Electric School Bus Operations in Hot Weather

Understanding AC and Range Impact

The Experience

A frequently cited challenge for electric school bus (ESB) operations is battery consumption and reduced range in cold weather, but what happens in hot weather? Is the impact of running air conditioning (AC) at full capacity less discussed because it's less of a concern? That is exactly what Modesto City Schools (MCS) and Stockton Unified School District (SUSD) wanted to find out as they deployed their ESBs in one of the hottest climates in the U.S.

Fleet Name	Modesto City Schools	Stockton Unified School District
Location	Modesto, CA	Stockton, CA
Area Type:	Primarily urban	Mix of urban and rural
Topography:	Very flat	Very flat
Ownership Model:	Fleet-owned and operated (school buses and depots)	Fleet-owned and operated (school buses and depots)
Technology Type:	Battery-electric school bus	Battery-electric school bus
Fleet Size:	90	127
Number of ESBs:	30	35 in service, additional 30 expected in 2026
Operating ESBs Since:	2023	2021

Modesto, CA, frequently experiences multiple summer days in a row with temperatures exceeding 100°F. Operating in a climate with an average annual high of 92°F in the summer and an average annual low of 42°F in the winter, MCS has taken a data-driven, proactive approach to their ESB deployment. They utilize telematics, charge management software, and track operations to understand their fleet of 30 ESBs. MCS also shares outcomes on the local education agency's Transportation Sustainability dashboard. Through data tracking, they can see everything from fuel savings to consumption of kW per mile to emissions reductions. This allows them to identify efficiencies in both vehicle performance and operational practices.

> "We are able to track down to the level where we can tell which drivers drive with a lead foot and which ones are effectively utilizing the regenerative braking."
>
> *Steven Fernandes, Director of Transportation, Modesto City Schools*

This level of data collection and review allows the MCS team to keep tabs on how heating and AC impact their routes. MCS reported that they see approximately a 30% range reduction when running heaters in the winter (average annual low of 42°F) and only a 10% reduction from running the AC in the summer, compared to operating the school buses without climate controls. MCS allows their drivers to run the heat and AC as needed, which often means the AC is at maximum output during the June summer school runs.

SUSD, operating in a similar climate, has observed comparable patterns. The district frequently experiences summer highs above 100°F, with averages around 93°F and average winter lows near 41°F. SUSD uses charge management and operational data to cross-reference energy usage with utility costs, ensuring alignment with consumption, billing, and cost savings. Based on their ESB operations, SUSD reports that high temperatures and AC use have minimal impact on range relative to cold weather operations.

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Because the additional battery demand is relatively small, SUSD allows drivers to use climate controls, like AC, freely to maintain comfort. This often results in heavy AC usage during the summer months, which does not adversely impact school bus routes. Having operated ESBs for 5 years, SUSD reports seeing a "remarkable" difference between the impact of heating and AC on their vehicles' range.

Cooling vs Heating: Why the Difference Matters for ESBs

Understanding why heating and AC have such different impacts on ESB operations starts with understanding why this imbalance does not occur with school buses that use internal combustion engines (ICEs).

In ICE school buses, waste heat generated by the engine helps warm the cabin, reducing the need for additional heating systems such as resistance heaters, heat pumps, or auxiliary fuel-fired heaters. While ESB batteries can generate waste heat when operating in warm weather, in cold weather, the school buses' battery thermal management systems must warm the batteries to bring them up to operational temperatures. Because ESBs do not have an engine that generates waste heat in cold weather, they fully rely on heating systems to raise temperatures in the cabin. When it comes to AC, both ICE school buses and ESBs operate similarly.

> "Generally, we see that even in our milder winters, cold weather has a greater impact than the heat."
>
> *Steven Fernandes, Director of Transportation, Modesto City Schools*

Air Conditioning Systems

Most school bus AC systems utilize a compressor to compress refrigerant gas, which raises the gas's temperature. The compressor is the main component of the AC system that draws energy from the school bus. In ICE school buses, the AC compressor, along with other peripheral systems, is powered directly from the vehicle's engine via the serpentine belts. In ESBs, however, the energy is pulled from the high voltage battery. After the refrigerant gas is heated and compressed, it passes through a condenser and enters the evaporator, where it absorbs heat from the cabin air, cooling it down to be circulated through the cabin via blower fans. Because this process primarily relies on the chemical refrigerant to absorb heat to lower the temperature, it can be more than 100% energy-efficient, having minor impacts on the battery and range. AC typically produces 2–4 kW of cooling per 1 kW of electrical input.

To help offset the impacts of heating or cooling on vehicle range, operators can precondition their ESBs. Preconditioning is the practice of heating up or cooling the school bus cabin while it is still plugged into its charger, thus drawing power from the grid and reserving battery power for the school bus route. Preconditioning to heat the bus in cold weather can be particularly effective at range maximization, as heating the cabin of the school bus will also help warm the battery up to its optimal temperature and reduce the energy needed by the battery thermal management system.

Heating Systems

Three types of heating are utilized in ESBs:

1. **Electric resistance:** This is the most common type of heater for ESBs. Resistance heating works similarly to a space heater in an office or home by running electricity through a conductor to produce heat at 100% efficiency. For each 1 kW of heating generated, 1 kW of energy is consumed. This process is effective at creating heat but is very energy-intensive, meaning a lot of electricity is needed to produce that heat, which can result in a 30%– 40% loss in vehicle range.

2. **Heat pump:** Less common in ESBs, heat pumps function similarly to air conditioners, but in the opposite direction. Like AC, chemical refrigerant is run through a compressor, where it is turned into high-temperature, high-pressure gas. The hot gas is then passed through a heat exchanger, which releases heat, while changing the gas back into a liquid. The resulting heat is then circulated into the cabin with blower fans. This process still uses electricity but can be up to three times more energy-efficient than resistive heating. The primary reason heat pumps are less common on ESBs is due to the higher costs of the technology.

3. **External fuel-fired heaters:** Some ESBs can also be equipped with external fuel-fired heaters, but because those heaters rely on their own fuel source (typically diesel), they do not impact the vehicle range. Because fuel-fired heaters produce their own local emissions, they are only recommended in climates that experience extreme cold, such as 20°F and below. Due to their added emissions, these are often ineligible for reimbursement under funding programs, such as those administered by the California Air Resources Board.

Key Learnings

So why do we hear so much about cold-weather range reduction for ESBs, but very little about high-heat operations?

The answer is simple: AC has a much smaller impact on range, often only one-third of the impact of heating, and even less when preconditioning is utilized. This highlights the importance of route planning for fleets. Operators should plan their routes based on winter operations. If an ESB can serve a route despite heater-related range reductions, it will perform reliably on the same route in warmer months. Even in high temperatures, drivers can use AC with confidence, knowing most of the vehicle's range will be preserved.

Images are illustrative and do not reflect the school districts featured in this case study.

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