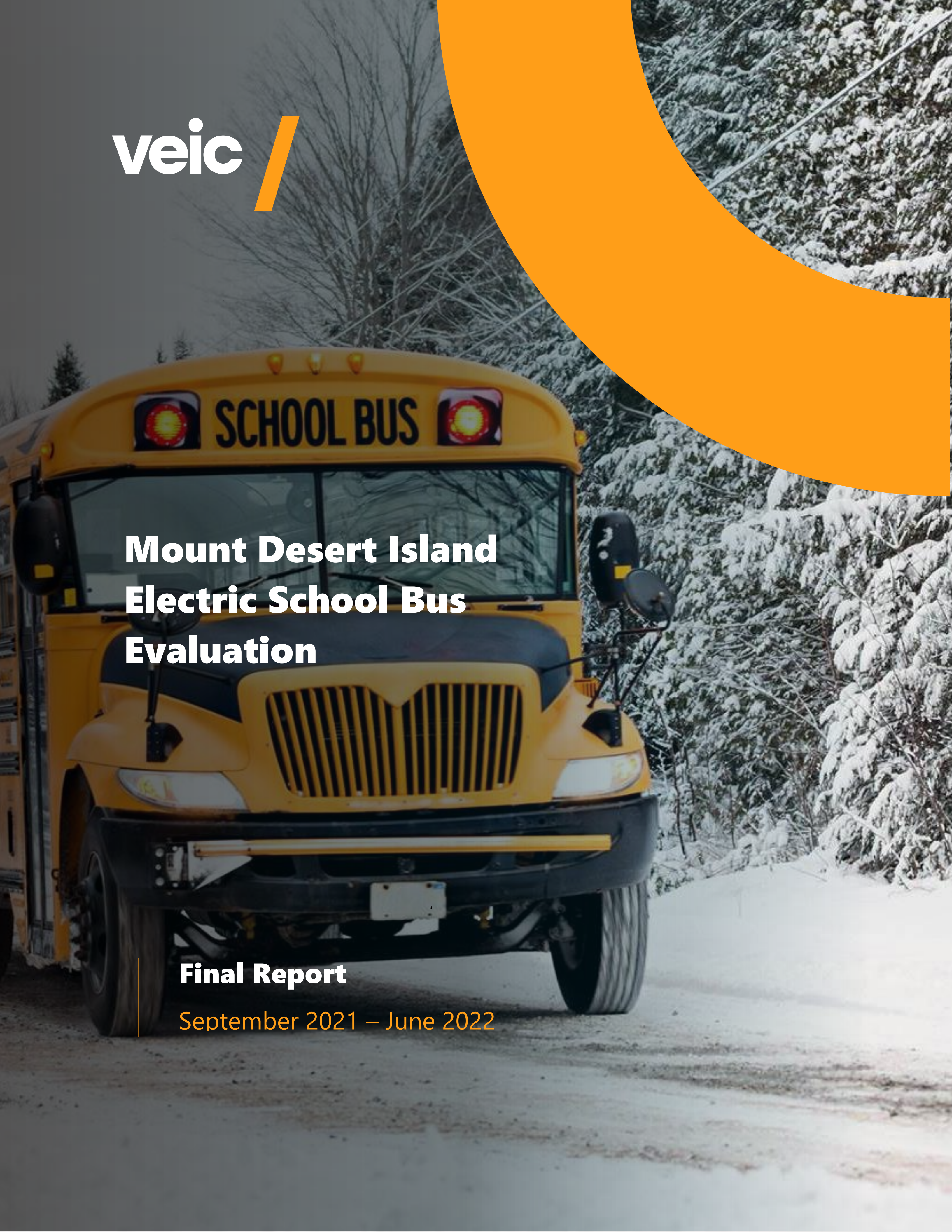

Mount Desert Island Electric School Bus Evaluation

Final Report

September 2021 – June 2022

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Thank you to the evaluation participants, Mount Desert Island High School and A Climate to Thrive, for their leadership on school bus electrification in Maine and cooperation on assembling the information needed for this evaluation. The evaluation team would like to especially thank Douglas Van Gorder and Eric Hann from MDIHS as well as Gordon Beck from A Climate to Thrive for their dedication to supporting this evaluation.

Executive Summary

In the summer of 2021, Mount Desert Island High School (MDIHS) purchased and deployed the first electric school bus (ESB) in Maine. Bus #3 served as a test to explore the viability of this emerging technology in a rural Maine setting. The funding for the project was secured through a federal program and MDIHS partnered with a local resiliency non-profit, A Climate to Thrive, for support equipment specifications and implementation. A Climate to Thrive (ACTT) partnered with VEIC to determine if anticipated emissions reductions and operational savings would be realized and to assess how the ESB performs in winter weather and a rural environment.

Despite global supply chain challenges due to the COVID-19 pandemic, the project was deployed on time and the bus maintained a satisfactory level of performance. The ESB was assigned to two routes and supported them for the full study period without any route modifications for weather or ESB performance. Additionally, the electric drive proved to be reliable with no downtime attributed to drivetrain-related issues. MDIHS has been satisfied by the performance of the ESB and is actively working to expand their ESB fleet.

Overview

MDI High School

MDIHS is part of the Mount Desert Island Regional School System and provides secondary education to the communities on Mount Desert Island (MDI) as well as some surrounding islands and communities on the mainland, an area of over 130 square miles. With a year-round population of roughly 11,500 people within the towns served, the population density is comparable to that of other rural Maine counties. As the home of Acadia National Park, environmental issues are important to the communities in and around MDI.

Electric School Buses

ESBs offer many benefits from an environmental standpoint as well as operational cost reduction. Because ESBs are roughly three times as efficient as diesel buses[1], the costs to charge an electric school bus versus fuel a diesel bus is 40 – 75% lower (depending on energy prices, routes, climate and driving style). ESBs have fewer moving parts, so there are fewer repairs, longer maintenance intervals, and reduced maintenance requirements[2]. As a result, ESBs can provide significant savings[3].

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[1] Argonne National Lab Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool - https://greet.es.anl.gov/afleet_tool

[2] https://www.epa.gov/cleanschoolbus/benefits-clean-school-buses

[3] Argonne National Lab Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool - https://greet.es.anl.gov/afleet_tool

Electric school buses have zero tailpipe emissions and improve the air quality inside and outside the bus. This is important for children, who spend between 20 minutes to several hours a day on school buses: air pollution levels inside older diesel buses can exceed surrounding areas by 5 – 10 times[4]. It is also important for school bus drivers, who benefit from cleaner, healthier, and quieter working conditions when driving ESBs.

Project

The MDIHS project was born from a desire within the community to benefit from the advantages of ESBs. Early champions of the project were bus driver Doug Van Gorder and local climate resiliency organization, A Climate to Thrive. Three years ago, Van Gorder learned of ESBs from ACTT; however, at the time the cost of adoption was out of the question. In 2020, the issue of cost was solved with a grant from Maine Department of Environmental protection. The State of Maine had received just over $21 million as compensation for emissions from Volkswagen diesel vehicles with "defeat devices" that created unlawful amounts of NOx emissions. MDI High School was able to fund 80% of their bus purchase using a grant from this program.

The COVID-19 pandemic caused a major disruption to shipping and global supply chains throughout the implementation of this project. Despite this unprecedented event, the project was able to remain on schedule with the only delays being caused by slow transit from Canada to the United States for warranty replacement items. Global events also affected diesel fuel prices further highlighting the benefits of ESBs. Nationally, retail diesel fuel prices saw a dramatic increase during the pilot period, climbing from $3.37 at the start of September of 2021 to $5.78 at the end of June 2022, a 71% percent increase[5]. Electricity prices are regulated by the Maine Public Utilities Commission and rate increases are much less frequent leading to greater budget stability.

Evaluation Goals

The overarching goal of this study is to assess the viability of electric school buses in Maine, especially in a rural context. The following categories were chosen to provide a model that could be evaluated by other Maine schools:

- Route coverage: The project investigated how the bus would fit in the operations of a rural, multi-town school district.
- Cold weather: The project wanted to establish what, if any, operational disruption would occur due to winter weather.
- Emissions: The local emissions benefits of electric school buses are well established, however the project wanted to quantify those benefits in an applied rural Maine context.

[4] https://www.slideshare.net/WorldResources/why-electric-school-buses
[5] https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_w.htm

- Cost savings: The project aimed to collect a real-world financial picture of operating an electric school bus in rural Maine.
- Reliability: As electric school buses are an emerging technology, the project sought to test the reliability of electric drivetrains in rural operational conditions.

MDIHS Fleet

The Mount Desert Island High School has a modest fleet of 7 buses that are individually owned by the towns served by the school. It consists of the Type C electric bus, one gasoline powered Type A minibus, and five conventional Type C diesel buses. Although the buses are individually owned by the towns, they are managed as a single fleet. The fleet is managed in-house by the district rather than being contracted out to a third-party provider; however, maintenance is contracted to a local mechanic. The bus fleet is stored at a central depot on the grounds of the high school. All buses, including the electric bus, are stored outdoors year-round. Charging facilities for the electric bus are located here while the fossil fueled buses are refueled offsite.

VEIC worked with ACTT and MDIHS to collect and analyze data on the older diesel bus MDIHS has replaced with their new ESB, as well as two comparable new diesel buses (Diesel Buses #4 and #6 which are operating concurrently in MDIHS's fleet) to determine baseline operational costs and emissions on a per-mile basis with which to compare the ESB. Bus #6 was used for baseline measurements from September through November 2021, and Bus #4 was used for baseline measurements from December 2021 through June 2022.

Top 5 Findings

1. **Range and performance are satisfactory for normal routes and can support longer-distance trips.**
2. **Bus was well received by staff and students, as well as created a better working environment for drivers.**
3. **The electric bus is three times as efficient (24 MPGe vs 9 MPG) as the comparable diesel buses, cutting operational energy expenses by 51% and reducing emissions significantly.**
4. **The electric drive train had flawless reliability and performance; However, there were warranty replacements of body related equipment.**
5. **When maintenance and warranty issues came up, having a manufacturer in Canada led to longer diagnostic and shipping times. Despite this being the first ESB in Maine, a local mechanic was able to complete the necessary repairs once support became available.**

Analysis

Equipment and Data Collection

MDIHS purchased a Lion C bus with the mid-level battery pack providing a factory-rated 125 miles of range. Lion is a Canadian vehicle manufacturer based in Saint-Jerome, Quebec that specializes in commercial electric vehicles. This type C school bus is just over 39 feet long and can carry up to 77 passengers. The bus came equipped with a standard AC Level 2 charge port and diesel-fueled auxiliary cabin heaters and has a top speed of 60 miles per hour. One particularly attractive feature of this bus model is the use of corrosion resistant composite and alloy materials in locations that are particularly rust prone such as steps and skirting. The bus also is equipped with an onboard cellular telematics system that sends information from the onboard computers to Lion's MyLionBeats website. A significant portion of the data contained in this report is from this source.

MDIHS followed the bus manufacturer's recommendation and purchased a Clipper Creek brand charging station (also called an Electric Vehicle Supply Equipment or EVSE). The CS-100 is an outdoor-rated Level 2 charging station with an 80A/19.2kW maximum charging capacity and a 25-foot-long charging cable. This unit is fully weatherproof, so the school chose to mount it on the outside of a storage building adjacent to the bus parking spot. While this charger offers more power than an average Level 2 charger, it does not have network or "smart" capability and will charge the vehicle at the highest permissible power until the vehicle is fully charged, regardless of utility rates. Additionally, this charger does not offer any energy monitoring capabilities which were necessary for the data evaluation in this study. To collect information on charging station and vehicle energy use, VEIC supplied a third-party power meter to monitor the energy usage.

The eGauge power meter provided by VEIC to MDIHS is a utility grade (better than +/- 2% accurate), true-RMS power monitoring device. It was installed to monitor the voltage, amperage, and harmonics of the power being supplied to MDIHS's charging station. The meter records data at a one-minute interval and allows for insight both into the specific level of power draw for the charger as well as insight into the exact timing of the charging station's power draws. The meter has a built-in server and is connected to the internet via the school's network. Thus, the data can be pulled remotely and backed up to an offsite location to ensure data integrity and avoid inconveniencing local site staff. Data from this device was used to verify information from the bus telematic system and provide insight into charging station energy use.

The installation process for the charging station was simple but did require a service upgrade to the building where the charger is located. This work was completed by a local electrician and did not require any electric vehicle specific expertise to complete. The work done to upgrade the electrical service was sufficient to supply the single charging station for a single bus but will likely need additional upgrades to support a larger fleet of ESBs with multiple charging stations. A secondary installation was required to install the eGauge power meter but did not require any significant modifications to the electrical panel to accommodate it.

Overall, the data collected provides a complete picture of the advantages afforded by an electric school bus in a rural environment; however, there were three events that caused anomalies in the data set.

1. The data collected for the diesel comparison in 2021 is from a different bus (Bus #6, 2017 Freightliner) than the data collected in 2022 (Bus #4, 2013 Bluebird). This was due to a staffing issue with the driver of the first bus. While these diesel buses ran different routes, the overall picture offered by them is similar enough to use in comparison to the electric bus (Bus #3). Indeed, Bus #3 had two routes and drivers over the course of the study and therefore exhibits some variation as well.

2. The second data anomaly was caused by a delay in replacement oil for the air ride suspension system. In December of 2021 Bus #3 began presenting error codes related to the compressor for the air suspension. With the help of Lion's support team, MDIHS's local mechanic traced the issue to water intrusion into the compressor lines. This required draining and replacing the oil in the compressor. Delays in shipping from Canada caused by the pandemic, end of year holidays and Customs and Border Patrol resulted in the bus being out of service for most of December as it waited for the replacement fluid to arrive. As a result, some figures may not contain data from December as it would skew the results and create an inaccurate picture. Information from December is included in sections addressing reliability.

3. The final data collection issue stemmed from a faulty telematics module that came with the bus. Within a few days of the start of school, the telematics module stopped recording most performance metrics. VEIC was able to recover the daily mileage records for the preceding few months before the problem was found and the module replaced. Unfortunately, State of Charge and other points were lost for the first half of the year; however, driver logs were available to fill the vital gaps. The module, a small hand-sized device under the dashboard, was quickly and easily replaced, providing data for the remainder of the evaluation.

Figures 1 and 2 – Usage and Routes

The ESB had two routes that it ran on a regular basis. One route brought students from MDI High School to the Hancock County Technical center in Ellsworth twice per day (Figure 1) and did not require the bus to recharge during the middle of the day. The other route brought students from off island to MDI High school and returned them home. This route required a midday recharge for sufficient range buffer (Figure 2). The bus was able to complete both routes year-round regardless of weather.

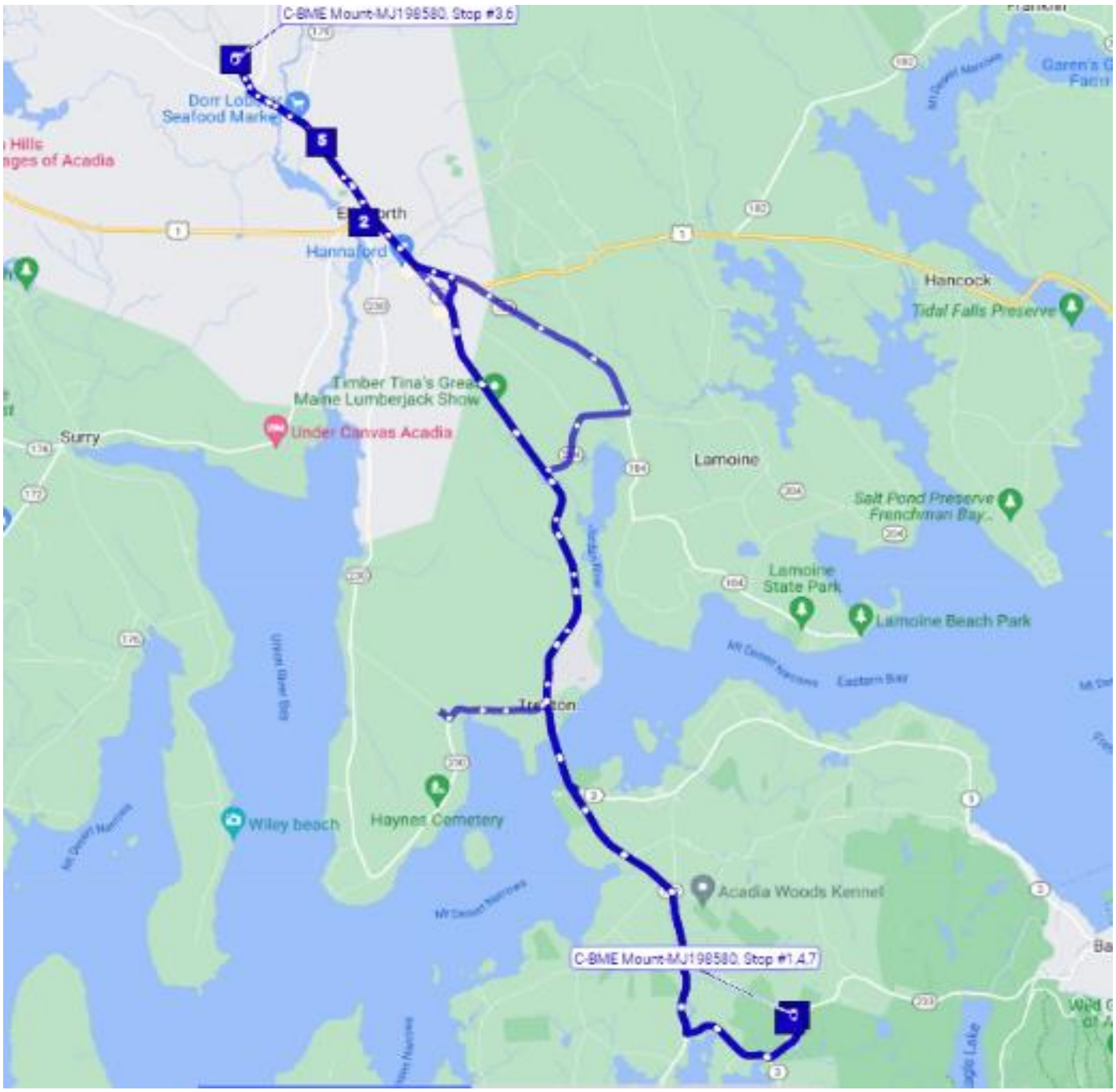

Figure 1 – Hancock County Technical Center Route (approximately 40 miles round trip)

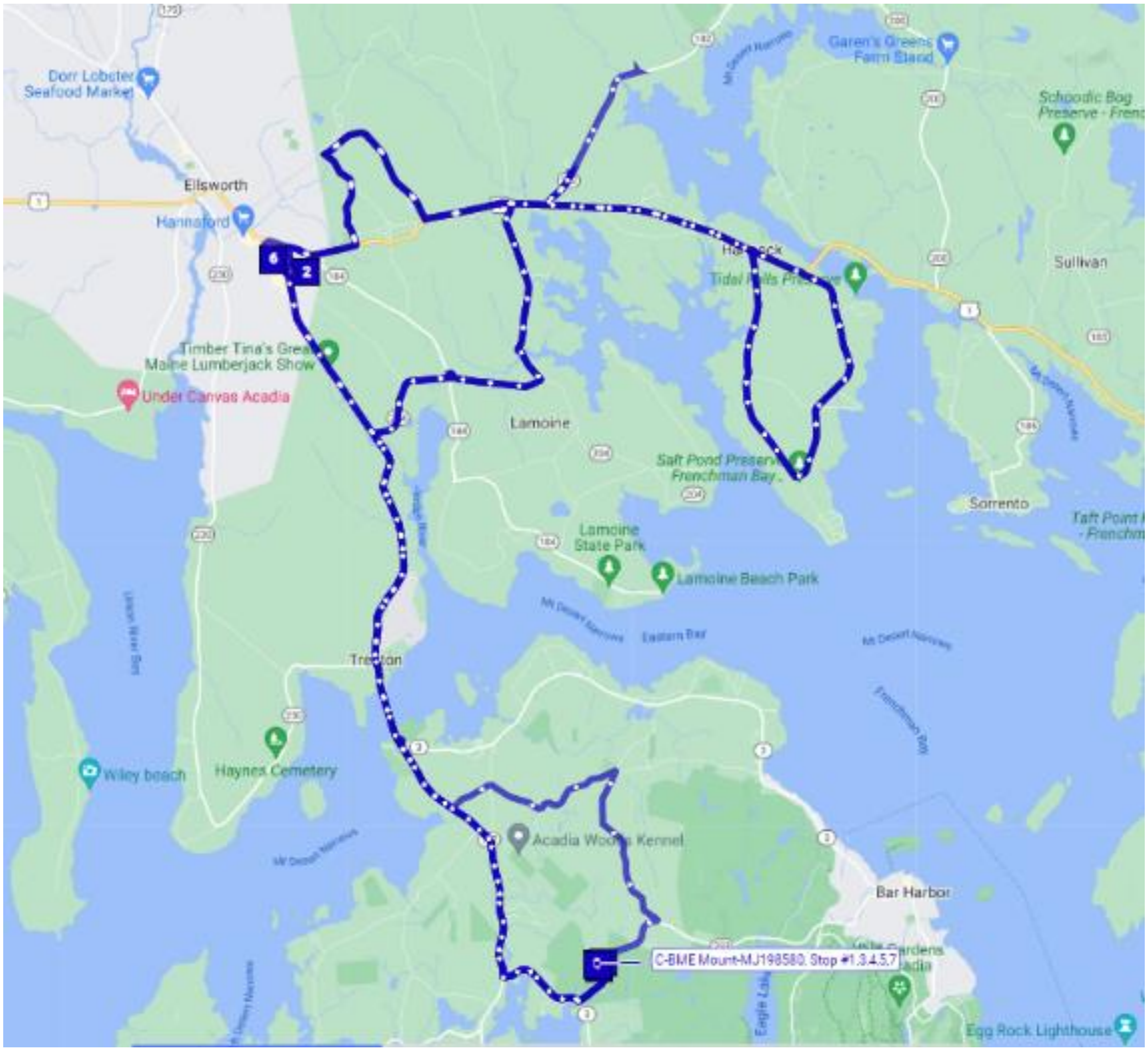

Figure 2 - Off-Island Student Route (approximately 57 miles round trip)

Figure 3 Effective Average Range

Figure 3 shows the average miles driven by the ESB as well as the average calculated total available range of the ESB compared to the monthly average temperature. Average miles driven shows the daily average milage for all in service days that month. Average calculated total range shows the daily average available range – that is the estimated miles available if the ESB was driven until the battery was depleted – for all in service days that month. Electric vehicles generally operate less-efficiently in colder weather, so it was expected that the range of the ESB would be reduced below the manufacturer's factory estimate during the winter.

The data collected showed that over the 3 months (January, February, March) when the average temperature was at or below freezing, the average estimated available range of the ESB dropped by 22% to 118 miles. The estimated available range was at or above the factory range for the six months where average temperatures were above freezing. The range estimation and miles driven were recorded by the bus drivers in a driver's log from the bus's dashboard readout. One driver noted that, "If there's a reduction in range during cold weather it's negligible." This underscores that the ESB range was sufficient for the routes assigned.

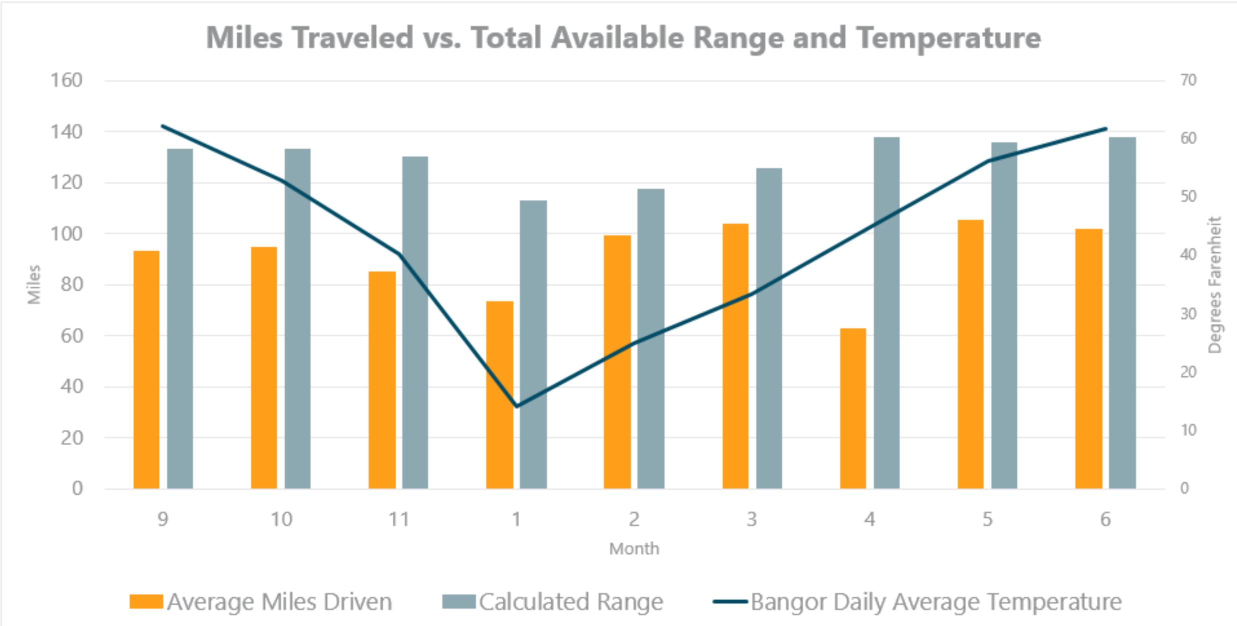

Figure 3

Over the course of the study, the average miles driven was only 70% of the estimated available range. A driver noted that additional routes could be assigned to an ESB: "If you're on a field trip where you're possibly beyond your range… it would be great if other schools or other places we went to had the same kind of capabilities to charge the bus that we have."

Figure 4 – Energy Cost Savings

Figure 4 shows a comparison of the monthly total energy costs of the electric and equivalent diesel buses, based on miles traveled by the electric bus, electric and diesel bus energy efficiency and recorded fuel consumption, and MDIHS's electricity and diesel prices during this period. Savings represent the difference between the diesel and electric bus monthly energy costs.

ESBs have a significant cost advantage over fossil-fueled school buses due to their superior efficiency (see Figure 5) and more stable energy cost. On average, the ESB provided over 50% savings compared to Bus #4 and Bus #6 even when efficiency dropped during the colder months. Diesel fuel costs for all buses were based on data from the Town of Mount Desert (from which the school purchases fuel). Electricity costs are based on utility data supplied by the school.

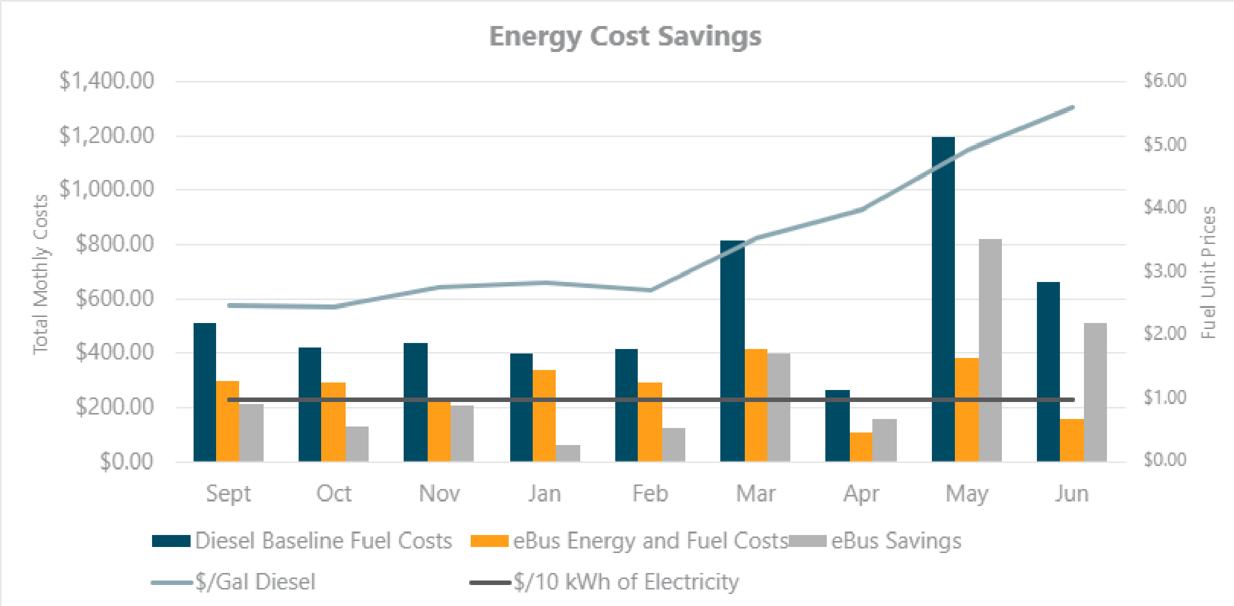

Figure 4

When asked about what they liked about the ESB, one staff member remarked "Fuel cost savings, especially now a days that diesel is over $6/gallon, I'm feeling a little smug about having this electric bus."

Figure 5 – Vehicle Efficiency

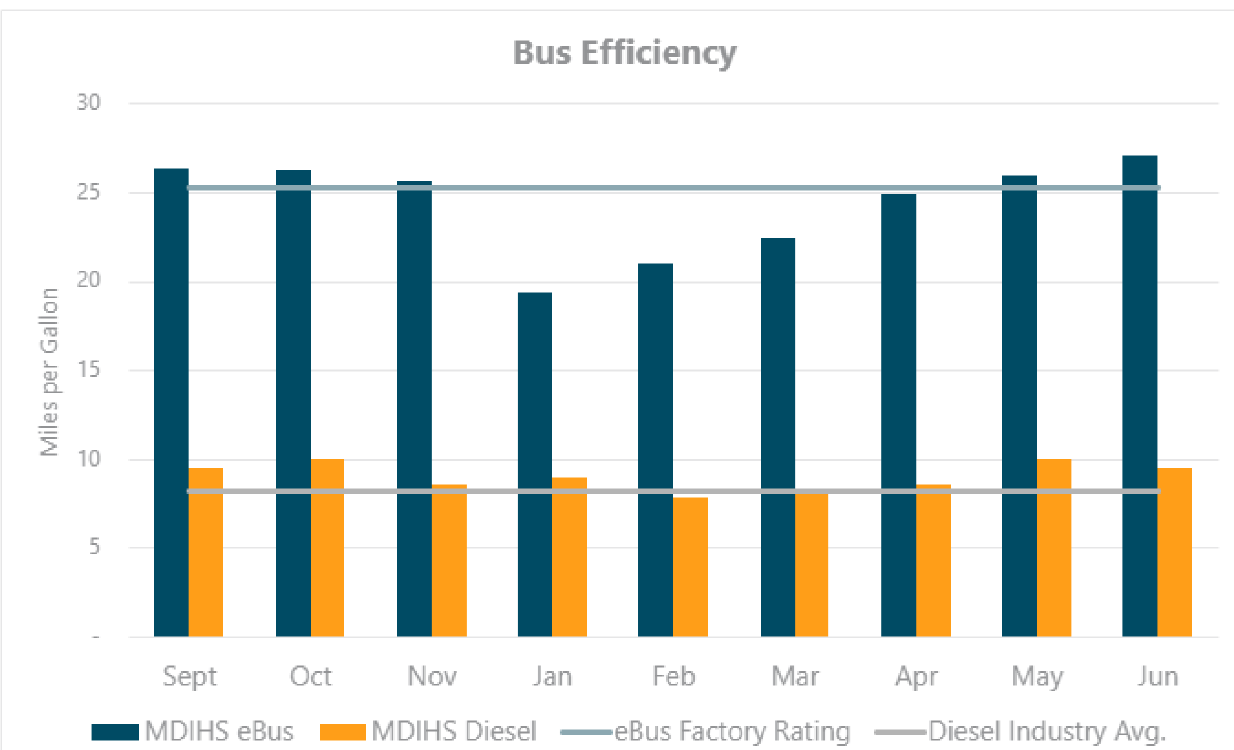

Figure 5

Figure 5 shows the monthly average operating efficiency of the ESB compared to the two diesel baseline buses (Bus #6 Sept – Nov 2021, and Bus #4 Dec 2021 – June 2022) in units of miles per diesel gallon equivalent. As expected, the ESB outperformed the comparable diesel buses every month of the year by delivering three times the miles per gallon equivalent.

Efficiency was greatest during the warmer months and, as expected, lowest in the colder months. This figure only includes energy used for driving and normal standby situations and does not include energy used by standby systems when the bus was left plugged in for extended periods of time.

Figure 6 – Diesel Fuel Savings

Figure 6 shows the quantity of diesel fuel consumed by the ESB auxiliary heater compared to an equivalent diesel bus.

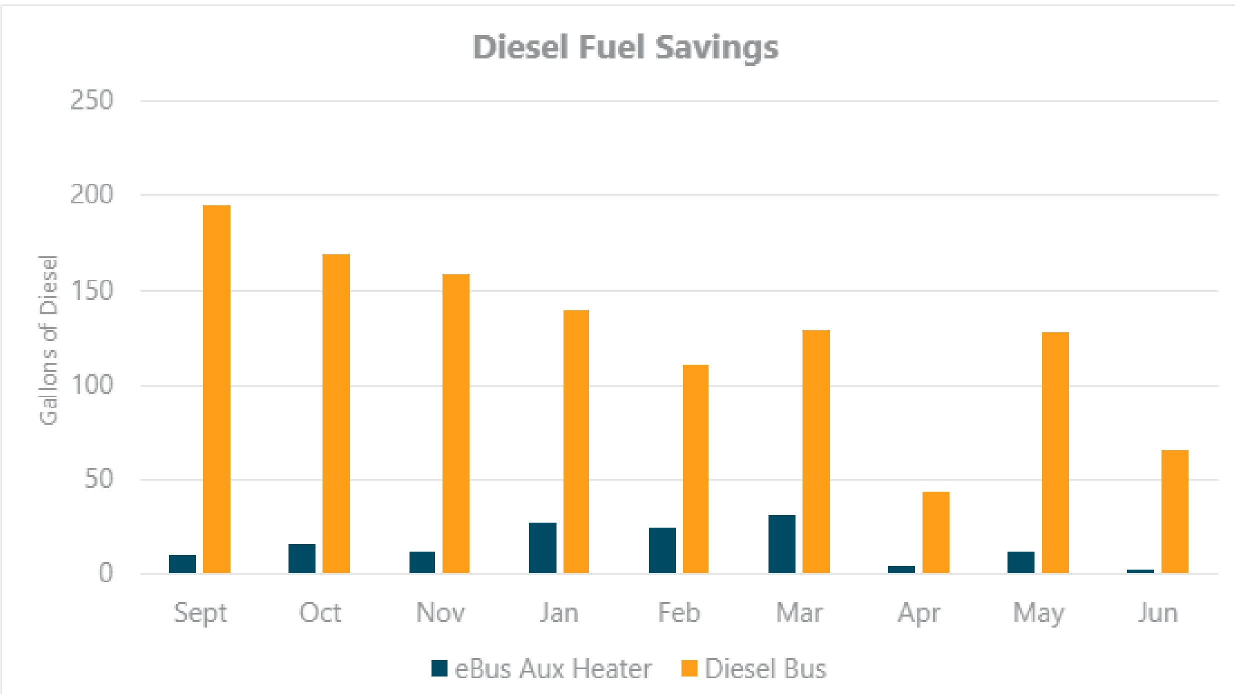

Figure 6

Estimated diesel fuel savings were greatest in fall and spring months when auxiliary heater fuel consumption was lower. Auxiliary heater fuel consumption peaked at 31 gallons in March. Total estimated net diesel fuel savings for the study period were 999 gallons.

Figures 7 and 8 – Charging Load Profiles

Figure 7 shows a representative charging load profile of the ESB over a 24-hour period in terms of electrical power (kilowatts, kW), representing a day where midday charging was not utilized.

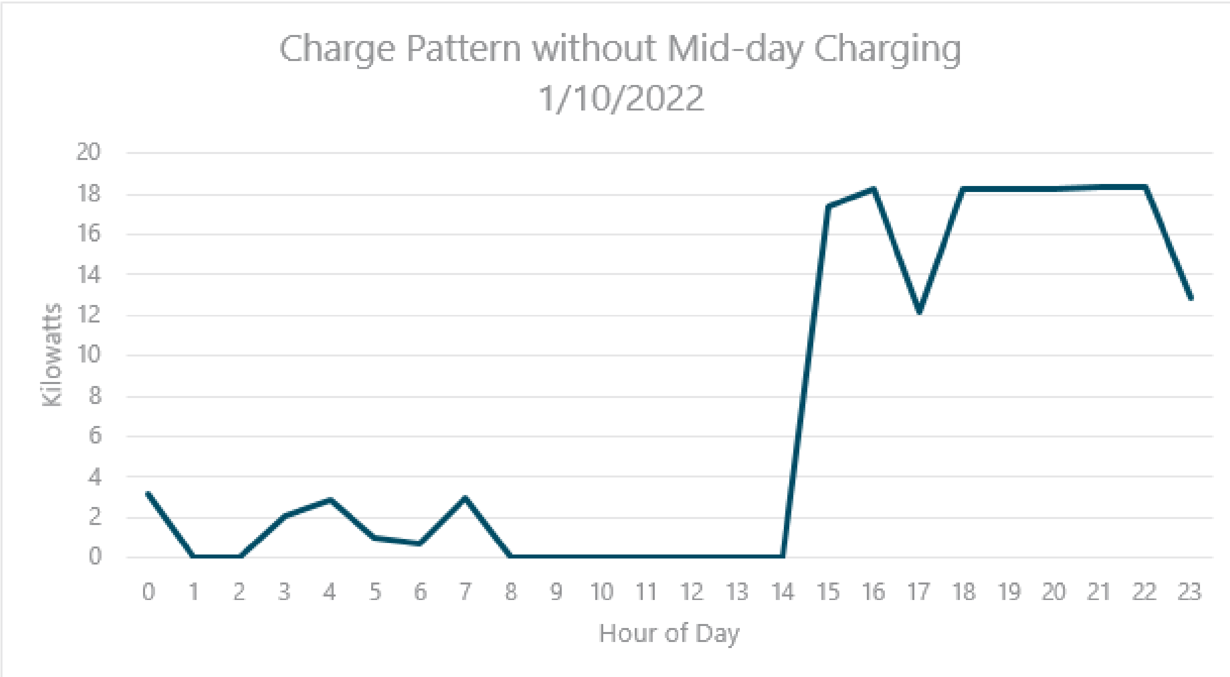

Figure 7

Figure 8 shows a representative charging load profile of the ESB over a 24-hour period in terms of electrical power (kilowatts, kW), representing a day where midday charging was utilized.

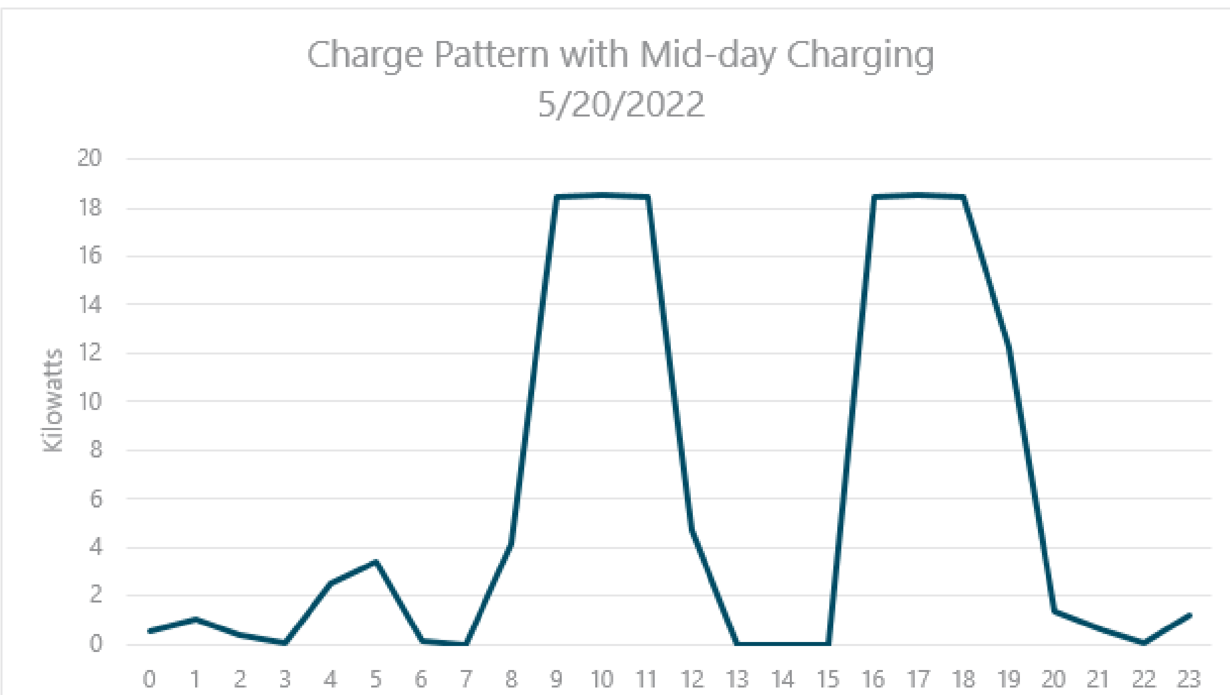

Figure 8

One common feature of both charging load profiles was a secondary power draw event after completing the main overnight charging cycle (see 10 PM and 3 AM in the above figures). This could have been caused by standby systems on the bus such as battery temperature controls (heaters or fans). This loss could potentially be mitigated with a networked charger that could manage energy draw or with further design refinements from Lion.

Maintenance and Reliability

Overall, the ESB maintained a significantly lower direct maintenance cost than Bus #4 or Bus #6 and demonstrated a high level of reliability with the electric drivetrain. Overall downtime of the ESB was focused on body-related systems and exacerbated by limited parts availability from the manufacturer in Canada. Unfortunately, downtime statistics for Bus #4 and Bus #6 were unavailable for the project period; however, both show brake and engine related repairs in their maintenance records which could have resulted in downtime.

The electric drivetrain on Bus #3 was reliable for the duration of the project; however, there were four maintenance and warranty issues for the chassis and body systems of the bus.

1. The major issue was the previously mentioned suspension compressor repair (see Equipment and Data Collection Section). The downtime was further extended due to border-related delays in shipping parts from Canada.
2. The second event was due to cabin heating equipment. A fan on this unit failed and was replaced under warranty. Coincidentally, diesel Bus #4 also experienced a similar fan failure during the study period.
3. Despite being sold as a vehicle for the U.S. market, the ESB arrived with a speedometer with a km/h faceplate rather than mph. This was replaced at no charge by the manufacturer.
4. As mentioned earlier, the telematics module (data link to monitoring website) was defective from the manufacturer and required replacement. This work was carried out by one of the bus drivers. Further detail can be found in the Equipment and Data Collection section of this report. Of these four issues, only the suspension compressor issues affected the drivability of the bus.

During the study period, Bus #6 (2017 Freightliner) had $6,796 of maintenance and repair costs with $2,182 of that due to routine maintenance (fluid and filter changes) and Bus #4 (2013 Bluebird) had $8,873 total cost with $2,694 due to routine maintenance. In contrast, Bus #3 was under warranty for repairs and only required $455 in fluid and filter costs (not including labor) to help diagnose the suspension compressor issue. While most of the maintenance and repair costs of the diesel buses can be attributed to repairs needed due to age, the diesel buses still had significantly higher routine maintenance costs than the ESB.

All three of the MDIHS staff interviewed discussed experiencing maintenance issues with the electric buses. These issues were with systems other than the electric drive components. One staff member reported: "Electric drive is great; it's performing beyond our expectations. Some of the other mechanical components on the bus have failed on us. The first one being the air compressor pump, the oil getting contaminated with water. And most recently… a fan inside the furnace failed. I'm a little disappointed with the mechanics of the bus."

The staff interviewed reported that the challenges these maintenance issues created were exacerbated by repair delays. "Those took forever to fix...you can't justify an economic return when you can't even use the bus." Staff attributed these delays to complications stemming from the manufacturer not having readily available parts, including the need to coordinate with resources in Canada. According to one staff member, "[There were] a couple issues that kept the bus down for a little over month, but that was partly because of trying to get parts across the Canadian border."

One staff member reported challenges related to the previously mentioned repairs, beyond the delays in completing them. "[The manufacturer was] trying to charge for stuff we felt was under warranty... I had to send an email to practically the whole company saying I wasn't going to pay the bill... it wasn't our fault it didn't work right.... after that they were very supportive." This payment-related challenge is consistent with an email the evaluation team received from the mechanic at the repair shop the team contacted for additional perspective. In that email, this mechanic wrote, "If the Manufacturer does not pay the bills in a time efficient manner and/or is half a world away and cannot be cajoled to pay a bill AND the end user is expecting no out of pocket repair costs during the warranty period then the repair facility is likely to put repair of the product on the back burner… Moral of the story: Don't sell product in a region so far away without establishing support for the product locally (and pay the damn bill when due)."

Workplace and Environmental Benefits

Beyond operational cost savings, ESBs offer better working environments for staff as well as reductions in local air pollution. The experience of operating an ESB is generally like a diesel bus while offering better acceleration and significant noise reduction. Of course, as there are no direct tailpipe emissions from drivetrain, the ESB has significantly lower emissions compared to a diesel bus. This is especially important considering diesel buses spend a significant amount of time idling to provide cabin heat at the expense of noise and tailpipe emissions.

The MDIHS drivers and third-party mechanic interviewed reported that the electric bus is more enjoyable to use than diesel buses. These benefits included the absence of smell from diesel exhaust and the elimination of engine noise ("The noise and the exhaust fumes you get from a diesel… are nonexistent in an electric bus, which makes it luxurious for me as a driver.") and the perceived health benefits of not inhaling exhaust ("I think it's good… for everybody's health.") One MDIHS staff member discussed these benefits extending to students riding the bus: "The kids seem to like [the electric bus]. Even when you're inside a diesel bus it's so loud whereas an electric bus is quiet."

MDIHS staff reported that the bus was easy to learn to operate for drivers experienced with diesel school buses: "[Training took] about two minutes, because that's all I needed. You turn a key just like anything else."

Despite this ease in learning basic operation, staff expressed dissatisfaction with the training provided by the manufacturer. "Whoever Lion sent down didn't know anything," one staff member said. "He couldn't get the bus started, then one of our drivers got the bus started. They need to send better people to train." Another staff member expressed interest in an additional training in the more detailed operation of the bus: “It's the same thing when you buy a new car… what's this button for? It would be good for them to come back." This more detailed training may have been omitted during the session the staff received. According to one staff member, “One the of the representatives gave us a quick walk around and showed us how the operations worked, but for me it was a lot of hands-on learning.”

Table 1 – Emissions Savings

Metric	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Cumulative
Total mileage	1954	1702	1360	0	1249	1190	1867	564	2422	1122	13430
NOx saved vs. scrapped bus [lbs.]	29.4	24.7	19.8	0.0	15.8	15.3	25.2	8.3	36.6	17.4	192.6
GHG saved vs. scrapped bus [short tons]	2.43	1.99	1.61	0	1.08	1.10	1.95	0.66	3.05	1.47	15.3
PM2.5 saved vs. scrapped bus [lbs.]	1.98	1.71	1.37	0	1.22	1.16	1.85	0.57	2.46	1.15	13.5
PM10 saved vs. scrapped bus [lbs.]	2.16	1.84	1.47	0	1.25	1.21	1.94	0.61	2.68	1.26	14.4
NOx saved vs. Comparison diesel [lbs.]	6.74	4.92	4.04	0	1.28	1.53	3.54	1.75	8.48	4.38	36.7
GHG saved vs. Comparison diesel [short tons]	2.43	1.99	1.61	0	1.08	1.10	1.95	0.66	3.05	1.47	15.3
PM2.5 saved vs. Comparison diesel [lbs.]	0.18	0.14	0.11	0	0.06	0.07	0.13	0.05	0.23	0.11	1.1
PM10 saved vs. Comparison diesel [lbs.]	0.15	0.09	0.08	0	-0.03	-0.02	0.02	0.03	0.19	0.11	0.6

Table 1 compares the cumulative savings of Nitrogen Oxide (NOx), Particulate Matter 10 (PM10) and 2.5 (PM2.5) and carbon dioxide equivalent (CO2e) emissions from the electric bus as compared to the model year 2006 diesel bus that it replaced (“scrapped bus”) and the model year 2017 buses that are currently in operation (“baseline diesel”). This table assumes that the ESB was recharged using local utility power which contains a higher percentage of renewable energy than the national average.

Carbon emissions reductions from electric bus operation are considerable for both baseline and scrapped buses, as diesel fuel economy for 2006 and 2017 model year buses are estimated to be the same. Total estimated carbon savings for this period were 15.3 short tons. This is equivalent to the carbon dioxide captured by 638 mature trees in a year.[6] While still noteworthy, NOx, PM and other Criteria Air Pollutant (CAP) emissions savings are less dramatic for the baseline diesels as compared to the scrapped bus due to tighter emission standards for newer diesel engines.

Findings

Vehicle and Charging Equipment

MDIHS experienced ample, reliable ESB range because they purchased a bus that had a correctly sized battery for their application. They selected a middle range battery which balanced upfront cost with usability.

MDIHS kept their charging set up simple. They purchased an ESB with Level 2 AC charging capability and installed basic charging equipment that was sufficient for supporting the project without inflating the budget. Additionally, they located the charging station close to their electrical panel and ESB parking spot which reduced installation costs. Some of this work may need to be upgraded further to accommodate a larger ESB fleet. While basic equipment satisfied the operational needs of the project, it did require the installation of a third-party energy monitor to collect data for this study. This provided some of the benefits of a networked or 'smart' charging station without the additional cost.

MDIHS has a pre-existing solar electric installation on site. Co-locating electric vehicles with renewable energy generation lays the groundwork for future opportunities around load management and vehicle to load applications.

MDI experienced one of the challenges of being first: there is often a learning curve to introducing new technology from young companies. In this case, delays caused by parts supply and diagnostic wait times put a strain on the MDIHS staff and resulted in excessive downtime for the bus. Evaluating a bus vendor on their support capabilities can help mitigate repair delays. Fortunately, MDIHS was able to successfully advocate for their case and find resolution for their warranty issues. Additionally, Lion will soon be opening a factory in the United States which will hopefully alleviate any cross-border shipping issues.

One of the MDI drivers noted that the bus did not have an air suspension seat. "I have no idea what was going through anybody's mind when they put a non-suspended seat in that bus... if you're a commercial driver, the air and suspension seat is a must have." While this is a minor issue to correct – the latest reports say that there is an air ride seat waiting to be installed – it highlights that the ESB needs to be equipped to the same standard or better than the existing fleet. Maintaining a similar driving experience is key to driver happiness and deployment success.

[6] https://www.arborday.org/trees/treefacts/

Fleet Management and Data Collection

Do not discount the workplace benefits of electric school buses. Multiple MDIHS bus drivers cited drivability and reduced exhaust exposure as reasons for preferring the electric bus. "I welcomed [the electric bus]. Not because I'm a green person - I like it because it's quiet and I don't have to breath diesel fumes." (MDIHS staff member)

MDIHS found that the training provided by the manufacturer was inadequate and much of the learning was conducted "on the job." For example, one of MDI's drivers reported that he needed to learn how to use regenerative breaking in certain conditions. "When the roads are slippery, I find it necessary to deactivate the regenerative braking because it tends to make the wheels lock up." MDIHS staff have a culture of sharing, so this information was passed along to the other drivers. Sharing information from official trainings and ad hoc learning is key to making ESB deployment a success. In addition to their own staff, MDIHS has been answering questions from other districts and stakeholders about the experience of having the first ESB in Maine.

Establish buy-in among service and maintenance staff. One MDIHS staff reported that some of the skills needed to maintain electric buses are different than those required to maintain diesel buses and advised that other districts considering electrifying their fleet "see if their mechanics are going to be willing to learn about the electric buses." This advice is consistent with what they evaluation term heard from a mechanic at the shop where the MIDHS electric bus is serviced: "All manufacturers appear to be of the impression local repair facilities are more than happy to support new product. This is not true." Since MDIHS contracts their maintenance to a third party; sourcing maintenance in-house could lead to different training and service outcomes.

Early on, the study relied upon the vehicle telematics for information regarding energy consumption and mileage. Due to hardware unreliability, some of the early data for the project was less detailed than hoped for. This was rectified by installing an inexpensive monitoring device on the electrical service for the charging station. This allowed for the comparison of the data from the bus to the data from the monitoring device to identify discrepancies. This extra point of reference was also helpful in identifying the non-charging loads that the ESB draws while plugged in. Installing an energy monitoring device or utilizing a smart charging station should be considered essential for measuring ESB success.

Utility and Charging Management

Often ESB projects require some work with the electric utility and charging management to ensure there are no excess fees and there is adequate local electric grid capacity to supply the charging needs of the bus. The only utility-related upgrade needed for this project was upgrading the electric service at the bus storage yard from 100-amp service to 200-amp service. As MDIHS adds additional ESBs to their fleet, they will likely need to upgrade their electric service again to accommodate additional charging stations as well as begin to consider how to manage their chargers to avoid being billed for excessive power draw (demand charges).

The charging station used for the MDIHS project did not include any smart features such as managed charge times or remote control of charger functions. When analyzing the data collected by the energy monitor there were significant amounts of power being used by the bus while plugged in even when not charging. See appendix B for additional information. These loads are likely due to heating and cooling equipment within the battery pack on the bus. While some power draw was expected, the amount contributed to a significant decrease in total energy efficiency, especially over weekends or school breaks. MDIHS did manually manage this situation by unplugging the bus for some longer school breaks, but more effective energy savings could have been achieved with a charger that could automatically curtail power on a scheduled basis. As MDIHS expands their ESB fleet, they may have the opportunity to upgrade their existing charger to a networked (smart) unit.

The Future

MDIHS is pleased with the performance and benefits of their ESB and is actively pursuing funding for additional buses including one with a wheelchair lift. Other school districts in Maine have following MDIHS's lead and procured or applied for funding for ESBs. Additionally, the State of Maine has set standards for the deployment of electric school buses with the passage of LD 1579 in May of 2022. The new law sets a goal for 75% of school bus acquisitions in the state to be zero emissions by 2035. Nationally, there is rapidly growing support for ESBs from bus manufacturers and the federal government. All major manufacturers now offer electric bus models, and the U.S. Environmental Protection Agency is providing up to $5 billion in Clean School Bus funding over the next five years to help schools to go electric.

MDIHS's project shows that with simple planning, ESB technology can be successfully implemented in a rural Maine location. Over the course of the study, the ESB's significant savings in both maintenance and energy costs combined with superior driving and riding experience made the advantages of ESBs over diesel buses very clear. And while this bus had some items that required warranty repair, none of these issues were related to the electric drivetrain. Additionally, feedback from the MDIHS staff and contractors was generally positive. Overall, the information collected during this study shows that this ESB is a good fit for MDIHS's needs and that ESBs will likely be a beneficial technology for other rural Maine schools.

Appendices

Appendix A – Data Table

	Pilot eBus 2021-2022										
Metric	**Sept**	**Oct**	**Nov**	**Dec**[1]	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Cumulative**
Total mileage*	1954	1702	1360	0	1249	1190	1867	564	2422	1122	13430
Average daily mileage on days in service*	93.0	94.6	85.0	0	99.2	103.7	62.7	105.3	102.0	92.6	92.6
NOx saved vs. scrapped bus [lbs]**	29.4	24.7	19.8	0.0	15.8	15.3	25.2	8.3	36.6	17.4	192.6
GHG saved vs. scrapped bus [short tons]**	2.43	1.99	1.61	0	1.08	1.10	1.95	0.66	3.05	1.47	15.3
PM2.5 saved vs. scrapped bus [lbs]**	1.98	1.71	1.37	0	1.22	1.16	1.85	0.57	2.46	1.15	13.5
PM10 saved vs. scrapped bus [lbs]**	2.16	1.84	1.47	0	1.25	1.21	1.94	0.61	2.68	1.26	14.4
NOx saved vs.Comparison diesel [lbs]**	6.74	4.92	4.04	0	1.28	1.53	3.54	1.75	8.48	4.38	36.7
GHG saved vs.Comparison diesel [short tons]**	2.43	1.99	1.61	0	1.08	1.10	1.95	0.66	3.05	1.47	15.3

PM2.5 saved vs.Comparison diesel [lbs]**	0.18	0.14	0.11	0	0.06	0.07	0.13	0.05	0.23	0.11	1.1
PM10 saved vs.Comparison diesel [lbs]**	0.15	0.09	0.08	0	-0.03	-0.02	0.02	0.03	0.19	0.11	0.6
Reliability: number of days vehicles were in service out of total (M-F, minus closures)***	21/20	18/20	16/18	0/16	17/18	12/15	18/23	9/16	23/21	11/8	145/175
Fuel consumption – electrical [kWh] *(Sep,Oct,Nov are estimates)****	2785	2586	2036	0.0	2677	2329	3145	928	3303	1475	21267
Daily Average kWh Consumed*	120	123	113	0.0	129.0	160.8	157.4	85.4	138.2	128.3	130.0
Fuel consumption – other [diesel gallons]*	9.8	15.7	11.8	0.0	27.5	24.5	31.2	3.9	11.8	2.0	2.0

Effective average range [Mi]**	133.1	133.4	130.5	no data	112.89	117.69	125.48	137.60	135.92	138.05	129.4
Vehicle efficiency [kWh/mi]**	1.3	1.3	1.3	no data	1.8	1.6	1.5	1.4	1.3	1.3	1.4
Vehicle efficiency [MPGe]**	26.3	26.2	25.7	no data	19.4	21.0	22.4	25.0	25.9	27.0	24.2
Estimated Energy Costs**	$268.90	$249.65	$196.60	no data	$258.49	$224.90	$303.61	$89.59	$318.87	$142.45	$2,053.06
Estimated fuel cost savings vs. Comparison Bus**	$213.42	$129.38	$207.18	$0.00	$57.37	$122.27	$397.58	$157.09	$815.56	$507.43	$2,607.27
Diesel gallons not consumed vs. Comparison Bus**	195.7	154.7	146.9	no data	111.7	128.2	199.2	61.9	230.7	116.1	1345.1

*Primary data from drivers logs and telematics

** Calculated field using primary data and AFLEET

*** Calculated field from telematics and school calendar

****eGauge data

1: December not included due to lack of data because of the ESB being out of service.

Appendix B – Off Duty Power Draw (Figures B1 & B2)

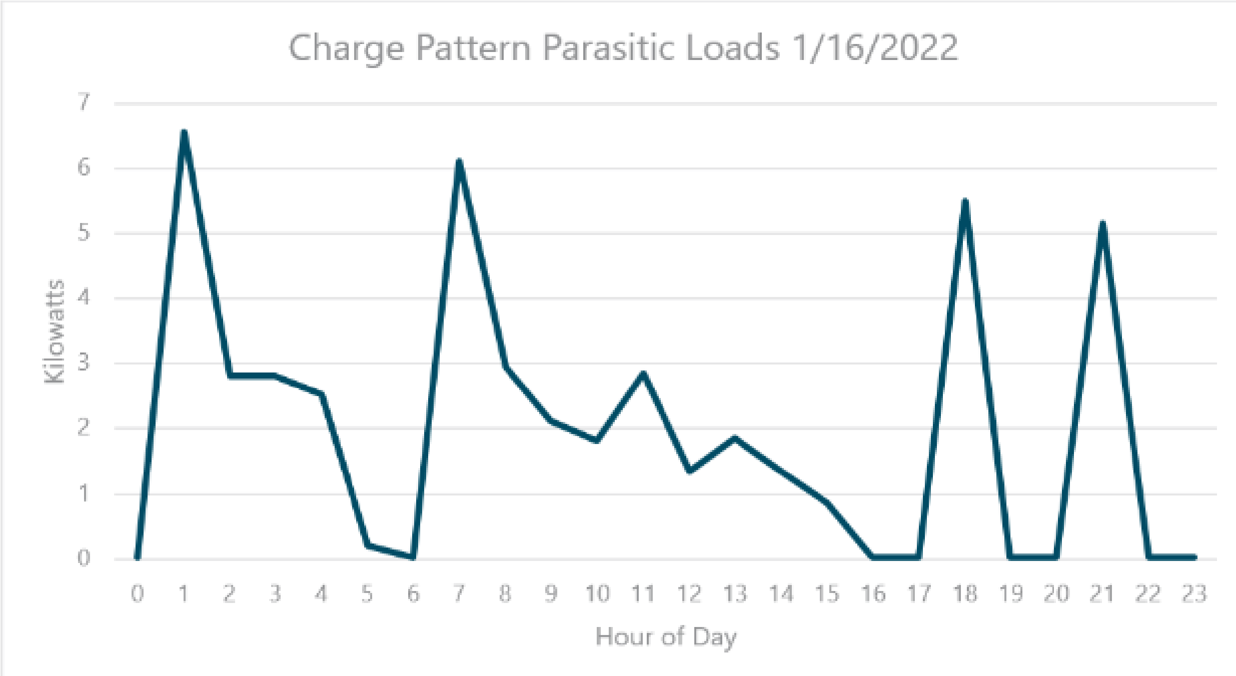

Figure B 1

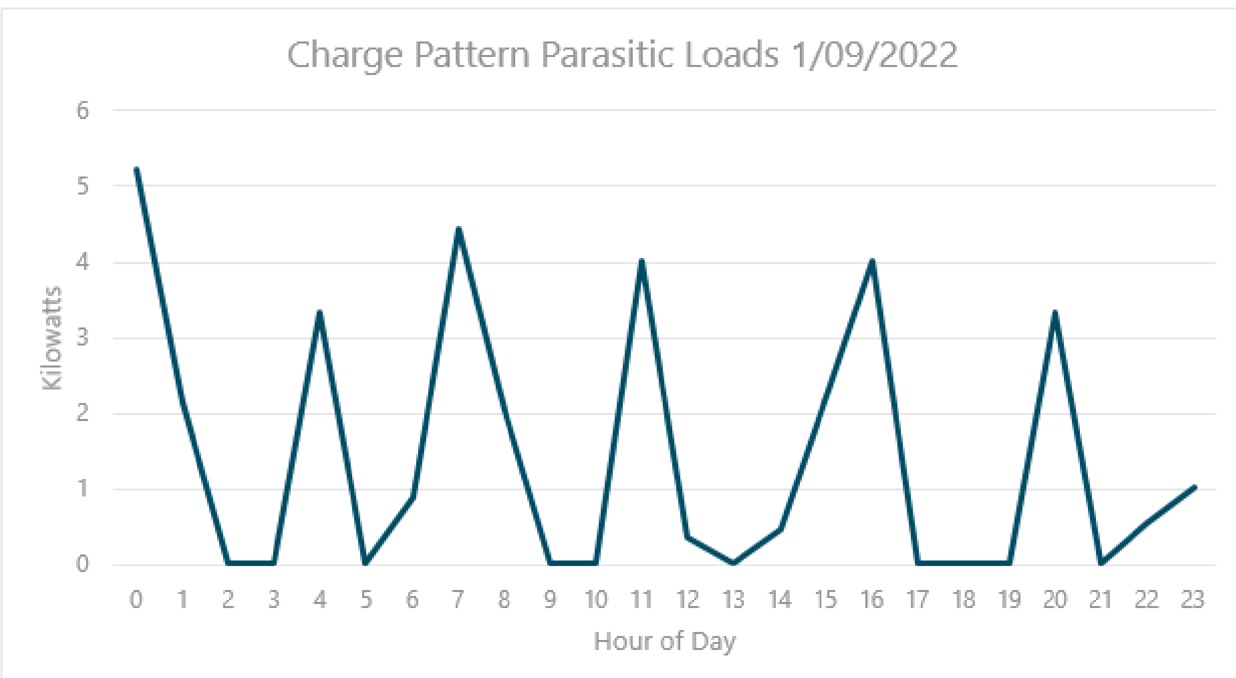

Figure B 2

Figures B1 and B2 show significant parasitic or standby power draw on sample off-duty days. It is unclear why the cycle of the power draw is drastically different between the two days. This additional power consumption could be avoided with managed charging with a smart charging station or simply unplugging the bus when fully charged.