VEHICLE-TO-GRID PILOT ASSESSMENT

STAFF REPORT OF THE EFFICIENCY MAINE TRUST

Submitted to the Joint Standing Committee on Energy, Utilities and Technology
of the Maine State Legislature

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1. Regulatory Framework

In 2023, the Legislature passed LD 519, *Resolve: to Evaluate a Vehicle-to-grid Pilot Project Using Electric School Buses*,[1] directing the Efficiency Maine Trust ("the Trust") to assess the feasibility of implementing a vehicle-to-grid (V2G) pilot project, located at the Wells-Ogunquit Community School District, in which the batteries in electric school buses are charged at times when demands on the electric grid are low and electricity stored in those batteries is discharged to the electric grid when demands on the grid are high.

The resolve also directed the Trust to work with interested parties and stakeholders to complete the assessment of the pilot project considering the following elements:

a. The likelihood of an electric school bus V2G pilot project becoming cost-effective in the future;
b. Options that will minimize the costs and maximize ratepayer benefits;
c. Forecasted costs inclusive of grid interconnection; and
d. Whether a pilot project could be implemented within the available budget in the Trust's Innovation Program.

The resolve also requires that the Trust submit a report to the Legislature's Energy, Utilities and Technology Committee by January 15, 2024 detailing the assessment of the pilot project and include a recommendation regarding its feasibility.

2. Background

The vast majority of electric vehicle (EV) charging in Maine and across the US has been unidirectional (one-way), where electricity flows from the grid into EV battery packs. The relatively new concept of V2G uses bidirectional (two-way) charging -- sending power from the grid to charge EVs, and dispatching power from EVs back to the grid. When dispatching power from EVs back to the grid is performed during periods of high electricity demand, the grid system can benefit by delaying or avoiding the deployment of transmission and distribution infrastructure and avoiding dirtier and more costly generation.

The Trust worked with two primary stakeholders in formulating an assessment of a potential V2G pilot project in Wells-Ogunquit school district. First, the Trust collaborated with Ledgemere Transportation, the local branch of the national organization Student Transportation of America (STA), which manages the electric school buses for the Wells-Ogunquit school district. Second, the Trust worked with Central Maine Power (CMP), the electric utility serving the school district. As a first step, the Trust conducted a literature review of completed and ongoing V2G pilots from around the country.

It then completed a benefit-cost analysis incorporating *known* benefits and costs. The Trust encountered a number of unknown costs that could not be quantified until the Chapter 324 Interconnection process can be completed by CMP. The existence and magnitude of unknown potential costs has made it challenging to conduct a comprehensive and accurate assessment.

[1] Resolves, Chapter 32, 131st Maine Legislature, First Regular Session, LD 519, *Resolve: to Evaluate a Vehicle-to-grid Pilot Project Using Electric School Buses.*

In the fall of 2023, STA submitted a "Level 2" interconnection application to CMP for the additional load of the bidirectional charger and for the V2G activities that would occur. Level 2 is the category of interconnection application assigned to generators sized between 25 kW and 2MW. On January 10, 2024, CMP informed STA that its Level 2 application failed to pass the screen requiring that "the Export Capacity of the Aggregated Generation shall not exceed fifteen percent (15%) of the line section's annual peak load as most recently measured or calculated at the substation."[2] STA was invited to pursue a more in-depth six-week study at a minimum cost of $2,500, or to reapply for a more rigorous "Level 4" review. The application fee for a Level 4 costs $3,000, and the Trust has been told the average cost of conducting a Level 4 study averages around $35,000. Level 4 studies commonly last months. Not until those studies are complete will the parties have a sense of the costs that may be needed to upgrade the circuit. STA has expressed that they do not intend to move forward in this process, citing time delays, the uncertainty of costs they would have to bear for the studies and the ultimate interconnection, and the lack of a known rate of return.

3. V2G School Bus Pilots in Other Jurisdictions

A. Active and Recently Concluded Pilots

There are several examples of V2G school bus pilots nationwide, but most are ongoing and have not published reports on their activities or results. Though these pilots have established proof-of-concept for the technology, they have yet to solidify the business case to support a reliably economic V2G model.

ConEdison: White Plains, NY[3]

From 2020 to 2021, this $1.08 million demonstration project examined the technical and operational viability of using school buses as both a grid resource and transportation asset." Two electric buses were operated as control, or base case without V2G, and were compared with the costs and performance of three buses configured to engage in V2G activities. The school district was compensated for V2G activities in the form of "bill credits" from the utility. While the final amount or formula used to calculate bill credits was not disclosed, the report mentioned that "bill credits provide value, but do not overcome costs of the hardware and software components enabling V2G." The pilot experienced many hardware, software, and maintenance challenges associated with V2G that reduced the uptime of V2G buses compared to control buses. The report claims that continuous innovation in electric school bus technology is expected to reduce these impacts eventually, but does not provide a timeframe. The project found that total cost of ownership (TCO) was higher for V2G buses than for control buses with managed, unidirectional charging.

National Grid: Beverly, MA[4]

This pilot started with one bus in 2021, increased to two buses in 2022, and then comprised three of the school district's four electric buses in 2023. The district installed 60 kW bidirectional chargers. In 2021, one bus participated in 30 load management events, averaging a discharge rate of 50 kW. In 2022, two

[2] 65-407 Code of Maine Rules Chapter 324 (Small Generator Interconnection Standards), Section 7, sub-section (a).
[3] ConEdison, REV Demonstration Project: Electric School Bus V2G Q1 2022 Quarterly Progress Report, May 2022.
[4] Highland Electric Fleets, "Highland Electric Fleets Coordinates Electric School Buses' Summer Job – Supporting Local Grid with Vehicle-to-Grid Technology," PR Newswire, August 25, 2022.

buses participated in over 32 events, averaging a discharge rate of 43.75 kW per bus. As of the writing of this report, data for 2023 is unavailable and the compensation structure is not disclosed.

Green Mountain Power: South Burlington, VT[5]

Starting in 2022, South Burlington's school district deployed four electric buses, each associated with a bidirectional charger. The buses were dispatched to target monthly Regional Network Service (RNS) peaks, as well as annual system peaks, as one of 33 participants in the Flexible Load Management (FLM) 2.0 Innovative Pilot. This 18-month pilot was large enough in kW to shift the local monthly RNS peak to adifferent hour. Details on the performance of individual pilot customers are unavailable. The program administrator paid performance incentives for the electric buses' impacts on both RNS peaks and annual peaks. While the pilot ran at an overall financial loss, Green Mountain Power (GMP) predicts that over three years, with additional load, the net present value (NPV) of the pilot would be positive. As a result of the pilot, GMP found that the use of baselining to calculate performance incentives was administratively burdensome, so the pilot will not continue forward to a full program. Instead, a new pilot (FLM 3.0) will test a critical peak rate structure. It is unknown if South Burlington will re-enroll its electric buses into FLM 3.0.

San Diego Gas and Electric: Cajon Valley, CA[6]

Buses in this district started participating in V2G in 2022. Seven of this district's 49 electric school buses are V2G-compatible. The buses charge at six 60 kW bidirectional chargers. Five V2G-compatible vehicles were acquired in 2019, and two more in 2021. The older buses are capable of discharging at a maximum speed of 28 kW, whereas the newer buses can discharge at a speed of 45 kW. These buses charge during off-peak hours to minimize strain on the grid. The program administrator helped the school district to obtain federal and state grants for the school buses, and paid for the charging infrastructure and electrical upgrades necessary to accommodate V2G activity. In exchange, the school district will share detailed data with the program administrator and others to disseminate the learnings. The district participates in the program administrator's Emergency Load Reduction Program (ELRP).[7] This program compensates participants at $2/kWh for energy dispatched to the grid or for reductions in behind-the-meter energy load during grid emergencies occurring from May through October.

The program administrator's ELRP is limited to a maximum of 60 hours/year. Assuming five buses discharging perfectly at 28 kW and two buses discharging perfectly at 45 kW, the fleet of electric buses in Cajon Valley have the potential to deliver a total of 230 kW. In the event of delivering the maximum of 60 hours at a compensation rate of $2/kWh, the most that the school district would receive is a total $27,600 in a year. This equates to an average of $3,942 per bus. In 2022, SDG&E ELRP events summed to 55 hours.[8] Actual performance data of the buses is currently unavailable.

[5] Vermont Public Utilities Commission, GMP Flexible Load Management 2.0: GMP Final Report, Case No. 21A-1111, January 2023.
[6] Electric School Bus Initiative, "The Electric School Bus Series: Powering the Grid with Cajon Valley Union School District," February 28, 2023.
[7] For more detail, see https://elrp.sdge.com/
[8] California Public Utilities Commission, Emergency Load Reduction Program (ELRP) Data and Information.

Pacific Gas and Electric: Multiple locations, CA[9]

Pacific Gas and Electric operates a Vehicle-to-Everything (V2X) pilot program that offers incentives for customers to access bidirectional charger technology. Open enrollment for commercial vehicles charging bidirectionally is ongoing. Customers are also required to participate in PG&E's Emergency Load Reduction Program,[10] which mirrors the ELRP for SDG&E mentioned above. In addition to ELRP incentives, this program compensates site hosts $2,500 to $3,000 upfront for chargers less than 50 kW, and $4,500 to $5,000 for chargers greater than or equal to 50 kW. Additionally, the program administrator will pay performance incentives.

B. Pilots that Did Not Advance

Not all V2G pilot proposals have come to fruition. Reasons discontinuing these pilot proposals include, but are not limited to, cost-effectiveness concerns, operational risk to school districts, and limited school district funding. The following examples outline some of these cases.

Massachusetts Department of Energy Resources: Multiple locations, MA[11]

In 2015, the first electric school bus pilot project operated in the towns of Amherst, Cambridge, and Concord, Massachusetts. The pilot was significant in generating findings about the charging and operation of early electric school buses. The pilot modeled a scenario of what might have happened had V2G been operational, based on actual usage of the electric school buses. However, it did not move forward with executing V2G activities, citing that "V2G or (vehicle-to-building) V2B electric school bus systems is most likely not cost-effective at present. Any V2X system would present relatively high risk to participating school districts and require close management by school or district staff to realize financial savings."[12]

PSEG Long Island: Suffolk Transportation Services, NY[13]

This proposed 3-year pilot, intended to run from summer 2020 to summer 2022, was designed to target constrained circuits as a non-wires alternative solution. While school is in session, electric buses would be charged off-peak with 19.2 kW chargers for the bus management company to maximize financial savings. While school is out of session, a third party would manage the battery resources in the electric buses at an ideal location, with 50 kW chargers to maximize grid benefits. In exchange for allowing the program administrator to operate the batteries during summertime, the program administrator would compensate the bus management company via a one-time $100,000 payment per bus to help offset the incremental cost of the bus compared to its diesel counterpart. For years 1 and 2, the budget for third-party pilot support was $190,000. The budget for materials and equipment was $80,000.

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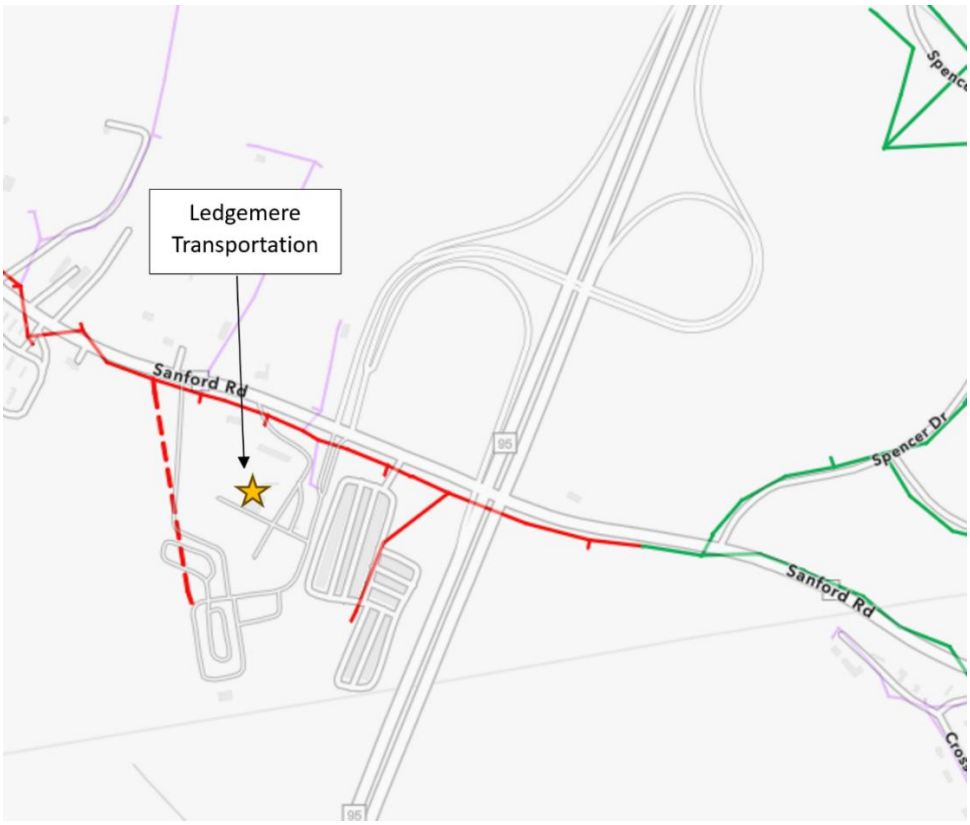
[9] Pacific Gas and Electric, Vehicle-to-Everything (V2X) pilot program.
[10] Pacific Gas and Electric, Emergency Load Reduction Program.
[11] Vermont Energy Investment Corporation, Electric School Bus Pilot Project Evaluation, Prepared for the Massachusetts Department of Energy Resources, April 20, 2018.
[12] *Id.,* p. 4.
[13] PSEG Long Island, Utility 2.0 Long Range Plan – 2019 Annual Update, Prepared for Long Island Power Authority, June 28, 2019.

The pilot was suspended in 2020 due to "challenges with the electric bus design, concerns from the bus company stemming from the pandemic, and the school district's limited availability of funds."[14] Ultimately, the budget for this pilot was withdrawn in 2022, noting that the program administrator and its customers "will continue to realize the benefits of transportation electrification through other…initiatives."[15]

4. Suitability Review of the Wells-Ogunquit School District Charging Site

By October 2024, the Wells-Ogunquit school district and its partner, Ledgemere Transportation, aim to have 11 electric school buses operational. On CMP's current Solar Photovoltaic (PV) hosting capacity map (Figure 1 below), the location of the charging site has less than 0.5 megavolt-ampere (MVA) of additional capacity on its 3-phase circuit.[16] CMP Staff indicated there is a substantial amount of solar generation under the associated Pratt & Whitney substation.

Figure 1: Current CMP PV Hosting Capacity Map



The base case, without V2G activities, is to install six 30 kW unidirectional fast chargers at the existing bus depot (pictured above). The installed cost for the 300 kilovolt-ampere (kVa) transformer in the base case is $65,000. The maximum additional load that this transformer can safely accommodate is

[14] PSEG Long Island, Utility 2.0 Long Range Plan & Energy Efficiency, Beneficial Electrification and Demand Response Plan - 2022 Annual Update, Prepared for Long Island Power Authority. July 1, 2022, p. 31.
[15] *Id.*
[16] CMP PV Hosting Capacity (arcgis.com)

approximately 50 kW. Any additional load would require a larger and more expensive transformer. This limits the potential pilot size.

In the hypothetical case of a V2G pilot, one of the 30 kW unidirectional chargers would be replaced by one 44 kW bidirectional charger. The incremental cost of this charger is approximately $20,000. The additional cost of relay upgrades for the transformer to accommodate V2G activities is unknown. CMP was unable to provide estimates of an interconnection cost for a V2G pilot because the application failed the Level 2 screening and did not proceed with a Level 4 study. In order for a pilot project to work for STA, the Trust would need to cover the incremental cost of the equipment, administrative burden, and any additional interconnection costs that the host site must pay to CMP.

As discussed earlier in Section 2, STA submitted a Level 2 interconnection application to CMP for the additional load of the bidirectional charger and for the V2G activities that would occur. The project manager for STA described the application as not set up for simple V2G projects and not intuitive for people who do not typically work on interconnection programs. As noted above, the Level 2 application failed due to the amount of existing generation already on the circuit. However, the project was offered the option to pursue a more thorough study at an additional cost. If the in-depth review were to fail, the site could reapply again at Level 4. A Level 3 review is for non-exporting projects, so is not applicable for V2G projects. As a result, V2G projects that do not pass Level 2 are escalated directly to Level 4, for which the review process is longer and more expensive.[17] As noted above, STA has expressed that its intention to discontinue its pursuit of this process.

5. Pilot Cost Effectiveness Analysis

The Trust has analyzed the potential cost-effectiveness of a hypothetical pilot at the Wells-Ogunquit school district specifically, and the likelihood that V2G might be cost effective more broadly across the state in the future.

The Trust used its approved avoided costs for Triennial Plan V, including the cost of carbon and avoided capacity, transmission and distribution.

To calculate the quantity of avoided carbon, the Trust took the difference in carbon intensity of ISO-NE locational marginal units between high demand days and the load-weighted annual average for all hours. The difference was applied to the expected kWh discharged by the site.

The hypothetical V2G pilot assumes that annual grid peaks only occur while school is out of session. This is a best-case scenario. In the past seven years, three annual peaks have fallen in June and September, two of which occurred during the typical K-12 school year in Maine.

The Trust also noted that batteries are not eligible for net metering. Therefore, site hosts (or bus operators) would not be compensated for their energy exports to the grid.

The Trust also considered the findings of studies about the impacts of V2G on the bus batteries. Previous V2G pilots and studies have found that a battery's lifetime is directly tied to the number of discharge cycles experienced by the battery. In all scenarios, the use case of V2G is targeted only at

[17] See CMP's interconnection resource webpage at https://www.cmpco.com/suppliersandpartners/servicesandresources/interconnection

annual peaks to minimize the number of discharges. Other use cases, such as energy arbitrage, require many more discharge cycles, further advancing the rate of battery degradation. Therefore, both scenarios assume 15 events per year at a duration of 3 hours each. Seventy percent (70%) of events occur while school is out-of-session, and 30% of events occur while school is in-session.

Costs for interconnection studies and for utility-side upgrades are unknown due to variability from site-to-site and circuit-to-circuit. It is important to note that these unknown costs can tip the scale from a positive economic value to a negative economic value.

Hypothetical two-year pilot project at Wells-Ogunquit

Before learning that the site failed its Level 2 screen, the Trust conducted an analysis of a hypothetical pilot project at the Wells-Ogunquit site only. Many of the costs are shown as unknown because the project hosts chose not to pursue a full interconnection study. The analysis assumes the following conditions exist:

- The Trust would conduct a two-year pilot project and the administrative cost would be determined through a competitive bidding process. The incentives to the site host would cover up to 100% of the incremental cost of the bidirectional charger, interconnection costs, administrative costs.
- As discussed above, interconnection costs are unknown.
- The warranty offered by the bus manufacturer allows for V2G activities without consequence.
- All annual grid peaks occur when there is a sufficiently charged bus on-site available to discharge, and a driver, maintenance worker, or other person is available to plug that bus into the only on-site bidirectional-capable charger. This is a reasonable assumption for Wells-Ogunquit, as the district will have eleven (11) buses capable of discharging. Buses discharge at a rate of 44 kW during events.
- Ledgemere Transportation successfully rotates buses performing V2G activities to minimize the number of discharge cycles to each bus. Because of this, battery degradation costs are negligible, and a battery replacement is not needed.

Table 1: Estimate of the Net Present Value (NPV) for the known costs and benefits

Item	Site Host NPV ($)	Ratepayer NPV ($)
Efficiency Maine payments to host site for administrative and interconnection costs	Unknown	(Unknown)
Third-party management of pilot		(Unknown)
Incremental cost of bidirectional equipment	($20,000)	
Efficiency Maine payments to host site for equipment	$20,000	($20,000)
Capacity, Transmission, and Distribution benefit		$39,022
Incremental cost for relay protections for transformer	(Unknown)	(Unknown)
Interconnection application	(Unknown)	(Unknown)
Interconnection study	(Unknown)	(Unknown)
Utility-side upgrades	(Unknown)	(Unknown)
Sum of Known Net Present Values	**($0)**	**$19,022**

There are some minor additional benefits to the project, the value of which could be attributed to the site host but are not included in Table 1 because they are either so small or speculative. For example, as noted above, the energy value for the electricity being dispatched from the battery to the grid is not eligible for compensation under the NEB program. In theory, an alternative program design might offer compensation to the site host equal to the value of the energy. Over the course of a 2-year pilot, the value of the electricity would be approximately $375 for the series of 15 dispatches during summer peak periods by a single electric bus. Also, there is some value for the avoidance of carbon that is achieved by these dispatches, which can be calculated by multiplying the number of tons of carbon avoided times a price per ton of carbon. If, for example, the Trust were to apply the levelized, marginal abatement cost for carbon in New England ($125 per short ton of CO_2), the value of the carbon savings from the dispatches of electricity to the grid from a single bus over a 2-year period would be approximately $44.

The Legislation asks the Trust to consider the likelihood that a more broad-based electric school bus V2G pilot project would become cost-effective in the future. This is a difficult assessment to make in the current regulatory environment, especially with the potential for interconnection procedures to introduce delays and costs. School districts are purchasing electric buses to move away from expensive and harmful fossil fuels, supported by a grant program from the US EPA. Based on the Trust's discussions with STA and its review of pilots from around the country, entities may consider adding V2G functionality if that functionality provides a potential extra revenue stream. To the extent that adding V2G functionality results in delays or creates uncertain costs, entities are unlikely to pursue V2G capabilities, the potential for incremental revenues notwithstanding. In this context, the Trust considers refinements to the current interconnection process governing V2G to be a prerequisite to an analysis of the potential cost-effectiveness of V2G incentives.

It also is useful to examine the reason the STA project in Wells-Ogunquit failed to qualify as a Level 2 generating facility under the interconnection procedures established under Chapter 324 of the Commission's Rules. Specifically, the STA project failed the technical screen described in Section 7(A):

§ 7. GENERAL TECHNICAL SCREENING CRITERIA

A. For interconnection of a proposed generator to a Radial Distribution Circuit, the Export Capacity of the Aggregated Generation shall not exceed fifteen percent (15%) of the line section's annual peak load as most recently measured or calculated at the substation. A line section is that portion of a distribution system connected to a Customer bounded by automatic sectionalizing devices or the end of the distribution line. The T&D Utility shall be permitted to apply this screen at each automatic sectionalizing device upstream of the ICGF, including the substation circuit breaker.

The application of the § 7(A) screen to the STA project makes clear that Chapter 324 rules do not currently account for the expected operating profile of a V2G installation. While a V2G installation has no incentive to export when conditions on the grid are at 15% of capacity, the screen lumps in the V2G project's full export capacity with the full export capacity of every other existing generation project and all of those with fully executed interconnection agreements. The current process assumes that V2G will contribute to a potentially dangerous situation during low load conditions and requires a more rigorous, costly and time-consuming Level 4 review. However, no well-designed V2G program would provide an incentive for vehicle discharge during low-load conditions. Why would a fleet operator take a bus out of service, plug it into the bi-directional charger, and start discharging without an incentive? They wouldn't. As already discussed in this report, each discharge cycle is valuable to the bus operator. Until the Chapter 324 rule creates a predictable, low-cost interconnection process for energy storage systems – including V2G systems – capable of controlling their export to the grid, it is unlikely that fleet operators will go to the trouble to experiment with V2G capabilities.

V2G installations participating in load shifting initiatives are only going to discharge on peak. Until interconnection procedures contemplate the reasonable operating characteristics of this type of installation, V2G project cost-effectiveness will remain an academic rather than practical consideration.

6. Conclusions

It appears that the Wells-Ogunquit school district and its vendor will not proceed further in the process, and as a result, will not pursue V2G in the immediate future.

Maine's current grid interconnection rules (see, Chapter 324 of the Public Utilities Commission's rules) create barriers to battery installations in general, but specifically disadvantage battery installations that export their capacity on to the grid. The Trust will continue to work with relevant stakeholders to improve this process for batteries while recognizing the need to maintain safety and reliability.

The Trust also is actively developing its Triennial Plan for fiscal years 2026-2028 (Triennial Plan VI). Based on the literature review completed for this study, the Trust Staff will work with its Board to consider adding V2G to its Demand Management Program in Triennial Plan VI and will support efforts to modify the interconnection process to accommodate electricity storage installations, such as those found in electric school buses, on a parallel timeline.