Electric school bus pilot project

Can battery-powered school buses replace diesel vehicles in Minnesota?

May 2024

MINNESOTA POLLUTION CONTROL AGENCY

Executive summary

Minnesota's electric school bus pilot project

The Minnesota Pollution Control Agency (MPCA) deployed Volkswagen settlement funds to create a pilot project to better understand electric school buses and how they operate in Minnesota. The information from this pilot project will inform future MPCA funding opportunities and provide school districts valuable information on electric school bus performance. For the pilot, the MPCA funded eight electric school buses in various regions across the state. The MPCA required the grantees to make quarterly reports for their first year of bus operation. Due to variations in bus delivery times, the pilot year for each bus ran sometime between September 2022 and February 2023.

The data collected from the grantees includes monthly mileage, energy consumed, kWh/mile, electricity cost, diesel cost, out-of-service days, number of charges per day, and maintenance activitie as well as qualitative data on driver training, driver comfort, and overall performance of the bus. Additionally, all five of the pilot grantees responded to a pilot project conclusion survey to provide final impressions of electric school buses and the pilot itself.

This pilot found that electric school buses can work in Minnesota, even in colder months. Below are the top school bus pilot results and key takeaways.

School bus pilot results

- Average daily mileage traveled by the buses was 71 miles, max daily mileage was 119 miles.
- Average efficiency of the electric vehicle drivetrain was 2.2 kWh per mile.
- Average fuel cost savings was approximately $430 per month per bus.
- Average availability of the electric school buses during the school year was 83%.

Average daily miles traveled

071

Average fuel cost savings

$430 /mo.

Lower maintenance costs

Significantly quieter

Little to no exhaust

p-gen4-23

- Top benefits noted by drivers: significant noise reduction allowing drivers to monitor passenger behavior more closely and stop bullying, no exhaust smell, smooth acceleration.
- Four out of five survey respondents indicated that their maintenance costs were less than that of a diesel bus.

Key takeaways

- Electric school buses *can work in Minnesota.*
- *Charging twice a day (oftentimes during midday break) is preferred to ensure adequate range during colder months.*
- *Parking inside, whether in a heated garage or not, can help improve winter performance.*
- *Overnight charging in the colder months conserves energy when warming up the bus in the morning.*
- *Muddy gravel roads can impact range as much as colder months.*
- *80% of grantee respondents said they might recommend electric school buses to other districts depending on their specific circumstances (the 20% who wouldn't indicated cost as the limiting factor).*
- *Early utility partnership is critical to ensuring enough amp service to power the charger and to build out needed infrastructure.*

Background

The MPCA deployed Volkswagen funds to create a pilot project to better understand electric school buses and how they operate in Minnesota. The MPCA funded approximately $275,000 per grantee for the bus and charger. The information from this pilot project will inform future MPCA funding opportunities for electric school buses and provide other school districts in the state valuable information on how electric school buses perform. One benefit to electric school buses are the emissions reductions. An electric school bus reduces approximately 140 short tons of greenhouse gas emissions, 0.7 short tons of NOx reductions, and 0.04 short tons of PM2.5 reductions as compared to a diesel bus. The pilot sought to learn other benefits to electric school buses in Minnesota in addition to emissions reductions. The initial goals the MPCA set forth to learn from the pilot program are as follows:

- Determine if electric school buses are a viable vehicle technology that can reliably be deployed in school bus operations.
- Determine if electric school buses are operable in cold weather climates, including in Minnesota winters.
- Identify what additional resources are needed to help districts maximize their success with electric school buses.

For the pilot project, the MPCA funded at least one bus from each of the four regions of the state identified in Figure 1 (right).

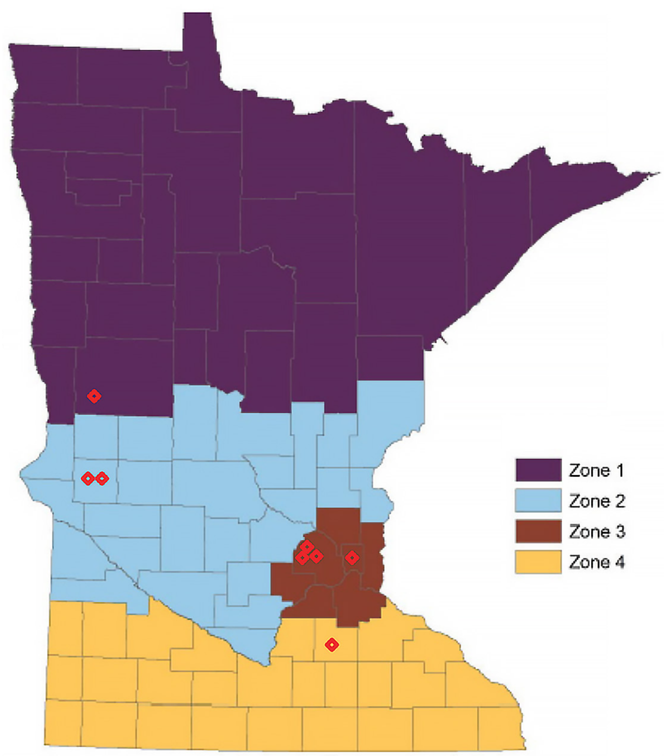


Figure 1: Electric School Bus Pilot Project Zones

- Zone 1: Northeast and Northwest Minnesota received one bus for Fergus Falls Public Schools.
- Zone 2: Central Minnesota received two buses for Morris Area School District.
- Zone 3: The Twin Cities Metro Area received three buses for Osseo Public School District and one bus for St. Paul/ Columbia Heights School District.
- Zone 4: Southeast and Southwest Minnesota received one bus for Faribault Public Schools.

This report uses the quarterly data that the MPCA collected from the grantees as well as a pilot program conclusion survey conducted after the pilot had ended. The data collected from grantees includes but is not limited to the bus or buses' monthly mileage, kWh consumed, kWh/mile, electricity cost, diesel cost, out of service days, number of charges per day, maintenance activities as well as qualitative data on driver training, driver comfort, and overall performance of the bus.

Summary of electric school bus pilot findings

With all eight pilot electric school buses operating for 1 to 2 years, and three others on the road before that, it has been proven that electric school buses can work in a Minnesota context. This pilot study collected data on route length, cost savings, winter weather performance, and reliability. The data in this study is reported in three categories: Operational performance, reliability, and cost savings. The grantee survey results are reported in the pilot survey section.

Top findings

- Average daily mileage traveled by the buses is 71 miles, max daily mileage was 119 miles.
- Average efficiency of the electric vehicle drivetrain was 2.2 kWh per mile.
- Average fuel cost savings is approximately $430 per month.
- Average availability of the electric school buses during a school year was 83%.
- Benefits noted by drivers: significant noise reduction (drivers able to watch passenger behavior more closely and stop bullying), no exhaust smell, smooth acceleration.
- 80% of grantee survey respondents indicated that their maintenance costs were less than that of a diesel bus.

Operational performance

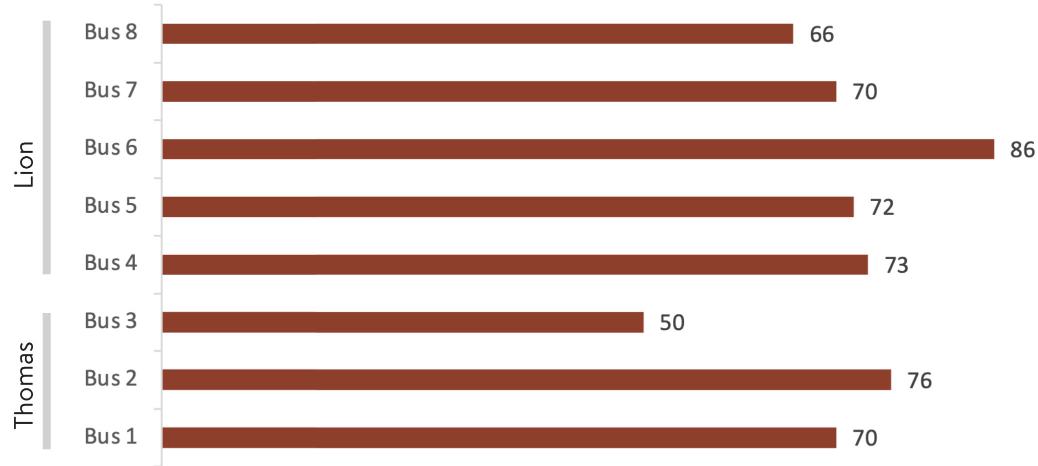
Performance varied between manufacturers and individual buses. All buses successfully handled a route for their school district although some were moved to different routes throughout the year. Each bus's overall performance was explored in these areas: range, cold weather performance, efficiency, auxiliary heater performance, maintenance, and driver comments.

Range

All the pilot electric school buses were able to run routes in their school districts. The buses covered an average of 71 miles per daily route. Route lengths varied by month for some districts as they reassigned the bus. The maximum daily route length driven was 119 miles. Some school districts noted having to charge in the middle of the day during the colder months to have the range to cover their routes. 60% of grantee respondents indicated that their colder month loss of range was manageable, with 20% noting that loss of range was challenging but were able to move the bus to a shorter route that worked better for the electric school bus, and the other 20% siting operational issues that did not allow them to operate the bus much in the winter. See Figure 2 for the average daily miles driven per bus.

Figure 2:

Daily Total Route Length (miles)



Cold weather performance

Ability to continue driving the same routes in the colder months varied between buses. Six buses continued to run the same routes during the colder months, while one bus was switched to a shorter route during the muddier months due to concerns over running out of range on the longer route over a muddy gravel road. That school district found that muddy gravel roads affected their range as much as cold weather. One other bus that struggled with operational issues was switched to only morning routes due to concerns of not having enough range for the afternoon route. The six buses that covered the same routes during the colder months typically charged during the midday break to ensure enough range to complete the afternoon route. All grantees indicated that they charged their bus overnight to conserve energy as it warmed up in the morning. Four of the five grantees parked their buses inside a structure, some were heated, some were not. The bus that was parked outside reported more issues operating in the cold than the other buses. See Figure 3 for a breakdown of the average performance of the buses during the colder and warmer months.

Season	Avg. Availability %	Avg. Out of service days	Avg. Charges per Day	Avg. kWh/mi
Colder months (Dec-Feb)	77%	4.1	2.0	2.5
Warmer months (Mar-Nov)	88%	2.2	1.8	2.0

Figure 3: Data describing variations in performance between the colder and warmer months.

Efficiency

As can be seen in Figure 3, efficiency varied between colder and warmer months, with warmer months requiring an average of 2 kWh per mile and colder months requiring an average of 2.5 kWh per mile. Overall, there was an average efficiency loss of 20% during the colder months, likely due to the increase in power needed to warm up the bus as well as the increase in air density that occurs as the temperature drops which results in more aerodynamic drag.[1] Even with the loss of efficiency in the winter months, on average electric school buses are 60% more efficient than diesel buses due to combustion engine loses.[2]

Auxiliary heater performance

This study also analyzed the difference between buses with diesel fired heaters and those with all-electric heaters. A diesel fired heater heats the cabin without drawing from the battery power, preserving energy for driving the route. However, diesel-fired heaters produce emissions. See Figure 4 for a breakdown of the different types of heaters.

Heater type	Bus manufacturer	Avg. KWh con-sumed per month	Avg. availability %	Avg. charges per day	Avg. daily route miles
Diesel	Lion	1,815	82%	2.0	74
Electric	Thomas	2,620	84%	1.7	65

Figure 4: Comparison between diesel and electric auxiliary heaters

The Thomas Built buses all had electric heaters. Data shows they drew more kWh to run and heat the bus in the winter months. The heaters reduced the Thomas Built buses' overall efficiency, requiring more kWh to run the same distance as a bus with a diesel heater. However, buses with electric heaters were still able to heat up and run their routes. Notably, the average charges per day were marginally different between a diesel and an electric heater at 2 and 1.7 charges a day respectively, with both being likely to charge during the midday break during colder months. Districts may find that they do not need a diesel heater for their routes. One grantee noted that they most likely would not get a diesel heater on an electric school bus again as it is not needed if the bus is plugged in while preheating to use power from the grid instead of the battery's power.

Driver comments on performance

Grantees also provided driver's comments on bus performance. Drivers noted these positives about the electric school bus:

- Dramatic reduction in noise without the diesel engine and lack of exhaust smell.
- Not having to get fuel for their bus every few days and not having to the check the oil.
- New physical features such as smooth acceleration, the backup camera, and wider aisles.
- How quickly the bus warms up.

Some negatives the drivers mentioned about the electric school buses were:

- The lack of cruise control, lack of storage areas for driver's items, layout of the parking brake and other controls.
- Reduced range in colder months.

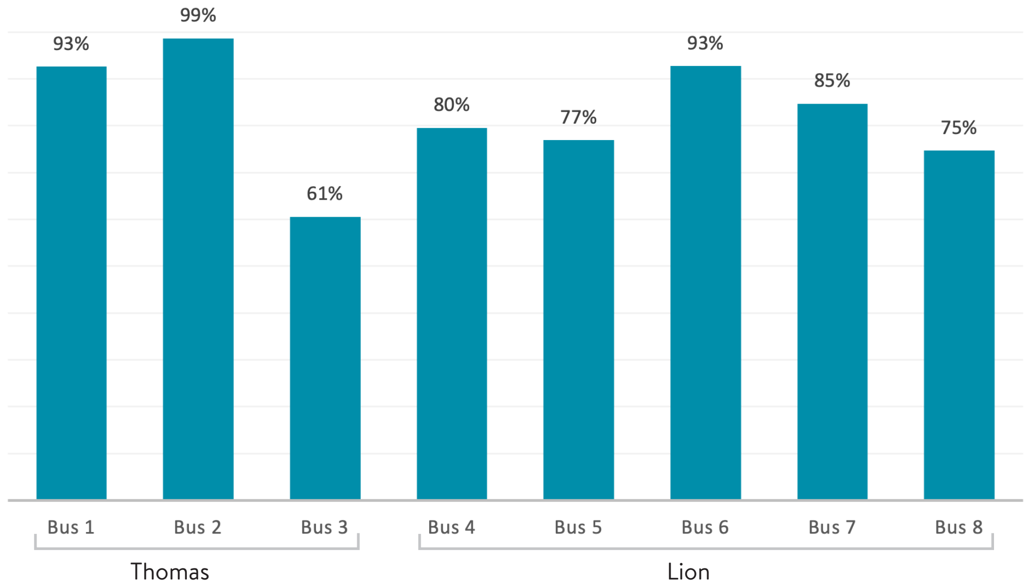
Some lessons learned that the drivers noted about electric school buses were:

- The learning curve with regenerative braking.
- It may be necessary to operate in "drive" not in "low" mode during the winter months and slow down far ahead of stops more so than a diesel bus (This could be due to the increased weight of an electric bus vs. a diesel bus).

Reliability

Availability of the bus is key to a successful integration into a school districts fleet. For this study, grantees reported the number of out of service days they experienced per month. The average availability percentage across all buses was 83%. See Figure 5 for the average percentage of days each bus was available in a month.

Figure 5:
Availability percentage of all buses

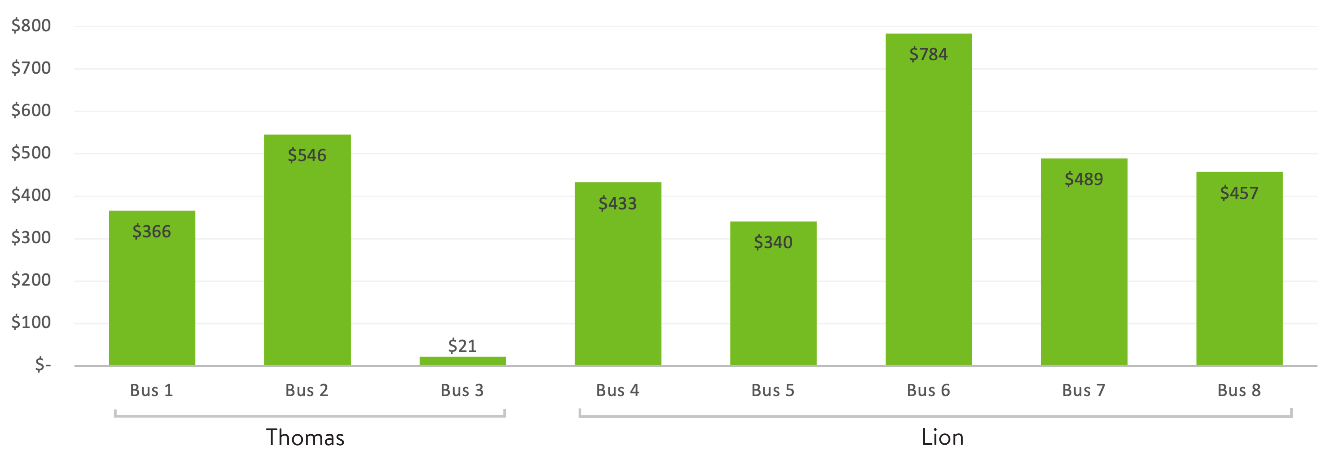


Maintenance reports varied by grantee, with some reporting no issues and no maintenance required, some reporting occasional maintenance, and one with significant operational challenges. Some low-level maintenance items reported across buses were body work due to body damage, a new clamp on an auxiliary heater box, inspections on fuses, work on the air compressor for a driver's seat, a 12volt battery replacement, windshield wiper replacement, and new air filters. Bus 8 in Figure 5 experienced persistent charging issues and a new inline resistor was installed from the batteries to remedy the issue. One bus of the eight (Bus 3 in Figure 5), experienced more significant availability issues due to issues with their battery. The bus ended up spending time at the dealership to get software updates and other fixes. These issues resulted in the bus not being able to make any routes during December and January. This impacted its overall availability percentage as well as its cost savings. All the data in this report includes that bus.

Cost savings

Operational cost savings is one of the major advantages to switching to an electric school bus from a diesel bus. The estimated average monthly fuel savings across all the electric school buses in this pilot program was $430, or $51,600 over the course of 10 years. See Figure 6 for the average monthly fuel savings per bus. The bus with operational challenges that was not working for a couple months is bus 3 in Figure 6 which impacted its average savings.

Figure 6:
Average monthly savings



Average Monthly Savings per bus divided between Thomas and Lion buses

The costs show above in Figure 6 are only fuel savings and do not include any additional maintenance savings that an electric school bus is estimated to have over a diesel bus. Overall, 80% of grantee respondents said that their electric bus has less maintenance costs than their diesel buses. Some grantees noted this may change after the warranty expires.

Pilot conclusion survey

In the pilot conclusion survey, 80% of grantee respondents said they might recommend electric school buses to other school districts, depending on their specific circumstance. One respondent recommended electric school buses for tar roads but not for dirt or gravel roads as they struggled with loss of range due to muddy roads. Another respondent noted that they expect electric school buses to work well in urban and suburban districts due to easier access to infrastructure and utility assistance. The other 20% of grantee respondents said they would not recommend electric school buses to other districts at this time, stating that costs are not economically feasible yet without grants or subsidies.

When asked what they think other school districts should know before adding an electric school bus to their fleet, the grantees recommended meeting with the utility serving their district, bus manufacturers, and their district stakeholders early and often. One grantee noted that the lack of support they received from their utility almost caused them to cancel their order. One grantee recommended considering items like warranties, vehicle specifications, proximity of dealer support, diesel fired vs. electric heaters, location of chargers and charging time, route applicability, and keeping in mind to plan for short- and long-term vehicle electrification.

One grantee respondent had this to say about their final thoughts on the pilot:

> *"This has been a great project. We know that some facet of transportation will be moving to electric from this point forward. It was nice to be a part of looking at how this works for school buses. I would encourage people to be cautious and thoughtful, but inquisitive and progressive as well. Many of these battles are the same ones we fought when propane was marketed. Propane has proven to be a strong fuel choice. As we evolve, I am sure electric will succeed also."*

Summary

Overall, the electric school bus pilot provided the MPCA with valuable information to inform future rounds of VW settlement grant funding. The data collected demonstrates that electric school buses can work in Minnesota even in the colder months, however it's important to consider specific school districts' range needs, infrastructure access, and proximity of service shops or dealers. The electric school buses' significant cost savings and positive driver feedback point to the advantages of an electric school bus over a diesel school bus. More electric school buses will come to Minnesota soon through the U.S. Environmental Protection Agency's Clean School Bus program which is providing up to $5 billion in funding over five years to electrify school bus fleets. Most recently, Minnesota school districts were awarded three electric school buses in the first round of rebates and 13 electric school buses in the first grant funding round. This pilot project found that electric school buses can be a good fit for Minnesota school districts and has helped lay the foundation for more electric school buses to come.

1. How Adverse Weather Affects Fuel Economy (freightliner.com)
2. ElectricSchoolBusFactSheet.pdf (edf.org)

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