ELECTRIC POWER RESEARCH INSTITUTE

Duke Energy:

Charging Demos Inform PEV Readiness Planning

Why Get Ready?

Duke Energy, headquartered in Charlotte, N.C., became the largest electric power holding company in the country after merging with Progress Energy in 2012. The new Duke Energy serves more than 7 million accounts in six Southeast and Midwest states.

A vertically integrated utility with its own generation and distribution resources, Duke Energy operates in diverse geographic regions, each with its own market response to plug-in electric vehicles (PEVs). For example, Raleigh, N.C. is said to have one of the nation's highest per capita PEV adoption rates. Still, the total number of Duke Energy PEV customers, about 4,000, is a small fraction of the 22 million people who rely daily on its electricity. In response, the company has positioned its PEV program to focus on activities that inform the company's long-range planning, so that as the PEV market grows, it will be ready.

This case study highlights several charging infrastructure demonstrations designed to collect data to support PEV planning and ensure reliable service for all of Duke Energy's customers.

Duke Energy initiated its charging station demonstration to develop a baseline understanding of charging technologies and their grid impacts. Duke Energy wanted to investigate customers' charging habits and know what PEV charging stations cost to purchase, install, and maintain. This information supports the company in its role as a transportation fuel provider and helps it assess the appropriate business role related to charging infrastructure.

Customer charging profiles enable the utility to model future adoption trends and potential revenue, cost, and distribution impacts. By analyzing data in-house, Duke Energy is able to monitor regional differences using real customers and utility rates.

The studies inform future rate-planning options and programs, such as those that pair PEV charging technology with rate signals or demand response. Such programs will provide customers the charging solutions they need while minimizing the potential peak demand impact to the grid.

Mindful of the transformative opportunities coming with the smart grid, Duke Energy is an active partner in R&D projects that involve communications protocols for PEV charging. It expects that PEVs will be similar to smart appliances and wants to ensure there are open standards to communicate with them.

Duke Energy embraces new technologies, recognizing both their potential and the need to mitigate risks. PEV load presents an opportunity to increase system utilization and efficiency, reduce costs, and maximize overall benefits to the customer.

Approach

Duke Energy started planning its charging station customer pilots in 2010 and launched several programs a year later. At the time, three separate operating utilities, all subsidiaries of Duke Energy Corporation, rolled out similar programs. All three programs provided a Level 2 PEV charging station with no up front cost, along with an installation subsidy in exchange for access to charging data that is collected through the charging station. Most participants are private PEV drivers with electric vehicle supply equipment (EVSE) installed in their homes. Commercial customers, such as retail stores, are also participating to provide public charging solutions. Each pilot is fully subscribed and in varying stages of evaluation.

Duke Energy Progress and Duke Energy Florida (previously Progress Energy Carolinas and Progress Energy Florida) call their demonstration the Plugged-In Program. Duke Energy Carolinas calls its demonstration Charge Carolinas. Duke Energy Indiana's demonstration is part of the broader, regional Project Plug-IN, under the umbrella of the Energy Systems Network initiative. All charging station programs are managed internally by Duke Energy. See Table 1 for comparisons of the three programs.

Duke Energy PEV in front of Marshall Solar Site.

Table 1. Comparison of three Duke Energy charging station demonstrations.

Program	Plugged-In Program	Charge Carolinas	Project Plug-IN
Operating Utility	Duke Energy Progress and Duke Energy Florida	Duke Energy Carolinas	Duke Energy Indiana
Number of Participants	188 residential and 116 commercial (public access)	150 residential	85 residential and 26 commercial (public access)
Start and End Dates	Commercial Start: February 2011 Residential Start: November 2011 End: April 2013 (all)	Two-year rolling contracts First subscriber joined June 2011 Last subscriber joined December 2012	Two-year rolling contracts First subscriber joined January 2011 Last subscriber joined December 2012
Geographic Distribution	N.C. and S.C. with high density in Raleigh; Central Florida	N.C. and S.C. with high density in Charlotte area	High density in greater Indianapolis, Bloomington, Lafayette, Ind.
Funding	U.S. DOE ARRA Smart Grid Investment Grant	Blend of U.S. DOE ARRA Smart Grid Investment Grant and ratepayer funds	U.S. DOE ARRA Smart Grid Investment Grant
Subsidy	Free charging station plus normal installation costs (up to $1,500 residential)	Free charging station plus up to $1,000 installation	Free charging station plus up to $1,000 installation
Terms at Program End	Customer retains charging station at no cost	Customer retains charging station for nominal fee, less than $300	Customer retains charging station at no cost

Recruiting Customers

To identify potential residential participants, the Plugged-In Program and Charge Carolinas tapped into relationships with General Motors and Nissan, the two early entrants to the PEV market. Both had begun their sales process through online ordering, and the utility subsidiaries' demonstrations were integrated into this early sales step. For example, during the Nissan LEAF Customer Journey online ordering process, if a PEV buyer's ZIP code was in the target utility service territory, the buyer automatically received information about the demonstration program.

The utilities also proactively reached out to local car dealers, provided brochures about the demonstration, and directed potential customers to their websites.

For public access deployments, the Plugged-In Program developed a selection ranking system that identified high-priority locations and potential host-site participants. The ranking system included factors such as existing public station locations, PEV adoption density, transit corridors, local activities, and historical interest of the host site in alternative energy programs.

Duke Energy Indiana relied primarily on Energy Systems Network's customer outreach through ride-and-drives.

SUCCESSES

- All three demonstrations are fully subscribed.
- In general, soliciting potential residential customers about the demonstrations turned out to be easier than expected. Since early PEV sales were to enthusiastic early adopters, news of the program spread rapidly through word-of-mouth.
- Even after the subscription period closed, Duke Energy continued to receive requests from new PEV owners who had been referred by dealerships, an indication that the utility's dealer outreach was successful.

CHALLENGES

- The timing of the vehicles' arrival in the different markets complicated planning and outreach efforts; everyone thought the cars would arrive faster and sooner than they did. In some regions, the program was delayed as customers had to wait to receive initial vehicle deliveries in their area.
- Vehicle variety, and the resulting charging data, was not very diverse because few models were available during the program enrollment period.
- Soliciting commercial host sites for public charging station locations took longer than expected due to contract language negotiations and host site concerns such as reserving parking spaces and liability.
- In each utility's service territory it is possible that some customers never heard about the program because local dealers' salespeople may not have been aware of the new PEV program. There may also have been conflicts with default charging solutions preferred by automakers or dealers.

Installation Logistics

The Plugged-In Program established direct vendor relationships with two charging infrastructure manufacturers to provide the hardware and manage the installation of stations for residential and commercial participants. Duke Energy developed the program details and processes, and solicited participants. If a participant or host site in the utility's service territory opted in to the program, the utility would verify the customer's account status for internal tracking and complete the contract paperwork. The vendor would manage the rest of the EVSE installation process using its chosen electrical contractors.

Charge Carolinas did not establish a formal vendor relationship to manage installations and had more hands-on contact with customers and the installation process. A separate charging manufacturer was selected in this program to provide the hardware and communications.

In both the Plugged-In Program and Charge Carolinas, the utilities have learned-by-doing. The logistics around installing EVSE – the initial site visit with a customer, contractors' bids, installation, and final city permitting – were more complex and time-consuming than expected. Because each customer's setting was different, the requirements and costs varied substantially. Even though each utility paid for the charging equipment and covered typical installation costs up to a cap, sometimes the allowance was insufficient to cover the full cost. In these cases the customer had to make up the difference. In all three demonstrations, customers are allowed to keep their charging stations after the demonstration period ends.

SUCCESSES

- Despite occasional challenges with installations, mostly with commercial installations, customers are generally happy with the programs. Residential customers know they received their charging station at little to no cost and they love their cars. Commercial customers were very pleased to have assistance with their first attempt at deploying charging stations for their customers and constituents.
- Utilizing a consistent network of electrical contractors allowed the utility to learn and gain experience quickly while ensuring consistency.
- These programs were the first PEV charging installations for many local government permitting and inspection authorities. The experience has helped pave the way for future installations.

CHALLENGES

- Electricians and local inspectors were unfamiliar with the charging equipment and new technology, a factor that contributed to higher-than-expected installation costs.
- Requirements that residential EVSE be hard-wired generally made installations more expensive and time-intensive. In the future, as requirements evolve and new EVSE that plugs directly into a wall socket comes to market, simpler installations may become the norm.
- Regional differences in construction practices and building styles, such as service panels located in a garage versus a basement, can complicate EVSE installations and affect costs.
- The biggest surprise was the time required for the entire installation process, especially in commercial settings. The legal contracts with commercial host sites often resulted in significant delays.

Collecting Data

To collect vehicle charging data, a data logging device, which transmits information via cellular communications network, was installed inside the charging stations. Cellular communication, although more expensive, was chosen because it was considered more reliable and less complex than Wi-Fi, which would entail installation of a router inside the customer's home.

Each subsidiary works through its respective vendor to access the data stored and presented on a custom web portal. Through the web interface, the utility can see each charging station and its status, and query data on kWh usage of individual stations, clusters of stations, or all stations, in 15-minute intervals.

Consumer privacy concerns were addressed early on in the planning phase of the programs, although no participants raised specific concerns regarding the EVSE data-collection efforts. The utility had communicated that it was collecting charging data in order to aggregate the result and that no private information was being shared. Duke Energy staff carefully vetted the data collection process with its Information Technology and Legal departments. Internal managers were satisfied when they understood that the equipment was identified solely by a number and that no customer personal information was collected or communicated through the data transmission.

SUCCESSES

- Given the relatively short timeframe of the project, the utility chose the most efficient route to collect the data – through an existing vendor solution.
- In general, the data collection process has worked well – better than might be expected given the multiple new technologies involved.
- On request, Duke Energy reports monthly usage data back to its commercial customers in the demonstration, some of whom are actively engaged and interested. Several retail customers carefully review the reports and regularly ask detailed questions about their usage.

CHALLENGES

- Some web portal designs are still in development. In the future, similar projects will benefit from improved data flow and presentation.
- The equipment can only communicate to the central servers in areas with sufficient cellular communications coverage. Areas with poor cellular coverage, such as underground garages, either could not be used or required additional relay hardware.
- Occasionally, the utility received questionable session data (either very high or very low energy amounts). As with all new technologies, there were some bugs in the data-collection process that were addressed over time.

Results

Learning how and when customers charge through data collected from their EVSE is the heart of the program.

Up until now, the industry has relied on theory about the likely load profile and diversification effects of large numbers of vehicles charging at varying rates. This demonstration provides Duke Energy with real data from real customers. It lets the utility know what time of day the customer returns home and begins charging, and the amount of time it takes to fully recharge. This valuable data helps the utility develop an average load profile and calculate a load shape.

Going forward, assumptions about future load profiles and grid impacts will be informed by this study while other important factors, such as PEV adoption rates and diversification, come in to clearer focus.

The Charge Carolinas and Project Plug-IN demonstrations were still collecting data at the time of this report, however the Plugged-In Program data collection ended in April 2013 and Duke Energy was able to provide a preliminary analysis of the residential data set.

The residential program consisted of 188 PEVs, nearly all Chevrolet Volts and Nissan LEAFs charging at ~3.4 kW. In all cases the power was supplied from the panel on the customer's side of the house meter and only a small fraction of the participants were on a whole house time-of-use (TOU) rate. The program allowed drivers to charge at will, enabling the utility to obtain a baseline understanding of how customers would normally charge their vehicles.

Figure 1 depicts the distribution of residental charging session durations and highlights that nearly 75% of all sessions are completed in less than three hours. The average energy transferred was also determined to be 7.3 kWh per session. The average load profile for the entire vehicle population is shown in Figure 2. As expected, weekday charging results in a pronounced curve that peaks between 8 p.m. and 10 p.m., reflecting the fact that people arrive home and immediately begin charging. This vehicle charging peak is a few hours later than the traditional late-afternoon system peak often experienced on hot summer days, although there is some degree of coincident load.

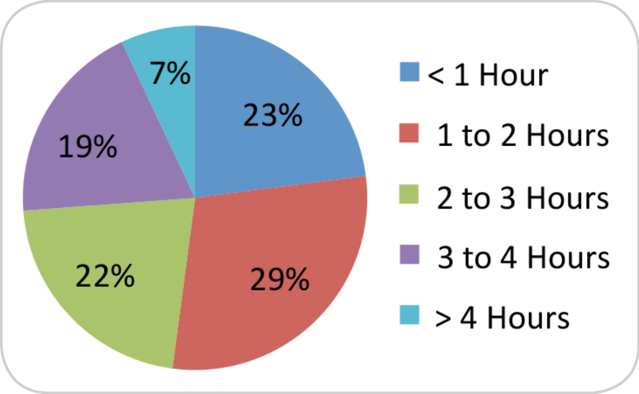

Figure 1. Charging session duration distribution for residential Plugged-In Program.

Of particular note is that the PEV peak load impact is only on the order of 0.6 kW per PEV, perhaps a surprising number given that each vehicle can charge at ~3.4 kW. Duke Energy's experience is consistent with the results of EPRI modeling on peak load impact. Duke Energy was one of the first utilities to prove and reiterate the original EPRI finding. This trend is continuing to show in other utilities as well.

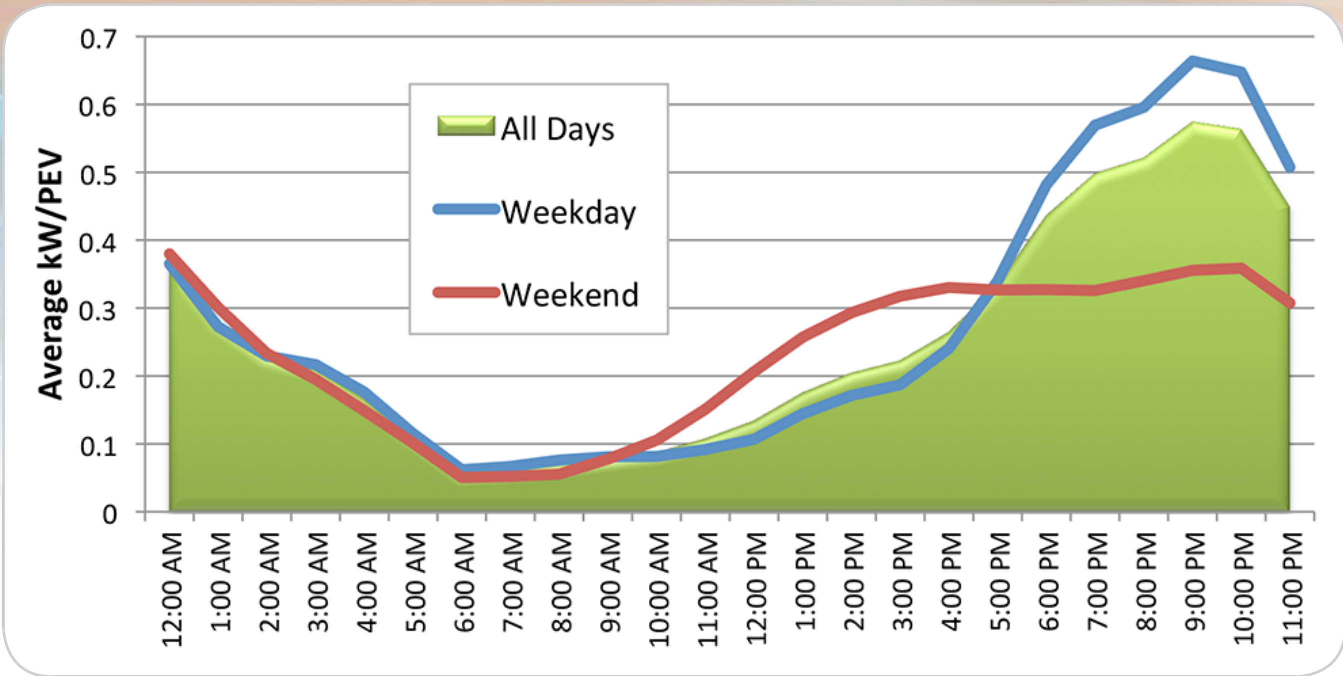

Figure 2. PEV load profile for residential Plugged-In Program (weekday vs. weekend).

This result underscores the role that diversity plays with large groups. Vehicles are plugged in across a wide distribution of time and with varying states of charge in the battery. As a result, only a fraction of the population set is charging at any one point in time. Although the charging power level on individual vehicles may increase in future models, changing the average load curve to some degree, the diversity effect will remain and will mitigate the aggregated impact to the system.

As noted earlier, about 20% of Plugged-In Program participants were already on a two-tier, whole-house TOU rate. Figure 3 provides a comparison of the charge profiles for participants on a constant residential rate (RES) versus those on the TOU rate. The analysis showed that 30% of all weekday charging for standard rate customers occurred during the peak rate time period (10 a.m. through 9 p.m. in the summer). TOU customers reduced this amount nearly in half, to about 17% of all charging. This was achieved by customers managing their charging time, likely through onboard vehicle options, just as they manage other loads in the house.

Although the demonstration was still underway in Indiana at the time of this report, early results point to a gradual decrease in home charging over the course of a year, as shown in Figure 4. The data could indicate that, as drivers grew more accustomed to the new technology, they charged their cars only when needed rather than every day. Alternatively, it could reflect increased access to work or public charging.

The demonstration has also informed Duke Energy's approach to metering and managing the peak impact to the grid. Based on results and customer feedback to date, the company does not currently plan to pursue separate metering or rate tariffs

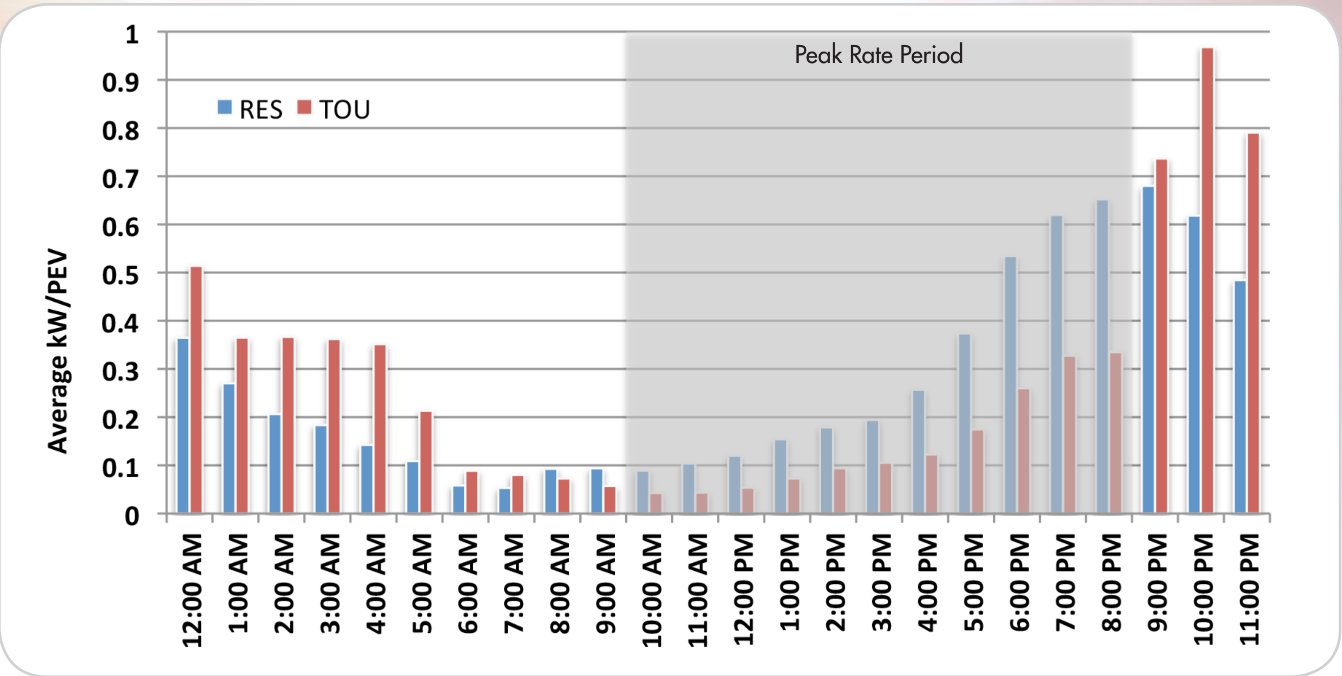

Figure 3. PEV load profile for residential Plugged-In Program (standard residential vs. whole-house TOU rate).

designed only for PEVs. The added cost and complexity of installing another meter and tailoring a rate structure specific to just one load in the home does not appear to be justified based on the benefits it may provide at this time. The company does currently offer whole-house TOU rates in the Carolinas and Ohio that can support a customer's desire to shift all types of load, including PEV load, off peak.

Duke Energy is also exploring other technologies and means to support customers in mitigating the peak grid impact of charging vehicles. For example, the company recently demonstrated a demand response event for several charging station participants in Indiana. The company is also partnering with a major automaker to develop and test enhanced, two-way vehicle communications to support managed charging directly with a PEV. These are believed to be the first utility-managed demand response demonstrations with PEV customers in the country. Duke Energy will continue to conduct market and technology research to give the company and its customers the tools to support vehicle charging with the least impact to the grid.

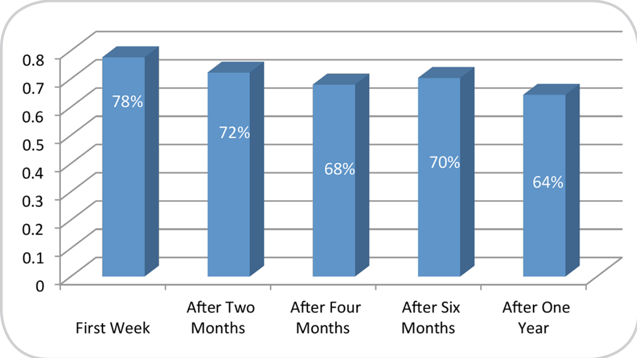

Figure 4. Percent of days car is charged at home – residential Project Plug-IN.

Lessons Learned

1. Create a seamless customer experience. Ensure that processes are in place to manage customer interactions and expectations, support charging station installation logistics, and establish clear channels of communications between and within the provider, vendors, and customers.

2. Streamline the customer interaction and hand-off process. Combine steps where possible and collect information ahead of time to minimize site visits.

3. The average session is only about 7-8 kWh of energy – less than $1 in energy costs in most markets. Charging this amount at AC Level 2 power levels can be accomplished in just 2-3 hours, allowing the potential to shift load to off-peak hours when necessary.

4. The demonstration raised questions about the current state of metering and data backhaul capabilities associated with the existing charging station technology. More work is necessary to meet accuracy requirements and standards necessary to protect consumers should they be billed directly.

5. Real-time, remote access to detailed charging data can be valuable for load research programs. However, communication and back office fees can be significant over time and more cost-effective utility solutions would be necessary for larger scale offerings.

6. Load diversification is important, especially at the system level. Different vehicles will charge at different levels at different times, creating a relatively low average load per vehicle – even at peak times. Transformer-level impacts may still occur on occasion, however this appears to be at a low frequency and within the utility's historical experience of serving evolving loads.

7. Choose locations wisely for public charging stations. Commercial installations tend to be more complex, costly, and time-consuming due to site variances as well as insurance, contractual, and compliance obligations.

8. Although not a significant issue for these pilots, the proprietary nature of many charging station communication and service solutions could pose future interoperability concerns at mass-market scale.

9. PEV drivers adjust their charging habits over time. As they become more comfortable with the technology and range, they tend to charge less often – even at home.

10. Utilities need to be an active stakeholder. By participating in research demonstrations and industry collaborations, utilities ensure that their perspective is represented in the broader PEV rollout. They can assess firsthand the potential grid impacts while educating and engaging with customers about their new role in fueling transportation.

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DUKE ENERGY BY THE NUMBERS

As of August 2013

1. States served in part by Duke Energy: **North Carolina, South Carolina, Florida, Indiana, Kentucky, Ohio**
2. Size of territory, in square miles: **104,000**
3. Number of residential accounts: **5.5 million**
4. Number of all retail accounts: **7.2 million**
5. Total population served: **22 million**
6. Major metropolitan areas engaged in PEV readiness: **Raleigh/Durham/Chapel Hill/Cary, N.C.; Charlotte, N.C.; Asheville, N.C.; Greenville-Spartanburg, S.C.; Orange County and Greater Orlando, Fla.; Pinellas County and St. Petersburg, Fla.; Greater Indianapolis, Ind.**
7. Number of employees: **27,775**
8. Number of employees involved in PEV readiness: **1 full time; many others equating to an additional 3-5 FTE**
9. Estimated number of PEV customers throughout territory: **3,000–4,000**
10. Number of plug-in fleet vehicles: **40; expected to double in 2014**
11. Approximate number of PEV charging stations deployed by the utility for residential and business customers, and owned by the utility for its own internal testing and use: **700**

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