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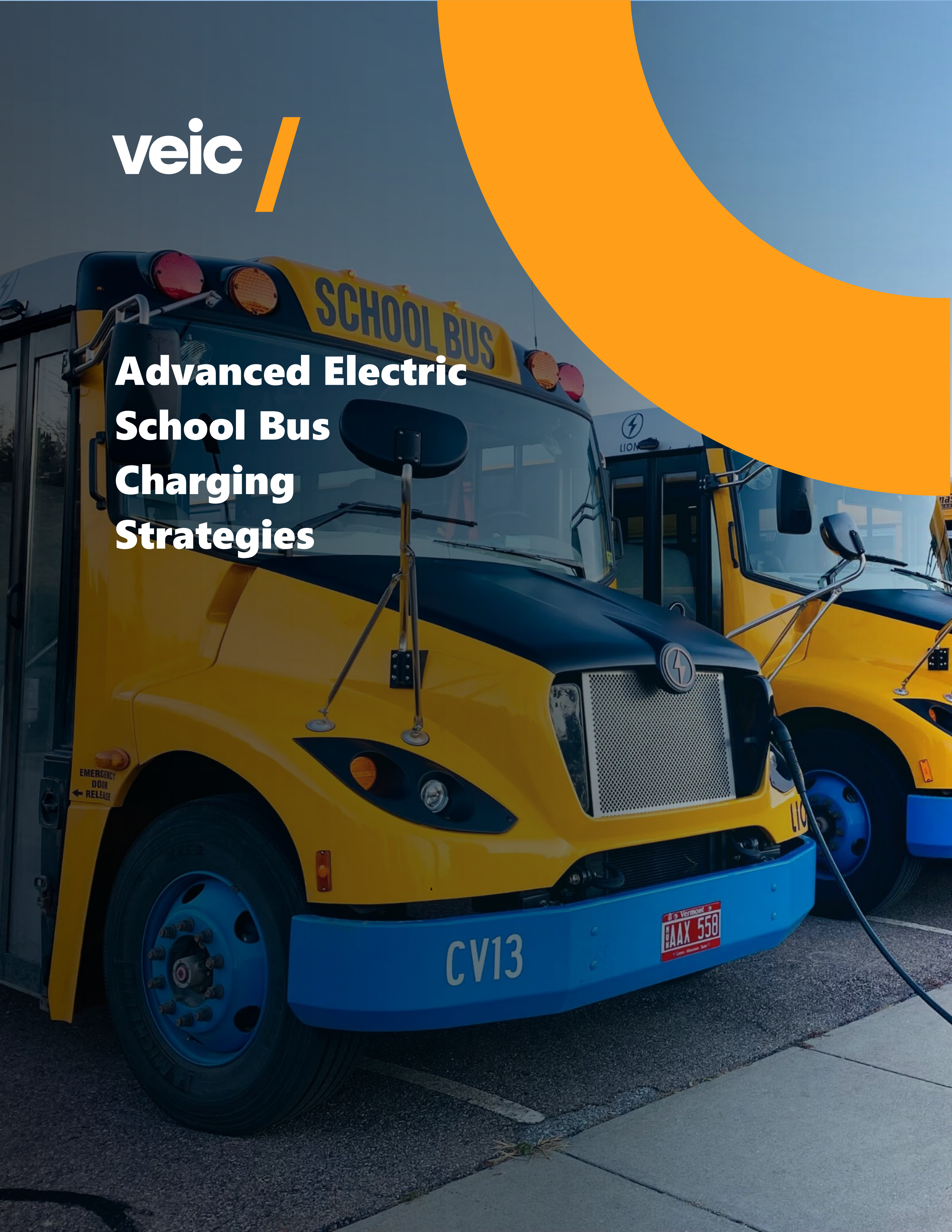
Advanced Electric School Bus Charging Strategies



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Introduction

This resource will assist school districts in evaluating evolving opportunities related to electric school bus (ESB) charging and load management. Examples of these opportunities include managed charging (sometimes called smart charging), vehicle-to-building, vehicle-to-grid and microgrids when connected to on-site solar. We are referring to these opportunities as "advanced charging" because they define activities beyond installing and basic usage of ESB chargers to plug in and fuel a bus. These opportunities can provide benefits to school districts but require districts to develop and manage enabling technologies.

Three categories of advanced charging opportunities relevant to ESB adoption will be discussed in this resource:

- **Managed Charging**: Managed charging describes strategies to automatically or manually control when and how much electricity your ESBs are drawing from the power grid to charge the batteries. Managed charging is emerging as a best practice for ESB operators to optimize fuel cost savings. Given the importance of managed charging to realize emissions reductions and operational savings expected from electric bus adoption, we have devoted a significant portion of this resource to this topic.
- **Vehicle-to-Building and Vehicle-to-Grid**: Vehicle-to-building (V2B) and vehicle-to-grid (V2G) broadly describe the practice of discharging ESB batteries to buildings or the grid during times when the buses are not in school transportation service. When referring to both practices, we will use "Vehicle-to-X" or "V2X." With V2X, vehicles, the grid and/or buildings are in a connected system, and the flow of electricity between the system components is controlled by a utility, a third-party or the fleet operator to the benefit of the grid and/or the school district.
- **Solar Energy Storage and Microgrids**: Solar generation, paired with a stationary energy storage system and/or a microgrid, can help to reduce emissions, manage electricity costs and provide energy resiliency to your school district and the community.

This resource provides a high-level summary of the purpose, an overview of technology and implementation guidance, and case studies for each strategy. It also provides tools to assess the potential costs and benefits of implementing each strategy.

Section 1: Benefits of Advanced Charging

Advanced charging[1] strategies can provide a variety of benefits to your school district, the community and to the power grid, which can then benefit all electricity customers.

Reduce ESB operational and infrastructure costs through managed charging

ESBs have the potential to reduce fuel and maintenance costs for school districts. The Electric School Bus Initiative estimates that ESBs can save schools $6,000 annually in fuel and maintenance costs.[2] Other estimates and evaluations of school buses have shown fueling costs are 40-75% less for ESBs. However, managed charging, discussed in Section 2, is often needed to fully realize these savings.

For example, in an evaluation of ESBs conducted by Vermont Energy Investment Corporation (VEIC) in Massachusetts, fuel costs were not reduced for school districts because they were plugged in at times of days when energy demand was at a peak (often after completing their second run of the day), and therefore utility costs to provide that electricity were higher due to assessed demand charges. In an evaluation of California utility programs for the California Public Utilities Commission, evaluators found significant, unnecessary energy consumption during system peak period from 4 PM to 9 PM.[3] Furthermore, 50% of charging energy and 40% of school bus charging sessions exhibited flexibility such that fleet operators could have avoided this charging behavior and still met their operational needs. School districts in both instances could have dramatically reduced their fuel costs by simply charging their school buses at night when fuel prices were lower. Managed charging systems can automate this process, eliminating the need for staff to be on site to plug in at beneficial times, such as later at night. They also reduce the chance for human error and inadvertently plugging in at the wrong time.

Optimize the use of ESB infrastructure to reduce school district energy use and costs

As your school district is planning for ESBs, it makes sense to think holistically about the school district's long term energy goals and how ESB infrastructure can be used to save money and meet aggressive clean air goals sooner and more affordably. For example, with the right hardware and software, ESB batteries can discharge power when they are not in school transportation service (see Section 3). This power can be discharged to a school building, which would be considered a V2B strategy. This can help to lower the electricity demand at peak times,

[1] "All About Managed Charging and 'Vehicle-to-Everything' or V2X | Electric School Bus Initiative" n.d.
[2] Huntington et al. 2023
[3] "Presentation-to-Cpuc-from-Cadmus-Team-on-Ey22-Evaluation_20230818.Pdf" n.d.

thereby reducing overall school district energy costs. Often when utilities are providing energy at peak demand times, they are drawing from more polluting sources of power generation. By using ESB infrastructure to manage energy use in your school district, you can also reduce the need for higher polluting generation sources to meet electricity demand.

Generate revenue for the school district.

ESB batteries can be grid resources to reduce peak demand on the grid, which is a V2G strategy (see Section 3). Some utility programs will compensate school districts for discharging power to the grid to manage system-wide peaks and renewable energy generation. It is important to understand if your utility offers these programs before investing in the technology to enable V2G activities.

Enable the utilization of renewable energy to power your ESBs

Many school districts have invested in installing solar panels on school property. If this generation is available to the school district and is of sufficient size, it can be used to power school buses (see Section 4). Using on-site solar generation to charge your buses can lower costs and increase the environmental benefit of ESBs. Equipment that enables advanced charging can be used to connect ESB infrastructure and renewable generation.

Provide on-site or neighborhood-scale energy resiliency in the event of power outages

ESB infrastructure, if planned out appropriately, can also be utilized to provide energy resiliency for the school district or neighborhood in which it is placed. School bus batteries that are fully charged can power buildings or critical operations during emergencies at sites without power. By connecting your buses to a solar and storage microgrid, buses can be recharged through the microgrid. These fully charged buses can then continue to operate when the power is out or can provide power to buildings or other operations in the event of an emergency.

Section 2: Planning for Managed Charging

Why Engage in Managed Charging?

Managed charging describes strategies to automatically or manually control when and how much electricity your ESBs are drawing from the power grid to charge the batteries. Managed charging is a best practice to fully optimize the fuel costs savings of ESBs, compared to diesel buses. The pricing structures in most electric utility rates[4] enable strategic charging behavior to unlock cost savings.

In many cases, utilities levy “demand charges” on non-residential customers to recoup system costs driven by a customer’s maximum power demand. Demand charges are typically assigned based on a customer’s highest monthly demand level, but they can also be based on demand level during the system’s peak period. Expanding the viable hours for charging means that lower power draws can be used over more hours to supply the same amount of energy. A managed charging strategy focused on site-level demand management would spread charging activity across the hours a vehicle is in the yard, or around existing energy uses, to avoid or mitigate increases to the site’s maximum instantaneous power demand.

Another impetus for managed charging is rate structures in which the cost for electricity varies throughout the day. As renewable energy generation continues to increase, grid operators increasingly face oversupply in the middle of the day and dramatic demand ramp-up in the evening. Rate makers are already considering opportunities for incentivizing midday charging to avoid curtailing that renewable generation and to smooth system-demand spikes. For example, if your utility experiences a lot of demand at a certain time of day, they may offer time-of-use rates with lower prices in off-peak times to incentivize customers to use electricity when there is less demand. Electricity bills can be lowered by avoiding charging buses during peak times or taking advantage of time-of-use rates that incentivize electric use during off-peak times (often at night). In the future, this may present opportunities for electric fleets with any midday electric vehicle downtime opportunities to charge (partially or fully) at a lower speed (and potentially lower cost) than overnight.

The strategy for incorporating managed charging into your electrification journey depends on your utility rate structure and your current school district or facility electrical load profile. Therefore, the first step in determining whether to engage in managed charging is to contact your utility. Your utility representative can help you with the following:

- Analyze current electricity usage and how ESBs may impact usage. This will help you understand if ESBs will move your district into a different rate category or if there is a risk of incurring demand charges.

[4] “Smart Charge Management Applications and Benefits for Federal Fleets” n.d.

- Provide information on demand charges and when they are likely to apply.
- Provide information on programs in which the school district could lower electricity rates or avoid demand charges.

In some cases, the addition of one or two ESBs will increase overall school district demand for electricity and risk incurring or increasing demand charges. In this case, it is prudent to consider a managed charging strategy. As fleets plan for greater electrification (and full transition to electric vehicles in the future) the benefits (and necessity) of managed charging will become more considerable for both ESB operators and utilities.

Given that charging stations may remain functional for over 10 years, selecting units with the capability to provide networking[5], managed charging and/or grid interactive charging may reduce or eliminate the need for early replacement if those features are desired later as the electric vehicle fleet grows before the end of the charging station's useful life. Networked capabilities can increase the cost of an L2 electric vehicle supply equipment (EVSE) by a couple thousand dollars upfront and an additional annual software subscription fee of around $500. [6], [7] So, if a managed charging strategy is estimated to generate at least that amount in bill savings over the lifetime of the unit, EVSE owners can expect a return on investment for these capabilities.

Managed Charging Technologies

There are various methods available to manage when and at what level charging occurs. These can include manual control (a person physically plugging/unplugging a charge port), mechanical timers, on-board vehicle controls (either vehicle telematics or a third-party smart device), a third-party networked software system tied into the chargers, or any combination of the above. The considerations for each are noted in Table 1 with detailed descriptions provided in the following paragraphs.

Manual Control

A human being can physically plug in and unplug vehicles. Some fleet operators can reduce energy costs by creating standard operating procedures around plugging in vehicles. The most basic strategy is to have drivers leave vehicles unplugged, and then rely on mechanics or other staff to plug in vehicles during off-peak hours, which are often later in the evening.

Though effective in theory, this system can result in inconsistent implementation over time and as ESB adoption scales up. The result is often higher-than-necessary energy and labor costs. Under certain rate structures, making a mistake for even a single 15-minute period could inadvertently raise a customer's recorded peak demand to a higher bracket for the entire rest of

[5] "Charging Networks | US Department of Transportation" n.d.
[6] Levinson et al. 2023
[7] Smith and Castellano 2015

the year, incurring thousands of dollars in utility charges. Manual control is not recommended as a long-term solution for fleet electrification.

Mechanical Timers

A mechanical timer device can be installed to prevent charging during certain hours of the day for many electric vehicle supply equipment (EVSE) options. These simple timers are inexpensive and do not require any monthly or annual fees. Programming these timers can be complicated work, so generally they should be set up to operate on the same schedule every day. Timers must be checked regularly for accuracy and to account for daylight savings time. Experience has also shown that timer system overrides may be triggered by staff and then forgotten, so it is prudent to include regular checks on the system in standard operating procedures. Timers can be a very economical solution for basic control of fleet charging because there are no subscription fees and installed costs are under $1,000 for a device that can control many vehicles.

On-Board Vehicle Control

Some electric vehicles have on-board controls and monitoring that allow operators to schedule charging start and stop times as well as track state of charge, odometer mileage, fault codes and other key metrics. These controls vary greatly in availability and capability. Some on-board controls can throttle the amount of power they draw. This allows the site to reduce demand charges for normal operations, with the ability to boost their charging level should a future need arise or at more favorable times of the day. In some cases, on-board vehicle charging controls can be a suitable alternative to manual control for small ESB fleets. School districts with more than two or three vehicles may struggle to keep all vehicles properly programmed without a central control system (see Networked Control below). Some newer on-board controls may be able to be networked and would follow a similar approach to what is below.

Networked Software Control

Both chargers and vehicles can be connected to web-based software platforms that allow fleet operators to monitor and control which vehicles are charged when, where and at what level. These systems may be simple or increasingly dynamic. The overall effect is much tighter control on both operations and power demand. Many ESBs come with cellular connectivity allowing the on-board telematics system to integrate with the charge management and EVSE systems. This provides the system operator with indicators for a vehicle’s current state of charge, how long it will need to draw power to get back to full, and when it is ready for service again. Depending on the EVSE installed, operators may also be able to throttle charging power to a desired level or deliver the minimum energy needed for a vehicle to complete its next run. Or this might be done through on-board vehicle controls. In either case, by spreading charging out over a longer period and minimizing peak energy demand, networked charging systems can reduce the demand charges incurred with the electric utility and also deliver cost savings by concentrating charging activity in off-peak periods when the fleet is subject to a TOU rate. World Resources Institute's Electric School Bus Initiative created a catalog of different charge management software providers to make it easy to compare charge management software options and learn about service provider options. [8]

Table 1. Advantages and Disadvantages of Various Managed Charging Strategies

	Pros	Cons	Cost range
Manual Control	* Simple and easy * No additional equipment/software needed	* Greater variance of exact timing * Not conducive to regular work hours * Prone to unreliable execution	Labor costs
Mechanical Timers	* With exception of seasonal changes, this is a "set it and forget it" solution * Can be deployed as a "fail-safe" for software-based methods	* Periodic changes in operations or rate structures require reconfiguration that can be overlooked * Often comes with a manual override that can be useful or lead to expensive mistakes * Not very sophisticated - if not carefully staggered, can lead to large fleet demand charges	$250 - $1,000 per unit
On-board Vehicle Control	* A good digital fail-safe * Scheduling each vehicle with intention can allow for staggered charging * May allow for throttling of power draw to extend charge times while reducing demand costs * Potentially able to be networked across fleet if vehicle software allows	* Level of controllability (and reliability) will vary from vendor to vendor *See notes for mechanical timers above	Included with some EV purchases
Networked Software	* May tie into vehicle telematics for greater monitoring capabilities – if telematics are available * Allows for visibility across fleet to more closely tailor charging to operations/ maintenance/ facility power draw * Remote access, control, troubleshooting * Precise, easily alterable control of timing and charging level	* Periodic changes in operations or rate structures require reconfiguration that can be overlooked * More expensive * Quality of software usability and features varies by vendor * Some software products are only compatible with certain charger brands. * Typically requires ongoing paid subscription	Up to $2,000/port / year Included in the purchase of some chargers

[8] "Charge Management Software Catalog | Electric School Bus Initiative" n.d.

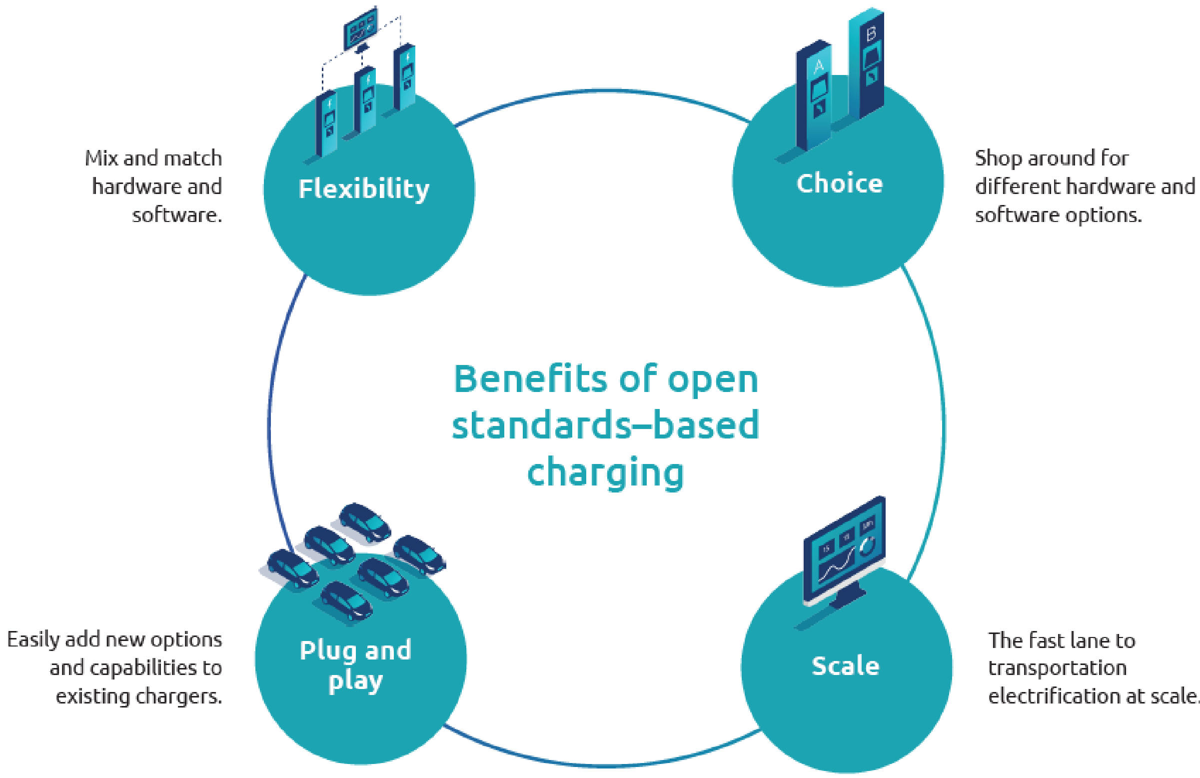
Open vs. Proprietary Charging Networks

The key to successful networked managed charging is software interoperability between the vehicles, the EVSE and the management platform. There are two types of networks for centralized, cloud-based control of electric vehicle charging: closed or proprietary networks, and networks based on the Open Charge Point Protocol (OCPP).

Proprietary networks are built on EVSE hardware and software developed by the same company. These networks can ensure seamless control since the EVSE design, its software and the cloud platform are all controlled by one entity. However, hardware that is sold with proprietary networking software generally cannot be unlocked for use with other software providers, thus locking users into subscription fees to maintain network connectivity through the vendor. Likewise, other manufacturers' products may not be able to be introduced and controlled by an existing proprietary software system.

OCPP is a set of international standards for communication between EVSE and central management software systems. OCPP-compliant EVSE can communicate with any software platform that also speaks OCPP, if the vendor has unlocked it to do so. OCPP-compliant EVSE still requires subscriptions to cloud-based software platforms to control charging, but the owner of an OCPP-compliant EVSE can switch to a new software provider without needing to buy new hardware and may likewise buy new hardware of a different make without changing charge management software. Even so, it is important to make sure interoperability is possible; while some EVSE manufacturers have made their chargers OCPP compliant, they still have a lock on the charger so that it will only work within that vendor's ecosystem of products. **Figure 1** below illustrates some of the benefits of using an open standard while **Table 2** below includes a summary comparison of OCPP and proprietary network EVSE.

Figure 1. Benefits of Open Standards-based Charging[9]



Note that most proprietary charging networks can control OCPP equipment.

Table 2. Open vs Proprietary EV Charging Comparison

	Unlocked OCPP-Compatible EVSE	Proprietary Network EVSE
Requires software subscription?	Yes	Yes
Can switch software vendor?	Yes	No
Can be controlled by proprietary network software?	Possibly	Yes (manufacturer's software only)
Can integrate other brands of OCPP EVSE?	Yes	Yes (integration fees may apply)
Can be integrated with another vendor's proprietary system?	Yes (Integration fees may apply)	No

[9] "Open-Standards-White-Paper.Pdf" n.d.

Managed Charging Lessons from Massachusetts ESB Pilot

The Massachusetts Department of Energy Resources (DOER) conducted a pilot project to evaluate ESB performance in 2016 and 2017.[10] VEIC administered this project and collected and analyzed data from the vehicles, chargers and drivers' logs to determine fuel cost savings and emissions reductions. The energy and cost savings from ESBs were smaller than anticipated. This was due in part to uncontrolled charging and demand charges that were incurred as a result. Emissions reductions were also impacted by uncontrolled charging as energy pulled from the grid at peak times tends to include higher polluting sources. **Figure 2** shows the actual fuel costs for three electric buses in the pilot that operated without managed charging and incurred $4,157 in avoidable costs. **Figure 3** shows the costs that could have been avoided with managed charging. In the managed charging scenario, the ESBs would have realized the operational and emissions benefits that are expected with electric vehicle adoption.

Figure 2: Total Energy Costs for Three Electric Buses Without Managed Charging

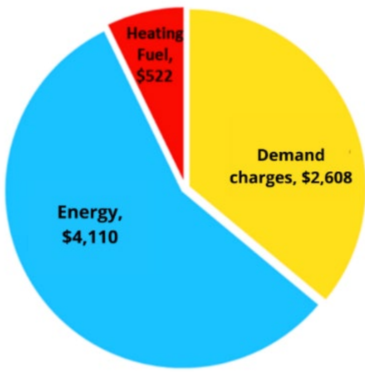
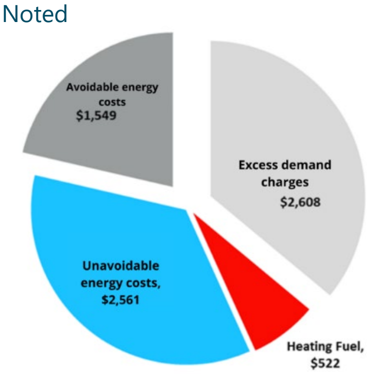


Figure 3: Total Energy Costs for Three Electric Buses with Managed Charging and Avoidable Costs Noted



Source: VEIC

Table 3 shows the impact of managed charging on the emissions associated with operating the three electric buses.

Table 3. ESB pilot total emissions. Equivalent diesel and managed charging ESB emissions provided for comparison.

School bus fuel type	Miles driven	GHG (tons)	CO (lbs.)	NO_x (lbs.)	PM_{10} (lbs.)	$PM_{2.5}$ (lbs.)	SO_x (lbs.)	VOC (lbs.)
Electric[11]	13,902	12.9	0	0	3.2	0.4	0	0
Diesel	13,902	31.4	31	19.6	3.5	0.7	0.3	2.9
Electric with managed charging [12]	13,902	8.7	0	0	3.2	0.4	0	0

Source: VEIC

[10] "Electric School Bus Pilot Project Evaluation" n.d.
[11] Assumes bus operating efficiency observed over the course of the study (2.38 kWh/mile); includes 135 gallons of diesel fuel for heating of school bus cabin.
[12] Assumes bus operating efficiency with minimized charge times (1.47 kWh/mile); includes 135 gallons of diesel fuel for heating of school bus cabin.

Section 3: Vehicle-to-Building and Vehicle-to-Grid

Vehicle-to-building (V2B) and vehicle-to-grid (V2G) broadly describe the practice of discharging ESB batteries to buildings or the grid during times when the buses are not in school transportation service. When referring to both practices, we will use “vehicle-to-X" or “V2X.”

The potential benefits of these activities are significant. U.S. school buses travel an average of 78 miles a day, for four or five hours, typically from late August through mid-June.[13] Because batteries in ESBs generally are in the vehicle yard for more hours than those during which they are actively charging, these excess hours present the opportunity to engage in V2X activities. For example, for a bus requiring five hours to recharge and depending on power level, there would be 14 to 16 hours per day during which the school bus battery could be connected to the grid,[14] but not actively recharging. The summer months are also a key opportunity for V2G with vehicles that are not in use, for example, in use for summer school, where buses can stay stationary for long periods of time.[15] During these “down” hours, the bus battery can be controlled to help offset facility demand (V2B) or to provide energy to the grid (V2G). WRI’s Electric School Bus Initiative published a representative example of the charging, in-route and non-charging demands of an electric school bus, “A School Day in the Life of an Electric School Bus.”[16]

If the nation’s 480,000 school buses were all replaced with electric vehicles[17], the total school bus battery capacity connected to the grid could provide 9 gigawatts and 43 gigawatt-hours, equivalent to the electricity used daily by 850,000 typical American homes.[18]

Interactive Charging and V2X

Basic managed charging programs are proactive in nature; ESB operators know when to avoid charging (based on their utility tariff) and will use the technologies described in Section 2 to ensure that vehicle charging does not occur during those peak times. In contrast, grid interactive charging is the practice of taking a signal from the utility to inform whether charging should be turned on, delayed or even if the vehicle should push power back out onto the grid. By avoiding peak demand periods and providing power back onto the grid when it is needed most, grid

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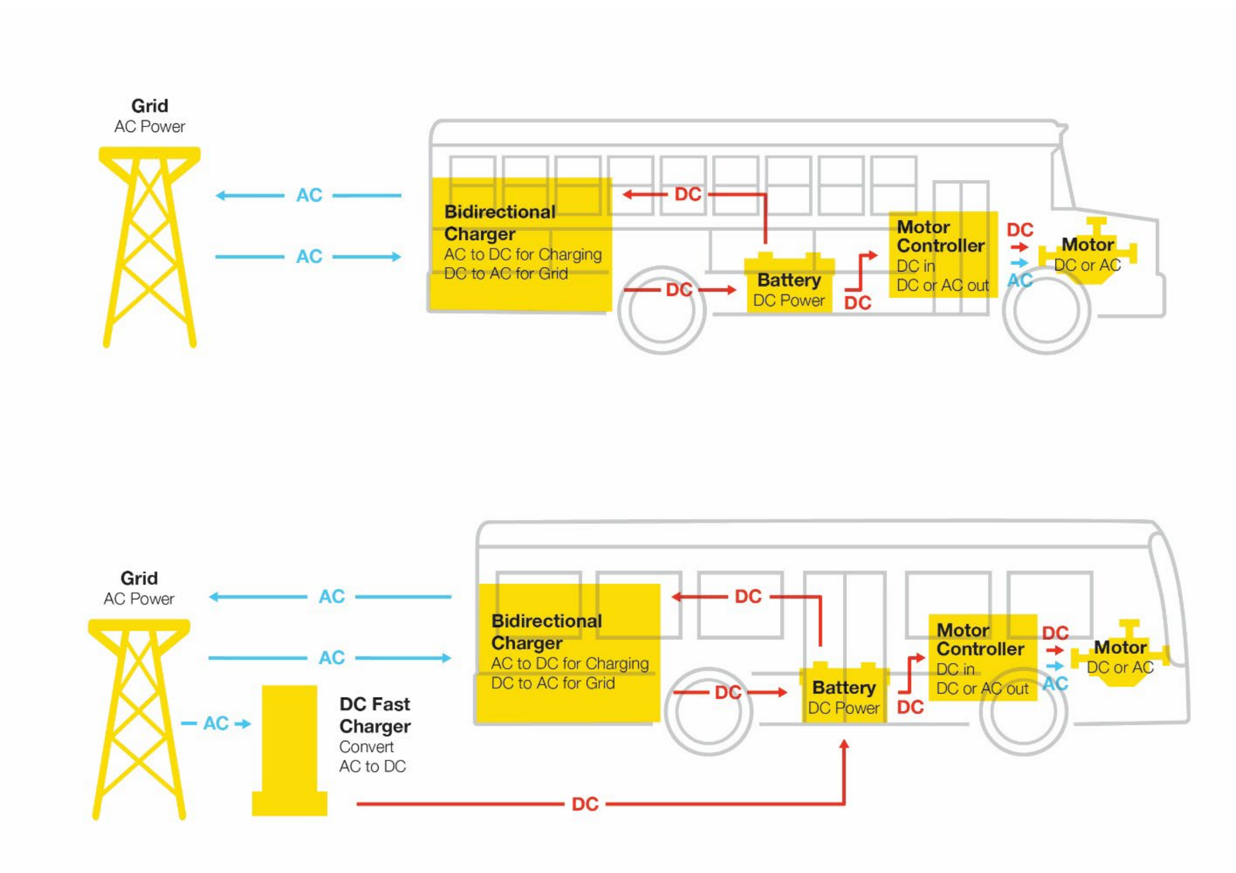
[13] Levinson et al.
[14] “A School Day in the Life of an Electric School Bus | Electric School Bus Initiative” n.d.
[15] Hampel 2022
[16] “A School Day in the Life of an Electric School Bus | Electric School Bus Initiative” n.d.
[17] ”American School Bus Council. Environmental Benefits: *Fact: You Can Go Green by Riding Yellow.”* N.d.
[18] This assumes consumption of 50 kWh for a typical family of four.

interactive charging can help reduce energy costs for ESB operators. These same strategies can be used to manage energy costs for school district facilities if buses are connected to buildings.

Grid interactive charging can be bi-directional or uni-directional. When electric buses and their charging stations are outfitted with **bi-directional** charging capabilities, this allows power to flow from the power grid to the bus as well as from the bus to a building or the power grid (see Figure 4). With bi-directional charging, electric buses can be connected to a specific building to provide supplemental energy during times of peak energy use when prices are higher, and even serve as a backup power source when emergency outages occur.

Figure 4: Bi-Directional Power Flow Between Buses and the Grid



Source: VEIC

Uni-directional charging (V1G) broadly refers to the use of grid-interactive managed charging to influence when vehicle charging is ramped up, ramped down or halted, to provide benefit to the electric grid – while still ensuring that vehicles are sufficiently charged when needed. V1G differs from managed charging described in Section 2 because it encompasses scenarios where the utility or a third-party entity would directly control the charging behavior of the vehicles - or indirectly influence it through sending price signals to the vehicle and charging station that would incentivize or discourage charging at certain times. Utilities may offer programs that provide incentives to their customers that enable them to control charging at more refined intervals than are contemplated under basic managed charging, with most allowing fleet owners/managers to maintain primary control and ensure buses are charged when they are needed to provide transportation services.[19]

How V2X Charging Works

V2X technologies are evolving and can support a range of actions that can benefit school districts, fleet operators and/or the grid. Table 4 shows the activities that can be supported and what you can do with the various non-interactive and interactive charging options.

Table 4. V2X Charging Functions and Supported Activities

		Functionality			Activities Supported		
EV Charging Connection Type	**V2X Acronym**	**One-way charging**	**Set time of charge**	**Set charging power**	**Access energy markets**	**Store + discharge energy**	**Sell energy back to the grid**
Basic Charging		✓					
Managed Charging		✓	✓	✓			
Vehicle-to-grid uni-directional charging	**V1G**	✓	✓	✓	✓		
Vehicle-to-building bi-directional charging	**V2B**	✓	✓	✓	✓	✓ **Behind the meter backup power**	
Vehicle-to-grid bi-directional charging	**V2G**	✓	✓	✓	✓	✓	✓

Source: Adapted from Nuuve. (2021, September 14). The real deal about the different types of electric vehicle charging. NUVVE Holding Corp. https://nuvve.com/different-types-of-ev-charging/

[19] "The State of Managed Charging in 2021" n.d.

The controls for V2G can be placed directly in the hands of the utility. The utility is then able to tell selected participating chargers to switch from one charging, or discharging, mode to another. Alternatively, and with increasing frequency, third-party operators may be tasked with maximizing V2G profits to the fleet operators, while also taking a percentage of that profit for their efforts. There is typically an "opt out" feature, by which a customer may prevent V2G modes activating for a particular event if it is not convenient at the moment, but this may come with a penalty for non-participation depending on the utility, its rates and customer agreements. In exchange for being able to use the customer's vehicle as an on-demand power resource, utilities may offer some significant financial incentives including reduced charging rates, equipment rebates and even direct payments. On the ground in South Burlington, Vermont, a school district teamed up with the local electric utility, service provider Highland Electric, and the state natural resources agency to deploy a V2G arrangement with an electric school bus that is expected to reduce costs for all utility customers.[20]

There is another option that may be available called "controlled charging", "demand response" or sometimes just "V1G" as it still includes a signal from the grid but does not allow power to flow in two directions. It entails using a signal from the electric utility to tell chargers when they should and should not charge with a little more specificity than the broad "peak period" brush strokes set up for time-of-use rate structures.

Considerations for Adopting V2X Strategies

V2X strategies and systems can provide benefits to school districts and the communities they serve. Before embarking on a V2X project it is important to determine how you intend to use this system and the benefits you expect to incur. The following are common benefits associated with V2X:

- Manage electrical load at school district facilities to avoid peak demand periods and reduce electricity bills
- Optimize site energy consumption to maximize utilization of on-site renewable generation
- Provide resiliency so school facilities can operate during a power outage
- Provide power to serve the community in the event of an emergency
- Participate in utility programs that offer incentives for charging off peak or for discharging power to the grid

After your school district has determined what the opportunities are for engaging in a V2X

[20] (Leah 2022)

project, there are some additional considerations before making the investment in equipment, software and staff training to support a V2X system.

- **School bus operations** – Consider when school buses are transporting students and when they will be charging to determine if and when vehicle batteries are available to discharge power to a building or the grid. A school bus which sits idle for many hours of the day may be an excellent candidate for grid interactive charging programs so long as the system ensures that the bus has plenty of charge for its afternoon run. [21] School vacations, weekends and summer are also times when school buses may not be in operation and available for V2X.
- **Emergency management plans** – Understand how school facilities serve as emergency shelters or how they are included as community resources in an emergency. Determine if school buses are expected to support community transportation needs in an emergency and consider a mutual aid agreement with a utility and other actors that creates a plan and process in place for ESBs to be readily deployed during an emergency. Williamsfield Central Schools in Illinois is one of the first school districts to enter a mutual aid agreement with Knox County to use its fleet of eight electric school buses as a source of back-up power when the grid is down.[22]
- **School district electrical load** - Work with your utility to analyze the school district's current electrical usage and whether the district is incurring demand charges. If yes, discharging the school bus battery to reduce school building energy use at times when the school district or the utility is experiencing peak demand could help lower the school district's electricity costs.
- **Utility programs** - Work with your utility to identify programs in which the school district could generate revenue from discharging electric bus batteries to the grid. While there is potential for a utility to benefit from this practice, utility programs designed to encourage customers to engage in V2X are nascent. Before investing in V2X systems, it is helpful to understand whether there is an opportunity to participate in programs that would generate revenue for the school district.
- **Battery health/longevity** – Engaging in V2X increases the number of battery charge/discharge cycles relative to solely transportation use. These additional charge/discharge cycles increase the wear and tear on batteries, which can increase battery degradation and shorten usable lifespan.[23] Work with your school bus vendor, ESB manufacturer and V2G program provider to determine whether engaging in a V2X program would impact your battery warranty or expected lifespan, and weigh this against the anticipated financial or other benefits of V2X participation.

[21] "A School Day in the Life of an Electric School Bus | Electric School Bus Initiative" n.d.
[22] Hosansky, Cruz, and Henderson 2024
[23] "Tips & Tools for Lowering Your Energy Bill | Con Edison" n.d.

WRI's Electric School Bus Initiative created a "V2X Implementation Guide and Mutual Aid Agreement Template" to help school districts understand best practices for implementing V2G and deploying ESBs as resiliency resources.[24]

Table 5 provides a checklist of questions to help you evaluate the feasibility and benefits of V2X for the school district, utility and community.

Table 5: V2X Feasibility and Benefits Checklist

Assess Feasibility of V2X					
Completed	**Action**	**Daily**	**Weekly**	**Monthly**	**Annually**
	Times when buses are not operating school transportation services				
	Times when your school district may be experiencing peak loads				
	Times when your utility may be experiencing peak loads				
	Impact of V2X on warranty or expected battery life				
Assess Benefits of V2X					
Completed	**Activity**	**Notes**			
	Identify utility programs that provide incentives or generate revenue for engaging in V2X				
	Determine if reducing peak loads at school district facilities through V2B will reduce energy costs for the school district				
	Assess role of school bus batteries in emergency preparedness: could school buses provide electricity to power school or other community buildings in the event of an emergency that includes a power outage				
	Assess role of school bus batteries to provide back-up electricity should the school district power go out				

The costs for setting up a V2G or V1G system depend on the features required. Several charging stations available on the market now allow for utility signal inputs to drive functionality for only minor increases in cost, with varying levels of sophistication. Over time, these services may

[24] "V2X Implementation Guide and Mutual Aid Agreement Template | Electric School Bus Initiative" n.d.

become more commonplace and affordable, but are again still somewhat experimental and the markets needed are still developing.

Over the next few decades, utility rates are likely to increase and load balancing will become increasingly difficult. This is due to a steady increase in renewable energy sources, the added loads of building heating and transportation becoming electrified, and larger and more severe weather events brought on by climate change. The financial incentives for customers to allow utilities to increase their control over large battery systems are projected to see steady growth over the coming years. As the technological hurdles are also tackled and overcome, V2G systems may soon become a major part of grid operations. However, it may be a few years before we see this control scheme developed to a level of sophistication that can handle the operational demands of a fleet operator.

Project Examples and Resources

- Beverly Massachusetts National Grid[25]
- White Plains New York and Con Edison[26]
- WRI Resource: "3 Design Considerations for Electric School Bus Vehicle-to-Grid Programs" [27]

[25] "Massachusetts Electric School Bus Delivered Power Back to Grid for 50+ Hours over the Summer; V2G" n.d.
[26] Lewis 2020
[27] Hutchinson and Kresge 2022

Section 4 – Solar Energy Storage and Microgrids

Many school districts serve as a site for solar generation and are wondering if it can be used to support ESB charging. This section will explore opportunities to use renewable generation paired with an energy storage system and/or a microgrid to reduce emissions, manage electricity costs and provide energy resiliency to your school district and the community.

How Solar Energy Can Support ESBs

Solar panels offer school districts[28] the ability to capture solar energy. When there is excess beyond the coincident site-level energy demand, solar energy can be stored and used during low solar-production hours to offset reliance on the utility to charge ESBs. Because solar and wind energy must be captured when the sun is out or the wind is blowing, energy storage is required to allow sites to use the energy when it is needed regardless of time of day. Below are a couple of ways you can pair your solar with ESBs to lower costs and increase energy resiliency at schools:

- **Solar energy**: Net metering programs allow school districts to charge using renewable energy when it is being produced, allowing excess energy production to flow back to the grid. Utilities compensate the solar array's owner for that excess energy, reducing overall energy costs.
- **Solar + storage:** This option includes a battery energy storage system (ESS). During daylight, the solar system stores excess energy it generates in batteries. That energy can be used later to help avoid peak demand charges or further reduce draw from the grid.
- **Solar + microgrid:** This option builds on solar and battery energy storage capabilities with a comprehensive controls system. Additional software, equipment and technologies are used to help you "island" from the grid and deliver the backup power you need during an outage.

What is a Microgrid?

Microgrids are small, self-contained generation, distribution and storage networks that can be both connected to the grid or fully self-sufficient when needed. The primary components are an energy generation system, an ESS and a control system.

An ESS is defined as one or more components assembled capable of storing energy for use at a future time. It can include (but is not limited to) batteries, capacitors and kinetic energy devices (e.g., flywheels and compressed air). ESSs are connected to energy generation sources such as

[28] "Solar for All Schools" n.d.

the local utility distribution system, renewable energy sources or a fossil fuel generator. There may be one or more sources connected to an ESS.

Renewable energy sources offer the best opportunity to integrate low-carbon energy generation into a fleet electrification plan. However, it is not possible to control when renewable energy is being generated. The microgrid leverages the ESS to store electricity until it is needed to power buildings or vehicles, or to participate in grid support programs by providing grid services. It is possible to integrate backup diesel generators into microgrids; some sites choose to keep a generator as an additional backup for peace of mind.

Figure 5 provides a visual of how a solar plus storage microgrid can be connected to support EV charging.

Figure 5: Solar + Storage Microgrid Connected to EVs

Source: VEIC

Pairing solar panels with an energy storage system, microgrid controls, software and other equipment can provide reliable backup power.

As your ESB fleet continues to grow, the school district should consider the following when deciding upon microgrid applications:

- **Provide power to charge ESBs when the power goes out** – School transportation is an essential service, so having a redundant source of energy to charge buses in the event of a power outage ensures reliable service.

- **Manage operational costs –** Microgrids can be a source of energy for school buses and school district facilities during peak demand, helping to lower costs overall. In addition, if the microgrid is of sufficient size it can provide baseline power to charge ESBs and reduce costs.
- **Provide energy resiliency in the event of power outages –** In addition to charging buses, a microgrid can be utilized to provide energy resiliency for the school district or neighborhood in which it is placed.
- **Enable the utilization of renewable energy to power ESBs –** Many school districts have invested in installing solar panels on school property. Equipment that enables advanced charging can be used to connect ESB infrastructure and renewable generation. This can lower costs and increase the environmental benefit of ESBs.
- **Participate in utility grid support programs –** Utility programs are quickly evolving. The programs offer utility customers financial benefits for participating in programs that help the utility support the grid. Peak shaving programs, or flexible load management, enable utilities to send signals to a microgrid to shift load to the storage asset to relieve grid load. Frequency regulation programs allow utilities to use the storage to manage grid frequency. The programs can open opportunities for microgrids to work for the site during normal operations while ensuring the site's needs are fully supported and backup resources are readily available in case of a grid outage event.

Communities around the country are now looking at utilizing a combination of solar and battery storage to fuel their vehicles. The Martha's Vineyard Transit Authority (VTA)[29] is fully electrifying its fleet of 32 transit buses supported by a solar plus storage microgrid. As part of VTA's microgrid they utilized 700 kW DC array canopies. The system also includes 16 vehicle charging stations underneath, with room for additional chargers to be added in the future. This is one of the first projects to build and deploy a microgrid. The VTA's goals are to lower fuel costs, decrease carbon emissions and support operations during outages.

Barriers to Implementing a Microgrid Project

While there are many benefits of advanced strategies such as microgrids, it is important to understand that these applications are in the early stages of adoption which means there are few examples of projects in which others in the industry can learn. The industry is also moving quickly with new players entering the market and new innovations frequently being introduced. With this fluid landscape there can be difficulties coordinating among component vendors and ensuring they are compatible.

Microgrid components are also expensive and securing funding can be challenging. Table 6 shows the costs of components of the VTA microgrid energy storage system. While federal

[29] "What If a Microgrid Could Ensure Reliability for Your Community and Your Electric Transit System?" n.d.

funding is available, batteries may not be compatible with Buy America requirements. Grant requirements can also be rigorous, particularly around safety plans for operation and transportation requirements to move batteries.

Finally, development of a microgrid project requires strong planning and project management to ensure proper phasing of procurement and engagement of project partners, coordination of onsite installation activities and engagement with your utility to support interconnection.

Table 6. Costs Estimates for Microgrid Energy Storage System

Component	Specs	Cost - High	Cost - Low
Energy Storage System	500 - 800 kWh 250 kW to 1.5 mW	$ 550,000	$ 350,000
Inverter	125 to 250 kW	$ 60,000	$ 40,000
Software control systems	integrates ESS, vehicles, solar, etc.	$ 200,000	$ 75,000
Interconnection upgrades	utility upgrades	$ 100,000	$ 50,000
Engineering and Design	design of system and interconnections	$ 100,000	$ 25,000
Total		**$1,010,000**	**$ 540,000**

Source: VEIC, Martha's Vineyard Transit Authority microgrid project

Acknowledgement

The Vermont Agency of Transportation generously granted permission to the World Resources Institute to use content from its *Managed Charging Memo,* which was prepared by VEIC, to support development of this resource.

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Appendix A: Glossary

Advanced Charging terms and definitions:

Battery Energy Storage System (BESS)	Are devices that enable energy from renewables, like solar and wind, to be stored and then released when customers need power most.
Capacity	The amount of power available for output from the electric grid at a given time.
Demand	The average amount of power that is pulled from the electric grid by one or more sites for a specific 15-minute period.
EVSE	Electric Vehicle Supply Equipment – in addition to chargers, this also includes all the supporting infrastructure such as mounting, charge cords and connectors, and protection features.
Grid-interactive charging	Charging management structure in which a signal from the utility or grid-operator is used to control the amount and direction of charging/power-offloading of vehicle batteries.
Microgrid	A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.
OCPP	Open Charge Point Protocol – an open (i.e., non-proprietary) standard for communications between electric vehicles and managed charging software platforms. The latest version is OCPP 2.0.
Off-Peak	The time period set by an electric utility for which electricity and power prices may be set lower due to a reduced average loading on the system. Exact days and times are set by the utility and are defined in the tariff sheet for each rate offered – typically overnight and weekends.
Peak-Period	Times and days of the week during which an electric utility may set costs higher for energy and/or power to disincentivize usage while the grid is heavily loaded, and generation is expensive. Exact days and times are set by the utility and are defined in the

tariff sheet for each rate offered – typically midday and evening, Monday through Friday.

V1G A managed charging program where time or magnitude of charging is controlled in relationship to a signal provided by the utility in exchange for reduced billing rates, incentives, or other remuneration.

V2G Any charging system in which power from electric vehicles is pushed back out onto the grid, usually at the request of the utility and according to an agreement for how the customer will be paid for the energy supplied.