FACT SHEET: COMBATTING RANGE LOSS IN EXTREME COLD

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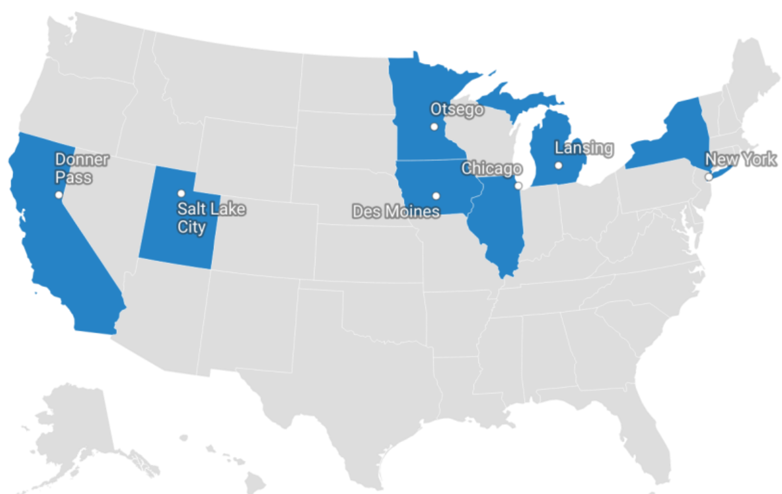
A review of solutions and strategies for electric buses and trucks

Cold weather range loss for electric vehicles is real. However, that has not stopped chilly cities from deploying electric buses and trucks. Technological solutions and operational strategies can be leveraged and implemented to enable successful electric truck routes in cold climates.

Figure 1: Examples of Cold Climates where Electric Trucks or Buses have been Deployed



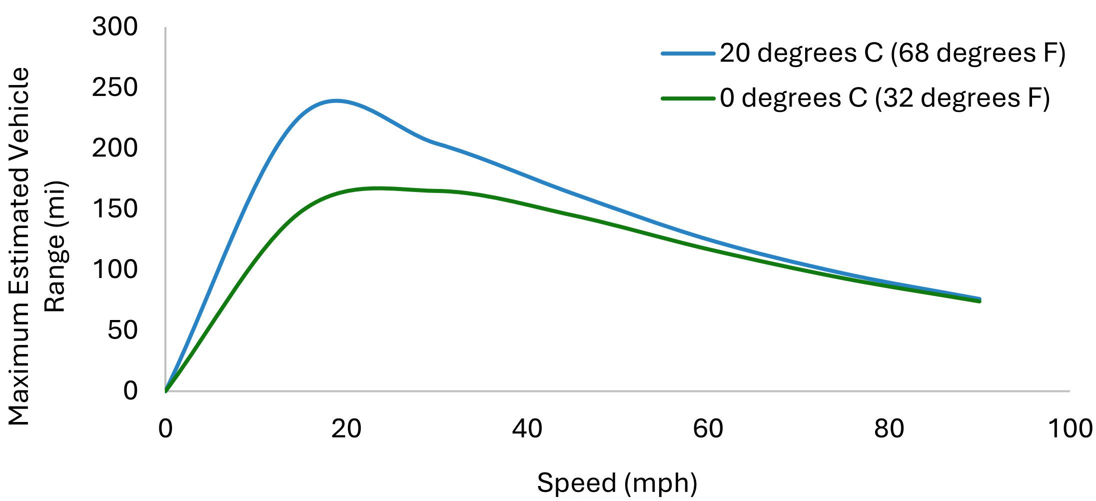
Source: Case studies referenced in this fact sheet

Freezing Temperatures Can Impact Performance

Range anxiety is a common barrier to electric vehicle adoption, particularly in areas that experience extremely cold weather. Both research and on-the-ground experience has shown that colder weather reduces the typical range of a battery electric vehicle (EV).[1] When temperatures drop, lithium ions within the battery move more slowly, causing the battery to operate less effectively and charge less efficiently. Furthermore, some of the battery's energy is directed towards maintaining optimal battery operating temperature and heating the interior cabin. In a vehicle with an internal combustion engine, excessive thermal energy is used for cabin heating, which is not possible in battery operated vehicles. Instead, EVs are equipped with either an electric resistance heater or heat pump which is sometimes supplemented with an auxiliary fuel-fired heater [1].

An analysis by Geotab suggests that, for electric passenger vehicles and cargo vans, the optimal temperature to maximize range is 20 degrees Celsius (68 degrees Fahrenheit) [2]. According to a study by CALSTART, temperature is one of the most influential factors impacting heavy-duty electric truck and bus efficiency [3]. The North American Council for Freight Efficiency (NACFE) conducted tests on EVs ranging from cargo vans to regional haulers and found that, for every 10 degrees Fahrenheit lost below 30 degrees, range decreased by 10 percent [4]. However, both the CALSTART and Geotab analyses agree that, for heavy-duty vehicles and cargo vans, respectively, average speed has a greater impact on driving range than temperature [3, 2]. Looking at the combined impact of speed and temperature, the estimated vehicle ranges at zero, 20, and 30 degrees Celsius (32, 68, and 86 degrees Fahrenheit) begin to converge at higher speeds, especially starting at around 40 miles per hour. At 60 miles per hour, the differences were almost insignificant, meaning that temperature has little effect on range at highway speeds (see Figure 2) [2].

Figure 2: Impact of Speed and Temperature on Electric Cargo Van Range

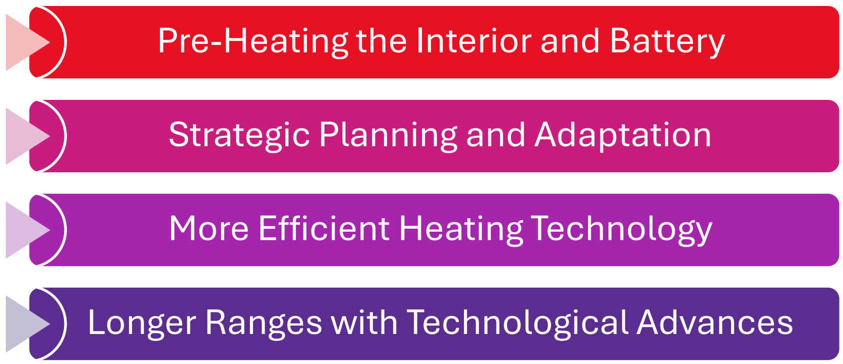


Source: Geotab's interactive temperature and speed simulation tool [2]

[1] Note: For the purposes of this fact sheet, "electric vehicle" or "EV" refers to battery electric vehicles.

To counteract cold weather range loss, fleets have taken advantage of technological advances in electric trucks and buses and have employed mitigation and adaptation strategies. We discuss four here that have seen on-the-ground success.

Figure 3: Technological Advances and Strategies to Mitigate Cold Weather Range Loss



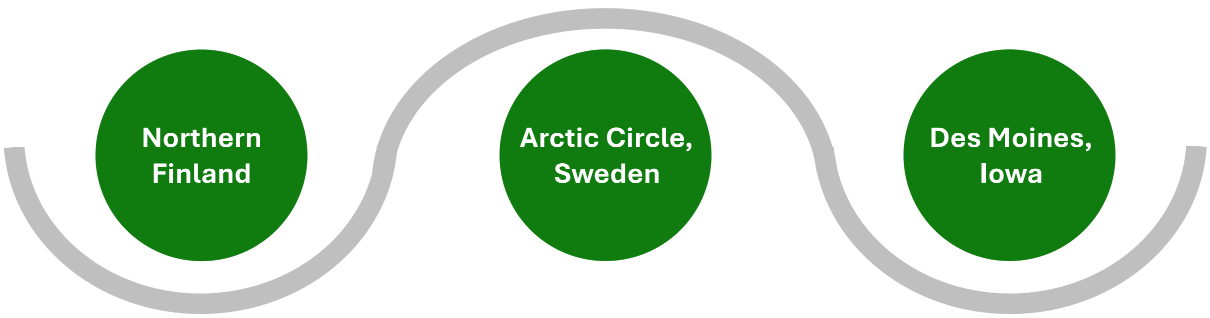
Vehicle Pre-Heating Can Help

A number of electric truck manufacturers have established extreme cold testing facilities to observe and adapt to the impact of subfreezing temperatures on electric trucks. At Daimler's testing facility in northern Finland, temperatures reach as low as -25 degrees Celsius. Two battery electric tractor-trailer semi-truck models were put through the paces in the cold, snow, and wind. Testing the thermal and energy management systems determined that the cab of an electric long-haul model heats faster than its diesel truck counterpart. Although there was range loss associated with this energy usage, it was counteracted by pre-conditioning, or heating the drivetrain and cab while the truck is charging. Overall, "even in very wintry conditions, [the] battery-powered trucks are fully operational" confirmed Dr. Christof Weber, Head of Global Testing Mercedes-Benz Trucks [5].

Volvo had similar results at their testing facility near the Arctic Circle in Sweden. Comprehensive tests were conducted on long-range heavy-duty electric trucks to confirm that all systems were able to function correctly, even when ice and snow built up on the trucks. As a result of its cold weather testing, Volvo introduced the Ready to Run feature, which allows the driver to start pre-heating the truck remotely, via an app. Similar to Daimler's recommendation for pre-conditioning, the Ready to Run feature allows the drivetrain and cabin to reach an optimal temperature while charging, thereby reducing range loss from cabin and battery heating [6].

On-the-ground experiences with pre-heating have also been positive. Winters in Des Moines, Iowa routinely bring subfreezing temperatures and blizzards. Nonetheless, in 2020, the city began transitioning its public vehicle fleet to EVs once they became cost-effective. Des Moines opted to first deploy EVs in its property inspection department in October, just ahead of the winter season. After six months of use, there were no known issues or major service needs. Drivers reported a largely positive experience and an inclination towards EVs for future vehicles. Although drivers did notice that range decreased as temperatures got colder, they alleviated the issue by pre-heating the vehicle before unplugging and parking the vehicle in a garage overnight. Given the success of and lessons learned from the EV pilot program, Des Moines is building a depot capable of charging 160 vehicles in anticipation of scaling up their EV fleet [7].

Figure 4: Examples of Automakers and Fleets that have Seen Success from Pre-Heating



Daimler tests showed that pre-heating counteracts range loss.

Volvo's 'Ready to Run' feature lets drivers pre-heat trucks remotely.

Based on pilot program results, the city is building a depot for pre-heating.

Technological Advances Have Improved Heating Efficiency

Technological advances have also improved efficiency and mitigated range loss of EVs during extreme cold. Inclusion of driver-targeted heating, such as heated seats and steering wheels, offers a low-energy heat source option [8]. One key development in heating efficiency, however, has been the replacement of resistance coil heaters with heat pumps. Both systems are powered by the battery but heat pumps are, on average, three times more efficient [9, 10]. EVs equipped with a heat pump therefore warm the cabin more efficiently and can direct more of the vehicle's battery energy to travel. However, in extreme cold temperatures, heat pumps show decreased efficiencies, and a separate resistance heater is sometimes relied upon as backup [9].

The Chicago Transit Authority (CTA) has observed the improved efficiency of a heat pump. In a city notorious for its cold winters, CTA began replacing its diesel-powered public buses with electric models in 2014, with a goal for all buses to be electric by 2040. Heating public buses can be particularly battery draining, given the need to repeatedly open doors for passengers. Over the past decade, they have seen that, not only do newer electric buses have longer ranges, but those that come equipped with heat pumps are more efficient [11].

Electric school buses in Michigan are one example where supplemental fuel fired heaters have been successful. In 2020, seven school districts in the state deployed electric school buses with five-gallon diesel heaters. These heaters were designed to keep the battery warm and, in part because of that direct energy flow, the cabin can heat up faster than it would in diesel buses. Even relying on fossil fuels, these heaters produce significantly lower emissions than an average diesel bus and reduce winter range loss such that the buses can easily make their 50-mile rounds twice a day. Overall, one school district reports that "the buses…often outperform their diesel counterparts in cold weather" [12].

In addition to technological advances to improve the efficiency of cabin heating, there is also a need to minimize energy spent to heat the battery. Rivian is one automaker working on this. Their battery is designed to be "self-heating" such that, rather than requiring an additional heater, the battery uses energy from the inverter and the motor to maintain optimal drivetrain temperatures. Rivian tested this technology by "cold soaking" their vehicles at -40 degrees Celsius. The results showed that if the vehicle is left plugged overnight in extreme cold, upon startup, the battery takes approximately only 20 minutes to warm up before it is able to reach full power and performance. According to Rivian, their battery system was designed to use as little energy as possible to maintain or reach optimal battery temperatures, and tests proved that to be true [13].

Strategic Planning is Key

Although the goal is for electric trucks to seamlessly replace internal combustion engine vehicles, the reality is that strategic planning is critical, and sometimes operational adaptations and adjustments need to be made. In January 2023, Meijer added two electric semi-trucks to its Lansing Distribution Center fleet in Michigan. Because the trucks can drive up to 200 miles per trip, Meijer will use them for daily deliveries between depots that provide charging. Part of a demonstration project funded by the U.S. Department of Energy's Vehicle Technologies Office, Meijer will store data on the performance of these semi-trucks, specifically during cold weather towards "accelerating the industry's transformation to electrification" [14].

In deploying their public electric buses, planning and adaptation was also part of CTA's strategy. During winter, their public buses start with 100 miles of range and can complete six one-way trips before falling below 50 percent state of charge. CTA adapted to cold weather range loss by building time into bus schedules for charging. They also installed fast charging sites at both ends of many bus routes so that buses could charge before restarting their routes. Given this additional planning, CTA is confident that their plan to go fully electric by 2040 "will work" [11].

Like CTA, the Salt Lake City School District (SLCSD) in Utah specifically makes use of downtime in between morning and afternoon routes to charge their electric school buses. SLCSD has eight electric school buses, none of which include a supplemental or backup heater. During winter months, temperatures can get as low as -30 degrees Celsius and about 18 percent of driving range is lost due to heating alone. To compensate for this, SLCSD established protocols for their buses to charge during the day, when not in use. This schedule adaptation, in combination with regenerative braking, allows the buses not only to complete their longest routes without running out of battery, but also to be used for skiing field trips and on mountain passes. SLCSD has ordered an additional four electric school buses towards their goal of electrifying all 100 buses in the district by 2024 [15].

Vehicle Ranges Are Improving

The range of electric heavy-duty trucks is increasing. In 2019, the average advertised range of zero-emission heavy-duty truck and step van models globally was less than 180 miles. That increased to 250 miles in 2021 and almost 300 miles in 2023 (see Figure 5) [16]. The U.S. Department of Transportation reports that 80 percent of truck routes are less than 100 miles per day [17]. As the range of EV trucks continues to increase, cold weather range loss could become less of a concern.

Figure 5: Range of Zero-Emission Heavy-Duty Trucks and Step Vans has Increased

Source: International Energy Agency [16]

NACFE's 'Run on Less' demonstration project collects data on zero-emission fleets during their operations. In 2021, Run on Less included participants from 13 fleets across the United States and Canada with battery electric vehicles ranging from Class 3 to Class 8. As these vehicles completed their regular routes, NACFE collected data about range, charge, weather, and more. Heavy-duty trucks that participated in the demonstration had an average range of 200 miles, making them more than sufficient for regional haul routes [18]. Furthermore, although the demonstration was conducted in September when temperatures were moderate, participants running battery electric trucks in Minnesota, Montreal, and New York all reported that their fleets operate without disruption throughout the winter [19].

The recently concluded Run on Less 2023 also showed successful results. Initial data from the demonstration suggest that Class 8 vehicles had ranges that were twice as long in this demonstration as the trucks that participated in Run on Less 2021. The battery electric Tesla Semi truck was particularly impressive, driving up to 410 miles on one charge and 1,076 miles over the course of 24 hours [20]. Over the first two weeks of the demonstration, 65 percent of miles driven by the Tesla Semi were with a gross vehicle weight plus load of at least 70,000 pounds [21]. One of its routes covered 7,000 feet of elevation gain over the Donner Pass in California. This elevation gain was compounded by minimum temperatures around freezing, and, even facing these extreme challenges, the Tesla Semi was able to travel 150 miles before charging at a depot while being unloaded [22].

Conclusion

Although some amount of cold weather range loss is unavoidable, municipal, and commercial fleets have demonstrated solutions and strategies to enable truck electrification. Improved vehicle system level designs, such as replacing resistance heaters with more efficient heat pumps and heated seating, are critical to reducing parasitic battery loads. Vehicle pre-heating can help to reduce range losses, and planning ahead for operational changes can set fleets up for success. Ongoing improvements in electric truck range could assist in reducing concerns. The results from NACFE's 2023 'Run on Less' demonstration suggest that electric truck technologies continue to improve at a rapid pace.

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