

# **PHEV Technology Demonstration: GridPoint**

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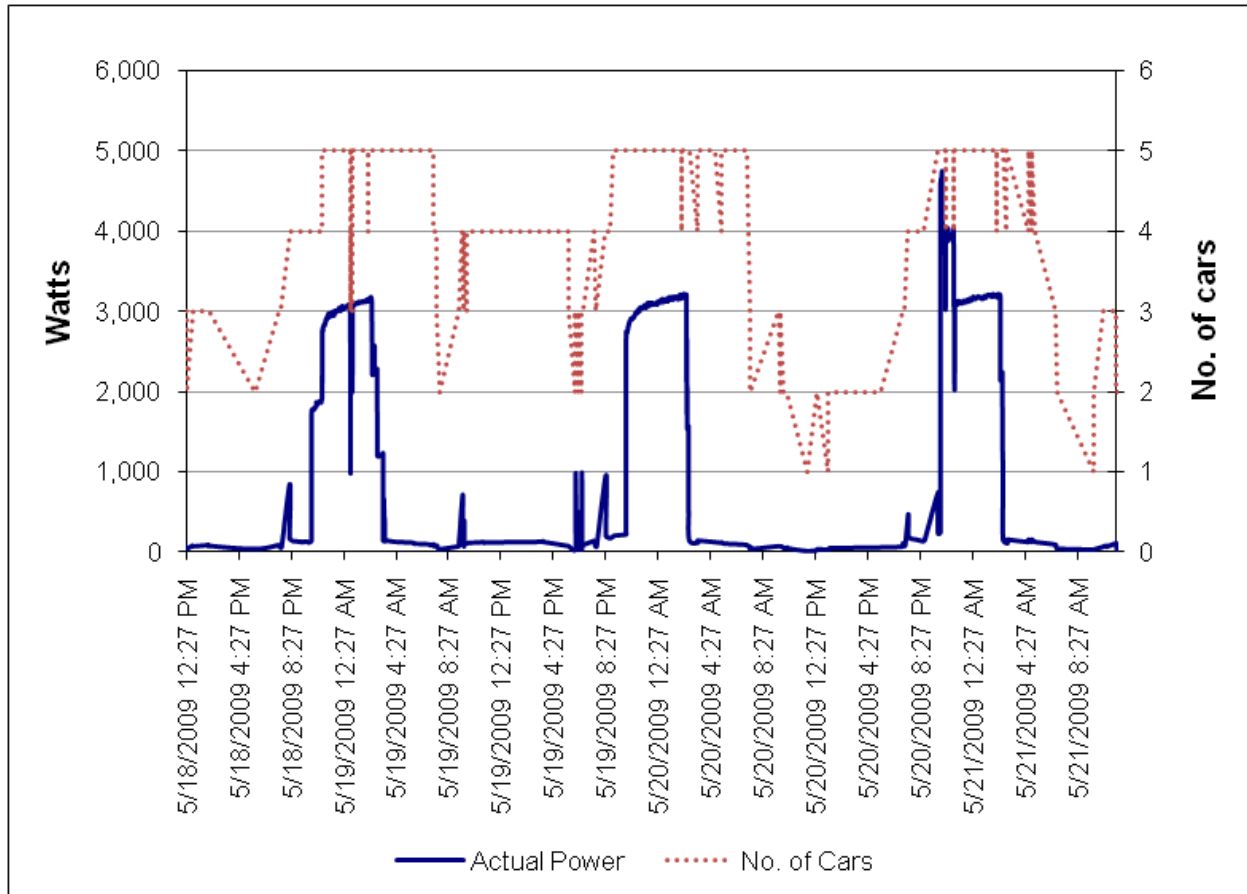
## ***Introduction***

Electric utilities are very interested in the widespread adoption of plug-in hybrid electric vehicles. However, there are concerns about the impact to the distribution system of uncontrolled charging. For this project, Advanced Energy evaluated GridPoint's Electric Vehicle Management (EVM) solution. This system enables data logging and smart charging via a combination of GridPoint's Vehicle Connectivity Module (VCM), an in-vehicle client that relies on cell phone or wifi for data transfer, and GridPoint's Smart Charging Portal, a web-based tool that manages the flow of electricity to plug-in vehicles and charging stations.

For this project, Advanced Energy evaluated the capabilities of each control scheme available through the Smart Charging Portal: time of day, energy demand, energy price, and charging location. Each control strategy was evaluated for a two week period on our "fleet" of vehicles. Our fleet consists of Toyota Priuses from Duke, Progress and Advanced Energy converted to plug-in using kits from A123 Systems. These vehicles are stationed in Kentucky, North Carolina, South Carolina and Florida but drive up and down the East Coast. Using the web portal, Advanced Energy is able to monitor the status of any vehicle and adjust the control strategy as often as desired.

### ***Control Strategy 1: Time of Day***

The simplest method of control works like a residential outlet timer. But instead of the consumer managing exactly when the charging starts, this control is placed in the hands of the grid operator. The grid operator works with customers to determine a mutually beneficial time during which charging can take place (for example, a customer may get a financial incentive from the grid operator to charge primarily during off-peak hours). This would give utilities the control of shifting all charging to off-peak based on customer incentive programs, or past usage patterns. For our evaluation, Advanced Energy selected to allow charging between the hours of 10 PM and 4 AM. Figure 1 illustrates the results of a three-day sample from the two week test period.



**Figure 1: Time-Based Charge Control**

As shown in the figure, fleet charging is limited to the hours of 10 PM to 4 AM. This control strategy is independent of all other factors such as location, energy price, energy demand or number of vehicles connected to the grid. It simply regulated charging based on a specified time and performed as expected. As seen above, the control strategy successfully limited charging to the specified hours regardless of the number of vehicles connected.

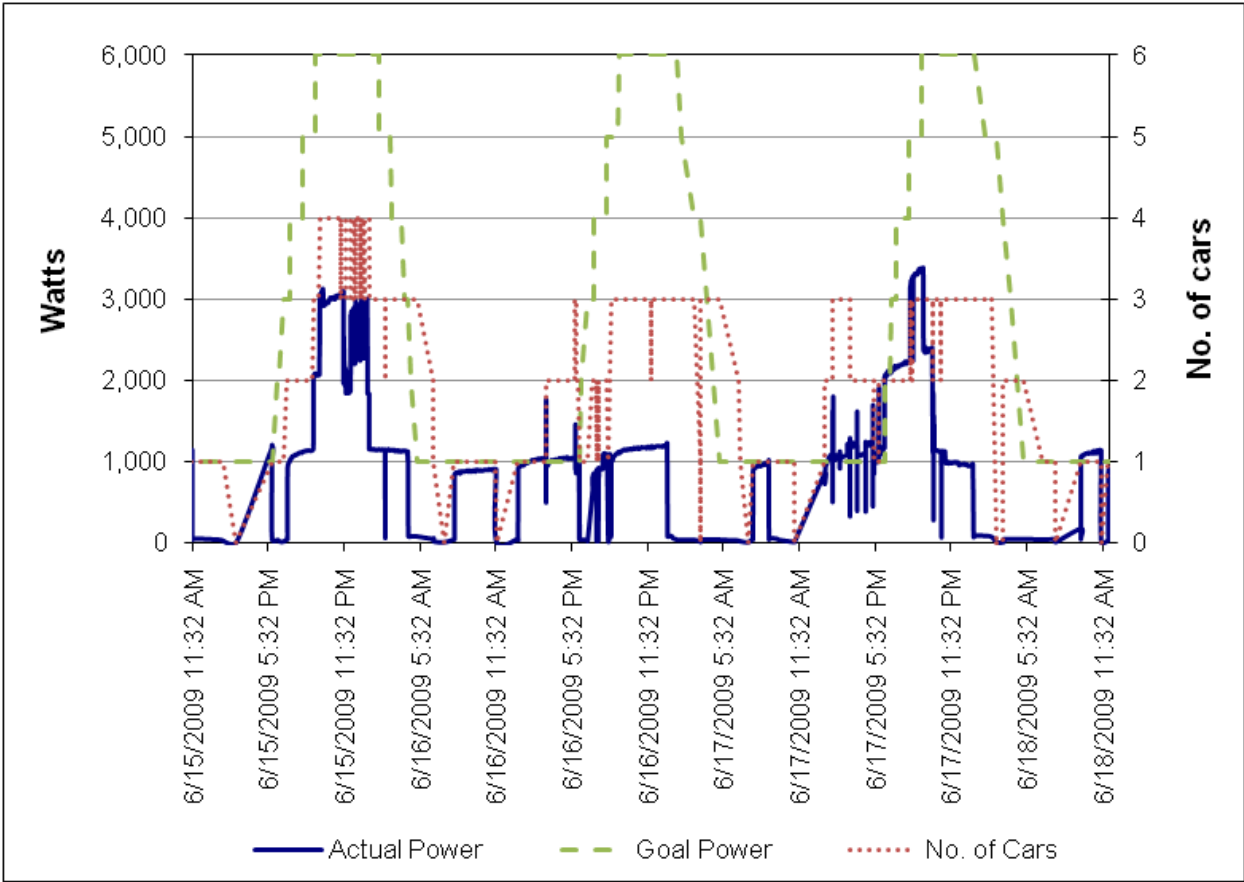
The data has several spikes in both curves. These are caused when the VCM loses connection to the GridPoint server and is a function of poor cellular modem reception. The default control strategy is to allow charging. Therefore, when server connection is lost, the individual vehicles begin charging at maximum power. This acts as a safeguard to ensure vehicles can still charge in the event that they lose connectivity to the server or are in a place where the communications do not work (i.e., deep parking garages, remote areas, etc.) The specified control strategy is resumed when server connection is re-established.

Advanced Energy noted one concern with this control strategy: the rapid increase in load at a precise time of day. Our fleet of ten vehicles only had five plugged in at any one time during our evaluation period. The maximum total power observed during the testing was nearly five kilowatts. This is not a problematic load when spread over several states. However, using this control strategy when the number of plug-in vehicles exceeds several thousand could result in substantial loads to the local grid. Advanced Energy notes that other control strategies can gradually ramp loads up and down rather than allowing “full on/full off” charging.

**Control Strategy 2: Energy Availability**

Goal-based charging reads kilowatt goal power values from a file, plotted in Figure 2, and attempts to target fleet charging to match the desired load. Advanced Energy developed a load profile to vary from full load at night to minimum load during the day. The shoulder periods from 4 AM to 7 AM and 8 PM to 11 PM are an attempt to smooth the drastic increase and decrease in load observed during the time-based charging.

This control scheme would allow a utility too moderate the power allotted to PHEVs based on real-time generation. PHEV fleet load will then react to power generation, not vice versa. This control strategy can also be used to charge based on any other signal from a grid operator, including the availability of renewables, automatic generation control signals, and environmental signals. The results from this control test are shown in Figure 2.



**Figure 2: Demand-Based Charge Control**

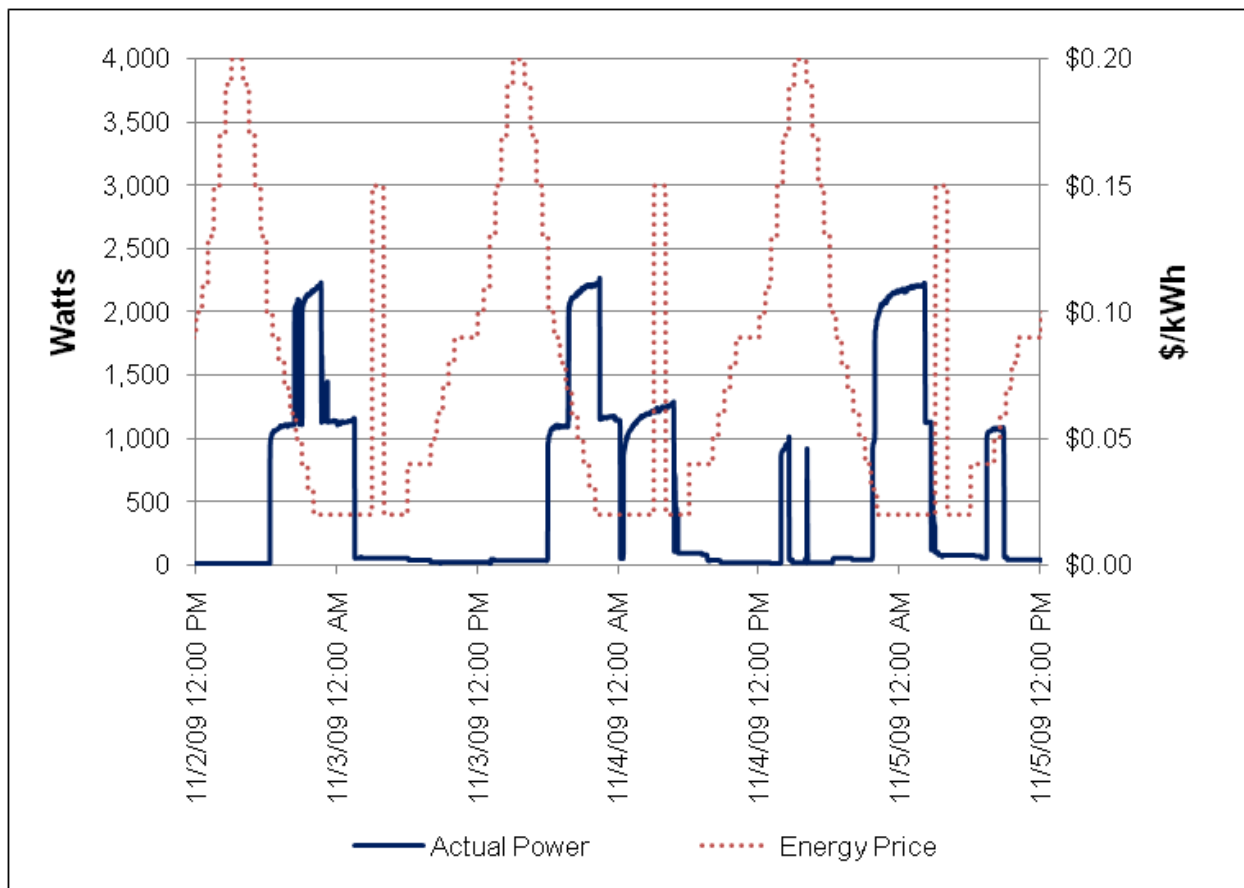
As illustrated, goal power varies daily from 1 kW to 6 kW, which is above the typical maximum load observed with our fleet size. The objective of this charge control strategy was to attempt to hit a targeted power value, determined from the goal power curve. In situations where actual power is well below goal power, the system allows all vehicles to charge at will. As shown, when goal power moves to 1 kW, the system regulates vehicle charging to target a load of 1 kW. Charging priority is determined based on the PHEVs' state of charge. The vehicles that have more energy stored in their batteries will be the first to have charging limited. GridPoint indicates that future versions of the software may also prioritize charging based on a target time to completely charge the battery pack.

This control strategy also resulted in several spikes in actual power consumption. Some of these were again caused by server connection issues. However, some of the spikes are inherent to this control strategy. As the software tries to regulate load, vehicles are connected to and disconnected from the grid. This can occur simultaneously for several vehicles, which creates instances where actual power may be above or below goal power. These instances are very brief and do not drastically affect the overall demand.

### Control Strategy 3: Energy Price

The next control strategy evaluated was based solely on the price of energy, and the customer's desire to purchase energy below a certain price. It is similar to the demand-based control in that load is managed based on input from real-time generation data. However, this strategy is aimed more for the electric customer rather than the utility. This strategy allows the consumer to establish when they would like their vehicle to charge based on a rate they are willing to pay. In addition, consumers may eventually have the ability to sell energy back to the grid, assuming two-way power flow at the plug (vehicle-to-grid). The customer can establish a "sell" price in the GridPoint software in addition to a "buy" price.

For this test, Advanced Energy uploaded an economic profile, shown in Figure 3. The profile had a price spike to \$0.15/kilowatt-hour (kWh) at 3 AM, dropped back down to \$0.02/kWh and then gradually rose to a peak of \$0.20/kWh at 3 PM before dropping back down to \$0.02/kWh. The 3 AM spike was put in place to ensure the control had an opportunity to work, as many of the fleet vehicles charge at night. Analysts set the maximum price at which a consumer would buy energy to \$0.10/kWh, which meant that anytime the price was at or below this value, vehicles would charge.



### **Figure 3: Economic-Based Charge Control**

As shown, actual power was successfully regulated by the price of energy. As energy either goes above or below the set price of \$0.10/kWh, fleet charging is either enabled or disabled. The same issue of drastic power surges placed on the grid is seen in this control scheme as in time of day control. As long as price is below \$0.10/kWh, vehicles will charge at will without any regulation. Actual power drastically increases at six instances as price dropped below its maximum price to buy. This control strategy test showed a good demonstration of how an electric customer can take advantage of load management on their vehicle, and do so in a way that benefits utilities. .

#### ***Control Strategy 4: Location***

The final control strategy tested regulated demand based on vehicle location. Each GridPoint unit has a global positioning system (GPS) that transmits real-time vehicle location. The goal of this control strategy was to regulate fleet demand by enabling or disabling charging based on GPS coordinates. There are several scenarios where utilities could utilize location-based control. For instance, if an energy provider knew it needed to complete infrastructure repair at a certain location, such as a neighborhood or mall, vehicle charging could be disabled to reduce the load on the grid. Similarly, if a certain location was notorious for consuming a large amount of power over a specific time period, such as a mall during the holiday season, the utility could remotely limit the charging of all PHEVs at that location. GridPoint developed this strategy primarily as proof of concept to show utilities that location based charging can be accomplished.

For the current version of the GridPoint software, utilities can designate “home” and “work” locations for each vehicle. Then, the fleet is either limited to charging only at “work” or only at “home”. For the purposes of this report we will use the terms “charge” and “no charge”. “Charge” and “no charge” locations were determined for each vehicle based on location charging frequency. We downloaded the charge locations for each vehicle over a period of one month and established the two most frequent charging locations. The location where the vehicle charged most frequently was selected as location type “charge”. The next most frequent location was selected as location type “no charge” for each vehicle. Once a vehicle in the fleet plugged in within a 300 foot radius of a “no charge” location, the vehicle charging was disabled.

Ideally this strategy would control vehicle charging, assuming that the majority of the fleet vehicles are driven by individuals who charge at two primary locations. However, this was not the case for the fleet tested. Many of the vehicles were used for travel and often charged at locations not configured in the system setup, e.g. a hotel, an airport or another company’s office building. This meant that the benefit of this control strategy was not often realized.

Another issue that was found with this strategy was the method of location designation. Locations were established based on GPS coordinates and were not associated with the vehicle. Hence, a specific location must be designated as either “charge” or “no charge” and this designation would be applied to all vehicles that attempted to charge at that location. This could cause problems in situations where two different vehicles are charged at the same location. If one vehicle used a specific location as type “charge” and another used type “no charge” one of the vehicles would not be controlled as it should. The default for the system is to choose the first location type set for that set of coordinates found in the list of vehicle locations for the fleet. So, the location type specified first for that location would regulate the charging of both vehicles.

Users are not limited to the amount of “charge” and “no charge” locations entered in the current GridPoint setup, but to properly regulate charging one would need to know almost everywhere each vehicle in the fleet plugs in or is going to plug in, and at what time of day. The idea of the current configuration of this strategy is really only applicable to a commuter who has the ability to plug in at work and home with the majority of their charge sessions occurring at these two locations. In this situation, the user could regulate charging to only off-peak, which is the overall goal of all of these control strategies. However, through Advanced Energy’s testing, it was concluded that this scenario was not the case. Overall this strategy proved to be least effective in fleet load management with the current GridPoint software. However, there are scenarios where utilities could see benefit from this type of control.

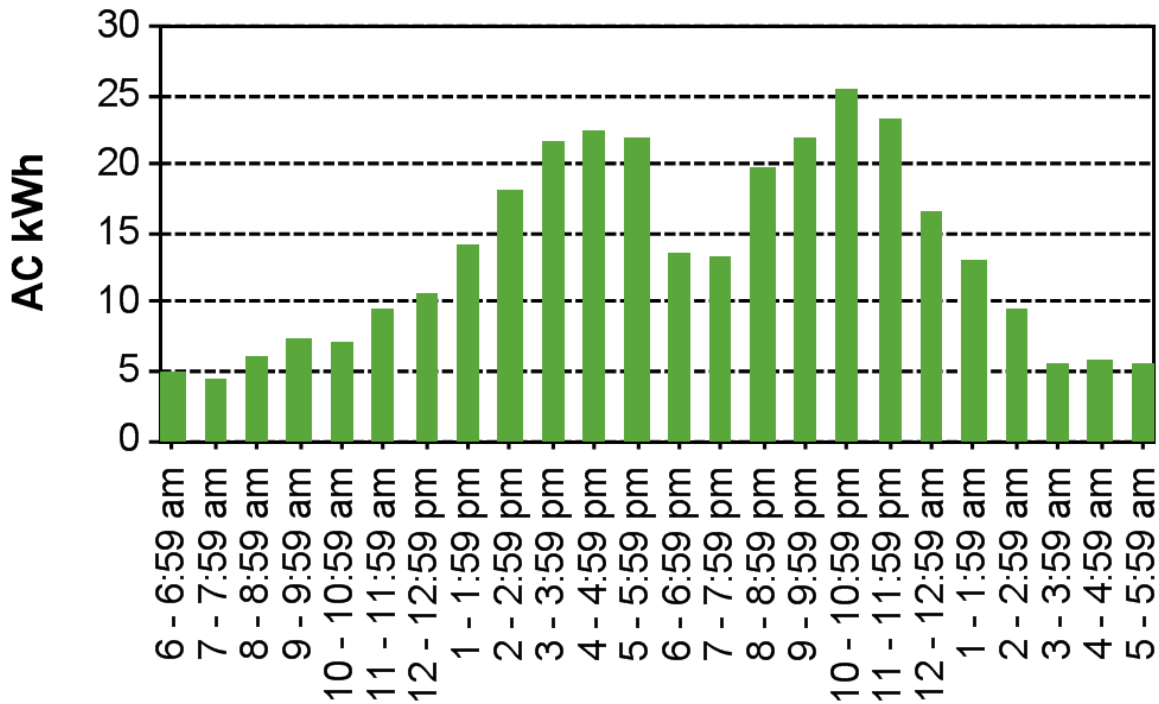
### ***Fleet Energy Consumption***

To better understand the overall fleet impact of PHEV charging, Advanced Energy contacted staff members of Idaho National Laboratories (INL) who manage the largest fleet of PHEVs in the United States. They published a summary report<sup>1</sup> on a fleet of 119 converted Priuses that included a plot of actual fleet energy consumption versus hour of day, seen in Figure 4 below. These are averages taken from April, 2008 – October 2009. All of the 119 vehicles in this fleet used GridPoint as the method of data collection. Out of those 119, the only vehicles to evaluate charge control strategies were Advanced Energy’s fleet of thirteen. Our evaluations had minimal impact on the results plotted below. As shown, the maximum energy consumption occurs from 10:00 PM – 11:00 PM and reaches approximately 26 kWh. Another peak to approximately 23 kWh is seen during the afternoon hours, which could correspond with a high demand situation for power generation. In that scenario, fleet load curtailment with a technology such as GridPoint would need to be implemented.

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<sup>1</sup> US DOE, *North American Fleet Demonstration: Fleet Summary Report*, <http://avt.inl.gov/pdf/phev/HymotionPriusV2GreenApr08-Oct09.pdf> (Dec. 8, 2009)

## Time of Day When Charging



**Figure 4: Average INL Fleet Energy Consumption**

### ***Encountered Problems and Solutions***

Throughout the course of this project, several issues arose that Advanced Energy worked with GridPoint to resolve. Below is a list of these problems and solutions.

- Advanced Energy worked with GridPoint to resolve issues with the online software. Through GridPoint, all the vehicle data is posted to a secure website. That website wasn't showing some of the information correctly and it had some formatting issues within the Firefox browser, e.g. pull-down menus were over to the side and could not be read. Those issues were corrected over the phone with GridPoint. We also discovered that we did not have access rights to the control group data. This was corrected as well and allowed us to view and analyze control group data and produce the plots that are included in this report.
- During each control strategy test, it was observed that cell connection was a problem. Advanced Energy established that the default behavior of the system is to allow the vehicles to charge at 100 percent if they lose connection to the server. Although there is no immediate fix to this issue, this helped bring this problem to GridPoint's attention and they have developed a feature available with their next release that will provide some scheduling to avoid a lot of the problems caused by intermittent communication. For now, GridPoint wants to see improvement in this area and has worked with customers to establish ways to work around it. For example, one customer

replaced his cell modems in favor of Wifi because he got terrible cell reception in his parking garage, but had Wifi available there.

- Advanced Energy discovered an issue with uploading charge control profiles through the GridPoint website. Advanced Energy worked with GridPoint to determine that the only files supported by their website are ANSI files.
- During the Location based charge control Advanced Energy established that there were issues with vehicles sharing location designations. Although there was no immediate fix because all vehicles were grouped together, Advanced Energy worked with GridPoint to determine that this problem could be remedied by using multiple location control groups.

In addition, GridPoint's online interface allowed Advanced Energy, Progress Energy, and Duke Energy the ability to view the status of vehicles real time. This served instrumental in ensuring all vehicles were charging and operating properly. There were instances where PHEV drivers did not realize that vehicles were not charging and the online interface provided a quick and easy method to determining if and when the vehicle stopped charging.

### ***Summary***

Advanced Energy's demonstration of the GridPoint software effectively controlled the fleet load in all four charging strategies. From these results, Advanced Energy was also able to see potential issues with fleet charge control and strategies for managing fleet load in the most effective way. In addition, there is the potential to use a combination of all four of these strategies to control fleet charging in a way that will provide the most benefit to utilities. By working closely with GridPoint, Advanced Energy was also able to resolve several technical issues with the software.