The geography of EV charging

How regional climates impact charging and driving behavior

GEOTAB

Energy

About Geotab Energy

Electric vehicle adoption is catching on and world-wide we are witnessing a transition from internal combustion vehicles to fully electric alternatives. This transition is for the better, but it does come with new challenges and new opportunities for those willing to help solve them.

One such challenge is that unmanaged electric vehicle charging load can negatively impact the electric grid. Many electric networks simply weren't built for the demand EV charging places on them. As more electric vehicles hit the road, the increased impact of additional load from EV charging stands to degrade infrastructure and increase the reliance on back-up generation.

There is however a great opportunity for utility companies. By integrating electric vehicles with the grid, electricity demand managers stand to gain additional energy resources which can be deployed to stabilize system wide energy demand, increase utilization of baseline or sustainable generation and mitigate the risk of EV charging on transmission and distribution networks.

To learn more, please visit www.geotab.com/energy

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Introduction

It is commonly understood that temperature, particularly the cold, impacts electric vehicles. More energy is used to maintain a comfortable cabin temperature and there are various forms of built-in battery conditioning. This results in reduced range for the vehicles in colder climates. However, studies have shown that higher temperatures also impact the range of an EV for the same reason maintaining comfortable temperatures, but in this case the energy is used for cooling.

Why is temperature important for those managing EV charging load?

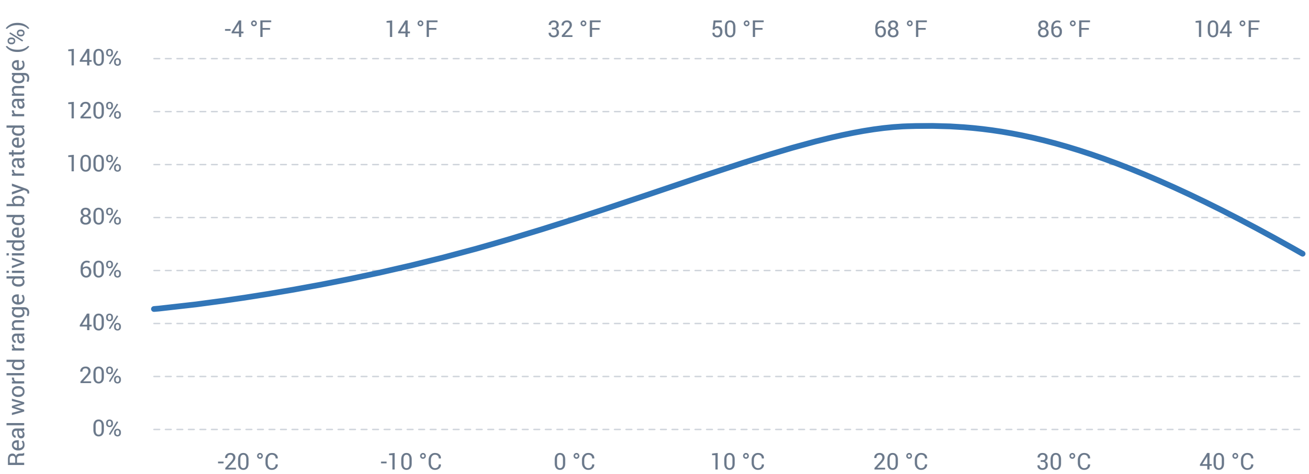
Utilities can benefit from knowing how temperature-related impacts to the range fundamentally alter the charging and driving behavior of the EV owner. It can influence when they charge, how often they charge and the overall distance they drive.

Utilities should take their service territories' climates into consideration when establishing a load management program, to help account for the impact of temperature.

There are multiple factors to consider when managing an EV charging load regardless of location, including: commuting patterns, vehicle market share and existing EV charging infrastructure. However, what this report will show is that understanding how climate and temperature influence driver behavior plays an important role in creating an effective strategy for managing EV charging load.

> "Utilities can benefit from knowing how temperature-related impacts to range fundamentally change the charging and driving behavior of the EV owner."

Real-world vs. rated range



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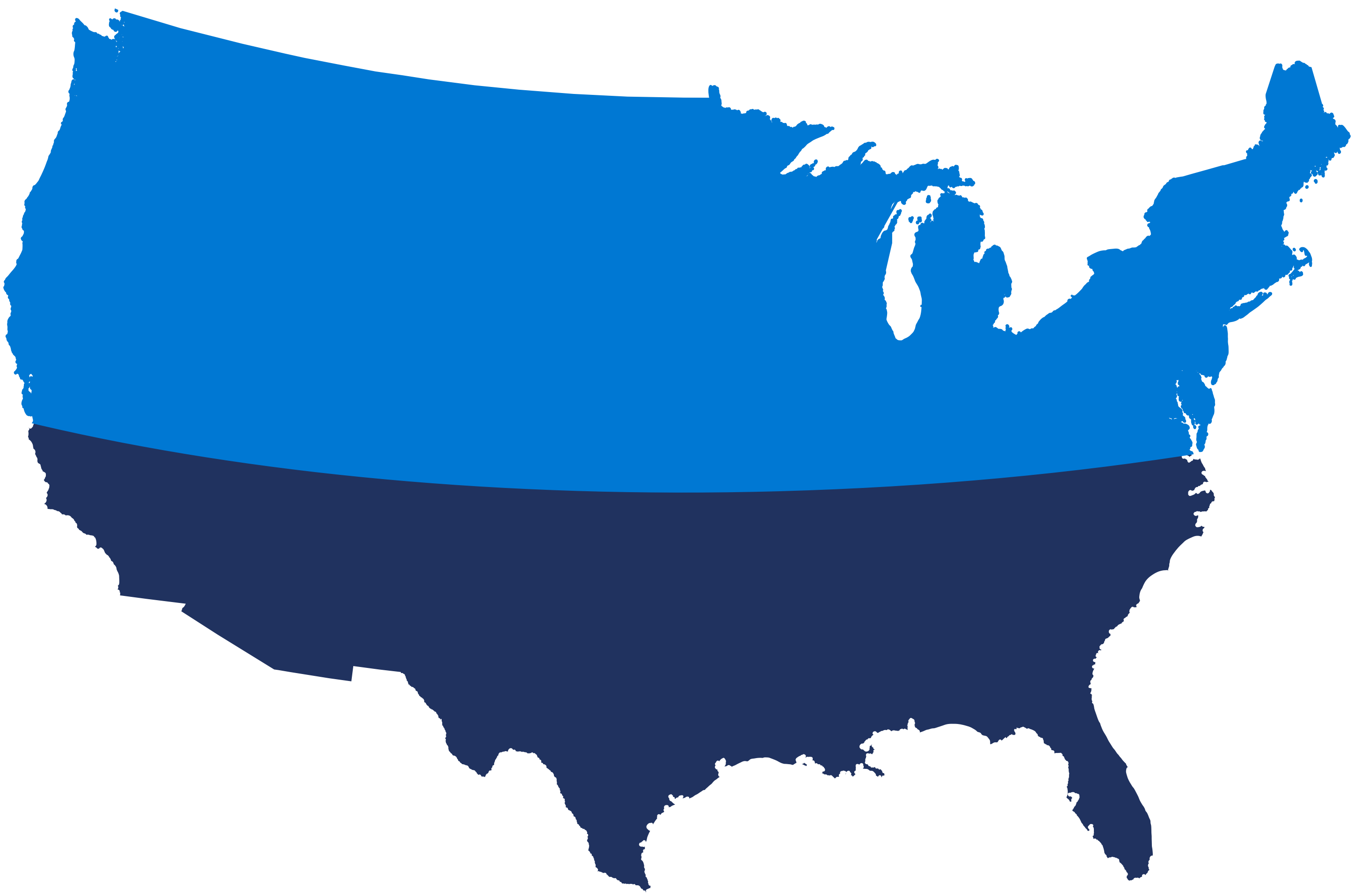
Further analysis from the world's largest electric vehicle dataset

The groundbreaking data-driven study titled EV Growing Pains was released in May 2020. This was one of the largest studies of EV charging load ever conducted and included an analysis of data from over 3,900 electric vehicles from across North America. This report is based on the same dataset and further examines real-world data in order to showcase the role that temperature and seasonal climate play in influencing charging and driving behavior.

The original dataset, which contained a full year's worth of information (from 1 January through 31 December 2019), has been broken down to reflect the summer and winter months in North America. The vehicles have also been sorted by geographic location into a group representing the North and the South. It includes 40 EV makes and models, as well as home and away charging from various EV charging stations.



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3,900
EV drivers

North vs South
Geographical comparison

40
EV makes and models

8,576
MWh of charging EV load

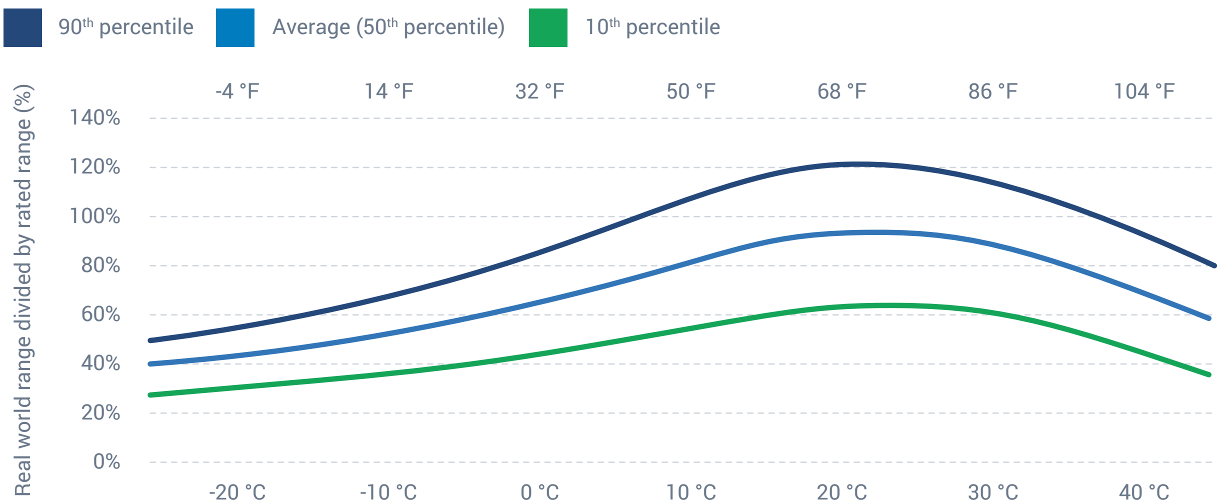
2019
Year of data collection

Summer vs Winter
Seasonal comparison

The impact of temperature and climate on EV range and battery health

Before examining the changes in driving and charging behavior, it is important to understand the impact temperature and climate have on the electric vehicle itself. Geotab has created two online tools that allow users to calculate the implications to an EV's range and battery state-of-health. With both of these tools, temperature plays a significant role.

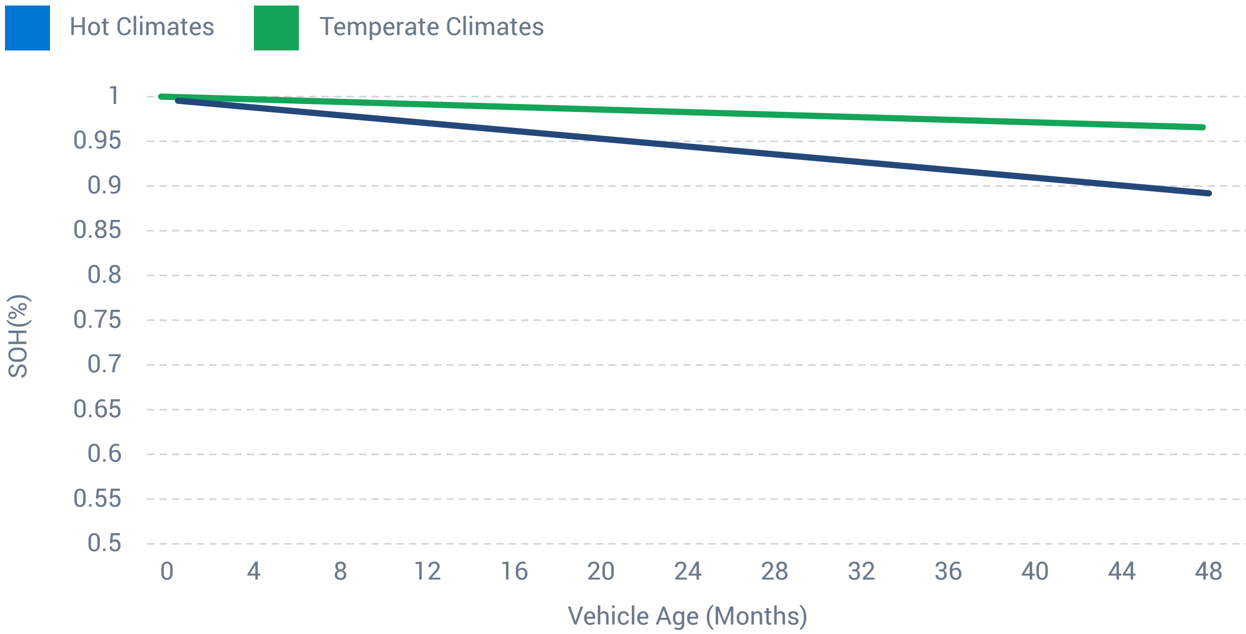
Real-world vs. rated range



Summary of findings:

- The data shows that on average EVs will maximize their range, exceeding their rated range, when operating in 70°F (21°C) weather.
- As external temperature either increases or decreases the overall range is reduced.
- Maintaining a comfortable temperature for the occupants and for the battery accounts for the majority of this loss of range.

Battery SOH vs. Time: Varying Climates



Another factor that will impact an EVs range is its battery's state-of-health (SOH) or how much the battery has degraded. Like all batteries, an EV will start to lose its ability to hold a charge over time. Their tool shows that prolonged exposure to high temperatures will accelerate the rate of degradation.

> "Utilities looking to grow EV adoption in their service territory need to know how to help their customers overcome these types of objections."

Why is this information important to utilities?

Firstly, it is important for customers. Potential EV owners are looking for more education about electric vehicles, particularly their range and what it means. Someone who lives in a colder climate may be deterred from buying an EV when they see that in the winter the range of their vehicle could be cut in half. The reality is that even at 50% of the range of today's most popular vehicles, long-range battery electric vehicles (BEV), far exceeds their average daily driving distance. Utilities looking to grow EV adoption in their service territory can help their customers overcome these types of objections through awareness campaigns.

Secondly, a vehicle's range will ultimately shape the owner's charging behavior. Do they charge every day? Is this behavior different when the seasons change? How does the average driving distance change and when are drivers more likely to use public charging infrastructure? All of these questions need to be examined to adequately plan for infrastructure needs and to create an effective EV load management program.

Average daily driving distances by region and by season

In general, EVs are driven less during the winter months than in the summer, and this was true for both the North and South group. EVs in the southern group drove more on average in both respective months. However the difference between the seasons is less extreme than with the northern group.

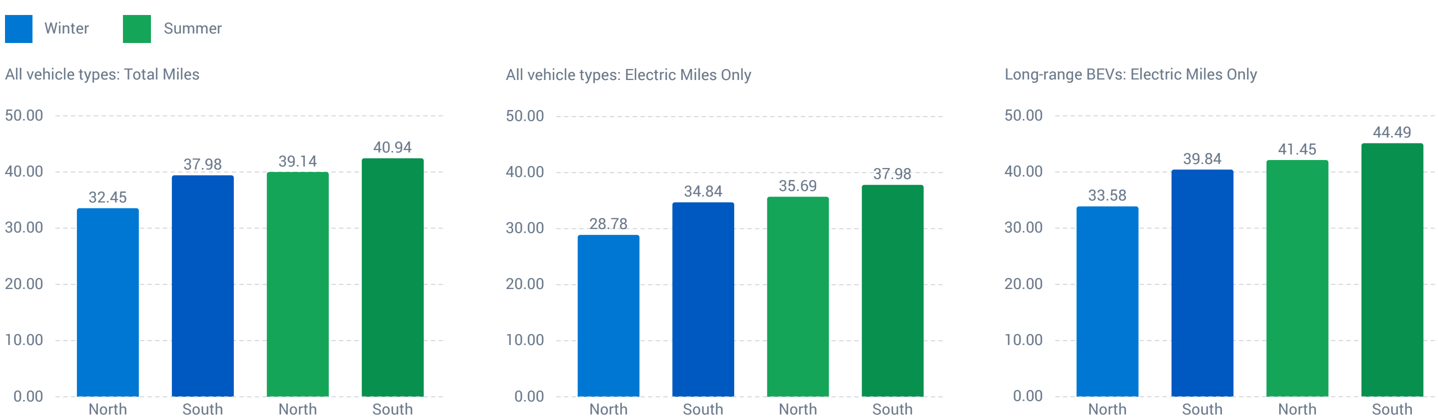
When reviewing driving data, it is important to note that it includes plug-in hybrid electric vehicles (PHEV), which operate on gasoline as well as electricity. In fact, during this study it was shown that approximately 60% of the miles driven by PHEVs were powered by electricity and this number drops to only 56% in northern-regions during winter.

Looking at electric-only miles reveals an average distance drop in daily driving for all vehicle types. That being said, PHEVs are declining in popularity. In 2019, PHEVs accounted for 26% of all new EV sales, down from 46% in 2014.

The fastest growing vehicle type is the long-range BEV, which made up 66% of new EVs sold in 2019. These electric vehicles not only have a larger impact on the grid, due to their larger battery capacities and higher power draws, but they are also driven more. When looked at on their own, long-range BEVs are driven more than the overall averages in both seasons and vehicle groups.

Overall, this data reveals that not only do daily driving patterns vary from one area to another, but that they may differ throughout the year depending on the seasonal temperature. Another consideration is that both of these groups consist of multiple service territories and averaged data. A territory that is predominantly suburban will typically have longer daily commutes than those in urban or rural areas. In order to accurately forecast driving distances territory-specific data should be used.

Daily Driving Statistics



> "Overall, this data reveals that not only do daily driving patterns vary from one area to another, but that they may differ throughout the year depending on the seasonal temperature."

More miles doesn't necessarily mean more energy (kWh)

One of the more interesting discoveries during this study was that the vehicle group that drove the most miles did not use the most charging energy. Although the North group drove the fewest miles in the winter, they used the most energy per vehicle.

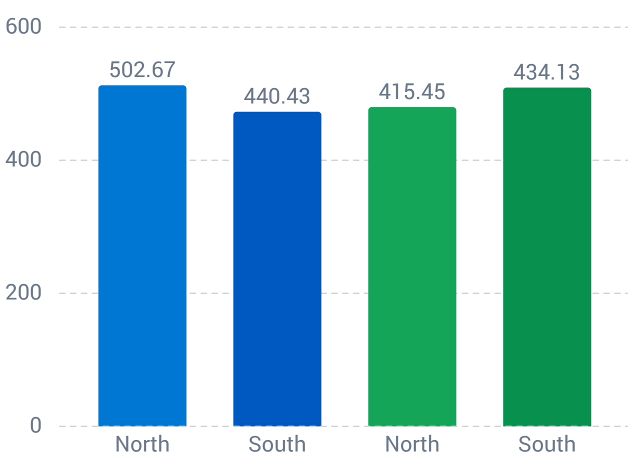
Both groups drew more energy in the winter months compared to the summer, with the North group experiencing the most drastic increase. This is a result of more energy being required to keep the cabin at a comfortable temperature. This fact is less pronounced for long-range BEVs, where the seasonal difference in energy use was not as drastic between the North and South groups. Per-vehicle averages for BEVs are higher overall. This appears to be the result of PHEVs relying more on gasoline during the colder winter.

So while it is important to understand how far an EV travels in a territory, it is only one of the factors that will contribute to its charging load. As temperature changes, so does the amount of energy being used.

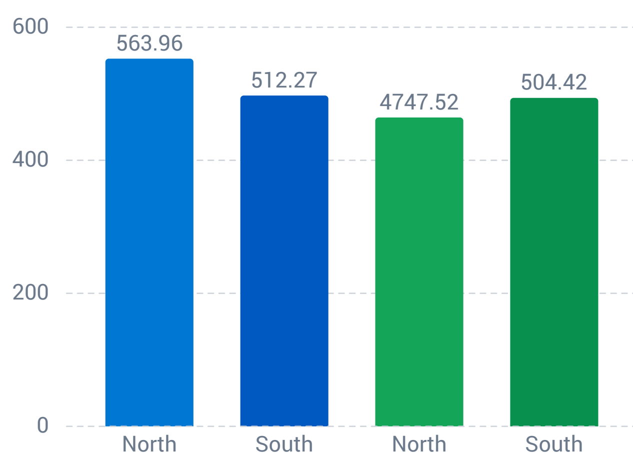
Average Monthly Charging Energy (kwh)

Winter Summer

All vehicle types



Long-range BEVs Only



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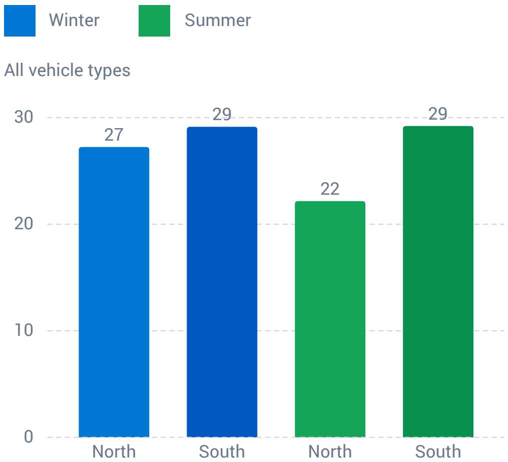
Region, season and vehicle type will determine an EV's charging pattern

One of the main lessons from the EV Growing Pains study was that long-range BEVs are gamechangers for utilities. Their larger battery capacities allow them to charge less frequently while still meeting their daily driving needs. This was proven again in this study as EVs on average did not charge every day regardless of season or location. However, EVs in the North were charged less frequently than those in the South.

Average Charge Sessions per Month



It is unclear exactly why there is less frequent charging in the North. One theory is that there was an earlier adoption of EVs in the South, as a result of the limited range of earlier EVs and the range reduction caused by cold weather. This would mean that those in the South were conditioned to charge every day, which has carried over even though their capabilities have changed. While this is purely speculative, it is worth noting that even when you compare the charging frequency by individual vehicle type the results are the same – the Southern group charges more often.

> "Unlike other forms of residential load, such as air conditioning, EV charging is much less predictable."

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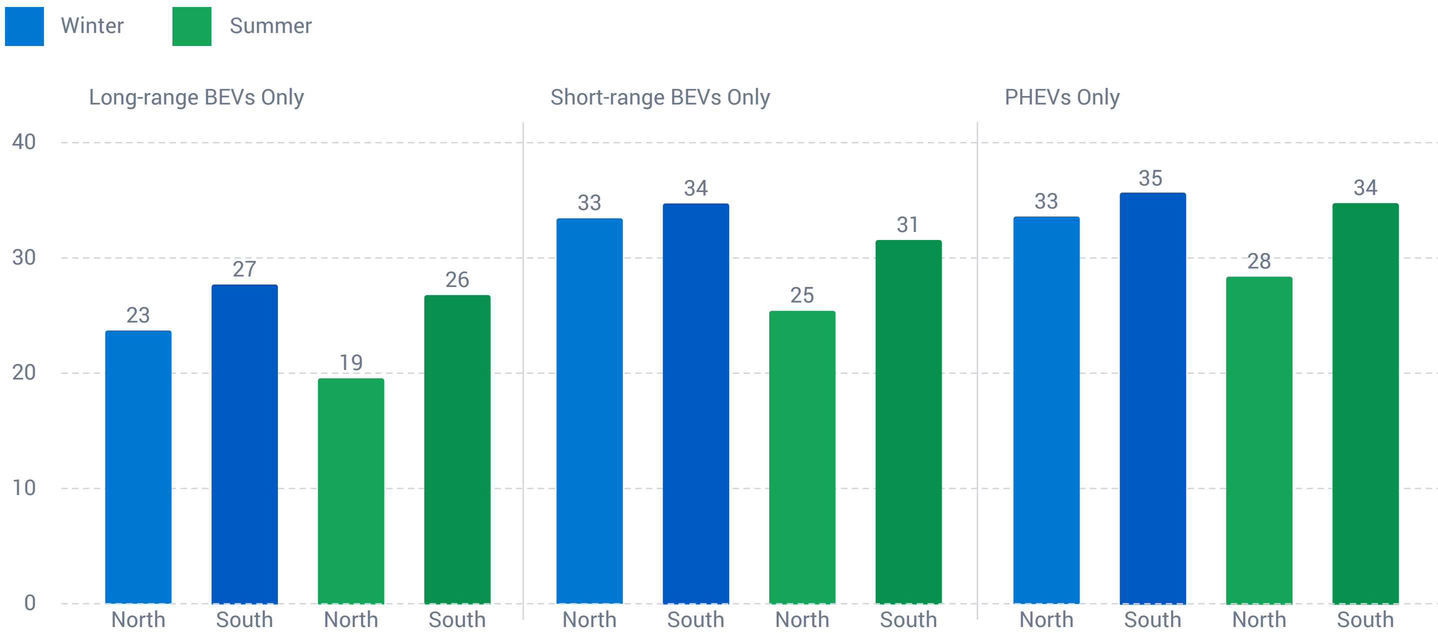
Average Charge Sessions per Month

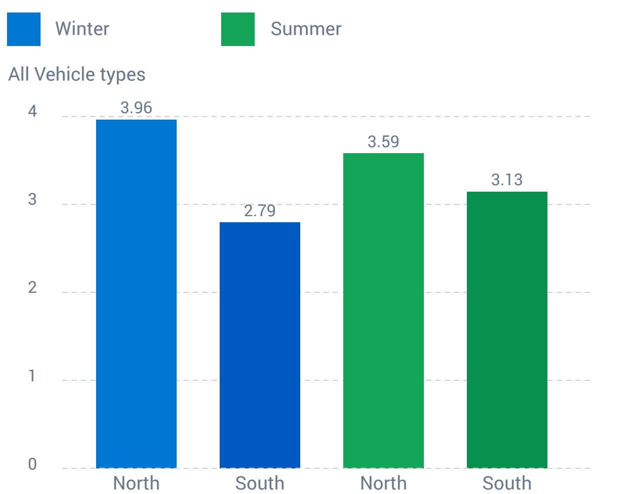


The frequency of charging in all three vehicle groups is higher during the winter, with more significant differences in the North. The data also shows that long-range BEVs are the only vehicles that consistently do not charge every day. In fact, in both regions short-range BEVs and PHEVs tend to charge more than once per day, which makes sense given their small battery capacity.

On average, EVs spent roughly three to four hours charging per session. The length of charging sessions were shorter in the South, which would align with the fact that they charge more frequently.

Unlike other forms of residential load, such as air conditioning, EV charging is much less predictable. Not only does every vehicle behave differently, every driver has their own set of unique circumstances that will define how they charge.

Average Time Spent Charging per Session (hours)



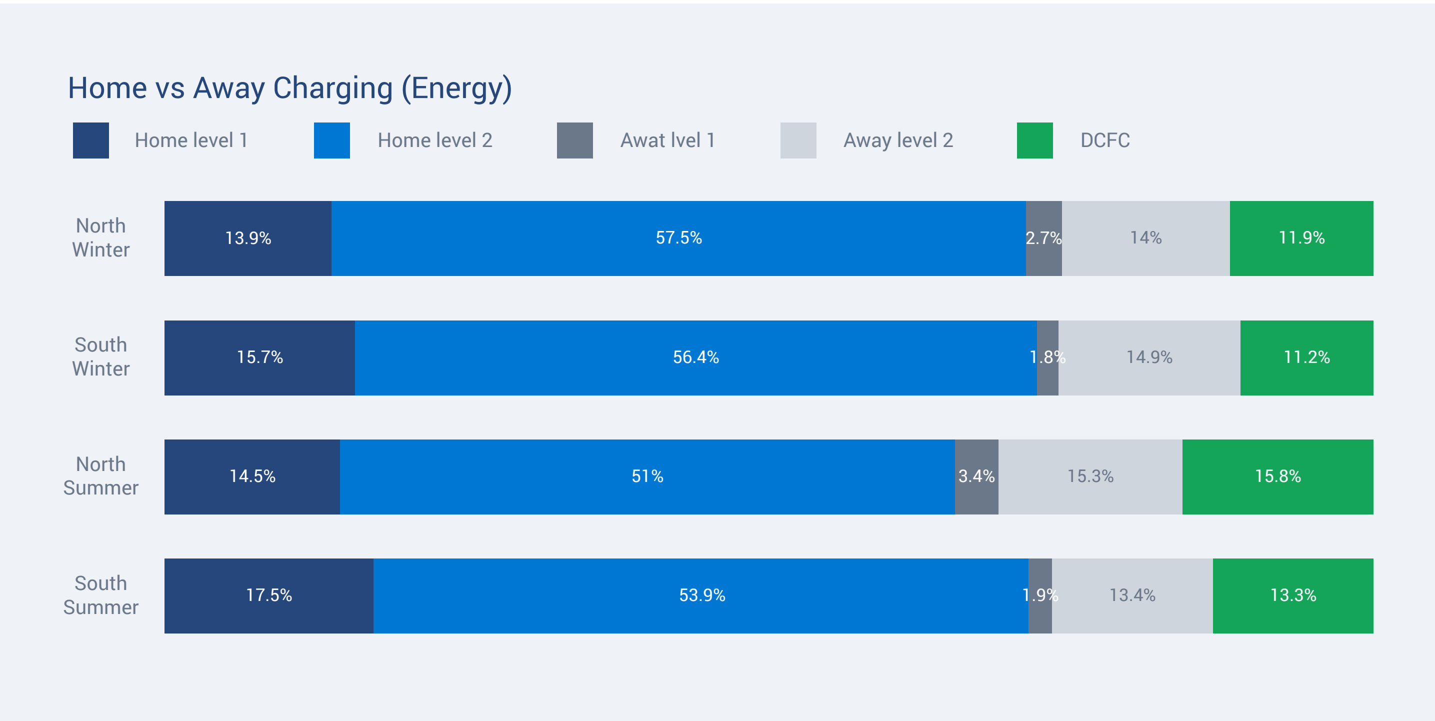
> "Unlike other forms of residential load, such as air conditioning, EV charging is much less predictable."

Regardless of where home is, it is still the most desirable place for drivers to charge

Regardless of season or region, the majority of EV charging occurs at home. However, multiple Geotab Energy studies have shown the percentage to be less than the often quoted 80%. This study showed that when reviewing charging by energy use, roughly 70% of charging occurred at home, with Level 2 charging accounting for the majority. In both regions, direct-current fast charger (DCFC) usage increased during the summer months, while home Level 2 charging decreased and Level 1 charging remained the same. This would indicate that it is most likely the result of drivers traveling and not having access to their Level 2 home charger.

When reviewing the charging data by number of sessions you see additional differences between the North and South groups. In general, there is a higher level of at home charging, closer to the standard 80%. However, in the North there is a much higher percentage of Level 1 charging in winter and double the amount of DCFC charging in the summer.

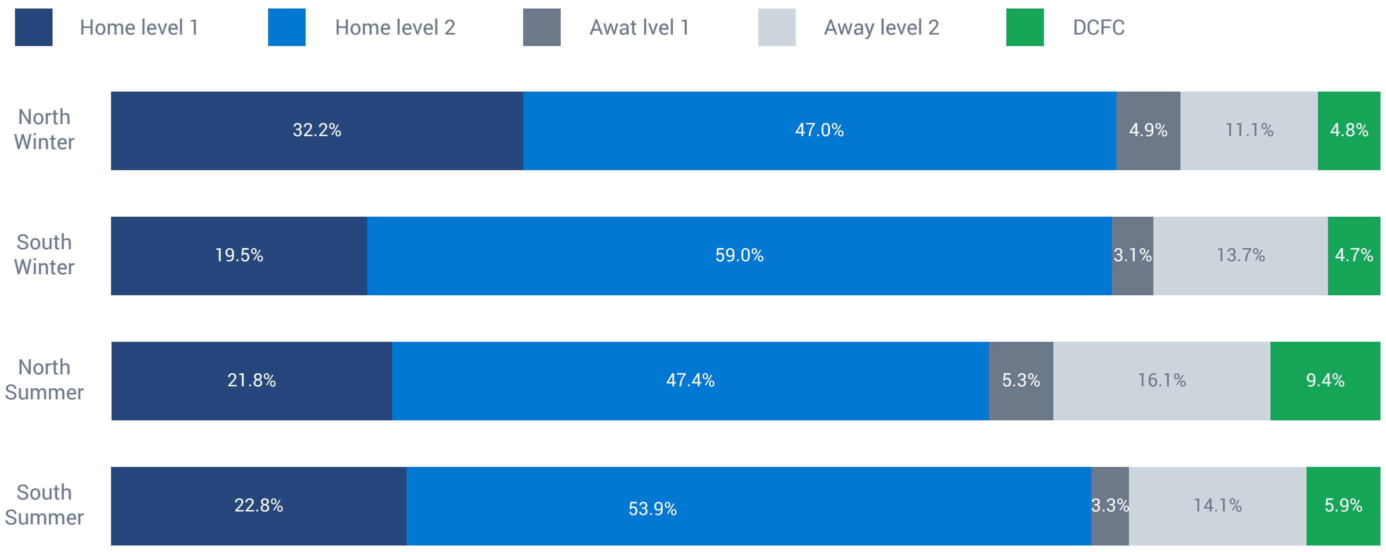
Both of these are indications that charging behavior is affected by differences in seasonal temperature. In the cold winter, drivers are more inclined to use home chargers, even if they don't have a Level 2 charger, to ensure they have the range they require. In the warmer summer months, drivers are more likely to travel out of town for vacationing, which makes them more likely to use DCFC.



Although it is important for utilities to ensure there are enough public charging stations in their territory, for those without access to home charging or for drivers who are from out of town, residential infrastructure should still take precedence. Regardless of where the home is, it is still the most desirable place for drivers to charge.

> "In the cold winter drivers are more inclined to use home chargers, even if they don't have a Level 2 charger, to ensure they have the range they require."

Home vs Away Charging (Sessions)

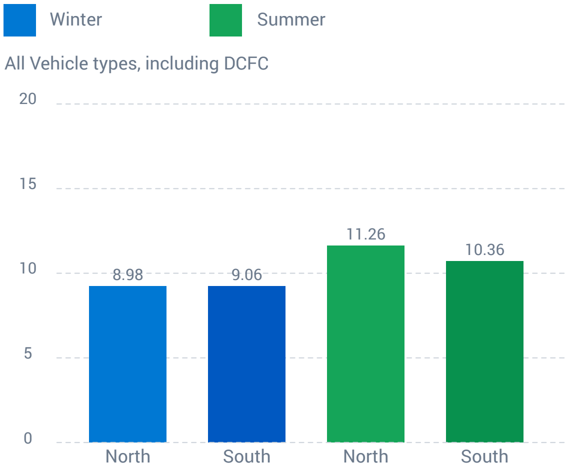


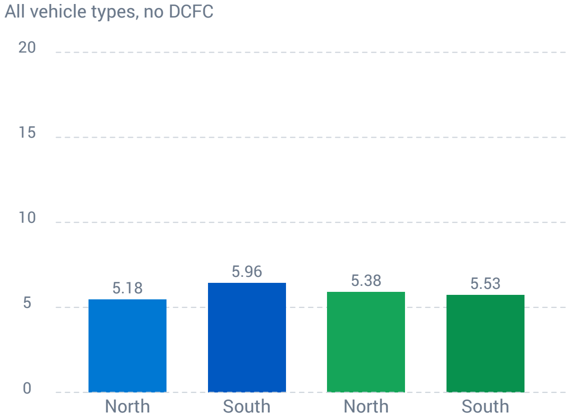
The impact of vehicle type on charging power

When looking at the per vehicle average power per charging session there was little difference between the North and South regions. Both groups had a slightly lower average power in the winter months, but as a whole they stayed the same with an average of roughly 9 kW in the winter and 11 kW in the summer.

Average power includes DCFC, which charges at a higher power. When DCFC charge sessions are removed, the average for all regions is between 5 and 6 kW. This further illustrates that DCFC plays a larger role in the summer months, most likely the result of people traveling away from home.

Average Power Per Session (kW)





Average Power Per Session (kW)

The most significant factor when reviewing the average power per vehicle relies more on the type of EV. Long-range BEVs charge at a significantly higher power, roughly three times as high as short-range BEVs and up to six times as high as PHEVs.

As well, while the average power for the short-range BEVs and PHEVs stayed relatively the same for both seasons, there was more of a difference in the long-range BEVs. Lastly, when you remove DCFC, long-range BEVs are the only vehicle group where the average power changes, meaning these charging stations are rarely being used by short-range BEVs or PHEVs.

When it comes to EV charging loads, long-range BEVs are revolutionary. In order to accommodate their larger batteries their charging capabilities have significantly increased. This is also the fastest growing segment of EVs and they are continuing to evolve. With larger vehicles entering the market, including SUVs and pickup trucks, we will continue to see an increase in charging power.

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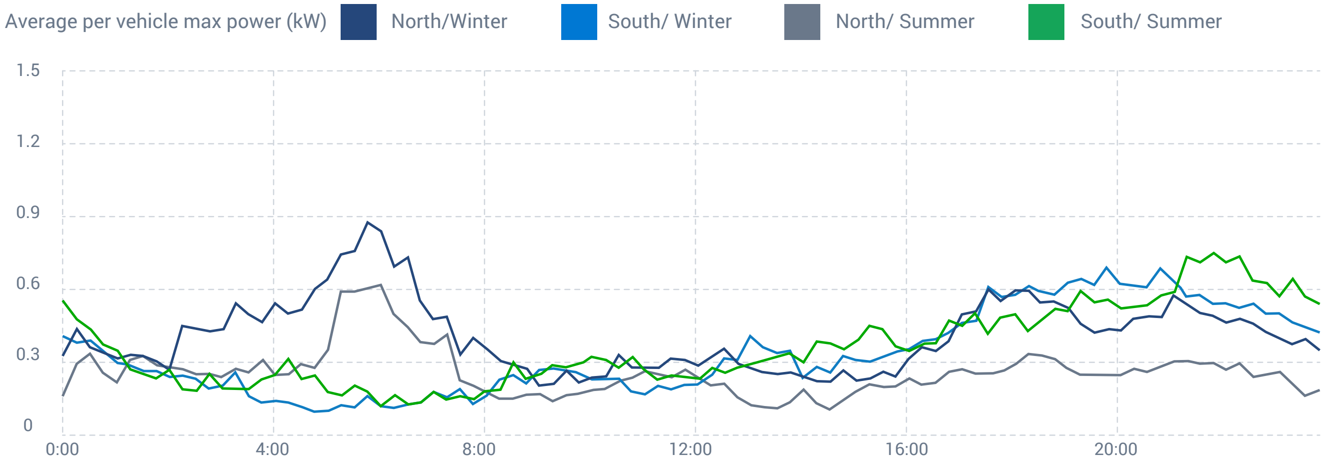
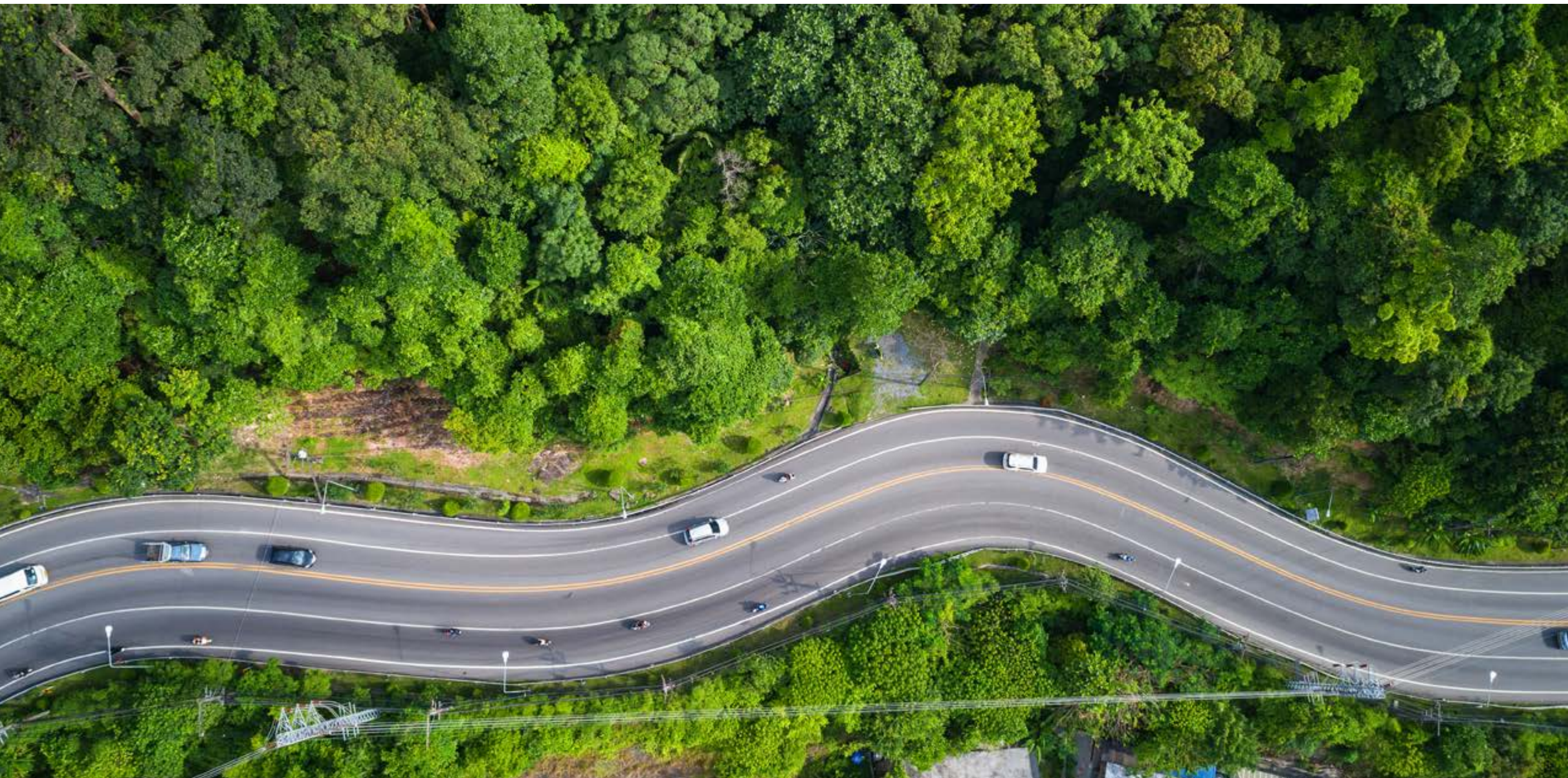
The differences in peak load

In a comparison of load curves, there is a clear difference in average peak load between the North and South groups. It should be noted that these curves represent the average load over a month, January for winter and July for summer, and that daily peaks may be higher. Also this load is strictly EV charging load and does not include any electricity transmission and distribution (T&D) losses, which could add an average of about 5% to the overall demand.

The most significant difference between the North and South group is that the load is spread out differently during the day. The northern group has a peak in the morning, which is a result of the vehicle being preconditioned before the work day with a higher peak during the winter. This earlier peak also appears to result in the evening peak being lower. Southern roads are relatively the same for both seasons, with peaks occurring at the end of the traditional workday.

Comparative Load Curves by Region and Season





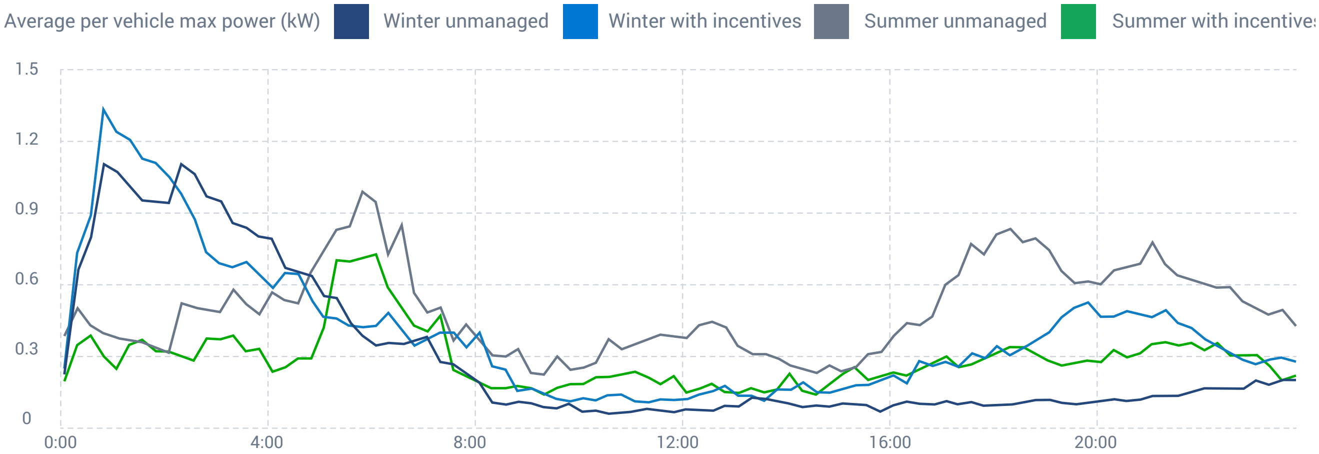
The ability to shift EV charging load

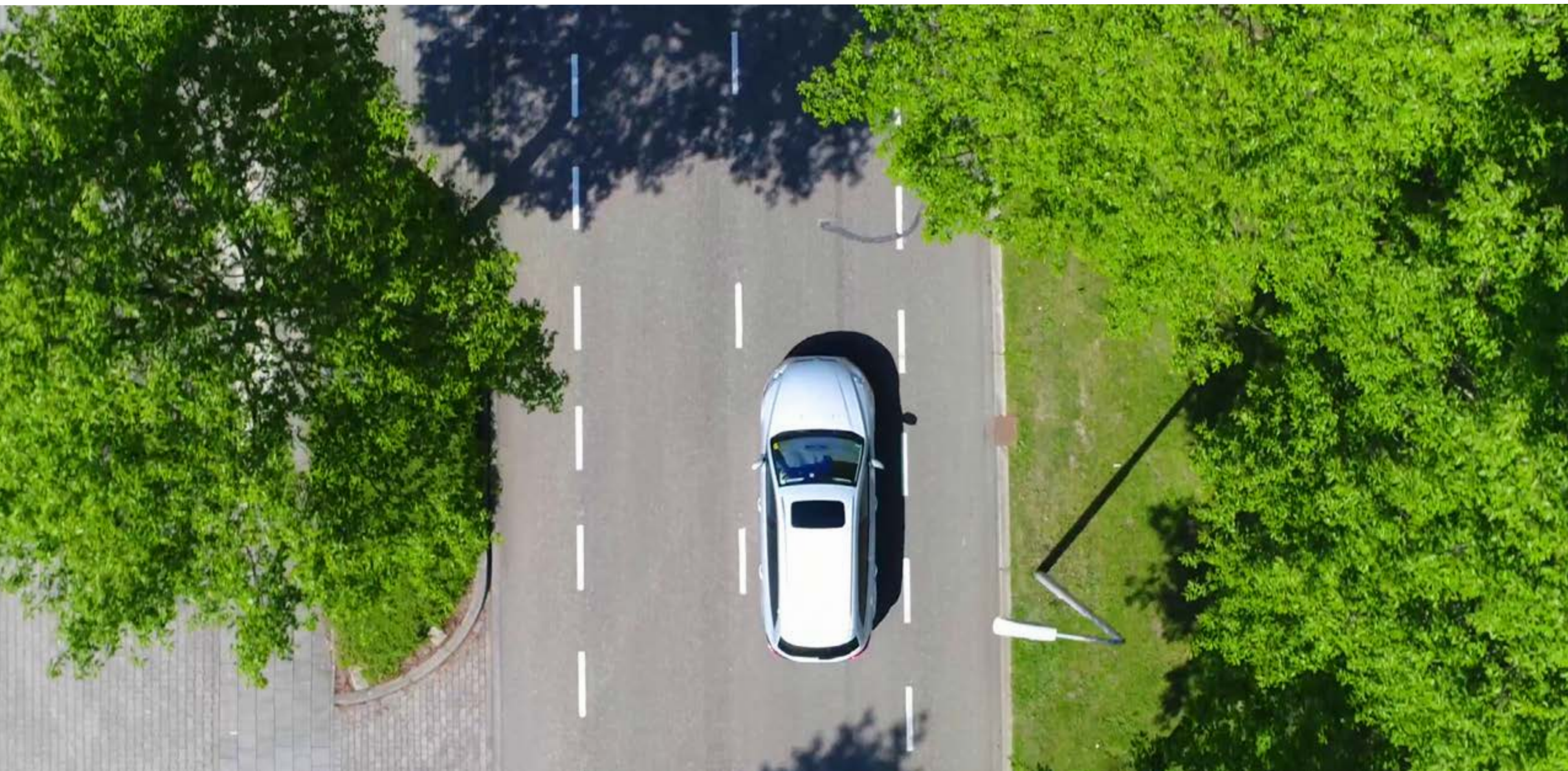
To showcase the ability to shift EV charging load, vehicles from the North were split in two groups. The first group was being intensified by a Time-of-Use (TOU) rate or reward program, encouraging off-peak charging, and the second group was left unmanaged.

When left unmanaged, peaks appeared leading up to the beginning of the workday, a result of preconditioning, and at the end of the work day for both summer and winter months. In areas where incentives were provided, the load was shifted off-peak to the middle of the night.

The impact that EVs have on the grid is evolving and if left unmanaged they pose a significant risk, particularly to distribution assets. Fortunately the EV charging load can be shifted and when managed properly it becomes an incredibly valuable asset as it can help support clean energy initiatives while boosting profitability.

Comparative Load Curves by Incentive and Season (North)





Conclusion

A key takeaway from this study is that the EV charging load is very nuanced. The vehicles in this report were simply grouped by North or South, and there were significant differences in the averaged data. Each individual service territory is going to have its own unique factors that will influence how EV owners will charge and drive. Commuting patterns, vehicle-specific market share, and pre-existing load management initiatives, in conjunction with seasonal temperatures, will all contribute to a one-of-a-kind load profile.

Glossary and resources

Calculating charging power for the per charge window statistics: These values were achieved by measuring the total amount of energy (kWh) provided by the charging station during charging events within a given charge window, and then dividing that sum by the total time spent charging.

Calculating maximum power in load curves utilizing charge slices: Charge slices are charging events that are broken into 15-minute intervals. From each charge slice, a maximum power, which is the highest power from the 15-minute interval, is measured. Each data point on a load curve is the average maximum power across charge slices for each 15-minute interval in a day.

Charge session: During analysis, it was discovered there were multiple occasions where a charge event occurred that lasted for a few seconds. It is hypothesized that these small events are a result of battery conditioning within the vehicle. To avoid skewing the data, all charging events that occured between consecutive trips were grouped together into a "session."

Line loss: None of the energy calculations consider any electricity transmission and distribution (T&D) losses, which could add an average of about 5% to the overall demand.

Long-range battery electric (LR BEV): A fully electric vehicle that has a battery capacity of 50 kWh or more.

Plug-in hybrid (PHEV): An electric vehicle which has both an internal combustion engine and an electric engine.

Short-range battery electric (SR BEV): A fully electric vehicle that has a battery capacity below 50 kWh.

Geotab Electric Vehicle Battery Degradation Tool: geotab.com/fleet-management-solutions/ev-battery-degradation-tool/

Geotab Temperature Tool for EV Range: geotab.com/fleet-management-solutions/ev-temperature-tool/

EV growing pains report: geotab.com/ev-growing-pains-report

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