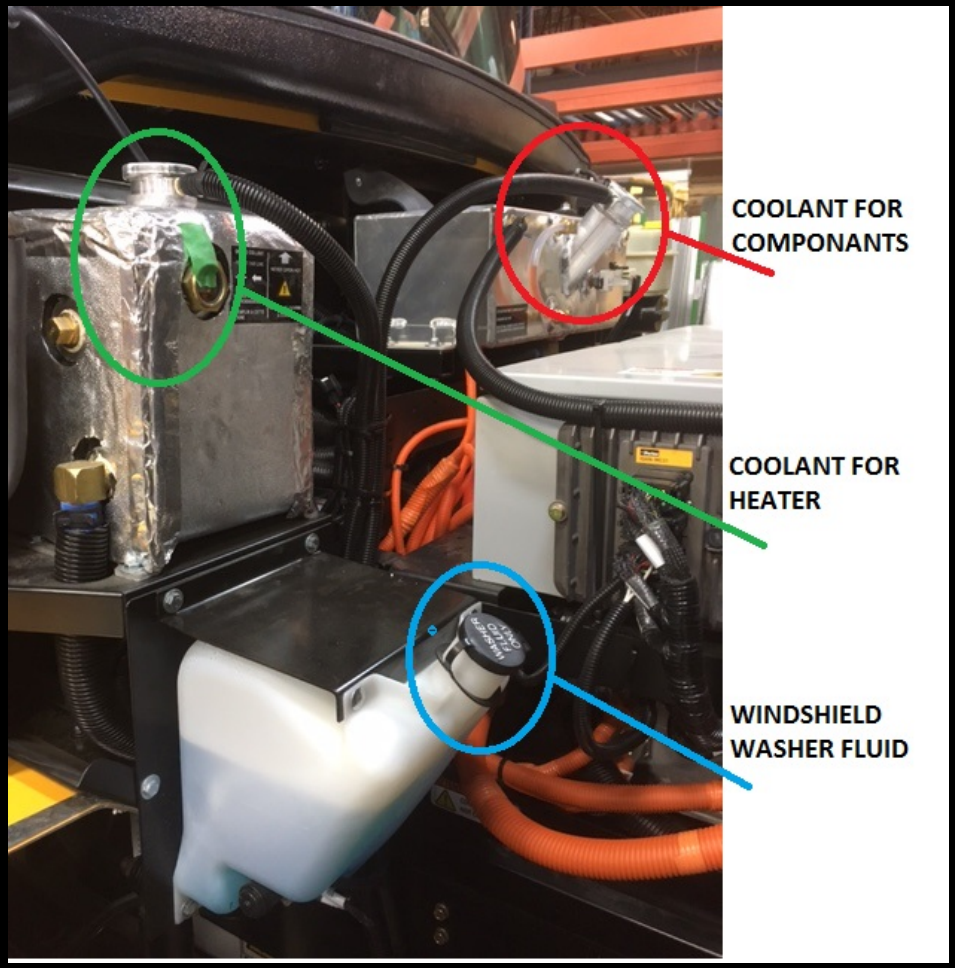
Massachusetts Electric School Bus Pilot
Vehicle Reliability

- 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

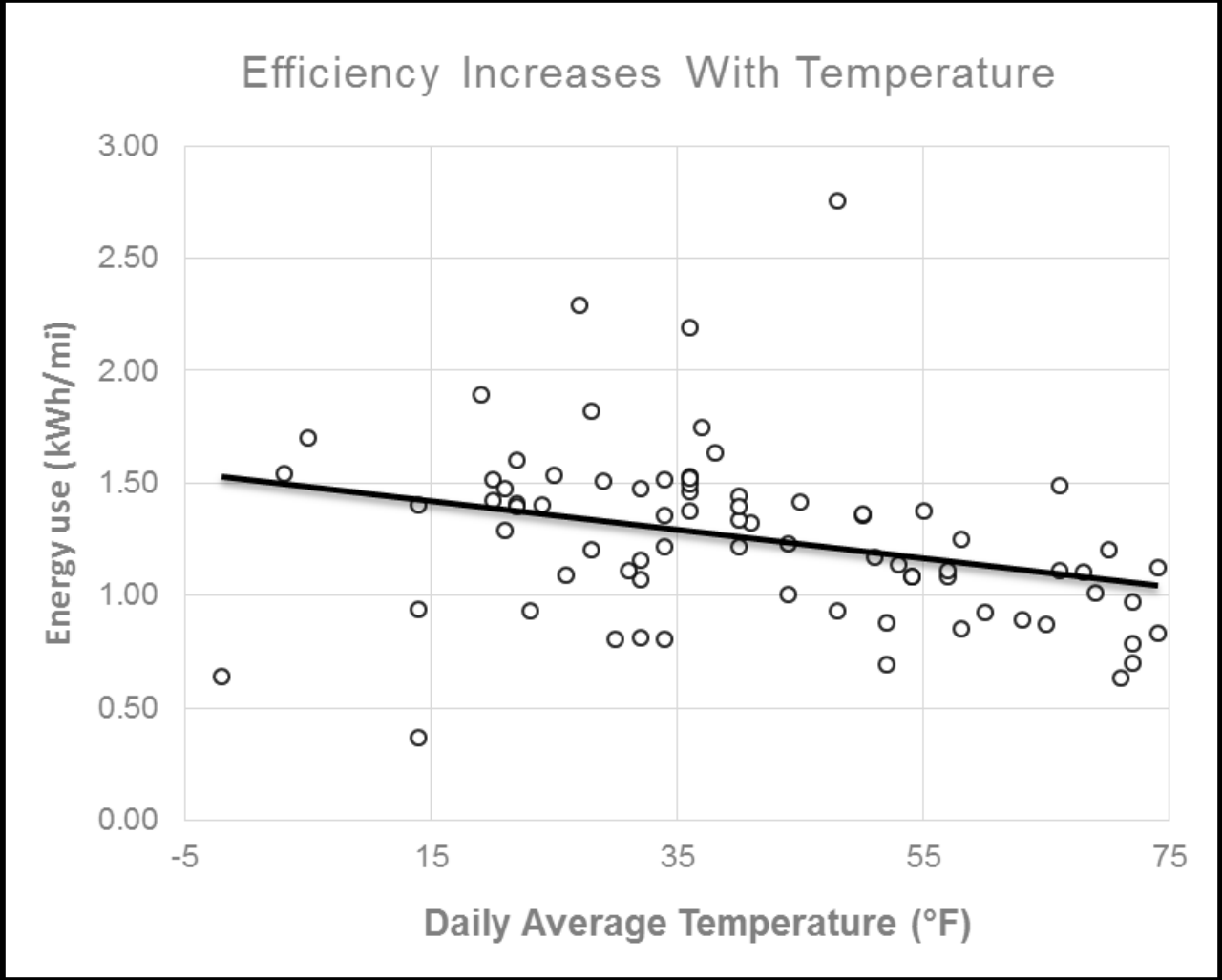
Massachusetts Electric School Bus Pilot
Energy Efficiency

- 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

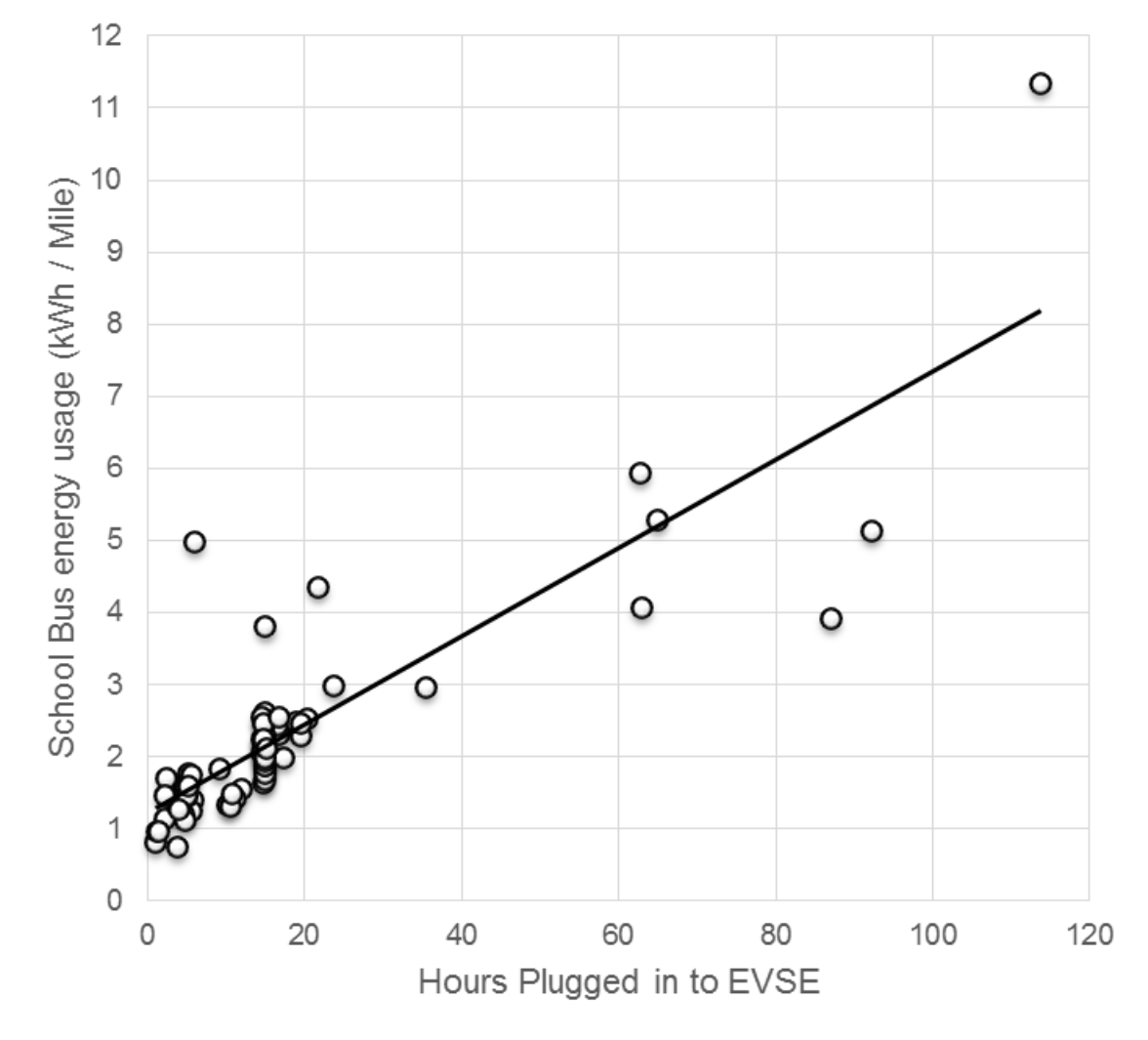
- But not efficient when charging is taken into consideration
  - Bus plugged in overnight, 2.38 kWh / mile
  - Bus plugged in over school break, 4.29 kWh / mile

Massachusetts Electric School Bus Pilot
Relationship between Temperature and Efficiency



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

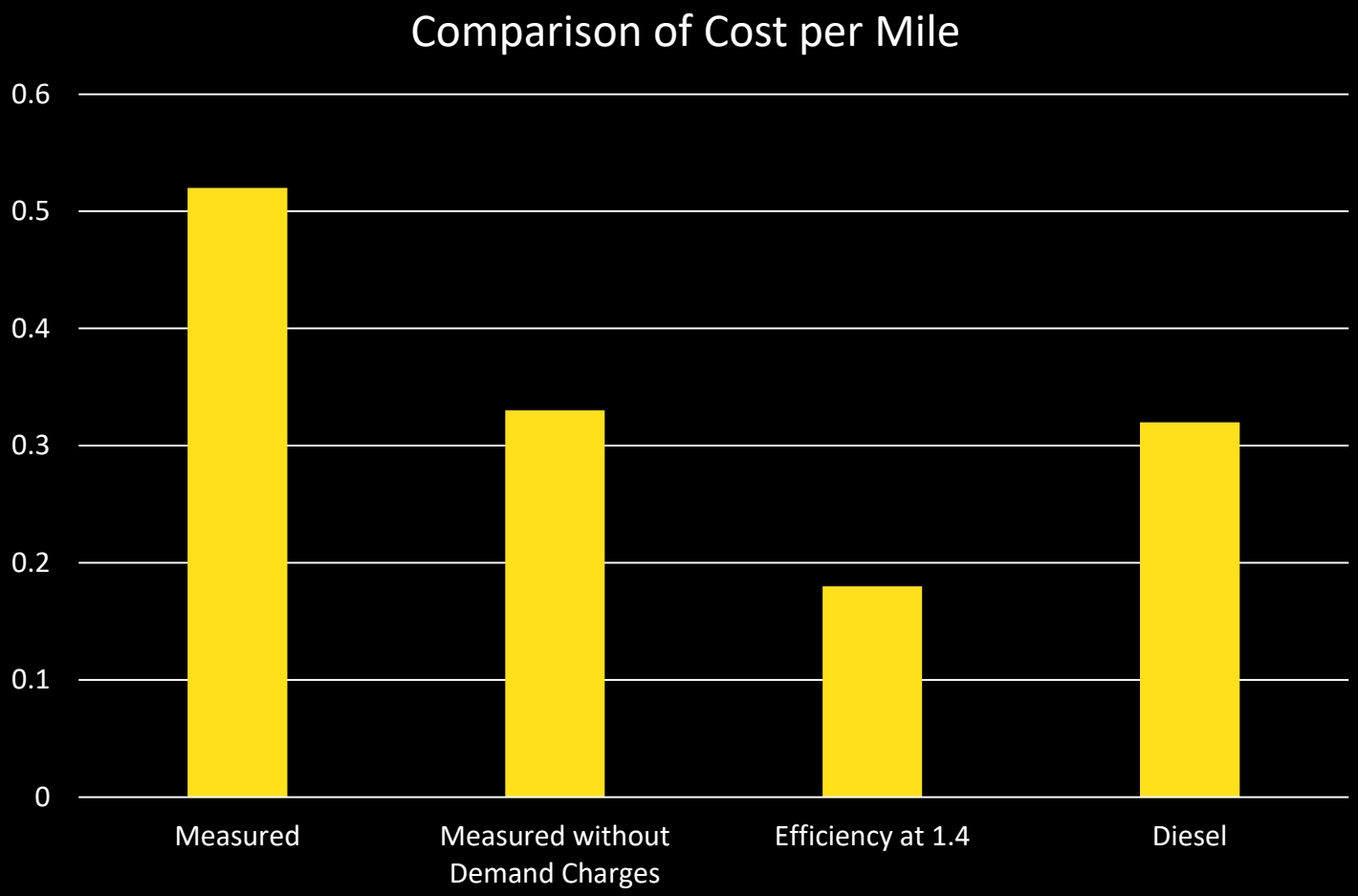
Electric School Bus

- 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



Massachusetts Electric School Bus Pilot

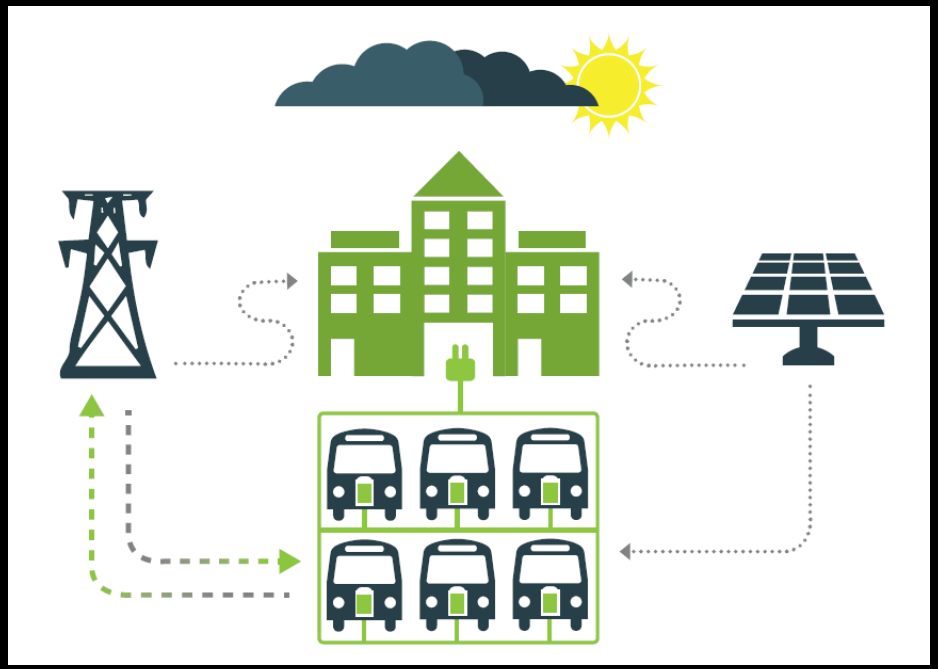
Cost Effectiveness

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

Bethany Whitaker
Vermont Energy Investment Corporation
(802) 540-7861
bwhitaker@veic.org