Electric School Buses

Feasibility in Vermont

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List of Acronyms

AC	alternate current
BTEMS	Barre Town Elementary and Middle School
DC	direct current
DERA	Diesel Emissions Reduction Act
EPA	U.S. Environmental Protection Agency
EVSE	electric vehicle supply equipment
GMP	Green Mountain Power
ISO-NE	Independent System Operator for New England
NHTSA	National Highway Traffic Safety Administration
RCPS	Rutland City Public Schools
V2B	vehicle-to-building
V2G	vehicle-to-grid

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Summary

Yellow school buses have been a part of the education experience for students across the United States for more than 100 years with school transportation provided by the majority of school districts in the country. Diesel school buses, however, contribute to numerous health and environmental risks. In addition to emitting greenhouse gases, diesel buses also expose children directly to diesel emissions including carcinogens, particulates, and other substances known to cause respiratory inflammation and other health risks. Powered only by electricity, plug-in electric school buses have no tailpipe emissions and are emerging as a clean alternative to diesel buses. However, there are challenges associated with electric buses, namely the purchase price of the vehicle. For their benefits to be realized, electric school buses must first be financially viable options for school districts.

School Transportation Policy and Management

In the State of Vermont, the State Board of Education sets general guidance for transportation programs, but local supervisory unions oversee school transportation. Supervisory unions in Vermont manage school districts, and include groups of schools spread over a single or multiple communities. The Vermont State Legislature passed Act 46 of 2015, intended to manage education costs and at the same time, provide the best possible educational outcomes. One of the fundamental goals of Act 46 is to reduce the number of supervisory units in the state through a system that provides incentives to schools that merge.

As Vermont transitions to fewer, but larger school districts, students will travel farther to school, making school transportation both more expensive and more important. Addressing these challenges could lead to fundamental shifts in how school transportation is operated and managed, as supervisory unions consider how to cost-effectively continue to provide transportation services. New systems, services, and/or technologies that can provide operational cost savings will likely be considered. School boards in Vermont, however, are ultimately responsible for approving policy and spending plans and school budgets are voted on each year by residents of the community. Citizen engagement through school boards and budget votes ensures decision-making is aligned with the values and goals of the community.

School transportation management includes a long list of activities related to service operations and fleet management. Supervisory unions may manage school transportation using their own staff, or they may contract with a private enterprise to provide some or all of the school transportation functions. Cost is the primary reason service is contracted out, either because a private operator can provide the same service for a lower price, or because the size of the school transportation service is too small to operate cost efficiently. In terms of purchasing practices, there is a fair amount of variation in how school districts and private contractors purchase vehicles, although in nearly every case, school buses are purchased outright. The average age of a school bus in the U.S. is 9.3 years, but recognizing the harsh climate of Vermont winters and accompanying road treatments, the Vermont Department of Education allows school districts to budget for a shorter vehicle life of seven years.

Safety and Health

Due to federal and state regulations, school transportation is one of the safest forms of transportation in the U.S. Safety regulations, however, primarily address outcomes related to vehicle crashes and students' safety getting on and off the bus, and there are few rules related to safety impacts associated with vehicle emissions and air quality. Fine particle pollution from diesel emissions (including school buses) is linked to serious health risks including asthma, cancer, cardiovascular harm, developmental harm, and many others. Children are among those most susceptible to these health risks.

In recognition of the health impacts of diesel emissions, the Diesel Emissions Reduction Act (DERA) was passed as part of the Energy Policy Act of 2005 and, among other things, provides funding to replace vehicles, or improve vehicle engines to reduce emissions. At the state level, the program is administered by the Vermont Department of Environmental Conservation, Air Quality and Control Division, which also receives funding through DERA, to support retrofits of diesel engines or to cover the costs of new vehicles.

Electric Alternative

Electric buses are an emerging technology being incorporated into school bus service. They offer considerable advantages over diesel powered vehicles including lower fuel costs, lower operating costs, cleaner, quieter operations, as well as health benefits. Electric vehicles are powered by electricity stored in batteries on-board the vehicle. Therefore, to power up, an electric bus uses charging equipment connected to the electric grid, rather than filling up with diesel. In terms of driving range, electric school buses currently available on the market can operate between 60 and 80 miles on a single charge, a range long enough to cover average routes in Vermont.

Electric school buses are considerably more expensive than traditional diesel buses, at least in terms of upfront costs. VEIC estimates the all-in purchase costs of an electric school bus at $350,000, compared to a conventional diesel bus which costs between $85,000 and $100,000. Operation costs, including fuel and maintenance, however, are lower for an electric school bus. But it is shown in this study, lower operating costs alone are not enough to offset the higher purchase price, at least with 2016 prices.

However, in addition to lower operation costs, electric school buses have the potential to create significant value. The health benefits are clear, but when connected to the electrical system, electric school buses also present a significant asset to the grid. One of the defining attributes of electricity is that it must be used when it is generated. This limitation can be overcome by converting electricity to another form of energy or storing it in a device, such as a battery. The potential to store energy, therefore, is an asset that has value to electricity producers and consumers. Additionally, energy storage systems have increased in importance in the past several years, as energy production has diversified to incorporate energy sources with intermittent supply, such as renewables. Because electric school bus batteries can be used to store and discharge energy, they have the ability to provide this valuable storage resource.

In addition to health benefits resulting from reduced diesel emissions, this study considers the value of electric school buses serving in three resource capacities:

- **Demand Side Management:** Demand side management efforts adjust load, or demand for energy, to spread electricity use more evenly throughout the day, allowing utilities to use existing infrastructure more efficiently. In most cases, school districts have flexibility about when they charge an electric school bus. Therefore, charging can be timed when demand on the grid and the price of electricity is low.

- **Vehicle-to-Building Integration:** When equipped with the necessary hardware and software, electric vehicle batteries have the ability to discharge power back to the grid or to a building. When connected to a building, an electric school bus battery can provide power to the building. This means that if power is lost, the school bus can serve as a valuable back-up power supply. Given that schools often serve as emergency shelters, the ability to provide even small amounts of power is a significant value that electric school buses create.

- **Vehicle-to-Grid Integration:** When an electric vehicle is equipped with the necessary inverters and control software, it also has the potential to discharge energy back to the electrical grid. Vehicle-to-grid (V2G) systems have been demonstrated to be able to provide many of the same reliability services to the grid traditionally provided by generation resources. This application of electric vehicles as resources in wholesale energy markets has the potential to directly generate revenue from providing reliability services to the grid.

Payback Analysis

A key part of being able to establish electric school buses as viable alternatives to diesel school buses is the ability to identify ongoing revenue generating opportunities, or a buses' ability to provide additional benefits to the community that are valued at or near the incremental cost of the electric school bus. However, because many of the benefits of electric school buses are less tangible, such as the health benefits from reduced diesel emissions, an important part of this analysis is determining if the direct financial benefits are substantial enough to offset the higher initial investment costs. A "payback period" analysis, or the period of time required to pay the higher investments costs, is used to do this. Four scenarios are examined:

- Federal grant programs to offset vehicle costs
- Joint ownership model with utilities to offset vehicle costs
- Reduced school operating costs through vehicle-to-building (V2B) opportunities
- Revenue generated from wholesale market participation

As a baseline, the payback analysis shows that operation costs, including fuel and maintenance, are lower for an electric school bus, but the lower operating costs alone are not enough to offset the higher purchase price, at current costs. Based on current estimates of costs, the lower ongoing operation costs of an electric school bus would pay back the higher upfront costs in 18 years. Because this is considerably longer than the expected useful life of a school bus of seven to ten years, this is not an economically feasible option for schools.

V2B or V2G strategies create opportunities for the school district (or school bus owner) to earn revenue, but they also require additional capital investments. In both cases, the revenue generated does not offset the investment cost, and neither strategy generates enough revenue to make an electric school bus financially feasible. Given the current state of the technology and retail and wholesale market structures, we suggest that the most promising – and the easiest – way to make an electric school bus project financially feasible is to use DERA funding to reduce the cost of the vehicle. Lower vehicle costs combined with lower fuel and reduced maintenance costs, means a school district can break even on an electric school bus investment. If some of the other cost savings or revenue generating scenarios can be implemented, then an electric school bus could be financially viable.

Framework for Implementation

School districts make transportation decisions that are influenced or directed by government policies and regulations, therefore making it essential to understand the policy and regulatory environment in which decision makers are operating.

State policies and regulation can either encourage and accelerate electric school bus adoption or may be barriers. Health in All Policies, carbon pricing, and the role of emissions standards are considered and their potential to impact electric school bus implementation is discussed. Additionally, because utilities must be engaged in a transition to electrified school transportation, a regulatory framework for how to assign benefits, costs, and risks would be helpful to make it easier for schools districts to understand the costs and issues with adopting this technology. And finally, at the local level, it's important to understand procurement practices and how they need to be adjusted to facilitate a transition to electric school buses.

Case Studies

This study concludes with a set of three case studies of schools in Vermont. It is not expected that any one school will be able to take advantage of all revenue generating opportunities. Site specific variables will determine the viability of various opportunities. For example, if school buses are not physically parked at the school, it is unlikely that vehicle-to-building opportunities will be feasible. Therefore, the structure of electric school bus integration business models will vary from school to school, as will the value of potential opportunities. Site-specific characteristics pertaining to each school are considered and the opportunities most applicable at each school are presented.

Introduction to Electric School Buses

Diesel school buses contribute to numerous health and environmental risks. In addition to emitting greenhouse gases, diesel buses also expose children directly to diesel emissions including carcinogens, particulates, and other substances known to cause respiratory inflammation and other health risks. Not only are children exposed to the harmful emissions, but studies have shown that the diesel pollution actually concentrates inside the bus increasing children's exposure while riding school buses. In the state of Vermont, there are more than 1,800 diesel-powered school buses carrying over 75,000 children.

Powered only by electricity, plug-in electric school buses have no tailpipe emissions and are emerging as a clean alternative to diesel buses. In addition to the notable air quality and health benefits, electric school buses offer considerable advantages over diesel powered vehicles in terms of energy efficiency, lower operating costs, and quieter operations. At the same time, there are challenges associated with electric buses, namely the purchase price of the vehicle. For the benefits to be realized, electric school buses must first be financially viable options for school districts.

Whether or not electric school buses can be economically viable is not currently well understood. There is the potential for the higher upfront capital costs to be offset over time by lower operating and maintenance costs. Additionally, the large on-board batteries which store the power for electric school buses may in fact have value as a resource in other capacities. Connecting the batteries into the electrical system has the potential to provide power to a school building, decreasing costly peak electricity charges for schools, and may even be able to generate revenue.

When connected to the electrical system, electric school buses present a significant asset to the grid. One of the defining attributes of electricity is that it must be used when it is generated. This limitation can be overcome by converting electricity to another form of energy or storing it in a device, such as a battery. The potential to store energy, therefore, is an asset that has value to electricity producers and consumers. Energy storage systems have increased in importance in the past several years, as energy production has diversified to incorporate energy sources with intermittent supply, such as renewables (solar and wind). Even without renewables, energy storage systems can help stabilize the grid or local energy use by storing energy when supply outpaces demand and/or by supplying stored energy when demand outstrips supply. Electric school bus batteries can be used to store and discharge energy, therefore qualifying them as a storage resource.

There have been a handful of pilot projects that have demonstrated the potential to use electric vehicle batteries as an energy storage resource. To date, these demonstration projects have largely shown functional capability of the systems, but have not attempted to assess the overall costs and benefits as a test of economic feasibility. Additionally, one theoretical cost-benefit analysis has been conducted of electric school buses,[1] but this study focused on one potential revenue generating opportunity and did not delve into the real world applicability, such as considerations of school transportation funding or regulation.

[1] Noel, L. & McCormack R. 2014. A cost benefit analysis of a V2G-capable electric school bus compared to a traditional diesel school bus. *Applied Energy*, 126: 246-265.

This study builds off of this existing research with the intentions of going further in considering a more complete assessment of the environment in which electric school buses would be feasible. School transportation policy and funding are considered, as well as regulation pertaining to safety and health, operations, and management of school buses. An economic feasibility study is developed including the costs of traditional diesel buses and electric school buses, as well as an assessment of the payback period of electric school buses. Various options are presented as potential mechanisms to overcome the cost differential of electric school buses, and a framework is presented to facilitate addressing the necessary regulatory and policy gaps to enable a transition to electric school transportation. This study concludes with case studies of 3 schools in Vermont. Site-specific characteristics pertaining to each school are considered and the opportunities most applicable at each school are presented.

Current State of Student Transportation

School Transportation Policy and Funding

Yellow school buses have been a part of the education experience for students across the United States for more than 100 years. Providing school transportation followed local and regional decisions both to make school attendance compulsory and to regionalize educational facilities. As a result, not only were all school-age children required to attend school, many of them had to travel and/or travel further to get to school. Transportation, therefore, became an integral part of the public education system. The Commonwealth of Massachusetts was the first state to fund school transportation in 1869, followed by the State of Vermont in 1876. Currently, although school transportation is not mandated by the federal government, it is provided by the majority of school districts in the United States.[2]

Federal Government

Funding and operating school bus transportation is the responsibility of states and local school districts. This arrangement is consistent with the broader public education administrative and funding structure in the United States, where states and local jurisdictions are largely responsible for the costs and administration of public instruction, including developing curricula and setting standards for enrollment and graduation. Consistent with this structure, of an estimated $1.15 trillion spent nationally on education, the majority of the funds are provided by state, local, and private sources. The federal government does play a role in developing education policy and programs, with funding and guidance provided by the Department of Education. The Department of Health and Human Services also assists with the Head Start program and the Department of Agriculture with their School Lunch program.[3]

At the federal level, the U.S. Department of Transportation participates in school bus transportation because it manages transportation safety and standards overall. In addition, the National Highway Traffic Safety Administration (NHTSA)[4] sets standards for vehicle safety, as well as rules and regulations regarding driver eligibility, licensing requirements, and training. School buses fall within the NHTSA's jurisdiction, but the federal government does not provide funding for school bus purchases or operations.

State of Vermont

The Vermont State Board of Education sets broad policy and regulations regarding overall education standards in the state, including curriculum and attendance requirements for independent and publically funded schools. The Vermont Agency of Education provides staff resources to implement policies set by the State Board.

One of the unique features of public education in Vermont is that local education is partially funded through a statewide property tax. The statewide tax (Act 68) was intended to help equalize education quality across communities, regardless of the local tax base. The statewide property tax gives the State Board of Education additional responsibilities for equalizing

[2] Industry White Paper prepared by the National School Transportation Association, 2013
[3] U.S. Department of Education website (www2.ed.gov/about/overview/fed/role.html).
[4] NHTSA is a division within the US Department of Transportation

educational opportunity in the state, largely through the distribution and management of statewide property tax revenues.

With respect to transportation, the State Board sets general guidance for transportation programs, while local school districts determine the details of the service. The State Board also sets guidelines on allowable transportation expenditures, including bus depreciation schedules and whether funding is distributed for extraordinary transportation expenditures.[5] The Vermont Board of Education, in turn, verifies that individual school transportation systems meet state laws. State school transportation policy and funding will likely be further tested and refined as part of Vermont's most recent school reform legislation, Act 46 of 2015, an act related to making amendments to education funding, education spending, and education governance to support the goals of equity and quality, which encourages increased regionalization of schools.[6] As Vermont transitions to fewer, but larger school districts, more students will need transportation and more students will travel longer distances to school, making school transportation more important, complex, and expensive.

Consistent with the federal government, the Vermont Agency of Transportation is also involved in school bus transportation through vehicle safety standards. Vermont State law sets specific requirements for the vehicle maintenance. State law requires buses be inspected three times a year. It also lays out requirements for preventative maintenance, ongoing maintenance, and pre-trip daily inspections.[7]

Local School Districts

School districts in Vermont are managed by supervisory unions, which include groups of schools spread over a single or multiple communities (see Figure 1). This means some supervisory unions are largely funded by and primarily serve the residents of a single community. In other cases, schools districts are unions consisting of multiple communities. Supervisory unions may include local primary schools and regional secondary schools, or all schools may be regional. As of 2016, Vermont had 61 supervisory unions. However, as mentioned, recent legislative changes are encouraging school consolidations, which should reduce the number of supervisory unions.

Supervisory unions oversee school transportation. Some supervisory unions manage school districts through the budgeting process and allow individual schools to arrange their own transportation. Other supervisory unions manage and arrange school transportation for the entire district. School boards are ultimately responsible for approving policy and spending plans and school budgets are voted on each year by residents of the community. Citizen engagement through school boards and budget votes ensures decision-making is aligned with the values and goals of the community.

In 2014, statewide school transportation funding in Vermont accounted for about 3.8% of public education expenditures, totaling about $55 million.[8] In this same year, there were just over 85,500 students enrolled in public schools in Vermont; on a per pupil basis, transportation costs were about $640.

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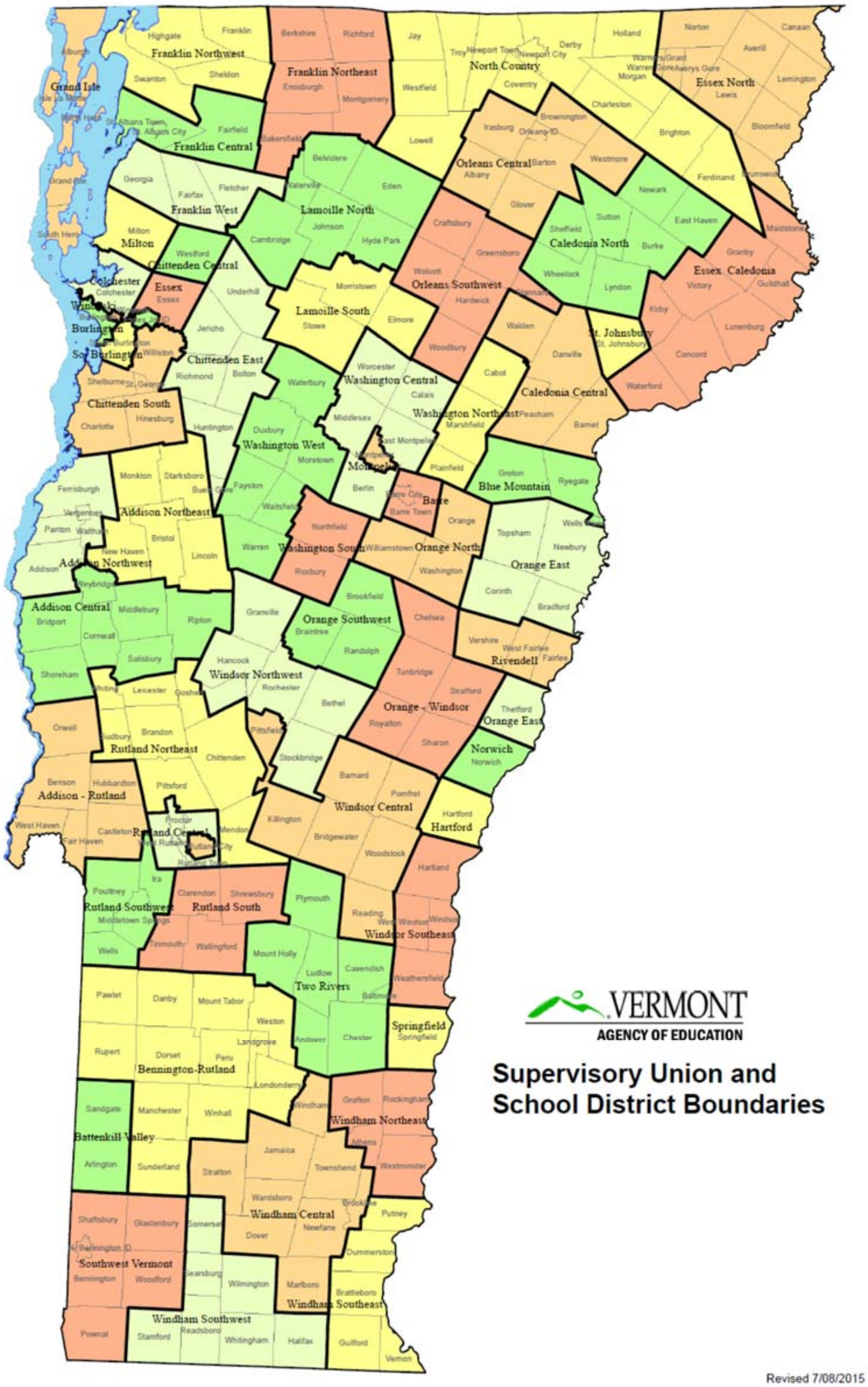
[5] http://education.vermont.gov/state-board
[6] http://education.vermont.gov/laws/2015/act-46#overview
[7] 23 VSA §1284 ~ Vehicle Maintenance
[8] Vermont State Board of Education (2015) Summary of Annual Statistical Report of Schools FY 2014. http://education.vermont.gov/documents/EDU-Data-SASRS_2014.pdf

Figure 1: Supervisory Unions and School Districts



Source: http://education.vermont.gov/documents/edu-map-supervisory-union-school-district-boundaries.pdf (current as of 07/08/2015)

Regulation

Safety

School buses are specialized vehicles that are among the most highly regulated vehicles in the United States.[9] At the federal level, the NHTSA sets standards for school buses, but states may add requirements as they see fit. For the most part, the regulations reflect stringent design characteristics intended to ensure a high level of safety for students. These safety regulations focus on the vehicle's visibility, protection during crashes, and ensuring students can travel as safely as possible to and from the bus.

In Vermont, school bus safety is governed through legislation and outlined in the Department of Motor Vehicles School Bus Safety Manual.[10] Safety requirements of drivers, safe operating procedures, student management, school bus routes, public relations, and vehicle maintenance are all covered in the manual. School bus drivers are required to undergo rigorous training and testing to receive a license for operating a school bus. They are required not only to have a commercial driver's license, but also specific training to operate a school bus.

As a result of federal and state regulations, school transportation is one of the safest forms of transportation in the U.S. Safety regulations, however, primarily address outcomes related to vehicle crashes and students' safety getting on and off the bus. There are fewer rules related to safety impacts associated with vehicle emissions and air quality.

Health

While students travelling on school buses are safer than those in cars, fine particle pollution from diesel emissions (including school buses) is linked to serious health risks including asthma, cancer, cardiovascular harm, developmental harm, and many others.[11] Those most susceptible to health risks from fine particle pollution include infants, children and teens.[12] Children are more vulnerable to health impacts from emissions because they are growing and because they have higher breathing rates.[13] In addition, studies in California and Connecticut show that children's exposure to harmful particulates on school buses may be higher inside the cabin of the school bus than outside of the bus. In some cases, particulate concentrations on school buses were 5-15 times higher than background concentrations.[14]

Recognizing the health impacts associated with diesel emissions on children, in 2007 the Vermont State Legislature enacted Title 23 V.S.A. § 1282(f), known as the Vermont School Bus Idling Rule. This law requires school bus operators to shut down their engines when they are on school properties until the bus is loaded or unloaded. The law allows some exceptions for special circumstances, but generally limits idling on school property to five minutes.

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[9] Industry White Paper prepared by the National School Transportation Association, 2013.
[10] http://dmv.vermont.gov/sites/dmv/files/pdf/DMV-VN003-Schoolbus_Manual.pdf
[11] U.S. Environmental Protection Agency, *Integrated Science Assessment for Particulate Matter*, December 2009. EPA 600/R-08/139F
[12] Mar TF, Larson TV, Stier RA, Claiborn C, Koenig JQ. An analysis of the association between respiratory symptoms in subjects with asthma and daily air pollution in Spokane, Washington. *Inhal Toxicol*, 2004; 16: 809-815.
[13] http://www.anr.state.vt.us/air/mobilesources/htm/Diesel.htm
[14] Wargo, John, Ph.D., Children's Exposure to Diesel Exhaust on School Buses. 2002. Environment and Human Health, Inc., p. 10.

Another recognition of the health impacts of diesel emissions at the federal level is the Diesel Emissions Reduction Act (DERA). This Act was first passed as part of the Energy Policy Act of 2005 and, among other things, provides funding to replace vehicles, or improve vehicle engines to reduce emissions. Generally, these funds are focused on replacing and retrofitting the oldest and most heavily polluting vehicles. This act has funded (for example) advanced emission control retrofits such as diesel oxidation catalysts, closed-crankcase ventilation systems, and auxiliary fuel operated heaters. DERA funds to reduce diesel emissions are administered by the U.S. Environmental Protection Agency (EPA) through a combination of funding grants administered nationally and funding provided to individual states to manage state programs. In 2016, the EPA is managing a national grant program that will fund up to 45% of the costs of retrofitting an existing vehicle or purchasing a new vehicle.

The state program administered by the Vermont Department of Environmental Conservation, Air Quality and Control Division also receives funding through DERA to retrofit school buses or replace diesel vehicles purchased before 2010. There are some restrictions on funding, but generally, the state program will pay 100% of the costs of a retrofit of a diesel engine or up to 25% of the cost of a new vehicle.

Operations

Most school buses in Vermont are in service for 175 days and travel between 65 and 70 miles per day. Average annual school bus mileage, therefore, is between 11,000 and 12,000. This estimate is consistent with national data[15] and data reported by school districts in Vermont.[16]

Nearly all school districts in Vermont follow a traditional academic calendar that begins in late August/early September and continues until the following June, with a long summer break and a handful of school holidays and breaks spread throughout the year. As a result most school buses are idle during the summer months of late June through mid-August (typically 10 to 12 weeks).

While the length of the school day is mandated in Vermont, there is some flexibility in when the school day begins and ends. Some school districts stagger their start and finish times to maximize the availability of buses. In general, most school buses operate consistently between 7:00am and 9:00am, and again between 2:00pm and 4:00pm, when students are being transported to and from school. Typically, most of the buses are parked between 9:00am and 2:00pm and again between 4:00pm and 7:00am. Transportation managers noted that some buses run a mid-day schedule in the event of half-day kindergarten and special needs trips. Additionally, buses are used outside of morning and afternoon runs for field trips and after school athletic events.

Fleet Management/Bus Replacement

School districts and private contractors typically manage their school bus fleet by purchasing vehicles on a rotating or ongoing basis. Consequently, school districts will purchase one or two vehicles per year, rather than purchasing ten vehicles in a single year. School districts and school bus operators manage this process with a vehicle replacement plan that allows them to budget vehicle replacements by tracking vehicle age, mileage, and the anticipated replacement schedule.

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[15] American School Bus Council, 2013
[16] Interviews with school districts

School bus manufacturers expect school buses to last between eight and twelve years, depending on use and maintenance. The average age of a school bus in the U.S. is 9.3 years, which is consistent with the expected life of a vehicle.[17] In Vermont, vehicle life is managed through the inspection process. School buses are inspected three times a year and as long as the vehicle passes inspection, it can be used in service. Recognizing the harsh climate of Vermont winters and accompanying road treatments, the Vermont Agency of Education allows school districts to budget for a shorter vehicle life of seven years.[18]

In terms of purchasing practices, there is a fair amount of variation in how school districts and private contractors purchase vehicles, although in nearly every case, school buses are purchased outright. Many operators contract directly with manufacturers or dealers to purchase buses; other school districts, especially smaller ones, work together to negotiate with school bus manufacturers (or dealers) to set vehicle prices for a specific period of time. Negotiated contracts provide volume discounts and also typically set prices for standard, but optional, features included in a school bus purchase, such as wheelchair lifts, seatbelts, and global positioning systems.

Management

School transportation management includes a long list of activities related to service operations and fleet management. Service operations consist of developing and scheduling school bus routes, hiring and training drivers, and carrying out all administrative and human resource activities related to staff. School transportation directors also typically handle a variety of reporting and budgeting tasks. Fleet management includes ensuring the school has a plan to manage the overall fleet as well as ensuring vehicles are well maintained, cleaned, safely stored, and adhere to all service standards and inspections.

Supervisory unions may manage school transportation using their own staff, or they may contract with a private enterprise to provide some or all of the school transportation functions. In both cases, however, supervisory units dedicate at least some staff time to manage part of the system and/or the private contractor.

School Managed

Supervisory unions that manage their own school transportation systems are responsible for the school transportation fleet management and service operations. The size of the staff associated with school transportation systems will vary based on the size of the school and amount of transportation provided. Small school districts can operate a system with a staff of between five to ten individuals. With the exception of the director of school transportation, most school transportation jobs are seasonal, with people working during the academic calendar only.

Service Contracting

Some supervisory unions in Vermont contract out their student transportation to private companies. Cost is the primary reason service is contracted out, either because a private operator can provide the same service for a lower price, or because the size of the school

[17] School bus fleet research, annual survey on vehicle maintenance, 2014.
[18] Vermont State Board of Education Rules and Practices 9302.2 and 9302.3 http://education.vermont.gov/documents/9100.pdf

transportation service is too small to operate cost efficiently. A handful of school districts also feel contracting helps them manage the capital costs associated with the service.[19]

Nationally, about 40 percent of student transportation services are contracted out to private companies.[20] Most contractors are responsible for both school bus operations and fleet management, which includes ongoing vehicle maintenance and replacement. However, there is considerable variation in the type and extent of services included in these contracts. Service levels range from managed services which provide day-to-day operations management to school districts which have their own fleets, to contracted services which provide all aspects of student transportation including vehicles, maintenance, drivers, fuel, etc.

Trends in Vermont

As a rural state, school enrollment in Vermont has been decreasing for at least a decade.[21] Yet, even as the number of students being educated decreases, education costs in the state have continued to grow. In response to this challenge, the Vermont State Legislature passed Act 46 of 2015. The Act is intended to manage education costs and at the same time, provide the best possible educational outcomes. One of the fundamental goals of Act 46 is to reduce the number of supervisory units in the state through a system that provides incentives to schools that merge.

As Vermont transitions to fewer, but larger school districts, students will travel farther to school, making school transportation both more expensive and more important. School transportation will also become more complex and more challenging to manage. Addressing these challenges could lead to fundamental shifts in how school transportation is operated and managed, as supervisory unions consider how to cost-effectively continue to provide transportation services. New systems, services, and/or technologies that can provide operational cost savings will likely be considered, and it is likely that many supervisory unions will consider or reconsider contracting out for transportation services.

[19] Adapted from national School Transportation Association website: http://www.yellowbuses.org/school-administrator/school-bus-contracting-information/
[20] Mark Price, Stephen Herzenberg, Sean Brandon, and Teresa Herzenberg, Keystone Research Center (2012) Runaway Spending: Private Contractors Increase the Cost of School Student Transportation Services in Pennsylvania. http://keystoneresearch.org/sites/default/files/RunawaySpending.pdf
[21] ttp://edw.vermont.gov/REPORTSERVER/Pages/ReportViewer.aspx?%2fPublic%2fEnrollment+Report

Economic Feasibility Analysis

School districts in the United States spend a combined $17.5 billion annually on school transportation; this equates to roughly $928 per year[22] for each student transported and indicates that schools districts spend between four and eight percent of their budget on transportation.[23] While this represents a relatively small portion of the overall school budget, the investment is significant in absolute terms. For example, a school district that transports 1,000 students may spend $1 million annually on transportation.

Traditional School Buses

Bus Types

School buses are broadly classified into four types of vehicles, largely based on vehicle size, weight, and internal configurations for passengers (see Figure 2). Type C vehicles make up the majority (70%) of new bus sales in the U.S. Another 20% are Type A/B and 10% are Type D vehicles.[24] With a couple of exceptions, most yellow school buses are manufactured by one of a handful companies. Three bus manufacturers in the United States build Type A school buses exclusively: Collins Bus, Starcraft, and TransTech. Lion Bus, based in Canada, manufacturers Type C school buses and three manufacturers (IC Bus, Thomas Built Bus, and Bluebird Bus) make Type A, C, and D vehicles.

Figure 2: School Bus Types

	**Type A Vehicles** – mini-buses or cutaway buses that are designed to carry between 16 and 20 passengers. Type A vehicles have a door on the driver's side and are built on a light duty van or truck chassis.
	**Type B Vehicles** – similar, but slightly larger than Type A vehicles. Vehicles can carry about 30 passengers.

[22] 2012-2013 National Center for Educational Statistics
[23] National Center for Educational Statistics; Fast Facts published in 2013 for 2011-2012 school year, constant $
[24] School Bus Fleet, U.S. Bus sales statistics, 2014

	**Type C Vehicles** – conventional school buses that carry between 36 and 72 passengers. Type C school buses are distinguished from Type D vehicles largely by the fact that the entry door is behind the front wheels. Engines are in the front of the vehicle.
	**Type D Vehicles** – are school buses with a less traditional shape that more closely resembles a transit vehicle. The entry way on these vehicles is placed in front of the front wheels. Engines may be place in the front, mid or rear of the vehicle.

Source: VEIC adapted from School Bus Fleet Data

Vehicle Costs, Traditional Diesel Buses

School bus costs vary by vehicle type as well as by vehicle configuration. Generally speaking, Type A school buses costs between $50,000 and $65,000 and a Type C school bus cost between $85,000 and $100,000. Type D schools buses, which are less common and slightly more expensive, have costs ranging between $95,000 and $110,000. Vehicle configurations also have an impact on the actual cost of a vehicle, as do vehicle specifications for heating or cooling systems, cameras, and other technologies.

School buses are sold with warranties that guarantee vehicle components; warranty lengths vary by component and manufacturer, but in general, a school district purchasing a new bus can expect the chassis and body frame to be under warranty for 5 years/100,000 miles.[25] Diesel engines are not included in the vehicle warranty and instead are provided by the manufacturer of the engine; new diesel engines are also typically under warranty for 5 years/100,000 miles.[26]

[25] Blue Bird Bus Warranty, Central States Bus Sales
[26] Cummins Warranty, All Engine U.S. and Canada, School Bus (http://www.thebusboys.com/files/2014/09/Cummins-School-Bus-Warranty-Document.pdf)

Electric School Buses

Basics

Electric buses are an emerging technology being incorporated into school bus service. As of 2016, most electric school buses in service are in California. They offer considerable advantages over diesel powered vehicles including lower fuel costs, lower operating costs, cleaner, quieter operations, as well as health benefits. At the same time, there are challenges associated with electric school buses, namely the purchase price of the vehicle and limited vehicle range.

Electric vehicles are powered by electricity stored in batteries on-board the vehicle. Therefore, to power up, an electric bus uses charging equipment connected to the electric grid, rather than filling up with diesel. In terms of driving range, electric school buses currently available on the market can operate between 60 and 80 miles on a single charge, depending on battery size and power train capabilities. In Vermont, the average daily school bus travel of 65 to 70 miles factors morning and afternoon trips, indicating that the average route distance is well within an electric school bus range. Weather will also impact vehicle range if the heating or cooling units draw energy from the vehicle engine. Several manufacturers are installing ancillary heating or cooling units as a strategy to maintain vehicle range across weather conditions.

Electric School Bus Manufacturers

Traditional school bus manufactures in the United States are not currently building electric school buses. Instead, a handful of companies—including Motive Power Systems, Adomani, and TransPower—have been working to develop electric motors and drive trains systems (but not batteries) and installing their systems into vehicles manufactured by someone else, such as BlueBird. Many of these manufacturers also develop electric motors and drive train systems for other medium and heavy duty vehicles, including transit vehicles, trucks, and tractors.

The separation of drive train systems from vehicle bodies is not unique to school buses and it is consistent with vehicle manufacturing generally where separate manufacturers often produce different vehicle parts, which are assembled by the manufacturer who finishes the product, applies their brand, and supplies the vehicle warranty. This approach also reflects the fact that the yellow school bus is highly standardized and the potential for valued added design and features is limited. In the U.S. electric power train manufacturers are exclusively based and largely working in California.

An alternative approach is being pioneered by Lion Bus, a school bus manufacturer in Quebec, Canada. Since its inception in 2011, Lion Bus has produced more than 500 diesel powered school buses, which are operated by school districts in Quebec, across Canada, and in the United States. Lion also manufactures electric school buses. Lion's first electric bus ("eLion") was funded by HydroQuebec and the Quebec Provincial Government. The bus went into service in September 2014 and began transporting students by the end of that year. In 2015, Lion Bus built six more eLion school buses, some of which were deployed in pilot projects in California. Lion Bus is in the process of producing an additional 20 electric school buses, which will be deployed in Quebec and California in late 2015 or early 2016.

Vehicle Costs, Electric School Buses

In 2015, the cost of conventional diesel school buses is between $85,000 and $100,000 (Type C), while an equivalent school bus with an electric drive train costs approximately $350,000, roughly three times the price of a conventional powered vehicle. The higher costs of electric school buses primarily relate to the cost of the battery (about 30% of the cost) and costs associated with electric motors and drive trains.

Overall, there are five main technologies and systems that determine the cost of an electric school bus as well as a vehicle's operational capabilities: vehicle body and chassis; electric drive train and operating systems; batteries; charging infrastructure; and software.

Vehicle Body and Chassis

Although the school bus is highly regulated, there are choices about how an electric school bus body and chassis are purchased that impact vehicle manufacturing and cost. There are three main options regarding electric school bus bodies and chassis: retrofitting a used school bus, retrofitting a new school bus, or manufacturing a purpose built electric school bus. These options primarily impact price, but not the functionality of the vehicle.

- **Purchase Used School Bus**: Electric school bus manufacturers can purchase a used school bus that is structurally sound and will pass vehicle inspection, but has a worn engine and transmission. These vehicles can be stripped of their engines and drive trains, and equipped with a new electric drive train and battery. Most of the prototype electric school buses developed have followed this model. Some of these vehicles have also since been certified for operations and are now carrying students.

- **Purchase New School Bus**: Electric drive train manufacturers are also installing drive train systems into new school bus bodies and chassis purchased from school bus manufacturers. To date, traditional yellow school bus manufacturers have been reluctant to sell an engine-less, "glider" vehicle. Instead, electric school bus manufacturers must purchase a new school bus and remove (and resell) the internal combustion engine, transmission, fuel tank, exhaust/emissions systems and replace these with the electric drive train. This approach ensures the vehicle has the newest systems, most upgraded safety features and interior designs, and a vehicle body built to last between eight and 12 years, more in line with the drive train system.

- **Purpose Built Electric School Bus**: There is one manufacturer, Lion Bus, which makes its own body, chassis, and electric drive train (but not the batteries). Lion Bus school buses are made in Canada but are deployed in the U.S., and meet both U.S. school bus and "Buy America" standards. The estimated cost of the eLion is within range of vehicles that have been re-powered. Lion Bus vehicles also use new construction methods that include a lighter body comprised of a fiberglass composite material and gel-coat that is anti-corrosive, lighter, and stronger. The vehicle body is also slightly wider as compared to traditional school buses and the roof is constructed as a single piece fiberglass, which reduces the potential for leaks. The body and vehicle chassis also come with a five-year/100,000 mile warranty.

Figure 3 below illustrates the breakdown of costs and shows an estimated total cost for each of these three main options for electric school bus bodies and chassis.

Figure 3: Electric School Bus Estimated Costs (2015)

	Used Vehicle (Repower)	**New Vehicle** (Repower)	**Purpose Built** (Single manufacturer)	**Notes**
Vehicle Body and Chassis	$10,000	$60,000	n/a	*Existing school bus purchased from San Diego School District.* *New vehicle purchased from manufacture, drive train stripped and sold.*
Develop/Repower Engine/ Drive Train (excluding battery system)	$140,000	$140,000	$225,000	*Estimated by manufacturers,* *Excludes batteries*
Battery System	$100,000	$100,000	$100,000	*Estimated based on four battery packs providing an 60-80 mile range*
Installation	$60,000	$60,000	n/a	*Estimated by manufacturers*
Warranty and Service	$30,000	$30,000	included	*Warranty fee estimated at 10% of vehicle cost*
Vehicle Delivery	$5,000	$5,000	$2,500	*Estimated – assumes one-way delivery of finished product*
Estimated Cost per Vehicle	**$345,000**	**$395,000**	**$327,500**	

Source: Conversations with manufacturers

Electric Drive Train and Operating Systems

The electric drive train and operating systems are proprietary to the manufacturer and in general, decisions regarding these will not significantly impact the price of the electric school bus. Therefore, electric drive trains and operating systems are not discussed in detail in this analysis.

Batteries

The storage capacity (or size) of a vehicle battery is a key determinant of the distance an electric vehicle can travel (vehicle range). Batteries are the most expensive component in an electric vehicle, so the number of batteries installed in a school bus is determined by balancing the competing needs of vehicle weight, range, and costs. Batteries tend to be deployed as individual units, or battery packs; in general one battery pack provides a maximum of 20 miles of range and costs between $20,000 and $35,000.[27] Most electric school buses deployed to date are equipped with four battery packs for a vehicle range of between 60 and 80 miles. These costs are included in Figure 3.

[27] Conversations with manufacturers

Charging Infrastructure

Electric school buses plug into an electrical source to power the vehicle and consequently, require access to a charging system, or electric vehicle supply equipment (EVSE). In most cases, EVSE provides a one-way connection between the grid and the vehicle, allowing the grid (or other energy source) to send energy to the vehicle. This is the most common model used by consumer electric vehicles and electric school buses.

However, it is also possible for electric vehicles to connect to a power source with bidirectional capacity. When electric vehicles are equipped with appropriate connections and communication technology, they can dispatch energy back to the grid or to a building in addition to pulling energy from the grid while charging. These concepts, termed vehicle-to-grid (V2G) and vehicle-to-building (V2B) power, present the opportunity for electric vehicles to provide various ancillary services. This is discussed in greater detail below, but with respect to charging infrastructure costs, it is important to note here that bidirectional electric vehicle charging equipment is more expensive to purchase than traditional EVSE.

EVSE systems currently accommodate three levels of charging. Alternate Current (AC) systems—including AC Level 1 and AC Level 2—charge vehicles with power that is converted to Direct Current (DC) power on the vehicles. DC Fast Charging systems charge vehicles by providing a DC connection directly from the EVSE to the vehicle, eliminating onboard conversion.

- **AC Level 1**: Uses a 120 volt (V) alternate current (AC) power connection to a standard residential/commercial outlet capable of supplying 12-16 amps of current, for a power draw of about 1.4 to 1.9 kW when charging. A Level 1 charger will charge an electric school bus with a battery size of 105 kWh in about eight hours. As of 2015, bidirectional charging systems are not commercially available for AC Level 1 charging equipment.

- **AC Level 2**: Uses a 208/240V AC power connection to an electrical outlet capable of supplying 30-80 amps of current for a power draw of approximately 19.2 kW. AC Level 2 EVSE can charge an electric school bus in between four and five hours. Some electric school bus manufacturers allow two AC Level 2 connections at the same time, as a way to decrease charging times. There are commercially available AC Level 2 bidirectional chargers, although the technology has only been used in limited applications.

- **DC Fast Charging**: Delivers high power directly into an electric vehicle battery system by converting AC power to DC using an inverter in the EVSE. DC Fast Charges use 208-600V AC for charging rates of up to 90 kW, enabling an electric school bus to be charged in between 20 and 30 minutes.

Software

In most cases school districts will want to automate how they charge their buses. This will allow schools to charge vehicles overnight to be sure vehicles are ready for operations in the morning. Basic managed software systems are included as part of the operating system for some electric school buses. Some schools will also want options to manage charging across multiple vehicles that are connected to a single charging system. Other potential customized software systems may allow charging to respond to price signals that let them know when prices are lowest; or in other cases, charging systems may allow a third party (such as a utility) to manage charging.

Software, over and above the managed charging system, is needed to facilitate bidirectional connections with the grid and/or a building. Like much of the equipment required for this effort, while the software has been developed, it is not currently available as an off-the-shelf, commercial product. This is advantageous because the software will be custom to the equipment and situation, but disadvantageous because it will be more expensive. Information collected as part of this study broadly estimates the costs at roughly $50,000.

Figure 4 below shows estimated costs of electric vehicle charging infrastructure and technology.

Figure 4: Electric Vehicle Charging Infrastructure and Technology - Estimated Costs

EVSE Type	Estimated Charge Time (105 kW battery)	Hardware Costs	Software Costs*		Installation Costs**	Annual Maintenance Costs	Key Determinant of Installation Cost
			Standard Equipment	Bi-directional Capable			
AC Level 1	8 hours	$450 - $1,000	$5,000	n/a	$800	n/a	
AC Level 2	4 hours	$1,500 - $3,000	$10,000	$50,000	$10,000	$300	Distance of hardware from breaker box
DC Fast Charge	20-30 minutes	$12,000 - $35,000	$15,000	$75,000	$15,000	$1,000 - $2,000	Distance from breaker box; need for 480V transformer

Source: Rocky Mountain Institute: Pulling Back the Veil on EV Charging Station Costs

*Notes: * Software for standard equipment assumes managed charging systems that allow vehicles to be charged unattended (at night); Bidirectional capable software permits charging software to communicate with building. Does not include ability to communicate with aggregator **Installation Costs assume high end estimates*

Summary and Discussion of Costs

VEIC estimates the all in costs of an electric school bus at $350,000, inclusive of:

- A purpose built electric school bus with battery pack that supports a vehicle range of 60 to 80 miles on a single charge
- Level 2 charging infrastructure
- Standard managed software system

Costs will likely be lower for each additional electric school bus added to the fleet. A single Level 2 charging system could likely be shared across two vehicles and the software system could support multiple vehicles.

The additional cost to develop software modules to establish bidirectional charging is estimated at roughly $50,000 for AC Level 2 systems. Equipping DC fast charging systems with bidirectional charging is estimated on the order of $75,000. As discussed, one of the reasons these costs are significant is because the software needs to be customized.

Capturing the Value Created by Electric School Buses

Electric school buses are considerably more expensive than traditional diesel buses, at least in terms of upfront costs. Operation costs, including fuel and maintenance, however, are lower for an electric school bus. But as shown in the next section, lower operating costs alone are not enough to offset the higher purchase price, at least with 2016 prices. A key part of being able to establish electric school buses as viable alternatives to diesel school buses, therefore, is the ability to identify ongoing revenue generating opportunities, or a buses' ability to provide additional benefits to the community that are valued at or near the incremental cost of the electric school bus. Potential benefits include:

- Transitioning from diesel to electric powered school buses eliminates harmful diesel emissions and reduces the associated health impacts. As discussed earlier, fine particle pollution from diesel emissions is linked to serious health risks. Electric school buses emit none of these harmful pollutants.

- Shifting to electric-powered transportation poses new opportunities for utility providers. Electric school buses will increase demand for electricity and the ability of the vehicle's battery to store energy has the potential to provide a significant asset to electric power systems. As energy providers continue to diversify their energy production and incorporate more renewable power sources, energy storage will likely increase in importance. With appropriate software, batteries on electric school buses can be equipped to draw energy from renewable sources, so when energy production exceeds demand (for example, solar panel production on a sunny cool day), the energy can be saved and deployed when needed.

- Establishing bidirectional capabilities also means electric school buses can discharge energy back to the grid or to buildings. In the case of buildings, this can supplement a building's energy use helping to reduce high demand charges on electricity bills. Fully charged batteries in an electric school bus could also help power a school or other building energy needs in emergency response situations.

- Vehicle-to-grid (V2G) applications are able to provide valuable reliability services to the grid.

The potential opportunities and financial values associated with each of these strategies are discussed in greater detail below. Our goal is to assess if the value of each strategy (or combination of strategies) can balance the higher upfront cost of an electric school bus. The value of these benefits, however, will vary considerably based on local circumstances and markets. Capturing these benefits, in many cases, is still theoretical, and it is therefore unknown how many aspects of the valuation will pan out. With that said, broad estimates do enable a consideration of the magnitude of potential benefits, allowing for comparison of various opportunities and consideration of those that hold the most promise for making electric school buses financially feasible for schools.

Health Benefits

One of the most powerful arguments for reducing children's exposure to diesel emissions is that children are more vulnerable to the health impacts from emissions because they have smaller lungs and are still developing. Negative health consequences are exacerbated by lost time at school through increased absences.

It is difficult to capture and monetize the value of health benefits resulting from reduced diesel emissions. The benefits are well documented and in many cases, have even been assigned value. However, even when methodologies exist to monetize health impacts, this does not represent actual dollars that someone can capture. These reflect socialized benefits, or benefits that are generally felt by society, rather than captured by any individual. The recognition of these health and air quality benefits does, however, open the door to various grant opportunities.

Health impacts are recognized as having societal costs through DERA and the School Bus Replacement Program funded by that program.[28] As discussed, DERA provides financial incentives to school districts looking to retrofit or replace existing diesel school buses with cleaner fuel vehicles, including electric school buses. In 2016, DERA will fund a national grant program with funding for up to 45% of the cost of a clean fuel vehicle to replace an older diesel fueled vehicle. Vermont has a similar program which funds up to 25% of the cost of cleaner fuel school buses.

Demand Side Management

As noted, electrifying transportation will increase the demand for electricity. While this benefits utilities selling electricity, if the demand is not introduced strategically it presents challenges, especially if new demand exceeds the system's existing capacity.

Electric systems are built for peak periods, when demand is highest. If peak demand increases, utilities need to generate more electricity. This can be a challenge for energy producers because unlike most other industries, the cost of each additional unit of electricity is more expensive than the previous unit. Developing energy systems for peak periods also means when demand is low, energy resources can be underutilized. If electricity use can be increased during periods of low demand, when capacity exists, the system functions more efficiently. In most cases, school districts have flexibility about when they charge an electric school bus, so charging can be scheduled to spread energy demand throughout the day. This type of management of the demand for electricity, therefore, allows utilities to use existing infrastructure more efficiently and meet increasing demand for electricity without needing system upgrades.

Efforts to maintain the balance between energy production (or generation) by influencing the load, or demand for energy, rather than ramping generators up and down, is often referred to as demand side management. Demand side management is becoming increasingly important with increased use of renewable resources because renewable resources (such as wind or solar) generate energy in intermittent and unpredictable ways, creating the need for significant balancing. Again, because the charging of electric school bus batteries can be shifted, it can be flexible to meet the needs of the grid. If renewable generation is outpacing demand,

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[28] http://www.epa.gov/sites/production/files/2016-02/documents/rfp-epa-oar-otaq-16-02_update.pdf

charging can be initiated; if renewable generation is slow and demand exceeds generation, charging can be slowed or stopped temporarily.

Valuing Demand Side Management through Utility Valuation

Demand side management, most fundamentally, benefits utilities. Spreading electric load more evenly throughout the day allows utilities to use existing infrastructure more efficiently. This benefit is ultimately felt by ratepayers, as it allows utilities to effectively manage costs, but the clearest benefit is to utilities. Therefore, it is in a utility's interest to acquire demand side resources and incentivize load management activities, as the consequences of not doing so could lead to increased peak demand requiring costly system upgrades to meet.

In the case of electric school buses, the resource value is in managing the charging of the battery. A utility can either incentivize a school to charge the vehicle battery at times most opportune for their operations—when demand on the grid is low—or they can potentially control this charging themselves. The value of managing the charging of a school bus battery could potentially be great enough to a utility that they would be willing to actually pay for and own the battery. This would allow the utility to use the battery resource in any capacity that is most useful to them. A joint ownership model could be developed in which the utility owns the vehicle battery and the school owns the vehicle body and chassis, with an agreement in place specifying when the school would require a fully charged battery for transportation. This type of arrangement would decrease the upfront costs of an electric school bus to a school district, and utility funding structures that tend to reward capital investments, could further encourage this type of shared asset model.

Although public infrastructure finance includes many shared resource and joint ownership models, VEIC is not aware of any joint ownership model that involves an electric vehicle battery. Significant research is required to evaluate the costs and benefits of this arrangement, specifically to a utility. For example, it is unknown if the benefit of the storage resource would be great enough to justify a utility paying the full upfront costs of the battery. Additionally, if a joint ownership model between a utility and a school district were developed, it would likely make sense to give the utility responsibility for ensuring the school bus is adequately charged to meet school transportation needs. Again, it is unknown if this could this be provided at no cost to the school or if the utility would need to determine some level of lease payment to cover their costs.

For the sake of this analysis, we will consider a scenario in which a utility pays the full upfront cost of the battery and provides it to the school fully charges at no cost. Additionally, we will consider a scenario in which a utility pays the full upfront cost of the battery but leases it to a school for transportation use.

Vehicle-to-Building Integration and Emergency Preparedness

While there is value to utilities in having access to energy storage resources as described above, there is also value to the school in owning and operating these resources. This value is created through vehicle-to-building (V2B) opportunities. When equipped with the necessary hardware and software, electric vehicle batteries have the ability to discharge power back to the grid or to a building. When connected to a building, an electric school bus battery can provide power to the building. This means that if power is lost, the school bus can serve as a valuable back-up power supply. Given that schools often serve as emergency shelters, the ability to provide even small amounts of power is a significant value that electric school buses create. Fully charged batteries on a single school bus could provide 20 kW – 60 kW of power for up to five hours, depending on charging equipment. This may be a sufficient resource to power critical energy needs, such as communication equipment, lights, refrigeration, and/or building ventilation.

Additionally, a battery resource that can supplement a building's energy use can provide great value in terms of reducing peak energy consumption, often referred to as peak shaving. While utilities most directly benefit from peak shaving, mechanisms are in place to incentivize this behavior and pass the value on to the entity reducing peak demand. Electricity bills typically include two types of charges: a fee based on the amount of electricity consumed during a given billing cycle ($/kWh); and demand charges that reflect the higher cost of providing peak power, calculated based on the greatest amount of electrical power used during a 15 minute interval in a billing cycle ($/kW). Some utilities also vary rates based on the time of the day to reflect overall demand in the utility's service area. Time of use charges are typically assigned to periods of time when demand is highest or lowest. Time of use charges may be in addition to peak demand charges.

With these types of electricity rate structures, a school district can use the bus battery to reduce peak demand charges, and/or take advantage of time of use rates. Instead of paying higher rates during peak demand, schools could use energy stored in the battery to power the school. The batteries could be then be recharged when rates are lower.

Valuing V2B Integration through Reduced Demand Charges

Quantifying and capturing the value of enhanced emergency preparedness is difficult, but the benefit is worth noting qualitatively. However, the benefit of V2B through peak shaving is quantifiable and represents a value that can be directly captured by a school in the form of reduced electricity bills. By reducing the peak amount of electricity consumed during a billing cycle, a school has the opportunity to significantly reduce their bills. Demand charges vary considerably, and using generalized cost data collected in Massachusetts, VEIC estimates that reducing 20 kW from a school's peak demand could save between $78 and $450 per month, or between $780 and $5,400 annually.

V2B opportunities, however, require additional software to enable and manage the bidirectional power flows into and out of the electric school bus battery. These systems have only been implemented in pilot projects and demonstrations, and are currently quite expensive. As noted, the software necessary for these applications is currently estimated at $50,000.

Vehicle-to-Grid Integration

As with V2B applications, when an electric vehicle is equipped with the necessary inverters and control software, it has the potential to discharge energy back to the electrical grid. Vehicle-to-grid (V2G) systems have been demonstrated to be able to provide many of the same reliability services to the grid traditionally provided by generation resources. As discussed, the electrical grid has limited storage resources, meaning energy must be utilized when it is produced. In regions with competitive wholesale markets, the grid operator is responsible for managing this grid level balance between generation and demand. The Independent System Operator for New England (ISO-NE) maintains this system balance through three main markets: energy, capacity, and ancillary service markets. Energy markets are the primary place power is bought and sold; capacity markets invest in future capacity resources; and ancillary service markets ensure reliability in electricity production and transmissions.[29]

Storage, however, provides the opportunity to decouple demand or load from generation, by charging or discharging the storage resource to restore balance. While batteries can theoretically serve as a resource in any of these markets, the structure of the ancillary service markets best match the strengths of EVs: taking or supplying small amounts of energy quickly. Operating reserves, one type of ancillary service, provide a margin of supply such that sudden disruptions or outages can be managed without service interruption. Regulation, the other main ancillary service, maintains optimal balance on the grid by adjusting to minute-to-minute variations in demand. Traditionally, both ancillary service markets are served by operators of natural gas plants because of their capability to modulate output rapidly and precisely.

This application of electric vehicles as resources in the ancillary service markets, specifically as regulation resources, has received the most attention to date, largely due to its promise in generating revenue. Various demonstration projects have successfully connected electric vehicles to the grid with the communication controls necessary to receive and respond to regulation instructions from the grid operator.[30] These demonstrations, however, have never been tested at scale and the software and controls necessary are not currently commercially available.

One complicating aspect of electric vehicles participating in these wholesale markets is the need for aggregation. ISO-NE requires a minimum resource size of 1 MW for participation in the regulation market. Therefore, at a power rating of 60 kW (a reasonable level for an electric school bus connected to the grid with a DC fast charger), 17 electric school buses would be required to be combined together to meet the minimum resource size. Alternatively, electric school bus batteries can be combined with other storage resources to meet the minimum resource size. However, regardless of the resources being combined, aggregation systems are required to present what appears to be one resource to ISO-NE and to dispatch the individual resources accordingly.

Valuing V2G Integration through Wholesale Market Participation

To assess the potential value of electric school buses serving as regulation market resources, we must first make the assumption that this participation is even possible. Currently, many details regarding aggregation models, interconnection, settlement, regulation, and the technological aspects of dispatch and control on ISO-NE's part must be resolved before this can be realized as a true revenue generating opportunity. However, if we were to assume all of these pieces were in place, we can evaluate the potential revenue one school bus could receive as part of a larger aggregated resource.

Regulation Clearing Prices, the price received by regulation resources, vary considerably. One range presented from ISO-NE shows variation from $6.74 to $46.66 / MWh.[31] Assuming a school bus is available to bid into the market 65% of the time (458 hours per month) using a DC fast charger (connected at 60 kW), this clearing price range equates to $185 - $1,257 per bus per month. A cost benefit analysis of electric school buses providing regulation services,

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[29] Brunette, Peter. "Introduction to Wholesale Electricity Markets (WEM 101)." Northampton, MA, September 2013. http://www.iso-ne.com/support/training/courses/wem101/01_overview_of_iso_ne_brunette.pdf.
[30] Electric Vehicles as Grid Resources in ISO-NE and Vermont, Stephanie Morse, May 2014
[31] Ibid

conducted at the University of Delaware,[32] found gross revenue generation potential of $15,274 per year, or $1,273 per month per bus.

However, as noted above, V2G opportunities, as with V2B opportunities, require additional software to enable and manage the bidirectional power flows into and out of the electric school bus battery. Additionally, for participation in the wholesale markets, these software needs are made more complex by the need for aggregation. Systems to aggregate electric vehicles and the necessary software are being demonstrated in pilot projects.

Software capabilities have been proven, but the demand for these systems mean the product is not available commercially. As a result, VEIC estimates the cost of such a system at $100,000, inclusive of software deployment, testing, and installation. These costs are in addition to the increased costs associated with DC Fast Charging, approximately $23,000 more than the cost of charging equipment necessary simply for transportation purposes. While not completely necessary, it would be advantageous to have DC Fast Charging when considering participation in wholesale markets to increase power levels and reduce aggregation needs. Once developed, software programs can be shared across multiple school buses, or even school districts. This will bring down the costs in the long run, but new projects must account for the entire costs.

[32] Noel, L. & McCormack R. 2014. A cost benefit analysis of a V2G-capable electric school bus compared to a traditional diesel school bus. *Applied Energy*, 126: 246-265.

Payback Period Assessment

Overview

As discussed, while many of the benefits of electric school buses are less tangible, such as the societal and health benefits from reduced diesel emissions, an important part of our analysis is determining if the direct financial benefits are substantial enough to offset the higher initial investment costs. The benefits presented in the previous section, in addition to lower ongoing operation costs, are considered.

VEIC used a "payback period" analysis, or the period of time required to pay the higher investment costs of an electric school bus with revenue saved from lower operating costs. VEIC opted to use a payback analysis because the calculation is easy to communicate and understand. The main flaw with a payback analysis is that it does not include the cost of money. However public entities, such as school districts, typically purchase school buses upfront and often cannot use the funds for a different investment. In these cases, the cost of money is less critical.

It is also worth noting that there is no such thing as an acceptable or "good" payback period per se, but generally speaking, shorter payback periods are preferred over longer ones. Private sector investments look for projects with shorter payback periods (typically three to five years), while public sector investments may be willing to accept longer payback periods to realize other non-financial benefits. However, for projects or investments to be financially viable, at a minimum, the payback periods must be equal to or less than the expected life of the project or investment. In this case, based on the data collected to date, a school bus in Vermont has an expected life of about seven to ten years. An electric school bus may be on the higher end of that scale, at say ten years. As a result, for an investment in an electric school bus to be financially feasible, the project must pay back the additional costs within ten years.

The payback analysis that follows suggests that while an electric school bus does cost less to operate and maintain, these cost savings do not cover the additional investment required to purchase the vehicle. There are some scenarios under which an electric school bus may be a worthwhile investment, with the most important variable being the availability of grants (or other funding source) to reduce the cost of the vehicle. It is also worth noting that the financial viability of the analysis will fluctuate with the number of miles a school bus is driven as well as price of diesel fuel and cost to maintain the vehicle. As a result, from a financial perspective, electric school buses are most economic when they replace older buses with poor fuel economy and high maintenance costs.

Payback Analysis Baseline

To construct the payback analysis of electric school buses, baseline assumptions must be developed. These define the investment costs as well as ongoing operating costs of both diesel and electric school buses.

Purchase Price

For this analysis, a cost of $349,500 for a "Type C" electric school bus is used, which includes $327,500 for vehicle, plus $12,000 for the cost of Level 2 charging equipment and installation, and $10,000 for basic software. For a traditional diesel school bus, we use a cost of $90,000, with no additional investment costs associated with refueling infrastructure. An electric school bus, therefore, costs $259,500 more than a diesel bus, indicating that the savings from operations must pay back that $259,500 within ten years – at a minimum.

Fuel Costs (Diesel and Electricity)

The cost of diesel fuel is fundamental to this analysis because electric school buses are both more fuel efficient and use lower cost fuel as compared with diesel buses. The cost of diesel as reported by the U.S. Energy Information Administration is quite low - $2.06 per gallon (March, 2016). Vermont school districts reported spending $2.50 per gallon when interviewed in 2015. Oil prices are expected to remain low over the next 12-18 months. Longer term forecasts, however, suggest prices will climb again.[33] Therefore, for our base case analysis, we use a price of $2.50 per gallon (2015 levels) and kept this price consistent over the lifetime of the project. Based on this price of $2.50 per gallon, fuel costs for a diesel school bus are estimated at $0.38 per mile, assuming the diesel school bus fuel efficiency is 6.5 miles per gallon.[34]

When comparing the costs to power school buses, it is important to consider electricity prices as well as diesel prices. The fueling cost of an electric school bus is $0.24 per mile, assuming a school bus requires 1.4 kWh to travel a mile and the cost per kWh is $0.17.

Maintenance Costs

The maintenance costs associated with electric school buses are also expected to be significantly lower as compared with diesel school buses. The lower costs reflect the fact that electric school buses don't need oil changes or replacement parts such as brake fluids and pads, spark plugs, and belts. Actual maintenance costs associated with electric school buses, however, have not been widely tested or recorded. Furthermore, the Vermont school districts participating in this study did not maintain detailed cost sheets for vehicle maintenance. This makes comparing potential savings against actual costs difficult. The University of Delaware research[35] on electric school buses estimated the cost to maintain a diesel school bus at $1.00 per mile and the cost to maintain an electric school bus at $0.20 per mile.

Mileage

Given the lower operating costs of an electric school bus, it is reasonable to assume that a fiscally prudent school district would drive the electric school bus as many miles as possible to reduce their overall transportation costs. A typical school bus is driven 12,000 miles per year, but given the potential savings, we assume that a school district will maximize this value and

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[33] Short Term Energy Outlook, U.S. Department of Energy (DOE) Energy Information Administration
[34] U.S. Energy Information Administration
[35] Noel, L. & McCormack R. 2014. A cost benefit analysis of a V2G-capable electric school bus compared to a traditional diesel school bus. *Applied Energy*, 126: 246-265.

drive their electric school bus an additional 3,000 miles each year it owns the bus (total annual miles of 15,000).

Using these data points, a school district would save roughly $14,000 per vehicle per year, inclusive of $2,100 in annual savings from lower fuel costs plus another $12,000 saved each year through lower maintenance costs. An electric school bus costs $259,500 more than a diesel bus, so with $14,000 in savings per year, the additional cost would be paid back in 18 years (see Figure 5). This is longer than the expected useful life of a school bus of 10 years. Based on this analysis, an electric school bus is not financially feasible.

The analysis is based on the best available information, but "real-world" experience with electric school buses is limited, and the analysis is vulnerable to differences between expected and actual experience. Our analysis, for example, expects a significant portion of the savings are realized through reduced maintenance costs. If the savings are over-estimated, the payback period will increase dramatically. Changes in diesel prices or annual mileage will also affect the payback period, but not as dramatically.

Figure 5: Payback Analysis, Baseline

Payback Analysis - Baseline	**Purchase Price**	**Annual Fuel Costs** (based on 15,000 miles annually)	**Annual Maintenance Costs** (based on 15,000 miles annually)	**Payback Period** (years)
Traditional Diesel Bus	$90,000	$5,700	$15,000	--
Electric School Bus	$349,500	$3,600	$3,000	18.4

Scenario Analysis

As shown, operating costs savings alone do not produce savings sufficient to warrant an investment in electric school buses. However, as discussed in the previous section, scenarios exist for further reducing the costs of electric school buses as well as some potential revenue generating opportunities. The VEIC team tested the assumptions of these various scenarios to determine if electric school buses may be a better investment under different conditions. For purposes of this project, the VEIC team tested four different scenarios:

- Federal grant programs to offset vehicle costs
- Joint ownership model with utilities to offset vehicle costs
- Reduced school operating costs through vehicle-to-building opportunities
- Revenue generated from wholesale market participation

Federal Grant Programs
The analysis suggests that reducing the upfront cost of the electric vehicle has a significant impact on the payback period. A DERA grant could reduce the purchase price of an electric school bus by 45%. Assuming this can only apply to the direct purchase price, we assume a reduced all-in price of $202,125 (purchase price reduced from $327,500 to $180,125; plus $12,000 for EVSE hardware and installation; plus $10,000 for software). With the reduced purchase price, the payback period for the electric school bus is reduced to eight years.

Joint Ownership Model with Utilities
As discussed, access to demand side resources provides significant value to utilities. A joint ownership model in which the utility owns the vehicle batteries and provides the school with a vehicle adequately charged to meet their transportation needs has a significant impact on the payback period. Assuming the utility pays the full cost of the electric school bus batteries, as well as any software necessary to control charging remotely, this will reduce the purchase price to the school by $100,000 (low- to mid-range estimate), resulting in an all-in purchase price of $239,500. Additionally, electricity charges will be eliminated, saving the school district $5,700 annually on fuel. This scenario assumes a utility would realize at least $136,000 in value through its ownership and access to the school bus battery. It has a payback period of slightly over eight years.

However, as noted, it is unlikely that a utility would receive sufficient value to warrant covering the full cost of the battery and electricity. A school district may be willing to pay an annual fee to cover the cost of the battery lease and electricity charging costs. Assuming a school district needs to achieve a payback period of ten years, they could “afford” an annual payment of $2,600 to cover the cost of the battery lease and electricity charge. While this does not cover the full cost of the electricity, a utility would earn $26,000 over 10 years to offset its investment in the project. Therefore, for this scenario to work, it assumes that the value a utility places on access to the vehicle battery is approximately $110,000.

Reduced School Costs through V2B
As described above, an electric school bus has the potential to supplement a building’s energy use, allowing a school to reduce their peak consumption and associated demand charges. Data available for Massachusetts presents a significant range in values; we will estimate the impact on the payback period of an electric school bus using a conservative estimate from this range. A $100 monthly reduction in electric bills from reduced demand charges is considered. However, to implement a demand charge reduction strategy, school districts would need to invest in bidirectional equipment and software, which would cost an additional $50,000 and increase total costs to $389,500.

The ability to reduce demand charges does not improve the financial viability of a school bus. With software costs of $50,000 and annual revenues of $1,200, it would take 42 years for lower electricity costs to pay back the cost of the software. It is worth noting that this analysis assumes one school bus is responsible for the entire cost of software development. If the software costs can be shared across multiple school buses, the investment makes more sense.

For the total system (electric school bus and software costs), the payback period is extended two years from 18 years to 20 years.

Revenue Generated from V2G

The revenue generating opportunities from electric school buses providing ancillary grid services has the potential to be significant. While there are many barriers that first need to be worked out before the opportunity becomes a reality, for the purposes of this analysis, we will assume one school bus has the ability to generate $1,000 per month. This value is slightly lower than the upper end of existing estimates, but is a reasonable mid-point estimate.

To generate this revenue however, the increased costs to establish a V2G equipped electric school bus are substantial. DC Fast Charging hardware and aggregation software increase the upfront costs by approximately $123,000 to a total all-in cost of $462,500. DC Fast Charging accounts for $23,000 of this ($35,000 over the $12,000 estimated for Level 2 charging equipment); aggregation software is estimated at $100,000.

In this case, the investment of $123,000 creates a revenue stream of $12,000 annually, which can be paid back in just about ten years. Similar to the V2B scenario, the development costs of the software can be shared among multiple vehicles, if a school were investing in more than one electric school bus. Even with a single school bus, however, an investment in V2G capabilities has a slightly positive impact on the payback of the electric school bus package, reducing the payback period from 18 years to 14 years. This payback period, however, is still longer than the useful life of the vehicle.

These scenarios are summarized below in Figure 6.

Figure 6: Payback Analysis, Scenario Development

Payback Analysis - Scenario Development	**Purchase Price**	**Annual Operational Costs, Fuel and Maintenance** (based on 15,000 miles annually)	**Annual Revenue Generation** or **Direct Savings to School**	**Payback Period** (years)
Traditional Diesel Bus	$90,000	$20,700	NA	--
Electric School Bus baseline	$349,500	$6,600	NA	18.4
DERA Grant Scenario	$202,125	$6,600	NA	8.0
Joint Ownership, free electricity to schools	$239,500	$3,000	NA	8.4
Joint Ownership, battery lease agreement	$239,500	$3,000	-$2,600	9.9
V2B	$389,500	$6,600	$1,200	19.6
V2G	$462,500	$6,600	$12,000	14.2

Key Economic Feasibility Findings

It is clear that electric school buses are considerably more expensive than traditional diesel buses, at least in terms of upfront costs. Operation costs, including fuel and maintenance, are lower for an electric school bus, but the lower operating costs alone are not enough to offset the higher purchase price, at current costs. Based on current estimates, the lower ongoing operation costs of an electric school bus would pay back the higher upfront costs in 18 years. Because this is considerably longer than the expected useful life of a school bus of 10 years, this is not an economically feasible option for schools.

Therefore, a key part of being able to establish electric school buses as viable alternatives to diesel school buses is the ability to identify ongoing revenue generating opportunities made possible by electric school buses or their ability to provide additional benefits to the community that are valued at or near the increased cost.

Four scenarios presented illustrate the potential for electric school buses to create ongoing value. But these scenarios do not represent the full suite of options or configuration of possibilities available to capture the value created by electric vehicles. For example, a school could choose to pursue demand side management opportunities on their own to manage generation from an on-site solar installation. Or a school and utility could structure a joint ownership model in which the utility combined the school bus battery with other storage resources and bid them into a wholesale market, sharing the revenue with the school. Rather, this is intended to be illustrative of the potential options that either currently exist or could be future opportunities to capture the value created by electric school buses, thereby making them more economically feasible.

It is worth noting that reduced operating costs of electric school buses are a critical component to their financial viability. However, of the $14,000 annual operating costs saving, $12,000 are realized through reduced maintenance costs. These savings are not as well documented with real world experience as fuel costs savings, and the ability to execute a business model by relying on these savings is challenging.

V2B or V2G strategies create opportunities for the school district (or school bus owner) to earn revenue, but they also require additional capital investments. In both cases, the revenue generated does not offset the investment cost, and neither strategy generates enough revenue to make an electric school bus financially feasible. However, it is also worth noting that our analysis assumes a single vehicle must absorb the software development costs. If software development costs can be shared across more vehicles, the financial feasibility of V2B or V2G increases.

Given the current state of the technology and retail and wholesale market structures, we suggest that the most promising – and the easiest – way to make an electric school bus project financially feasible is to use DERA funding to reduce the cost of the vehicle. Lower vehicle costs combined with lower fuel and reduced maintenance costs, means a school district should break even on an electric school bus investment. If some of the other cost savings or revenue generating scenarios can be implemented, then an electric school bus could be financially viable.

Framework for Electric School Bus Implementation

School districts make transportation decisions that are influenced or directed by government policies and regulations. So far, this study has solely focused on the financial feasibility of electric school bus adoption. It is also essential to understand the policy and regulatory environment in which decision makers are operating. State policies and regulation can either encourage and accelerate electric school bus adoption or may be barriers. Because utilities must be engaged, a regulatory framework for how to assign benefits, costs, and risks would be helpful to make it easier for schools districts to understand the costs and issues with adopting this technology. And finally, at the local level, it's important to understand procurement practices and how they need to be adjusted to facilitate a transition to electric school buses.

Policy

Health in All Policies

School districts may be motivated to switch to electric school buses to address the negative health and environmental consequences from diesel emissions. This is particularly important as children are more susceptible to health risks from fine particle pollution. While this is easily understood and compelling, it is difficult to incorporate these costs and benefits into a financial analysis. Negative health impacts are externalities and benefits to improving health are socialized and not realized by one entity or sector.

Health in All Policies is an emerging approach that incorporates health considerations into decision-making across sectors and policy areas. The World Health Organization defines health in all policies as "an approach to public policies across sectors that systemically takes into account the health implications of decisions, seeks synergies, and avoids harmful health impacts, in order to improve population health and health equity."[36] Using this approach, school administrators would consider the health consequences of various policy options during the policy development process.[37] Health in All Policies could be adopted at the state or local level, although having a state policy would give direction and encouragement to local school district decision-making.

Vermont has adopted Health in All Policies as a framework for state decision making. The Vermont Department of Health is leading an interagency task force to identify strategies to more fully integrate health considerations into all state programs and policies. If fully embraced and implemented, this could provide an imperative to consider the health impacts of school transportation, when making decisions about vehicles.

A Health Impact Assessment (HIA) is a tool planners and decision makers can use to implement Health in All Policies. Current policy in Vermont charges the state with "recommending a plan to institute a public health impact assessment process to ensure appropriate consideration of the impacts on public health resulting from major policy or

[36] http://www.healthpromotion2013.org/health-promotion/health-in-all-policies
[37] http://www.phi.org/resources/?resource=hiapguide

planning decisions made by municipalities, local entities, and state agencies."[38] The HIA is a systematic process, engaging stakeholders and relying on data sources and analytical methods, to determine the potential effects of a proposed policy, plan, program, or project on the health of a population. The process identifies appropriate recommendations, mitigations and/or design alternatives. In Vermont, HIAs have been used at the state and local level to evaluate policies and programs as widely divergent as marijuana legalization and transportation corridor studies. It is gaining more acceptance and adoption with technical support provided by the Vermont Department of Health. It is a tool that the state Agency of Education or school districts could use to evaluate the health impacts of school transportation, and set the stage for a transition to cleaner vehicles.

Carbon Pricing

Carbon pricing is a way to disincentive fossil fuel use by putting a price on the negative societal impacts and costs of pollution. There are different mechanisms for putting a price on carbon, with the most prominent being carbon taxes and establishment of economy-wide cap and trade programs. A carbon tax was introduced in the Vermont legislature in 2015, which would be an assessment on carbon pollution, applied to fossil fuels sold in the state. The legislation calls for a $100/ton assessment, starting at $10/ton in 2018 and ramping up by $10/ton over the following 10 years. The assessment would be collected at the distributor level. Revenue raised would primarily be used to reduce taxes for Vermonters. Programs to reduce fossil fuel consumption in the transportation sector are not funded in this proposal, but could be in future iterations of this legislation.

Vermont is also a participant in the Renewable Greenhouse Gas Initiative (RGGI), which is a market-based cooperative effort among several Northeast states, including Vermont, to cap and reduce power sector carbon emissions.[39] It is not currently an economy-wide program and therefore does not include carbon emissions from the transportation sector. However, if expanded, it offers another opportunity to price carbon pollution from the transportation sector, generating revenue for programs that reduce fossil fuel consumption. The Western Climate Initiative is an existing economy-wide program for California and several Canadian provinces, including Quebec. In California, revenue generated from this market has been used for strategies to reduce greenhouse gas emissions from the transportation sector.

Regardless of the way carbon is priced, it would ideally serve two purposes: disincentivize fossil fuel use, by increasing the price, and generate revenue that could be used to support a transition to cleaner, more efficient vehicles. If a carbon pricing program that met these goals was implemented, it could provide school districts with the appropriate mix of financial disincentives and incentives to transition their school bus fleets.

Reward Fuel Efficient and Alternative Fuel Transportation

Diesel emissions are regulated by the federal government, primarily the EPA, which mandates fuel blends and engine exhaust systems. These regulations are designed to improve air quality and protect public health; they are also accompanied by grant programs to help transportation operators speed up adoption of newer cleaner emission technologies. Some states, such as California, have stricter emission standards. California has had success with its emissions

[38] Vermont Act 48 Sec. 11. Health System Planning, Regulation, and Public Health
[39] https://www.rggi.org/design

standards, but implementing and managing stricter vehicle emission standards in a small state, such as Vermont, is challenging.

Regulation

Distribution of Benefits and Risks

Electric school buses are an emerging technology, which is expanding, but to date has not been widely adopted outside the State of California. V2G and V2B strategies, likewise, are emerging. The technology has been demonstrated, but systems don't exist to support broad adoption in the marketplace. Needed systems include structures to set market values for energy storage resources and distribute financial gains. Without a trusted structure to share financial benefits and reasonable assurances on return of investment, organizations will be reluctant to engage in these markets.

A key role for regulators, therefore, is to help the interested and affected parties, such as the State Agency of Education, local school districts, school bus manufacturers and leasing companies, and distribution utilities, understand the costs and benefits of deploying electric school buses. This could be achieved through demonstration projects to gain greater understanding of the issues. Ideally, regulation would set the stage for how school districts and utilities would work together to maximize the financial benefits to each. For example, utilities benefit from having access to storage resources – either using them for load management or even bidding them into various markets. A key question regulators could help resolve would be how the financial benefits of storage are distributed, such that schools get some of the value thereby helping defray the increased cost of the vehicle.

Joint Ownership Models

We have contemplated opportunities to share the increased cost of electric schools buses between schools and utilities through a joint ownership model: a utility could potentially purchase the battery and lease it to the school and the school would purchase the bus. This model offers a real opportunity to encourage adoption of electric school buses by reducing the upfront cost to school districts. But limited data is available to guide and structure the relationship between partners. The cost of the electric school bus is clear as is the cost of the vehicle battery. However, the value of the battery to a utility is largely unknown. The ability of the utility and the school districts, therefore, to negotiate and share the risks and rewards of this type of joint ownership model are limited. Again, this is an opportunity to learn from a demonstration project that could inform a regulatory framework that among other things, sets a fair price for leasing the battery and assigns benefits of using the battery for storage or discharging to the grid.

Rate Structures

Electric school bus charging systems envisioned and described in this analysis involve developing operating practices so that school buses are charged at night and use level 2 charging equipment. This type of small scale (one or two vehicles) system is expected to have a minimal impact on the demand for electricity or a school district's electric charges.

As the fleet size changes, so will these assumptions. More vehicles charging at night and using level 2 chargers will increase electricity use and costs. Operating more electric vehicles may make the purchase of faster charging systems more cost effective. As fast chargers integrate into school transportation systems, the feasibility and potential need to charge mid-day increases. At the same time, more vehicles available to charge and discharge combined with faster grid connections increases the potential for adding value to the grid or managing the building's electric consumption.

There is, therefore, a "chicken and egg" type of situation with regards to school bus technology. Electricity rate structures will impact how electric school bus systems develop and set up their charging systems. At the same time, electric school bus systems and their capacity as energy storage resources can influence rate structures. Time of use rates, for example, could discourage midday charging because school buses will be charged at substantially higher rates; on the other hand, time of use rates could encourage mid-day discharging (peak shaving) because schools could generate more revenue.

Some of these challenges can be worked out in the marketplace. Utilities can set prices to encourage the type of consumer behavior that supports their operations. Schools can react to these prices in ways that benefit them financially. At the same time, state regulators could help by establishing new rate structures that benefit all parties. Given that utilities and school districts are often both public entities – and in some cases can serve the same taxpayers – there are clear reasons to collaborate on pricing structures and policies to maximize benefits to the broader community.

Inherent in this analysis is an assumption that school districts understand the intricacies of utility rate structures. At the very least utilities must be engaged early in the process when a decision to purchase an electric school bus is being contemplated to provide information on expected increased load to the school district and how to manage charging to avoid unexpected peak demand costs.

Aggregation

Energy storage resources, like electric school bus batteries, hold promise for V2G opportunities. However, regional transmission operators require participants in the wholesale market to offer a minimum resource size. The requirement is designed to simplify the market. These requirements vary by region, but in Vermont, ISO-NE set the minimum resource size at 1 MW. As a result, employing electric school buses as a wholesale storage resource requires at least 17 buses be available at the times when the vehicles are participating in the market. For electric school buses, participating in the wholesale markets is a longer term strategy.

In the shorter term, there are considerations that warrant attention, especially regarding how to aggregate multiple energy storage devices into a single grid resource and how to distribute benefits (and revenues) among parties. Another question is if the wholesale market is robust enough to support aggregation. Aggregation services would likely be provided by a third party entity that will charge owners of energy storage devices for participating in the market. It is unclear if the revenue generated from the wholesale market will be sufficient to pay for aggregation services, especially given potential degradation to the energy storage device (i.e. the battery). Regulation would be needed to establish the structure and rules around this and ensure that all parties are fairly compensated.

Operations

Bus Procurement Processes and Service Contracts

For school districts that purchase and operate their fleet, a potential path to advance clean transportation systems may be to change the procurement process. Vehicle procurement practices and systems are designed to benefit bidders that offer vehicles with the lowest purchase price. Rarely do these systems reward vehicles that are more fuel efficient or easier to maintain. Without protocols and systems to evaluate vehicles on a total cost of ownership basis, electric school buses cannot be justified.

Another potential barrier are joint vehicle procurement contracts that are negotiated on behalf of smaller purchasers. If electric school buses are not part of a previous contract, they tend not to be included in the next one. This makes it difficult for new technologies to be adopted.

Finally, contracts with service providers should be structured so they reward contractors for pursuing fuel efficient vehicles and/or vehicles that have lower maintenance costs. Contracts often allow service providers to charge for fuel or maintenance separately; contractors prefer this type of contract because it protects them against a poorly maintained or fuel inefficient fleet. However, at the same time, it doesn’t directly reward fleet managers for operating fuel efficient or low maintenance vehicles. One potential approach may involve reimbursing operators on a cost per mile basis, rather than reimbursing fuel costs separately.

In each case, the state could play a role in influencing this process by adopting policy requiring consideration of fuel efficiency of vehicles. Changes to practice could also be adopted at the local level. In addition, alternative fuel vehicles should be included in state school bus procurement contracts. Vermont may not currently have statewide procurement contracts for all types of school buses, but these could be developed specifically to encourage electric school buses.

Case Studies

As part of this research, we reached out to multiple schools in Vermont. We collected information about school bus operations, fleets, and funding. These schools were selected at random and are intended to serve as examples of the types of issues facing school districts in Vermont.

It is not expected that any one school will be able to take advantage of all revenue generating opportunities. Site specific variables will determine the viability of various opportunities. For example, if school buses are not physically parked at the school, it is unlikely that vehicle-to-building opportunities will be feasible. Therefore, the structure of electric school bus integration business models will vary from school to school, as will the value of potential opportunities.

It is for this reason that we have included in this feasibility study a set of case studies. Three schools serve as case studies and site specific variables are considered in assessing the feasibility of electric school buses for each specific school. The opportunities possible are discussed for each.

Rutland

The Rutland City Public Schools (RCPS) serves students residing in the City of Rutland, a community of roughly 18,000 people. The district consists of six schools plus two alternative sites and the regional Stafford Technical Center. In total, there are some 2,300 students attending RCPS schools. This number includes some students from neighboring communities who pay a tuition to attend Rutland High School. The high school and the Stafford Technical Center are co-located making this site both the largest physical complex in the district and home to the most students, 1,125.

Transportation services are managed through the RCPS Central Office and are available to Rutland City residents only. Students attending Rutland schools from adjacent towns must arrange their own transportation. The transportation office manages a fleet of 24 buses, inclusive of 17 full sized buses, three vans and four mini-buses. According to the Director of Transportation, on an average day, eleven buses will be on the road from roughly 7:00 am to 9:00 am and then again from 1:00 pm to 4:00 pm. Buses travel roughly 44 miles a day in regular service or 60 miles if they are used for after school programs. School is in session 178 days, suggesting annual mileage is between 7,800 and 10,680.

The City of Rutland's electric utility is Green Mountain Power (GMP). GMP is the utility for much of Vermont, including nearly all of southern Vermont. GMP has multiple local clean energy initiatives. In Rutland, GMP worked to establish Rutland County as the solar capital of New England. This goal was recently achieved and as of 2016, the City of Rutland has the most solar per capita of any city in New England. Solar investments in Rutland County include a large solar farm located at Stafford Hill that has 7,700 solar panels on 15 acres site. Solar power resources at Stafford Hill generate 2.0 MW of power, enough to power 2,000 homes during full sun, or 365 homes year-round.

The Stafford Hill Solar Farm is also unique because it includes 4.0 MW of battery storage for solar generation. Battery storage resources at Stafford Hill allow solar to be stored and saved for use at a later time. Not all solar sites have storage resources on site, and according to GMP, there are a handful of locations in the Rutland County solar network where the production of solar energy occasionally outstrips the need for energy on the grid. Ideally – from both a financial and a clean energy perspective – excess energy would be stored temporarily and sold to the grid when it is needed.

One potential option to raise revenues from an electric school bus is to place it at a site needing temporary energy storage. The fact that it is a vehicle means the storage resource can be deployed when and where it is needed. Another advantage of electric school buses is they are not in use during the summertime, which is also the time when Vermont has long days and more sunshine. Summertime also typically has periods of high demand for electricity, especially in afternoons when many buildings operate air conditioning in addition to other equipment and machinery.

There are a number of ways a school district, like RCPS, may work with a utility. RCPS could rent or lease their school buses to GMP during the summertime when school is not in session. GMP would benefit because it would be able to use the vehicle battery as an energy storage resource when it needs it. RCPS would benefit because it could earn revenue from the school bus when it is not needed. This type of arrangement may also work during other times, such as over the school breaks, or potentially even on weekends. Another option would be for GMP to own the school bus battery, lease it RCPS for specific days and times of the year but have the ability to control it at other times.

In theory, using the battery on an electric school bus sounds like a fairly straight-forward arrangement. The conditions also appear to be ready in Rutland County, where the utility has experience using battery storage at solar sites and the school district offers appropriate conditions for electric school bus operations. Challenges, however, remain. The technology has not been widely tested so the costs and benefits of the storage system are not well known. This means understanding the business case from both the school and utility perspective are not readily available. Rutland County, therefore, would be an excellent demonstration site for both electric school bus technology but also as a way to develop experience and solutions with a variety of challenges facing wider spread adoption of electric school buses. The ancillary lessons learned through a demonstration project in Rutland County include:

- A business case or business plan to examine the financial feasibility of renting/leasing an electric school bus (or just the battery) for use as an energy storage resource. Frequent charging and discharging the battery will impact the longevity of the battery – it will also impact the warranty – but the precise impacts are not well understood.

- A rental or leasing arrangement would also require **developing a compensation protocol.** One of the complicating factors in developing a compensation package is that the price of electricity varies by time of the day. Depending on the price of electricity and the fee or fare paid to the school bus owner (and the amount of money the school bus owner is being paid), it may or may not make economic sense for one of the two parties to buy or sell electricity. Some sell or buy prices may be advantageous for the utility, but not the vehicle owner (or vice versa). As part of moving forward, therefore, both parties need to agree to price ranges.

- The feasibility and functionality of **bidirectional charging equipment and technology.** The use of bidirectional systems with school buses has not been widely tested to date, although the Commonwealth of Massachusetts is gearing up to test bidirectional charging with school buses later in 2016. For vehicles that are not currently equipped with bidirectional capabilities, there is likely additional cost for this technology.

- Testing the durability of school bus batteries. Using the school bus battery as an energy storage resource means the **battery would be charged and discharged a lot,** potentially as frequently as every day and possibly more than once a day. Depending on the battery chemistry, charging and discharging a battery can wear it down and impact the useful life of the battery. The impact of frequent battery charging and discharging needs would need to be investigated prior to moving forward with any type of demonstration program.

	Rutland City Public Schools **2,300 students total** **900 high school; 1,400 elementary and middle school students**
Budget	2017 School budget: $50.4 million **Transportation budget: $1.2 million** (2% of total budget) – Annual fuel costs $90,000 (estimated)
School Bus Service	**Daily Routes: 11** - Three HS routes - Four MS routes - Four other routes (special needs)
School Bus Fleet	**Fleet size: 24 buses** - 17 Type C (full sized buses) o Three spares - Four Type A (minibuses) - Three vans
School Bus Operations	Average daily mileage per bus: 44 Average annual mileage per bus: 12,000 Bus fuel economy (average): 5.5 mpg Bus route scheduling is done electronically using Versatrans software
Management	City of Rutland School District/Central Office at Supervisory Union level. Replace roughly two buses per year at roughly $85,000 per bus; Average vehicle useful life is 10 years or 100,000, but most don't make it that long
Maintenance	Maintenance is contracted out, spending is roughly $45,000 per year. Warranty work is done in Jericho, with the only International Bus warranty mechanic
Transportation Facility	Vehicles parked at transportation office (156 Porter Place) – Electricity on site but not 3 phased power
Local Utility	Green Mountain Power

Barre

Barre School District in central Vermont serves residents of Barre City and Barre Town. Although the two municipalities are distinct, Barre City has a population of just over 9,000 people and is nearly completely surrounded by Barre Town, with a population of about 8,000 residents. The two municipalities are part of the same supervisory unit (Barre Supervisory Unit) and have a shared high school (Spaulding High School and Central Vermont Career Center). Each of the two communities has separate elementary and middle schools.

The Barre Town Elementary and Middle School (BTEMS) manages its own transportation services, with a fleet of 12 buses; nine of which are in daily service and three of which are backup vehicles. Historically, the school has not followed a school bus replacement plan but instead has replaced vehicles when grant or school funding became available. Although BTEMS will add three or four school buses in the 2015/2016 school year, the schools will still have an aging fleet with several vehicles purchased before 2010 and with 100,000 miles or more.

BTEMS' fleet of older vehicles, many of which were built before 2010 and operate with older diesel exhaust equipment, are heavily polluting. Additionally, being an elementary and middle school, BTEMS serves younger children who are more sensitive to air pollutants because they have smaller lungs and have higher respiration rates. The combination of these factors—heavily polluting buses and serving young children—makes BTEMS an excellent candidate for state or federal clean diesel grant programs (DERA) that could offset the cost of an electric school bus. The Vermont Department of Environmental Conservation, for example, is providing incentives for qualifying supervisory unions and school districts in Vermont to replace older, more heavily polluting buses with new buses equipped with more advanced pollution control technology. These grants are designed to help reduce the exposure of children and school personnel to diesel exhaust from school buses. DERA grants present one of the easiest and most reliable ways to fund school bus purchases, and many schools already take advantage of these grant programs.

BTEMS therefore offers an excellent potential demonstration of electric school bus technology because there is significant opportunity to make an impact on public health, using DERA grant money. BTEMS is also an excellent demonstration project for operational reasons. The service area is relatively small, so the vehicle range should be sufficient for most or all of the school bus routes. At the same time, local conditions will test electric vehicle operations with cold winters (January temperatures ranging from eight degrees (low) to 25 degrees Fahrenheit) and a hilly terrain. Testing electric school bus performance in this environment, therefore, should demonstrate the technology's ability to meet school needs in challenging conditions.

	Barre Town Elementary and Middle School **850 students total**
Finances	2017 School budget: $11.5 million **Transportation budget: n/a**
School Bus Service	**11 daily routes serve (+6 trip buses)** - Nine short routes (less than 30 minutes one-way) - Two longer distance routes - Ten afterschool routes - Two buses used for afterschool , mileage is ~60 miles
School Bus Fleet	**Fleet size: 12 buses** - Three spares - Replacing three buses in 2016
School Bus Operations	Average daily mileage per vehicle: 50 - 70 Approximate annual mileage per bus: 12,000
Management	Maintenance is contracted out, spending is roughly $90,000 plus another $10,000 or so for equipment and contract work. Most maintenance work is down by Town staff. Useful life is roughly 10 years or 100,000, but most don’t make it that long
Transportation Facility	Vehicles parked at Barre Town Parking Lot (with police and other city vehicles) Have electricity on site but not sure about 3-phase power
Local Utility	Green Mountain Power
Emergency Preparedness	School bus fleet needs to be able to evacuate the entire student population. School is designated as a shelter, but not fully equipped. Do not own a generator, but interested in purchasing one; school is exploring other ways to strengthen their emergency preparedness.

South Burlington

The City of South Burlington is the second largest city in the State of Vermont with nearly 19,000 residents. It is also one of the largest school districts in the state with five schools (three elementary, one middle school and one high school), a student body of some 2,500 students and an annual budget of nearly $47 million.

One of the unique aspects of the South Burlington school district as compared with other Vermont schools is that the middle school and the high school are located at the same facility and the location is close to the center of community activity, including the superintendent's office and South Burlington's Community Library. The schools are also located across the street from South Burlington City Hall and the Fire Station. All of these sites are located on Dorset Street, which is being developing as a "city center". As part of this effort, the City of South Burlington is encouraging development along the Dorset Street corridor and creating a cluster of services and activity centers, including shopping, medical services and housing. Infrastructure supporting the city center also includes a well-connected network of bike paths and sidewalks that link services along Dorset Street and provide connections to the middle and high schools.

The location of the South Burlington school complex and its position relative to other community resources makes it an excellent location for a community shelter in times of an emergency – the site is well known to many members of the community, it is easy to get to, and it is close to other important amenities and essential resources. Indeed, the City of South Burlington's All-Hazards Mitigation Plan Annex 14, which is part of the Chittenden County Multi-Jurisdictional All-Hazards Mitigation Plan[40], identifies schools as the primary and secondary emergency shelters.

An electric school bus could further strengthen the community's emergency response capabilities because the vehicles can:

- **Export electricity.** Energy stored in the vehicle battery can be exported to power equipment, such as lighting systems, communication equipment and/or to power appliances. This means the bus could essentially function as a primary or back-up generator. Depending on how they are equipped, electric school buses could also provide several hours' worth of power to neighborhoods or areas experiencing a prolonged period of no power. Shorter periods of power to charge cell phones and computers, fire up hot water heaters, or repower refrigeration do not solve all challenges but could allow for people to stay in their homes and avoid evacuations.

  School bus batteries also have an additional advantage of being on a vehicle, meaning they are mobile and able to be transported to where power is needed. An electric school bus could, for example, power fuel pumps or street lights.

- **Provide alternative fueled transportation.** An electric vehicle can become a critical resource in emergency situations when conventional fuel supplies are compromised or limited. Electricity distribution systems that rely on poles and overhead wires mean electricity can be one of the first systems to be disabled in emergencies. However, electricity is typically restored fairly quickly. When fuel supplies, such as gasoline or

[40] City of South Burlington All-Hazards Mitigation Plan, Annex 14, adopted by South Burlington City Council on April 19, 2011.

diesel, are compromised restoring supplies often takes longer. In these types of situations, access to an electric vehicle gives emergency response planners a form of transportation that may be the only option.

South Burlington's All-Hazards Mitigation Plan would be enhanced by the addition of an electric school bus because the plan calls for restoring electrical power to critical sites such as hospitals and nursing homes first. This means there may be a short-term need for electrical power in other areas while they wait for power to be restored. The Plan also calls for the City to seek funding or public-private partnerships to help the community expand its network of generators and/or electric transfer panels at critical locations. In addition, it calls for identifying smaller shelters that could "potentially significantly reduce the physical, psychological and social impacts of a disaster." An auxiliary and flexible source of electricity would give emergency response teams the ability to bring power to where it is needed including to back fill power needs as needed.

A short-term consideration with South Burlington transitioning to electric school bus transportation is that the buses are currently parked off-site, on Patchen Road in a space co-located with the Chittenden Solid Waste District. The off-site location would not affect the operations of electric school buses, but ideally for the buses to support emergency response needs, they would to be parked and stored at the middle/high school complex.

There are two additional challenges associated with maximizing the emergency response capabilities of electric school buses both of which relate to funding and costs. For an electric school bus to be able to export power, or to be V2G or V2B enabled, a school would need to invest in additional equipment and technology, estimated at roughly $50,000. These resources are over and above the premium cost of an electric school bus as compared with a diesel one. Staff from the school district, emergency response teams, and utility would also need to be trained on how to use the vehicle to export power. At the same time, while these additional capabilities may be highly valued (and efficient) there is not necessarily funding available to support them. In the most optimistic of scenarios, the City of South Burlington may be able to find grant funding to help support the cost of the electric school bus and the technology required to equip the bus with grid (or building) interactive systems.

	South Burlington School District **2,500 students total** **850 high school and 1,600 elementary and middle school students**
Budget	2017 School budget: $47 million **Transportation budget: $1.7 million** (4% of total budget) – Annual fuel costs $180,000 (estimated)
School Bus Service	**Daily Routes: 19** - 16 short routes (less than 30 minutes per one-way trip) - Three long distance routes (Grand Isle, Georgia, Isle LaMotte) - Three buses used for midday service o Burlington Technical Center o Activities - Five buses used for Special Needs Transportation o Less structured routes o Vehicles in service all day
School Bus Fleet	**Fleet size: 25 buses** – 23 are in regular service – Two spares
School Bus Operations	Average mileage: varies by vehicle
Management	South Burlington School District
Transportation Facility	Vehicles parked on Landfill Road off Patchen Road – Small facility on site with electricity – Shared site with Chittenden County Solid Waste
Local Utility	Green Mountain Power
Unique Features	SBHS has a lot of school choice students. They operate three longer distance routes to pick up students in Grand Isle, Isle LaMotte and Georgia SBHS is a designated emergency shelter.