CAMPUS SUSTAINABILITY GRANT REPORT: Analyzing Electric Vehicle Use in the University of Georgia and Athens Community

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Project Description

Electric Vehicles (EVs) are becoming popular in the United States, driven by the government for both federal and state incentives [1] and by the automotive industry to provide more environmentally friendly and energy-efficient EVs [2, 3]. The United States has been the largest EV market in the world for the past few years [3]. Unlike gasoline and diesel cars, battery electric vehicles (BEVs) are powered exclusively by electricity and require electricity charging stations. These stations can be classified into three different power levels according to how quickly they can charge: level 1, level 2, and DC fast charging [4]. Level 1 is the basic charge station, which provides 110 V at a maximum of 3.3 kW of power. Level 2 raises the charge voltage to 240 V at a maximum of 19.2 kW. DC fast charging provides 480 V at around 50 kW, aiming to charge most EVs from zero to 80% in less than 30 minutes [5]. Unlike traditional plug-in charging stations, wireless charging has the advantages of no plug-in cables required, minimal tear and wear, and vandalism, making the charging experience convenient for EV drivers.

Installing more EV charging stations could encourage EV usage and improve the sustainability of the UGA campus and Athens local community. Practical issues, such as where to put the charging stations, whether plug-in or wireless chargers should be installed, and how the additional charging stations would affect EV users' driving behaviors, will have to be considered during the planning phases of charging station installations.

In this project, EV usage and charging patterns were recorded and analyzed over a duration of ten months. The study results provide practical insights for city planning for future installations of plug-in and wireless EV charging infrastructure. Analysis results were displayed in two conferences: 2015 Bioenergy System Research Institute Annual Retreat as a poster and 2015 Wireless Power Transfer Conference in Boulder, CO as a poster and a presentation. Six local EV users were involved to help record EV usage data. One leading charging station provider, ChargePoint, was willing to give more charging station data all across the Georgia State. EV usage data Recruitment poster was spread out on UGA campus and EV Club of the South, which has 805 members in south US. During the past six months, two new plug-in level 2 charging stations were implemented on campus, in south and east parking deck respectively. The first wireless charging station on campus was built in Driftmier Engineering center for initial study and comparison with traditional plug-in charging station. EV usage on campus was increasing significantly during past few months. More and more drivers are interested in electrical vehicles because of the clean energy and high efficient equivalent MPG. By improving awareness and usage of EVs, Based on the results of this project, one IEEE conference paper has been published and presented to more than 150 international scholars in University of Colorado-Boulder and one journal paper is under preparation.

The project will continue going on to the next stage, involving more EV users both on campus and in GA State. More charging station data will be analyzed and monitored. Suggestions on locations of new charging facilities will be provided based on EV charging demand analyzed according to usage data that obtained from individual participants and ChargePoint Inc.

Project Expenses

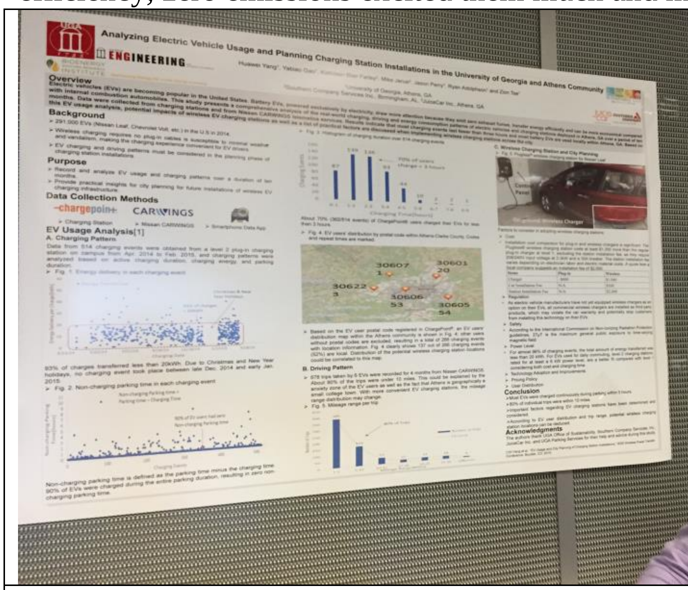
As this project going on, data collection method was changed due to practical reasons. The data was collected directly from EV users Carwings account, a Nissan leaf App that records usage information and generates data, and charging stations. A $20 dollar Amazon gift card was given to every participant, in total of $100. 2 smartphones and one tablet with data service were used for data collection and test, in total of $650. One wireless charging station was implemented in college of engineering for test and study, worth $3,000. Total expense is $3,750. The budget is $4,800. By changing of data collection methods, we successfully save $1,000 and installed the first wireless charging station in Athens.

Academic Impact

One poster about this project was displayed in 2015 Bioenergy Systems Research Institute Annual Retreat in University of Georgia on May 5th, 2015. About 100 scholars and company representatives participated in this retreat.

One poster and one presentation were given to more than 150 international scholars in 2015 Wireless Power Transfer Conference in University of Colorado-Boulder from May 12 to 15th.

Many participants in these two academic conferences showed highly interests and curiosity about our work. We talked to many people who are not well aware of Electrical Vehicles. The benefits including energy efficiency, zero emissions excited them much and many showed the interests to have one in near future.



Poster in 2015 WPTC Conference

Presentation in 2015 WPTC Conference by Dr. Zion Tse

Research Value

This paper presents a comprehensive analysis of the real-world charging, driving and energy consumption patterns of electric vehicles and charging stations deployed in a college town over a period of ten months. Data collection approaches include data from charging stations and from Nissan CARWINGS telematics services. Results indicate that most charging events last fewer than three hours and most battery EVs are used locally within Athens, GA. Based on this EV usage analysis, potential impacts of wireless EV charging stations as well as a list of practical factors are discussed when implementing wireless charging stations across the city.

For future study, charging behavior in GA State will be analyzed based on charging station data. Our partner, ChargePoint Inc. has agreed to provide State wide data to us.

Engagement

a) List partnerships formed or enhanced through this project.
   1) JuiceCar Company, a start company aims at providing green transportation for UGA, has shown great interests in this project. The company has two Nissan leafs, and they have already participated in our pilot test.

   2) EV Club of the South would play a big role in leaf driver recruitment. The club has many enthusiastic leaf owners over Georgia and by analyzing their usage would provide a realistic database as a reference for promoting EV usage and developing associated EV infrastructure such as chargers, parking in Georgia.

   3) Southern Company Services, Inc., an existing collaborator and sponsor with the project advisor, Dr. Tse, has shown support in Electric Vehicles related research. A Nissan leaf has been sent from Southern Company Services to Dr. Tse's group for EV researches conducted in this lab. Such a partnership would assist in further usage study and EV researches over Georgia.

   4) UGA Office of Parking Service would be a great help to obtain charge station data in Athens community. This data would be a good supplementary to analyze charge behavior at user end.
   5) ChargePoint Inc. was involved recently and has agreed to provide charging station data State wide.

b) List beneficiaries of this project.
   UGA students and faculties, EV users in Athens, JuiceCar Company, Southern Company Services.
c) List any outreach events, activities, or media in which your grant project was featured. To the extent possible, include specific numbers of individuals that engaged with your project at these events or activities. Also to the extent possible, include any statistics regarding social media engagement.

Events	Participants Number	Location
2015 Bioenergy Systems Research Institute Annual Retreat	Approximately 100	Athens, GA
2015 Wireless Power Transfer Conference	150 international scholars	Boulder, CO
Red&Black News Report	N/A	Athens, GA

Project-specific Metrics

Each grant project is unique. Most projects will include measurable outcomes regarding specific resource conservation (i.e. dollars saved / return on investment; pounds of materials diverted from the landfill; kWH electricity generated or avoided; gallons of water conserved; pounds of CO2 equivalent emissions avoided, etc.). Many projects will include social benefits such as # of individuals, children or families served. List any specific metrics that help to convey the impact or success of your program.

With this project, more and more students, staff, EV enthusiastic and international scholars are aware of EV benefits and the research conducted in college of engineering, University of Georgia. Less CO2 were produced thanks to EV usage. Approximately, EV only has half of the CO2 emission compared to conventional gas cars [6]. EV charging station number has increased from 6 public stations to 16 in less than one year.

EV charging and driving patterns in Athens, a college town, have been analyzed, and factors that may affect usage of wireless charging stations are discussed. In the future, after a full year of data collection, a model comparing the impact of plug-in versus wireless charging stations on driving and charging patterns will be proposed. Furthermore, evaluation of battery size, charge levels, and battery health reduction will be included.

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Appendix:

Conference Paper Published in 2015 IEEE Wireless Power Transfer Conference, Boulder, CO.

EV Usage and City Planning of Charging Station Installations

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***Abstract* — Electric vehicles (EVs) are becoming popular in the United States. Battery EVs, powered exclusively by electricity, draw more attention because they emit zero exhaust fumes, transfer energy efficiently and can be more economical compared with internal combustion automobiles. This paper presents a comprehensive analysis of the real-world charging, driving and energy consumption patterns of electric vehicles and charging stations deployed in a college town over a period of ten months. Data collection approaches include data from charging stations and from Nissan CARWINGS telematics services. Results indicate that most charging events last fewer than three hours and most battery EVs are used locally within Athens, GA. Based on this EV usage analysis, potential impacts of wireless EV charging stations as well as a list of practical factors are discussed when implementing wireless charging stations across the city.**

Index Terms: Electric vehicles, wireless EV charging station, EV usage analysis, charging pattern, driving pattern.

I. Introduction

Electric Vehicles (EVs) are becoming popular in the United States, driven by the government for both federal and state incentives [1] and by the automotive industry to provide more environmentally friendly and energy-efficient EVs [2, 3]. The United States has been the largest EV market in the world for the past few years [3]. Unlike gasoline and diesel cars, battery electric vehicles (BEVs) are powered exclusively by electricity and require electricity charging stations. These stations can be classified into three different power levels according to how quickly they can charge: level 1, level 2, and DC fast charging [4]. Level 1 is the basic charge station, which provides 110 V at a maximum of 3.3 kW of power. Level 2 raises the charge voltage to 240 V at a maximum of 19.2 kW. DC fast charging provides 480 V at around 50 kW, aiming to charge most EVs from zero to 80% in less than 30 minutes [5]. Unlike traditional plug-in charging stations, wireless charging has the advantages of no plug-in cables required, minimal tear and wear, and vandalism, making the charging experience convenient for EV drivers.

Installing more EV charging stations could encourage EV usage and improve the sustainability of the UGA campus and Athens local community. Practical issues, such as where to put the charging stations, whether plug-in or wireless chargers should be installed, and how the additional charging stations would affect EV users' driving behaviors, will have to be considered during the planning phases of charging station installations.

In this paper, a study of EV usage in Athens, GA, a college town, is presented. EV usage and charging patterns were recorded and analyzed over a duration of ten months. The study results provide practical insights for city planning for future installations of wireless EV charging infrastructure.

II. Data Collection and Test Fleet

This study was conducted in Athens, GA, home of the University of Georgia, with a total population of 115,452 [6]. In Athens, ten public chargers are available, including one DC fast charger, six level 2 chargers and three level 1 chargers [7]. In order to compare the impact of plug-in and wireless charge stations on local EV usage, preliminary usage data was collected and one wireless charge station was built in March, 2015, at the University of Georgia. The data collection included a range of operational use cases and conditions, charging stations, personal EVs and rental EVs [8]. Data were obtained from a ChargePoint® level 2 charge station with two charging ports in Athens, two battery EVs from a local EV rental company, JuiceCar Inc., four EVs for daily commute. The pilot data collected in Athens includes 514 charge events and 678 trips, in which the driving and charging patterns were analyzed.

A. Charging Pattern

Charging data were obtained from a level 2 plug-in charging station on campus, and charging patterns were analyzed based on active charging duration, charging energy, and parking duration.

Fig. 1 shows the energy delivery for each EV charge at ChargePoint® from April 10, 2014 to February 26, 2015. 93% of charges transferred less than 20kWh. Due to Christmas and New Year holidays, no charging event took place between late Dec. 2014 and early Jan. 2015. Fig. 2 shows the amount of non-charging parking time for each charging event. Non-charging parking time is defined as the parking time minus the charging time. 90% of EVs were charged during the entire parking duration, resulting in zero non-charging parking time. Fig. 3 displays the histogram of the charging time intervals over 514 charging events from 04/2014 to 02/2015. About 70% (362/514 events) of ChargePoint® users charged their EVs for less than 3 hours. The maximum power rating of the station is 6.6 kW. 93% of events, not 70%, were charged less than 20 kWh, equivalently 3 hours at maximum charging power. Possible reasons are not all of the charging events were charged at the maximum power and batteries were still partially charged when charging started.

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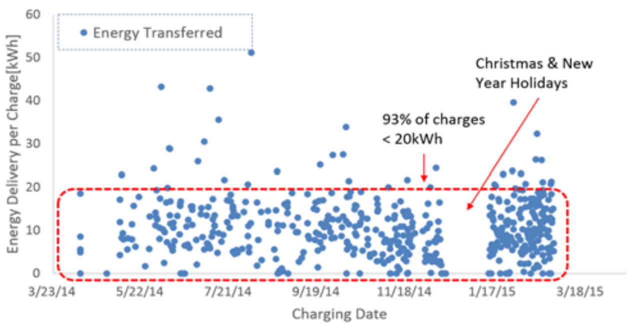

Fig. 1 Energy delivery for each EV charging event.

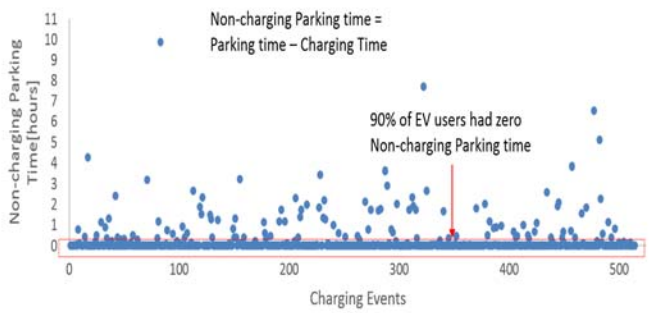

Fig. 2 Non-charging parking time in each charging event.

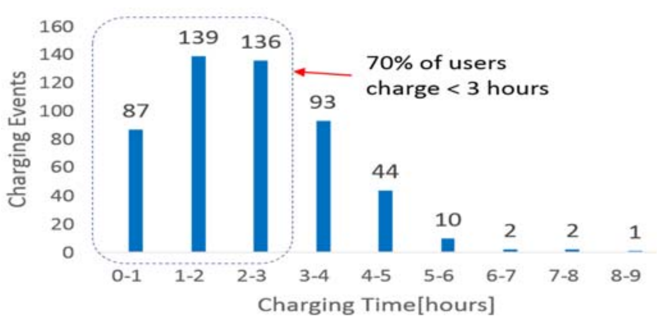

Fig. 3 Histogram of the charging time over 514 charging events.

Based on the EV user postal code registered in ChargePoint®, an EV users' distribution map within the Athens community is shown in Fig. 4; other users without postal codes are excluded, resulting in a total of 266 charging events with location information. Fig. 4 clearly shows 137 out of 266 charging events (52%) are local. Distribution of the potential wireless charging station locations could be correlated to this map.

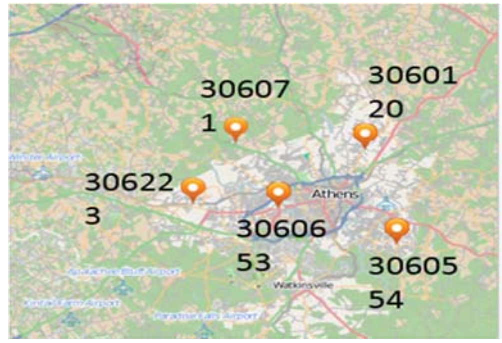

Fig. 4 EV users' distribution by postal code within Athens-Clarke County. Codes and repeat times are marked.

B. Driving Pattern

In this study, 678 trips taken by 6 EVs were recorded for 4 months. The range distribution was analyzed, as Fig. 5 depicts. About 80% of the trips were under 10 miles. This could be explained by the anxiety zone of the EV users as well as the fact that Athens is geographically a small college town. With more convenient EV charging stations, the mileage range distribution may change. A comparison will be made later when more charging stations have been installed.

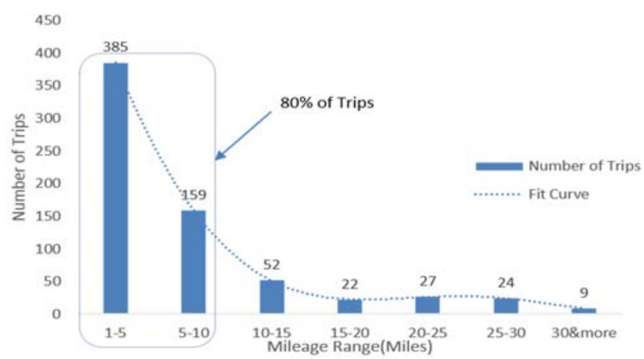

Fig. 5 Mileage range per trip.

III. OTHER CONSIDERATIONS

A Plugless® wireless charging station was installed at the UGA College of Engineering as Fig. 6 depicts. The transmitter is designed for on-ground use. Experiments are still ongoing to evaluate this technology to be used for public charging. Seven factors were identified to be important when considering to adopt commercial wireless charging technologies across the city.

Fig. 6. Plugeless® wireless charging station for Nissan Leaf.

1) Cost

Table 1 shows the installation cost comparison for plug-in and wireless chargers. The Plugless® wireless charging station costs at least $1,300 more than the regular plug-in charger at level 1, excluding the station installation fee, as they require 208/240V input voltage at 3.3kW and a 30A breaker. The station installation fee varies depending on electrician labor and electric material costs. A quote from a local company suggests an installation fee of $2,000. In addition, if a charging pad is installed on concrete parking surfaces, which may contain ferrous materials such as rebar, wire mesh or steel beams, a magnetic shield ($300) is needed to reduce electromagnetic interference between the wireless charger and the metal underground.

Table 1. Cost Comparison

Items	Plug-in	Wireless
Charger	~$900	$1,940
Car Installation Fee	N/A	$300
Station Installation Fee	N/A	$2,000

2) Regulation

As electric vehicle manufacturers have not yet equipped wireless chargers as an option on their EVs, all commercial wireless chargers are installed as third party products, which may violate the car warranty and potentially stop customers from installing this technology on their EVs. Additionally, level 2 or higher power wireless charging stations, which are more desirable for public charging than their level 1 counterparts, require at least 6 kW at 240V input voltage from the power grid. Therefore, charging stations installed in public parking places will cost significantly more because they frequently require trenching to run conduit and wires to the stations.

3) Safety

Safety concerns include electromagnetic field exposure and metal material exposure during charging. According to the International Commissionon Non-Ionizing Radiation Protection guidelines, 27μT is the maximum general public exposure to time-varying magnetic field [9, 10]. The measured magnetic field strength, according to our in-house measurements, reached more than 2,000μT near or between the wireless charger's transmitter and receiver. This could be dangerous when animals and humans are close enough to be exposed to such strong electromagnetic fields. Furthermore, our experiments also showed that small to medium metal materials, such as metal debris and soda cans, when exposed to the field, were failed to be detected by the wireless charger, causing severe radio-frequency reduced heating of > 70^{o}C (in a soda can).

4) Technology Adoption and Improvements

Customer feedback on the wireless charging experience was also collected. The drivers of the test fleet found it difficult to align the charging pads, so their parking had to be readjusted multiple times, which caused more trouble than just simply plugging a regular charger in. Drivers may need some time to practice the new parking technique.

5) Power Level

As revealed by Fig. 1-3, 78% of charging events demanded less than 3 hours of charging, and 75% of those events included zero non-charging parking time. For almost 96% of charging events, the total amount of energy transferred was less than 20 kWh. For EVs used for daily commuting, level 2 charging stations, rated for at least a 6 kW power level, are a better fit compared with level 1 considering both cost and charging time.

6) Pricing Policy

Pricing policy has an impact on user charging behavior and is another consideration when using public charging. Some charging stations have pricing policies that encourage efficient use of public EV chargers to minimize idle time. For example, charging fees can be increased after the first 2-3 charging hours as well as during-on peak hours. Students and staff can benefit from lower charging fees to encourage the use of EVs within the campus. According to Fig. 3, the most frequent charging duration is from 1 to 2 hours, which is consistent to the pricing policy at the UGA parking services, where lower charging fees are implemented for first two hours of EV charging.

7) User Distribution

EVs are still in an early technology adoption stage and have not yet taken a role of major daily transportation. For most affordable battery EVs, such as Nissan leaf, Volkswagen E-golf, the drive range is below 100 miles per full charge [3]. Optimization of charging station locations could help extend EV drive range [11-13]. Different groups have been working on optimal charging station locations in big cities [12-14]. As a small town with 306.2 km^2, the Athens model is much simpler compared with former studies in bigger cities. As derived from Fig. 5, 80% of individual trips are within 10 miles. Based on the postal codes distribution shown in Fig. 4, most repeated postal codes are in the southwest and east side of Athens. Particularly, UGA has more than 40,000 students and staff on its campus area of 3.07 km^2, with the largest population density far beyond any other areas in Athens during work hours. The primary locations for wireless charging stations should be places with the largest traffic density and parking demands on campus. Optimal locations for charging visiting EVs should be places that visitors and travelers mostly stay when they are in Athens, like student centers, business centers and sports stadiums. Optimal locations for EV chargers could be based on the EV distribution according to the city traffic and the EV registration information.

IV. Conclusion

EV charging and driving patterns in Athens, a college town, have been analyzed, and factors that may affect usage of wireless charging stations are discussed. Most EVs were charged continuously during parking within 3 hours. 80% of individual trips were within 10 miles. Important factors regarding EV charging stations have been listed. According to EV user distribution and trip range, potential wireless charging station locations could be deduced. Since data were collected in Athens, a small college town, conclusions may not be accurate in other cities. In the future, after a full year of data collection, a model comparing the impact of plug-in versus wireless charging stations on driving and charging patterns will be proposed. Furthermore, evaluation of battery size, charge levels, and battery health reduction will be included.

Acknowledgement

This project was sponsored by Southern Company Services, Inc. and the UGA Office of Sustainability. The authors thank JuiceCar Inc. and UGA Parking Services for their advice during the study.

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