EVTC

Electric Vehicle Transportation Center

Semi-annual Program Progress Performance Report for
University Transportation Systems

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Submitted by:
University of Central Florida

I. Accomplishments

What are the major goals and objectives of the program?

The Electric Vehicle Transportation Center (EVTC) supports the U.S. Department of Transportation's strategic goal of planning for near-term integration of alternative fuel vehicles as a means to build a sustainable transportation system. The project objectives are to evaluate technologies, standards, planning and policies to ensure seamless integration of electric vehicles (EVs) into a complex transportation network and electricity grid. The EVTC will bridge the gap between deployment of electric vehicles and the traditional transportation system.

What was accomplished under these goals?

Summary

A summary of the major activities reported in the following pages is as follows. In the research area, the collection and analysis of data from the Nissan funded DC fast charger at FSEC (Project #3), the development of a student and faculty battery laboratory at Tuskegee University (Project #8), the opening of a new University of Hawaii battery test lab (Project #9), a computer model to optimize electrical costs for Tallahassee StarMetro buses (Project #14), and the installation and beginning of data collection from the FSEC wireless charging laboratory (Project #15). Detailed industry interactions for the period included Nissan, NovaCharge, General Motors, Florida Power & Light and Alabama and Florida DOTs. In the education and STEM area, twelve courses were offered or are under development and twelve STEM and K-12 education events were held.

Research and Development Accomplishments

The EVTC R&D agenda identified 21 projects and respective teams have been conducting detailed research. A summary of results for each project are presented in the following sections. Reference for additional details of each project is made to the EVTC website. Note that the project results have produced 23 referenced publications. These publications are presented by reference numbers in the R&D section with the formal citations and are listed in the results dissemination section on pages 18-19.

1. **Implications of Electric Vehicle Penetration on Federal and State Highway Revenues**

Objective: *Research the impact that increased use of electric vehicles will have on federal and state highway revenue sources. This work will identify existing laws and policies that govern highway, gas, and vehicle taxes and fees imposed on vehicles and summarize current trends and policy recommendations that may influence both the growth of the electric vehicle market and impact highway revenues.*

Accomplishments: The project has reviewed existing industry and government reports detailing current and future predicted fuel tax revenues for the federal highway programs. All research data points to critical shortfalls in highway funding, however, this shortfall is attributed to more fuel efficient internal combustion engine (ICE) vehicles, to the increased cost in highway construction and repairs and to no increase in the federal gas tax. Results have also presented impacts and shortfalls to highway funding as a result of EV market penetration. EV penetration, although increasing, has not yet made any significant impact on highway fuel tax revenues. As of August 2015, the lost revenues from EV sales were $88.5M out of a total tax revenue of $36.1B. Federal, state and local government policies and laws affecting highway funding are looking at variety of alternate means of support. This project is considered completed with the publication of a project report.

***2.* Identify and Analyze Policies that Impact the Acceleration of Electric Vehicle Adoption**

Objective: *Examine state and national regulatory policies to determine their impact on the long term adoption of electric vehicles. The work will include discussion with Florida utility companies and with existing electric vehicle stakeholder groups. New policies and or regulations will be developed and suggested to the appropriate authorities. This project will also include Hawaii and Alabama.*

Accomplishments: The project's efforts have been to review existing state and national policies and to form a partnership with Drive Electric Florida, a non-profit consortium of approximately 20 organizations (electric utilities, local government, universities, others). Drive Electric Florida has the objective of advancing the energy, economic, and environmental security of the state of Florida by promoting the growth of electric vehicle ownership and accompanying infrastructure. Drive Electric Florida has continued to hold education and policy committee meetings on a regular basis and took the opportunity during National Drive Electric Week (September 14-18, 2015) to host a high profile event in Tallahassee, FL. This event engaged state legislators and their staff members, as well as state agency representatives, by giving them first hand experiences with a wide variety of electric vehicles. The Florida Senate Transportation Committee Chairman was a key participant and was featured in a video produced during the event, which is available on the EVTC website. The other major activity was EVTC participated in a U.S. DOT and DOE regional workshop that was held in Portland, Oregon (July 2015) for the purpose of assisting state and local transportation agencies interested in EVs and EVSE corridor development. The workshop sponsors developed a toolkit following the meeting. The two main components of the toolkit are the Resource Library, which is a collection of online resources relevant to EV corridors and state DOTs, and the Workshop Materials, including a one-page factsheet on the workshop, the summary report, and workshop presentations.

***3.* Electric Vehicle Charging Technologies Analysis and Standards**

Objective: *Assess current and emerging technologies, codes and standards associated with Electric Vehicle Service Equipment (EVSE), Electric Vehicles (EVs) and the related infrastructure. The work will recommend policies and best practices to advance both vehicle and EVSE deployment. Collect and analyze 50kW DC fast charger usage data to evaluate electrical power impact.*

Accomplishments: This project evaluated the technologies and standards associated with Electric Vehicles (EVs), Electric Vehicle Service Equipment (EVSE) and the related infrastructure. The initial project output was a report on current and emerging EVSE technologies and an assessment of codes and standards. The report also reviewed barriers and challenges to the installation of EVSE and made recommendations on policies and standards to support charging network deployment.

Other project activities have included the installation of a DC Fast Charger (DCFC) and the collection and analysis of data from its use. EVTC staff efforts resulted in the installation of a DCFC charging station donated by Nissan and NovaCharge. The 50kW station was installed on the Florida Solar Energy Center (FSEC) site in January 2015 and is used for both research and public charging. The site dedication occurred on March 20, 2015 with numerous dignitaries attending. Six months of data from the DC Fast Charger has now been collected and analyzed. This data shows that the DCFC increased the monthly peak demand by 23.4 kW in February and by 2.1 kW in March, 2015. Future program research will evaluate processes on how to effectively manage the impact of this high voltage device on FSEC's utility bill. This application will provide results on how to minimize "demand charges" in a commercial account environment.

***4.* Transportation Planning for Electric Vehicle and Associated Infrastructure**

Objective: *Identify and examine the transportation infrastructure planning models and related policy issues associated with the deployment of Electric Vehicles (EVs). Recommendations for planning and policy actions to accommodate EVs and EVSE infrastructure will be provided and an assessment of the* *how EVSE infrastructure planning will enhance EV acceptance will be produced. Infrastructure deployment feasibility models will also be developed.*

Accomplishments: The project focus has been to identify existing transportation planning models, to develop partnerships and to evaluate planning activities occurring in Florida and the U.S. The major activities have been the review of the literature on planning and planning models. These models do not presently have EV considerations, thus, they are being evaluated on the inclusion of EVs and of other alternative fueled vehicles. Model development has also included exploring partnerships with the Florida Department of Transportation and the Center for Urban Transportation Research (CUTR) at the University of South Florida. The second major activity has been planning for the EV Transportation and Technology Summit and EV Market & Technology Workshop. This Summit meeting will focus on the transportation planning and infrastructure requirements needed to support the adoption and application of many forms of electric vehicles. The Summit will host three days of meetings with key EV stakeholders at the Florida Solar Energy Center, October 20-22, 2015. The Summit and Workshop will also provide an update on the current state of EV deployment, technology and planning.

5. Prediction of Electric Vehicle Penetration

Objective: *Identify past and present trends in electric vehicle sales to establish a baseline of electric vehicle penetration and to predict electric vehicle sales and sales characteristics within the U.S. Compare EV sales by states and evaluate the types of barriers to EV usage and the actions or incentives to overcome the barriers.*

Accomplishments: Sales figures are now available for the 8 month period of 2015. The 2015 figures show that EV sales are not experiencing the same growth as in 2014. Once the 2015 yearly sales are completed, the trend analysis will be further evaluated. The major factor for the slower growth is almost entirely attributed to the significant price drop in U.S. gasoline. The average cost of gasoline in the U.S. for 2015 was $2.60/gallon as compared to $3.44/gallon in 2014 (a low of $2.02/gallon in February 2015). The bright spots for EV sales are that the U.S. EV fleet is the largest in the world with 349,000 vehicles and California is the largest market with 143,000 vehicles sold (46% of the U.S. total). The largest selling EV is the Nissan Leaf with over 82,000 vehicles sold followed by the Chevrolet Volt with about 79,000 vehicles sold. The U.S. market now has over 20 EV models from 12 manufacturers. The work also evaluated the types of barriers to EV usage and the actions or incentives to overcome the barriers. The barriers to large scale EV usages are vehicle cost, mileage between charging, perceived battery life, availability of charging stations, charging time, resale, infrastructure and public knowledge and education. The work on overcoming EV barriers continues.

6. Electric Vehicle Life Cycle Cost Analysis

Objective: *Compare total life cycle costs of electric vehicles, plug-in hybrid electric vehicles, hybrid electric vehicles, and compare with internal combustion engine vehicles. The analysis will consider both capital and operating costs in order to present an accurate assessment of lifetime ownership costs. The analysis will include vehicle charging scenarios of photovoltaic (solar electric) powered charging and workplace charging.*

Accomplishments: This project compared total life cycle costs (LCC) of battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), hybrid electric vehicles (HEV), to vehicles with internal combustion engines (ICE). The analysis considered capital and operating costs in order to present an equal comparison of differing types of vehicles. The analysis compared the total cost of ownership over 5, 10, and 15 year life expectancies and used actual cost values for 16 production vehicles all sold in the United States. The results were presented as a paper and as a computer program of life cycle costs (LCC) that will allow for any user to download and use the developed LCC model, and to evaluate photovoltaics (PV) as a power option for electric vehicles. The LCC results were compared with the DOT cost calculator and Kelly blue book 5-year cost of ownership estimates. Continuing activities are to update the computer model as new vehicle models are added by manufacturers.

7. Assess Existing Software and Databases

Objective: *Evaluate the feasibility of using the existing software and data bases as platforms for analyzing the attributes of electric vehicles within present and future transportation infrastructure projects and models.*

Accomplishments: The project results showed that the Florida based SunGuide® and STEWARD database were abandoned by the Florida DOT and, thus, an alternate Regional Integrated Transportation Information System (RITIS) database was evaluated. The RITIS data was then used to provide current vehicle information on the Florida Turnpike for a transportation simulation model (See Project 13). The Florida Turnpike data set has been completed. Work this period refined the Turnpike data and evaluated software programs that use the data bases. Examples of measured data, vehicle volume and speed information and roadway schematic drawings may be seen at the project web site.

8. Battery Technologies for Mass Deployment of Electric Vehicles

Objective: *Assess current and emerging battery technologies and the requirements for their commercialization; align with DOE targets for future EV batteries. Focus will be placed on battery technologies, charging cycles, lifetimes, safety, codes and standards, and economics.*

Accomplishments: The initial project results were to evaluate the performance of commercially-available Li-ion batteries by conducting a search of the existing literature and evaluation of the data from over 100 peer-reviewed papers. This material has been compiled into a database of battery performance degradation as a function of electrode chemistry, temperature and state of charge (SOC). Currently, the degradation rates are being analyzed for calendar aging studies, following which cycling aging studies will be examined.

Another project accomplishment was an analysis of national driving trends and battery size to determine where and when electric vehicles will likely recharge. The analysis was also able to determine how many miles the average consumer has driven as a function of both time and place, and to correlate these parameters to the expected SOC of an electric vehicle. The results were published in the *Journal of Power Sources* and *Electrochemical Society Interface*.[1, 2]

A third project effort was the investigation and creation of a battery laboratory at Tuskegee University for research on characterization of Lithium-Ion polymer batteries by electrochemical impedance spectroscopy. In this lab, Tuskegee is setting up a complete laboratory with impedance analyzer, potentiostat, power supply and infra-red camera in which electrode performance can be characterized by charge transport, ohmic resistance and mass transport, all of which are accessible by using the impedance spectroscopy setup. An infra-red camera will be used to determine how heat is evolved during battery usage, so as to design better coolant systems. This setup will enable students and faculty to investigate battery performance parameters as well as the temperature effects of battery charging/discharging cycles.

9. Electric Vehicle Battery Durability and Reliability under Electric Utility Grid Operations

Objective: *Determine the impact of electric vehicle use on battery life including charging cycles and vehicle-to-grid (V2G) applications. The work will identify conditions that improve battery performance and durability. Focus will be placed on providing battery data for system engineering, grid modeling and cost-benefit analysis.*

Accomplishments: Battery degradation is extremely important to EV technologies and is sensitive to usage and chemistry. Batteries can be sensitive to temperature, state of charge and other factors. This raises concerns over battery durability in hot climates. Additionally, with the integration of more and more renewables on the power grid, there is a push to use EV batteries as energy storage systems which may stress the batteries even more. The goal of this research is to assess such impact. Two main tasks were assigned to the first year of this project: a literature review on the effect of calendar aging on main Li-ion chemistries and an initial set of laboratory testing to assess the impact of V2G and G2V strategies on commercial cells similar to the ones found in Tesla EVs.

Figure 1 - Battery testing laboratory entrance, inside temperature chamber, temperature chamber and battery tester & a commercial "18650" Li-ion cell used for the EVTC project in battery holder. (Photos: Dr. Arnaud Devie, HNEI)

The literature review was completed and a report is being written. Laboratory testing of the cells is also well underway in the new battery testing facility which has been operational since April 2015. The new UH Battery testing laboratory includes a temperature chamber, a battery tester and a commercial "18650" Li-ion cell used for the tests. The battery test plan that uses the "design of experiment" methodology has been finalized. This plan consists of two separate experiments: a cycling experiment to assess the impact of V2G and G2V strategies and a calendar aging experiment to assess the impact of temperature and state of charge. In order to carry out these experiments, 100 cells were purchased from a retailer and the entire batch was tested for consistency. The results of this initial characterization test were reported in June 2015. Out of the 100 cells, 36 cells were selected to perform the cycling experiment and as of September 30, 2015, the cells have cycled the equivalent of 200 driving days. Sixteen of the remaining 74 cells were selected for the calendar aging experiments and they have now aged between 10 and 15 weeks at their target temperature and state of charge.[3, 4]

10. Fuel Cell Vehicle Technologies, Infrastructure and Requirements

Objective: *Investigate state-of-the-art fuel cell vehicle technologies, and current infrastructure developments. Conduct comparative study of fuel cell vehicles and battery electric vehicles in terms of technical and economic viability.*

Accomplishments: This project continues to evaluate state-of-the-art of fuel cell (FC) vehicles technologies and current and future fuel station infrastructure roll-outs for the deployment of large scale fuel cell vehicles. As previously reported, three reports have been completed and are as follows:

1. Fuel Cell Vehicles – This report is based on an analysis of over a hundred fuel cell vehicle concepts and models.
2. FC as Range Extender — For this project, EVTC researchers modeled a 2012 Chevy Volt equipped with a fuel cell stack as a range extender using the FASTSim program.
3. Hydrogen Fueling Stations – In this report, researchers identified the most feasible types of future hydrogen fueling stations.

Activity conducted during this reporting period was the development of an electric vehicle powertrain model using the Matlab/Simulink platform. This powertrain model was used to simulate the energy consumption for the comparative economic analysis among passenger size fuel cell vehicles, battery electric vehicles, and fuel cell range extender vehicles.[5]

11. Electric Vehicle Grid Experiments and Analysis

Objective: *Provide experimental data from vehicle-to-grid laboratory simulations. The results of the experimental data will be used in the EVTC techno-economic simulation project.*

Accomplishments: The project has concentrated on laboratory measurements from different battery types and from electric vehicle chargers (type, rating, programmability). In the first phase, the efforts concentrated on developing a building energy management system (EMS) that is directed toward processes for reducing peak electrical demand for an office building. The FSEC office building was selected for this analysis. Dedicated data recorders were installed to monitor facility energy use. Existing charging stations, including a DC fast charger, are continually monitored.

The EMS system has been coupled to the building energy profile and to the EV charging station demands. The EMS system follows the building loads (primarily monthly peak loads) and disables the workplace chargers when the building peak demand exceeds the previous recorded maximum demand. The previous month's demand is reset each month, using 90% of the previous month's peak demand, to: 1) allow the EMS system to adjust to monthly (seasonal) changes in peak demand, and 2) allow a target demand value that will not disable the workplace chargers for several days at the beginning of the new month. Future work will continue to develop the control algorithm, to add other distributed load resources into the EMS system and to include a battery backup load reduction system that will allow demand limiting when vehicles are charging. The battery backup system will allow for the minimizing of the impact of public EV chargers (limited or no controllability) on facility electric demand. This project's efforts to develop a low-cost building EMS that includes workplace chargers will allow commercial building operators to minimize electric utility bills while providing a benefit to employees through free or low-cost workplace chargers. Other building resources (e.g., lighting or other equipment) could also be included to further minimize commercial electric costs. If building owners and operators are convinced that costs can be controlled, free workplace charging could be widely deployed without reservation.[6-8]

12. Electric Vehicle Interaction at the Electrical Circuit Level

Objective: *Investigate the effect of electric vehicle adoption on the circuit level utility distribution grid for both residential and commercial applications by determining the impact of electric vehicle charging and discharging to the grid.*

Accomplishments: The impacts of electric vehicles (EVs) on the electricity distribution grid are not well understood. A literature review has been conducted on the current state of EV charger technology and on over-voltage mitigation focusing on power ratings, control capabilities, embedded sensors, and international standards. These report results are available on the project website. Additionally, a transient time domain model of a sub-circuit service area has been developed, which includes EV charging and integrated PV load generation. The model utilizes EV charging as a means of mitigating transient over-voltages (TOVs) in various scenarios, using the sub-circuit model. Furthermore, a novel methodology for early detection of TOVs has been developed. It has been shown that the technical topology of the charging station combined with the connected load of the EV can be used to prevent and eliminate over-voltage peaks.

This effect can be used to increase the response time and reliability of inverter-based islanding detection and, thus, increase grid reliability. The proposed over-voltage detection and prevention methodology is currently being verified for practicability with real data sets. A report and a conference publication is being prepared that features the outcomes of the modeling efforts, including EV charging, its integration into the grid at the sub circuit level, and TOV prevention. To collect the required data, a measurement unit has been designed and developed to record the current of a power line (installed in the residential power box) and send the results to a server with sample frequency of 1 Hz. The data collected will be used to understand the load variability. A charge profile will be then designed to support distribution grid assets.

13. Optimal Charging Scheduler for Electric Vehicles on the Florida Turnpike

Objective: *Develop the methodology for analyzing the roadway traffic patterns and expected penetration and timing of electric vehicles (EVs) on the Florida Turnpike. The work will determine the requirements for electric vehicle supply equipment at turnpike plazas, the options for equipment siting and the economics.*

Accomplishments: The first steps of the project were to develop the systematic methodology for analyzing expected penetration of electric vehicles (EVs) and their impacts on the overall transportation infrastructure. The analytical model consisted of three components: (1) A dynamic model which, for a highway with a total of N nodes (entrances and exits), admits either instantaneous or average traffic flow passing through entrances/exits; (2) A queueing model on the number of EVs waiting at a given service station; (3) A network level model that prescribes the decision making process of individual drivers as well as any coordination among service stations and individual drivers (using V2V and V2I communication).

Discussion with Florida Turnpike Authority staff has determined that six Tesla charging stations have been installed at both the Drum (Yeehaw Junction area) and Turkey Lake (Orlando area) service plazas. These stations were installed and are owned by Tesla under a sub-lease agreement with Areas USA, the service plaza concession firm. The Turnpike Authority expects to get yearly operational data from Tesla.

The Florida Turnpike network has been used as a test system for this network project. Using real-world data that were collected and compiled from Regional Integrated Transportation Information System (RITIS) database (Project 7), case studies via computer simulations were conducted for 24-hour Florida Turnpike roadway traffic data and the currently installed electric vehicle charging equipment data at the turnpike plazas. The charging equipment utilization and electric vehicle waiting time are compared for different EVs penetration rate and charging strategies. It was demonstrated that the proposed strategy results in a uniform utilization of the charging equipment at the service stations. As a result of year one and two research efforts, two peer-refereed papers on the modeling have been published. A journal article on scheduling of EVs on the Turnpike is in preparation.

14. Electric Vehicle Bus Systems

Objective: *Investigate the implementation strategy and the operation of an electric bus fleet and compare the operational data with a baseline diesel bus fleet. Model an electric public bus transportation system in a selected city.*

Accomplishments: Pure electric buses (EBs) present an alternative fuel for use in the transit bus arena and are being manufactured and sold by several US companies. In this project, an electric bus fleet (Tallahassee StarMetro's five electric bus fleet) was investigated as a case study. For the study, the implementing strategy, route distance and timing, charging times, fuel economy, impact of type of chargers, maintenance and operational characteristics of the StarMetro EB fleet were analyzed and the results were compared with the StarMetro diesel bus fleet. The StarMetro EBs use lithium titanate batteries which enabled them to complete charges within 10 minutes using a fast charger.

From the original comparative results, the electrical demand charge was shown to contribute as high as 74% of the total electricity bill. This result was due to EBs' fast charging ability and could cause a major challenge in the adoption of electric buses. Demand charges are a utility fee based on the peak power used during a given billing cycle (normally one month). The demand charge is calculated as the peak demand (measured in kW) multiplied by a demand charge rate ($/kW). Utility companies measure the average power delivered in a 15 or 30 min window, and the peak demand is identified as the highest power during a billing cycle. Due to the high demand charges, a research effort was undertaken to find means to reduce the charges.

For this analysis, a Matlab computer model was developed to simulate the energy consumption and charging behaviors of the EBs and then using the model to study charging times and the scheduling of the buses for charging based on the bus state of charge. Using measured data from the StarMetro EB, the computer model optimization results were compared. These results showed that the highest measured peak for a one day period of operation was a measurement of 200 kW. For the same period, buses running on the optimized schedule gave a daily demand of 130 kW or 35% lower. The reason for this lowering of demand is that the program schedules the buses to be charging in such a fashion that only one bus will be charging during any 30 minute time frame. The results also showed that this demand reduction can be achieved by commanding the electric buses to charge when the bus state of charge is below the 60% charging threshold. Therefore, by simply adopting an optimized charging strategy, the demand charges can be reduced up to 45%.[9]

Future project activities will be to apply the EB energy consumption model and the charging strategy model to simulate the scheduling and demand charges of different electric transit bus systems with various driving cycles and routes. In addition, the model can also be utilized to explore methods such as battery energy storage systems to reduce demand charges, as well as conduct comparative studies between electric buses that use lithium iron phosphate batteries and lithium titanate batteries.

15. Electric Vehicle and Wireless Charging Laboratory

Objective: *Furnish, equip and operate an EV and Wireless Charging Laboratory within the FSEC laboratory facilities. This facility will function as a laboratory where EV vehicles are charged and discharged through a computer assisted communication network and where wireless chargers are evaluated.*

Accomplishments: The EV laboratory has been completed and experiments on an EV vehicle (Nissan Leaf) have been conducted. The Leaf is connected electronically through its CHAdeMO charging port to become part of a computer based communications network. A controller was built to allow the vehicle battery to be accessed for discharging through external load supply equipment. Lab experiments have also successfully coupled an EV for storage interactions with the output of a PV system. In addition, the project has completed the purchase of two Nissan EVs dedicated to experiments. Power monitoring of the AC input and DC output will be added for efficiency tests. A controlled DC load will be used to allow measurements at variable power loads.

Figure 2 - Automated Test Stand w/ Stepper Motor Actuator (Photo: FSEC)

For the wireless lab experiments, a Plugless wireless charger has been installed for testing. To perform the testing, a frame device has been constructed which allow multiple repeated measurements of the magnetic field around the charging system by slowly moving a sensor through the EM field while data is recorded at about 1.5 second intervals. Future wireless plans are to purchase two additional wireless charging products in order to expand the number of manufacturers included in the wireless experiments. The measurements will include system efficiency of transmitters and receiver pairs at various distances and offsets. The results will document electric and magnetic field strength according to standards and measurements. One or more of these wireless charging systems will be installed on laboratory vehicles and the measurements repeated.

16. Electric Vehicle Fleet Implications and Analysis

Objective: *Evaluate the implementation and effectiveness of electrical vehicles used in fleet operations. The project will evaluate present usage through case studies. The results will be used to evaluate other* *vehicle applications and to determine how EV fleet adoptions could impact overall rates of market penetration and what are the programs or incentives that could encourage EV fleets.*

Accomplishments: According to the U.S. Department of Transportation, there are more that 11 million fleet cars and trucks in the United States. Fleet vehicles regularly cover predictable routes and often return to central depots at night, having a centralized recharging location makes them excellent candidates for conversion to electric. PEVs are particularly attractive for light-duty fleet use because of their reduced fueling expense and lower overall maintenance cost. Combining reduced operating cost with the attractive financing and leasing options offered by EV dealers can provide a compelling justification for governmental and other fleet owners to switch from conventionally fuel vehicles to PEVs. Significant momentum is developing for the conversion of the nation's federal governmental vehicle fleets to electric drive. President Obama's Memorandum of March 2015, directs the federal government to increase its purchasing of zero-emission vehicles to 50% of the Federal fleet by 2025 and the U.S. Postal Service's issuance of an RFI in February of 2015 has initiated the process of selecting a next-generation delivery vehicle to replace the majority of its fleet of more than 200,000 vehicles. Future project activities will continue case studies and use the collected results to determine how EV fleet adoptions could impact overall rates of market penetration and determine the programs or incentives that could encourage EV fleets. A fleet vehicle cost and fuel comparison modeling program is also being developed.

17. Electric Vehicle Energy Impacts

Objective: *Evaluate the impacts of electric vehicles and associated renewable power generation on reduction of petroleum imports to Hawaii. The analysis will concentrate on the Island of Oahu and will include the effects of number of vehicles, charging strategies, renewable energy penetration levels and green-house gas reductions.*

Accomplishments: The project analysis will quantify net petroleum savings by EVs on Oahu, EV mileage and emissions under controlled charging profiles, and EVs with and without high penetrations of renewable resources at the transmission level of the grid. Results will be compared to different vehicle types and fuel mixes; gasoline-powered vehicles, hydrogen and fuel cell vehicles.

In the first year, analysis was conducted on EV integration in Hawaii building on two grid models. These modeling and analysis efforts quantified the amount of curtailed energy captured by EVs under controlled charging profiles and future Oahu renewable energy scenarios. The initial analysis revealed that day-to-day variations in total wind and solar resources reduced the effectiveness of controlled EV charging in capturing curtailed energy. Even exceptionally large fleets of EVs and, assuming 100 percent participation in a controlled charging profile, curtailed energy was reduced by only 18 to 46 percent. Analysis of the effect of curtailed wind and solar energy on EV mileage and emissions indicated that overall fuel and emissions savings can be made on Oahu by replacing average mileage gasoline vehicles with EVs. In the modeled future scenarios, 268 to 322 gallons of gasoline would be saved each year for each average gasoline vehicle replaced with an EV. Considering Oahu's entire passenger vehicle fleet, this represents an overall improvement of approximately 1 to 4 MPG to achieve the same gasoline savings. However, EV mileage only exceeded that of a 50 MPG gasoline-powered hybrid vehicle when powered by curtailed energy in the especially high wind, 23 percent curtailment scenario. By comparison, EVs currently fueled by Oahu's electric power system achieve approximately 32 miles per gallon equivalent to gasoline (MPGe).[10]

In the next HNEI and GE modeling study, curtailment of wind and solar energy on Oahu and Maui was reduced significantly through mitigation measures and changes to the utilities' operating practices. The modeled future scenarios result in curtailment ranging from less than 1 percent, up to 12 percent. For this EV analysis, RPS study Scenario 9 is the focus, with 200MW of wind, 560MW of distributed PV and 300 MW of central PV on Oahu. This scenario resulted in delivered renewable energy approaching 34 percent (installed MW capacity), with 3.4% curtailed energy (69.3 GWh per year). The RPS study with the highest available renewable energy, Scenario 18 is also being considered for the EV analysis. This scenario achieves 55 percent renewable energy potential with an interisland cable linking Oahu and Maui as well as a cable bringing 200 MW of wind capacity (whether from off-shore wind or from another island). Along with the 200 MW from this generation-tie cable, Scenario 18 includes 200 MW of wind, 460MW of distributed PV, 400 MW of central PV on Oahu, and 272 MW of wind, 78 MW of distributed PV and 100 MW of central PV on Maui. Overall, curtailment in this scenario is 12 percent.

With the tremendous growth in distributed PV, Hawaii's 2015 Renewable Portfolio Standards (RPS) target of 15% renewable penetration has already been exceeded. Hawaii's new RPS target is 100% renewable generation by 2045. Accommodating additional renewable energy will be increasingly challenging. Further modeling is planned to help prepare island grids to accept the continued rapid growth of PV together with other renewables.

18. **Socio-economic Implications of Large-scale Electric Vehicle Systems**

Objective: *Develop models to evaluate the socio-economic implications of a large-scale electrified transportation sector. Model factors include effects of vehicle and infrastructure safety requirements, standardization of vehicle components for safety and charging, electric vehicle supply and after-market economies, displacement of petroleum fuels and impacts of sustainable development (social, environmental and economic).*

Accomplishments: During the past year, the inherent uncertainty in optimizing the transportation fleet and predicting the future market penetration of EVs are being addressed by developing two new models: the Electric Vehicles Regional Optimizer (EVRO), and Electric Vehicle Regional Market Penetration (EVReMP). Using these two models, decision makers can predict the optimal combination of drivetrains (gasoline, plug-in hybrid EVs, gasoline extended-range EVs, and all-electric EVs) and the market penetration of the EVs in different regions of the United States for the year 2030. First, the life cycle cost and life cycle environmental emissions of internal combustion engine vehicles, gasoline hybrid electric vehicles, and three different EV types (gasoline plug-in hybrid EVs, gasoline extended-range EVs, and all-electric EVs) are evaluated with their inherent uncertainties fully considered. Then, the environmental damage costs of the studied drivetrains are estimated. Additionally, using an Exploratory Modeling and Analysis method, the uncertainties related to the life cycle costs, environmental damage costs, and water footprints of the studied vehicle types are modeled for different U.S. electricity grid regions. Next, an optimization model is used in conjunction with the Exploratory Modeling and Analysis method to find the ideal combination of different vehicle types in each U.S. region for the year 2030. Finally, an agent-based model is developed to identify the market shares of the studied vehicles in each of 22 electric regions in the United States. The findings of this research will help policy makers and transportation planners to prepare our nation's transportation system for the future influx of EVs. The results of EVRO model are published in the journal of Energy and the EVReMP model is currently under review.[11-15]

Moreover, V2G systems are promising substitutes for traditional gas turbine generators, which are relatively inefficient and have high emissions impacts. Recently, the future net revenue and life cycle emissions savings of V2G technologies are predicted for use in ancillary (regulation) services on a regional basis in the U. S. The results of this study has been submitted to the Applied Energy journal. In the near future, the research team is planning to estimate the net revenue and emissions savings of V2G technologies for delivery trucks, and transit and schools buses.

19. **Economic Impacts of Electric Vehicle Adoption**.

Objective: *Examine the predicted levels of electric vehicle adoption to analyze the opportunity of using EVs as a grid stabilization tool for Hawaii. The analysis will focus on the effect EVs on the electric sector in terms of electricity generation, costs and GHG emissions and on the consumer sector in terms of impacts to gross state product, sector activity and household income.*

Accomplishments: This project will examine likely levels of EV adoption in order to estimate the impact to the State of Hawaii's economy and to determine the level of opportunity in EV's as a grid stabilization tool. Analysis will include determining a set of scenarios for EV adoption in Hawaii over time (to the year

2040) based on literature estimates and Hawaii-specific trends, identifying the impact of EV penetration to the electric sector in terms of electricity generation, costs and GHG emissions, and estimating the effect of EV adoption to the state economy in terms of impacts to gross state product, sector activity and household welfare.

To date, researchers have collected Hawaii data on vehicle adoption rates and practices as applied to Hawaii-specific vehicle ownership data. As part of the calibration, researchers requested and received data from the Hawaii Department of Transportation on Hawaii's existing registered vehicles (over a million vehicles), including the vehicle makes and models as well as gathered available data from the Hawaii Automobile Dealers Association. A report that evaluates EV penetration rate estimates and provides an assessment of expected EV penetration over time has been completed. The results estimate there will be 140,000 EVs on the road in Hawaii by the year 2040 in the reference scenario. In the low scenario, the estimate is 110,000 and, in the high scenario, 280,000. The vehicle adoption scenarios will then be used to help determine impacts of EVs to Hawaii's electric sector and overall economy.[16-17] To complement the Hawaii EV-adoption scenarios, an analysis of lifecycle ownership costs of EVs in comparison to ICEs and HEVs in Hawaii has been completed. The scenarios assess the impact of the federal tax credit for EVs, differences in purchase, finance and lease options, impacts of household solar photovoltaic and the Hawaii utility's pilot and proposed time-of-use electricity rates for EV owners. Researchers are now working on calibrating a model of Hawaii's economy and electric sector to include more detail within the ground transportation sector for EVs.

20. Techno-economic Analyses of Large-scale Electric Vehicle Systems

Objective: *Develop a computer model to evaluate the techno-economic implications of a large-scale electrified transportation sector. The model factors include developing a network of electric vehicles that interact with the electric grid, the infrastructure for electric vehicle charging, integrating the transportation and power systems into the urban setting, studying the impact of distributed energy storage and determining the economic impact of increased renewable energy and EVs on the grid.*

Accomplishments: This project will develop computer models to evaluate the techno economic implications of a large-scale electrified transportation sector. The model factors include developing and interacting with a network of EVs and the electric grid, the infrastructure for EV charging, integrating the transportation and power systems into the urban setting, studying the impact of distributed energy storage and determining the economic impact of increased renewable energy and EVs on the electricity grid.

The current research focuses upon several innovative aspects of grid to vehicle (G2V) charging and vehicle to grid (V2G) feeding development, including such advances as plug-and-play operation, load/generation estimation through integrating renewable energy, distributed protection algorithm, and improving electric grid efficiency and delivery capacity by enabling reactive power compensation and voltage control (which does not affect battery life). For example, energy storage and reactive power supplied by EVs through vehicle-to-grid (V2G) operation can be coordinated to provide voltage support, thus reducing the need of grid reinforcement and active power curtailment and in turn improving EV charging capacity of the overall system. Hence, an optimization and control framework is needed to manage energy storage availability in the near future while using the remaining capacity of V2G to generate reactive power and cooperatively perform voltage control.

As a result of the year one and two research efforts, seven peer-reviewed papers were published and presented at national meetings. During the second and third year, the resilience analysis of power grid with a high level of renewable and EV penetration is being investigated. To present this result, a resiliency index is proposed that will capture the total loads which cannot be supplied under line removal due to extreme weather conditions. The analysis can then be used as a means to control the topology of the grid via switches in order to guarantee the power delivery to critical loads.[18-23]

Subsequent efforts will be made to conduct research in consultation with external partners on: 1) development of a scalable model of large-scale EV and power grid systems, 2) investigation of interactions between large-scale EVs and their power grid systems, 3) development and optimization of both G2V charging and V2G feeding algorithms, and 4) optimization of transportation network and electric power grid.

21. Effect of Electric Vehicles on Power System Expansion and Operation

Objective: *Examine the effects of electric vehicles on electric power systems and their operation. This work includes using an existing Hawaii developed model that will be validated against a large scale utility model. The work will evaluate the benefits of optimally-timed EV charging, the requirements and costs of electric grid infrastructure to serve different types of vehicle fleets, and the effects of battery duty cycles used in the vehicle and in vehicle-to-grid applications.*

Accomplishments: This project has setup a version of the SWITCH power system model using Hawaii data. Data for the SWITCH-Hawaii version model are now available for any users who want to study integration of EVs and renewable energy in Hawaii. The SWITCH model has been used to provide technically grounded guidance to Hawaii policymakers as they make plans to meet the state's new 100% renewable electricity target by 2045. Numerous additional capabilities have been added to SWITCH that include spinning reserves; part-load heat rates; fuel markets; battery storage; modeling of arbitrary, high-complexity demand functions. Other developments have included novel techniques to represent the charging requirements and flexibility of the EV fleet, based on first principles and nationally representative transportation surveys. Profiles of business-as-usual charging and fleet flexibility are now available for other users. Additional techniques have been developed to integrate a variety of load and energy profiles efficiently into power system production cost models and capacity expansion models. Finally, the SWITCH power system model has been rewritten to eliminate any dependencies on proprietary frameworks and is now available as free and open-source software for all users. Work in the near future will compare SWITCH results with those from GE MAPS, identify duty cycles for EVs when providing hour-to-hour demand response, use data on power plant forced-outage rates to estimate the frequency and magnitude of response required from V2G systems operating in "emergency response" mode and determine second-by-second variability of the power system with large amounts of wind and solar power. The model will also provide the emergency-response, demand-response and frequency control profiles to other team members for degradation analysis.

Industry Collaboration Accomplishments

Key industry collaborations are listed as follows:

1. University of South Florida, Center for Urban Transportation Research (CUTR)—Collaboration to develop a joint project to develop recommendations, policies and guidelines for EVs in the transportation planning process. First draft of project scope has been completed. *Project 4*
2. Florida Department of Transportation—Initial meeting with FDOT senior staff members on 9/28 to explore collaborations on transportation planning and advanced vehicle technologies. *Project 4*
3. Tito Domoto, IKS USA, Inc., Manufacturer of Leaf compatible bi-directional 10 kVA power supply with energy storage – *Project 11*
4. Tom Wilke, Project Engineer, Florida Turnpike Authority. Provided Turnpike data. *Project 13*.
5. Ralph Wilder, Superintendent of Transit Maintenance, Tallahassee StarMetro Transit. Provided bus data. *Project 14*.
6. Tom Gillman, City of Tallahassee, Utility Customer Operations. Provided Tallahassee electricity rate structure. *Project 14*.
7. Sam Shartzer, Controls Engineering Manager, Proterra Electric Bus. Provided electric bus charging profiles which was used in the bus simulations. *Project 14*.
8. Russell Vare, Corporate Planning, Nissan. Provided two Nissan Leafs for EVTC lab use. *Project 15*.
9. Carlos Perez, EV Manager, and Manager, Customer Solutions Department, Hawaiian Electric Companies (HECO). *Project 17*
10. Michael Colon, Director, New Customer Initiatives, Customer Solutions Department, HECO. *Project 17*
11. Mark Yamamoto, Customer Solutions Engineering Division HECO. *Project 17*

12. Sharon Williams, Campus Planning Architect, Office of Planning and Facilities, University of Hawaii at Manoa. *Project 17*
13. Siemens – Weekly telecon on organizing students and research activities for 2016 Distribu-Tech Conference. *Project 20*
14. Texas Instruments – Monthly telecon and research collaborations on smart grid control. Project 20
15. Carnegie Mellon University, University of Kentucky – University of Central Florida led the three universities and submitted an NSF NRT proposal on resilient energy systems. *Project 20*
16. University of California at San Diego, San Diego State University, Oregon Institute of Technology, University of Texas at Dallas, and University of Hawaii at Manoa – University of Central Florida led these universities and submitted a DoE STEP proposal on smart grid education and research. *Project 20*

Education and Workforce Development Accomplishments

University of Central Florida

The UCF Department of Civil, Environmental, and Construction Engineering (CECE) offered two courses that were taught by UTC project faculty:

CCE 6938 Dynamics of Sustainable Systems: This course uses dynamic modeling as an experimental platform to study and analyze the dynamics of socio-technical problems in the engineering and construction industry. The course has two broad objectives: The first one is to learn dynamic systems approach and systems simulation as a methodology to study and understand complex, dynamic problems as they relate to sustainability. The second objective of the course is to expose the students to a variety of real dynamic problems related to civil infrastructure systems and the built environment, and how to analyze the social, economic, and environmental issues as they relate to sustainability.

CCE 5220 Sustainable Infrastructure Systems: Introduce the principles of sustainability as they relate to the built environment and infrastructure systems; sustainability metrics; life cycle assessment; resilience; green building principles; electric vehicles and green transportation.

Within the UCF Electrical Engineering Department, two new courses were offered in Spring 2015 as an undergraduate elective and an entry-level graduate courses:

EEL 5593 ECS-ECE --Distributed Control and Optimization for Smart Grid: Electric power systems, transmission and distribution networks, voltage stability and VAR control, dispatch of distributed generation, optimization, frequency control, electricity markets and incentive controls. The course will specifically address grid-to-vehicle (G2V) and vehicle-to-grid (V2G) operations and will be broadcast to eight other universities as part of a U.S. Department of Energy project at UCF.

EEL 4216 ECS-ECE -- Fundamentals of Electric Power Systems: Three-phase power representation and analysis, transformers, per unit system, symmetrical components, faults and transmission lines.

And in Fall 2015, the following five classes are to be offered:

EEL 4205 Electric Machinery: Fundamentals of DC and AC electric machines

EEL 4216 Fundamentals of Electric Power Systems: Three-phase power representation and analysis, transformers, per unit system, symmetrical components, faults, and transmission lines

EEL 4932 Global Energy Issues: The course critically examines issues associated with the technical, economic, societal, environmental, and geopolitical aspects of energy

EEL 5937 Communication and Networking for Smart Grid: Communication solutions to increase grid efficiency, reliability, and safety

EEL 6255 Advanced Power Systems Analysis: Topics to include symmetrical and unsymmetrical fault analysis, power system estimation and control and power system stability

University of Hawaii

The University of Hawaii at Manoa, College of Engineering's Department of Mechanical and Electrical Engineering will offer in the fall and spring respectively the following two courses:

ME 482 - Fall 2015: Modern Electrical Grids and Electricity Markets for 100% Renewable Energy*:* This class provides an overview of the operation of the electrical grid as well as electricity markets to provide a framework for identifying specific technical and economic challenges to maintaining grid reliability and grids that generate electricity with large amounts of renewable energy. Students will then apply their knowledge to identify and develop solutions including EV integration.

EE 635 - Spring 2016: Smart Grids and Renewable Energy Integration: This class focuses on the challenges of integrating intermittent renewable energy sources into the power system. The focus is on "smart grid" solutions and potential solutions offered by EV "smart charging".

Tuskegee University

Tuskegee University offered in Spring 2015 semester the course Physics 499-02-- *"Renewable Energy and Electric Vehicles"*. The course covers both energy sources and the interactions with electric vehicles. The course is for physics and engineering majors at senior level and first year graduate students and is done in collaboration with Alabama Power Company EV experts.

The other major educational activity was the development and procurement of laboratory equipment for a research laboratory for work on "characterization of Lithium-Ion polymer batteries by electrochemical impedance spectroscopy". Electrical impedance spectroscopy (EIS) is an indispensable tool to study the performance of batteries. EIS works on simple principle, in which a sinusoidal voltage or current is applied to the battery and its impedance is measured for a wide range of frequencies. The results are plotted and analyzed. Based on the measured value of cell impedance in the form of real and imaginary components, these values can determine (a) Electronic/ionic conduction in the electrode and electrolytes, (b) Interfacial charging either at the surface films or the double-layer and, (c) charge transfer processes and the mass transfer effects. This lab will support student research and the results will be part of the EVTC battery work reported in project #8.

Tuskegee also held its summer STEM workshop for participants from local high school and university students on July 9, 2015, and did the planning for the second Tuskegee University Electric Vehicle Transportation Center (EVTC) Day event on October 6, 2015. Detailed information on these two events is presented in the STEM Accomplishment section.

Workforce Development

As part of the STEM program and STEM presentations, staff has investigated the career opportunities as related to EVs. The EVTC has also partnered with the Central Florida Clean Cities Coalition on several workforce initiatives that have been offered in partnership with Florida workforce agencies. Part of this program is the offering of online and live electric vehicle safety training courses to first responders. These offerings include the professionally videotape of a one-day live EV safety workshop for first responders in cooperation with the Palm Beach County Florida Fire Rescue Department. This video will be available to the EVTC to use as a training tool for a wide range of audiences. The coalition is currently participating in the Argonne National Laboratory's Clean Cities University Workforce Development Program and has hired an intern that is funded by that program.

Technology Transfer Accomplishments

As previously reported, UCF and the Central Florida region have established extensive business incubator types of programs. These programs are the Innovative Corps, a NSF funded effort, the Florida Advanced Manufacturing Research Center (FAMRC) which has a targeted completion date of spring 2016 and will be used to pioneer manufacturing processes and materials designed to advance the production of smart sensors and the International Consortium for Advance Manufacturing Research (ICAMR) which is focused on smart sensors and photonics devices. EVTC is presently reviewing the U.S. EV manufacturing spectrum for manufacturing locations and technology developments. This review will also include workforce considerations. Another technology transfer effort is the upcoming EVTC Summit. Planning for the EV Transportation and Technology Summit and EV Market & Technology Workshop began in June. The summit will be offered in three days of meetings with key EV stakeholders at the Florida Solar Energy Center on October 20-22, 2015

Diversity Accomplishments

University of Central Florida

The primary components of the EVTC diversity program efforts are the STEM and K-12 activities. These efforts have grown considerably since the project began. Because of the many and diverse program activities, both UCF events are presented by activity date as follows:

1. April 11, 2015 – EnergyWhiz Expo in Alachua County, FL – Featured Junior Solar Sprint, a solar electric design competition and race – 200 participants
2. April 22, 2015 – Earth Day at Kennedy Space Center – FSEC & EVTC Exhibit – approx. 3800 attended
3. April 24, 2015 – Engineering Conference for Teachers at UCF - EVTC Information given to approximately 200 middle and high school teachers
4. April 28, 2015 – Space Congress – EVTC Information distributed to 200 Visitors
5. May 3, 2015 – EnergyWhiz at FSEC - Approximately 1100 attendees that included 4th – 12th grade students, parents, teachers and volunteers – Junior Solar Sprint 188 students participated, Hydrogen Horizon Automotive Challenge 110 high school students participated, Energy Innovations – 62 middle & high school students, Energy Transfer Machine (FKA Hydrogen Challenge) – 84 middle & high school
6. June 17 -18, 2015, FSEC education staff facilitated a hands-on electricity and hydrogen STEM lesson to a group of teachers participating in the Florida Energy Teachers Network (FETN) workshop-- Information about the EVTC program was provided to all participants
7. July 16, 2015 - Camp Connect at UCF –6 hour hands-on STEM workshop (31 minority students)
8. August 2015 – Freshmen orientation program – Discussion of EV charging research
9. September 9, 2015 – Brevard Zoo Teacher Open House – FSEC STEM exhibit handouts to 275 teachers
10. September 21, 2015 – Eastern Fl. State College pre-engineering students at FSEC – EVTC presentation, EVTC handouts & information about EVTC Summit and Workshop - 21 students
11. September 24, 2015 – STEM Solar Workshop for Teachers at FSEC, FPL sponsored, EVTC handouts about EVTC Summit were provided to 34 teachers
12. September 28, 2015 – Brevard STEM Mini-Conference, Brevard School Board, EVTC handouts about EVTC Summit were provided to approximately 200, 6-8 grade math, science and media specialists

Figure 3 - Energy Whiz at FSEC, May 2015 (Photo: FSEC)

Planning for future events were:

1. August 2015 – planning for Fall STEM teacher workshops, Outreach & FAST (Fl. Association of Science Teachers) Conference – 6 Teacher workshops scheduled through December 31, 2015
2. September 2015 – UCF Diversity Week – October 12-16, 2015
3. September 2015 – UCF STEM Day – EVTC faculty and staff will have EV exhibit and demonstrate hydrogen fuel cell technology- Expect 1300 students/teachers form Orange Co, FL on Nov. 6, 2015

Tuskegee University

The second Tuskegee University one day Electric Vehicle workshop for local high school and college students was held on July 9, 2015. The event was attended by 35 students and their teachers and was hosted by the Tuskegee College of Arts and Sciences Physics Department with participation from the Florida Solar Energy Center (Kevin Schleith) and the Alabama Department of Transportation (Michelle Ovens and Ron Johnson). The workshop focus was an outreach to the local high school students in order to encourage student interest in STEM education and careers. Using the Electric Vehicle program as a back drop, the presentations focused on STEM research and job creation in the renewable energy fields.

The day started with three presentations on solar energy and the evolving development of the electric vehicles. These presentations described solar energy, analyzed sustainable transportation and presented high paying job opportunities in the fields of roadway improvements, transportation research, and electric vehicle production and sales. The highlight of the day was a hands on demonstration, led by Dr. Chen of Tuskegee University and his physics students, showing the science applications involving electric vehicles. The use of a number of different mechanical and chemical reactions showed the audience how solar, water, and wind can produce the necessary resources to power not only cars, but also homes and businesses. This demonstration was a firsthand look at STEM in action and was enjoyed by all students in attendance (as well as the faculty). Finally, the day concluded with a question and answer period and an informal group discussion that allowed the high school students to interact one on one with faculty about opportunities at Tuskegee University.

Figure 4 - Tuskegee University One Day Electric Vehicle Workshop – July 9, 2015: Physics and engineering majors investigating solar products. *(Photo: Tuskegee University)*

Also, planning was completed for the holding of the second Tuskegee University Electric Vehicle Transportation Center (EVTC) Day event to be held on October 6, 2015. The EVTC Day event is expected to attract an audience of about 120 students and their teachers from high schools and middle schools. It is again supported by Alabama Power and the Alabama Department of Transportation for the purpose of enhancing STEM education.

Metrics

Performance metrics for the EVTC project are designed to drive improvement and characterize progress and effectiveness. The metrics performance table for PPPR#4 with evaluation criteria is provided below.

Metric	Research Activities	Industry Collaboration	Educ. & Workforce Dev.	Tech. Transfer	Diversity
Productivity	EG	EG	EG	EG	EG
Timeliness	S	S	EG	EG	EG
Quality	EG	EG	S	S	EG

NI - Needs improvement, S - Satisfactory, EG - Exceeds goals, or C - Completed.

In addition to the above metrics, a part of EVTC peer review has been the updating of every project’s Schedule F. Using these documents, the EVTC Technical team, has made its project reviews. Discussions were also held with the project PIs. Upon completion of the reviews, the written material was used to update the projects and the TRB RiP UTC Research and EVTC websites. The updated websites are to be completed in late October 2015.

What opportunities for training and professional development has the program provided?

Training and professional development activities have been provided to students, industry professionals and the public by the three partner universities. These activities have been previously presented in the Education and Workforce Development Accomplishment sections above and in the following section of results dissemination.

How have the results been disseminated?

Project results have been disseminated by presentations, publications, workshops and conferences.

Presentations:

1. Fripp, M. (June 2015) "Using Variable Pricing to Balance Demand with Variable Supply from Renewables? A Case Study of Oahu, Hawaii". Western Economic Association International, Honolulu, HI
2. Haghi, H., & Qu, Z. (July 2015). Implementing Smart Grid Optimal Operation Using Model-based Analytics. Panel presentation at 2015 IEEE PES General Meeting, Denver, CO.
3. Fenton, J. (July 2015) "PV, EV and Your Home: How Transportation and Grid Infrastructures Work Together", Presentation sponsored by the U.S. Department of Transportation, Office of the Assistant Secretary for Research and Technology Transportation Innovation Series, UTC Program.
4. Onat N.C., Kucukvar, M., Tatari, O. (July 2015). "System Dynamics Approach to Analyze the Environmental, Social, and Economic Sustainability of Transportation Systems". Big Data Analytic and Education Conference, Europe, July 30-31, Istanbul, Turkey.
5. Eshraghi, A. Ghorbani, R., (July 2015) "Islanding Detection and Transient Over Voltage Mitigation Using Wireless Sensor Networks". Poster at 2015 IEEE PES General Meeting, Denver, CO.
6. Fripp, M. (September 2015) "Benefits of Demand Response". Presentation to Hawaii policymakers on 100% RPS, Honolulu, HI
7. Ghorbani, R. (September 2015) "Electrical Vehicle Interaction at the Electrical Circuit Level" (EVTC - Project 12). Presentation to SmartGrid Corporation, Honolulu, HI.

Publications:

1. Brooker, P., & Qin, N. (2015). Identification of Potential Locations of Electric Vehicle Supply Equipment", Journal of Power Sources, Vol. 299, 76-84. *Project 8*
2. Click, D. (2015). PV and Batteries: From a Past of Remote Power to a Future of Saving the Grid. The Electrochemical Society Interface, Vol. 24, No. 1, 49-51. *Project 8.*
3. Dubarry, M., Truchot, C., Devie, A., & Liaw, B. (2015). "State-of-Charge Determination in Lithium-Ion Battery Packs Based on Two-Point Measurements in Life", Journal of Electromechanical Society, 162 (6) A877-A884. *Project 9*
4. Dubarry, M., & Devie, A. (2015). Initial Conditioning Characterization Test and Other Preliminary Testing (HNEI Pro. No. HNEI-06-15). Honolulu, HI: Hawaii Natural Energy Institute, University of Hawaii at Manoa. *Project 9*
5. Brooker, P., Qin, N., & Mohajeri, N. (2015). Fuel Cell Vehicles as Back-Up Power Options. The Electrochemical Society Interface, Vol. 24, No. 1, 57-59. *Project 10*
6. Fenton, J. (2015). PV, EV, and Your Home at Less Than $1 a Gallon. The Electrochemical Society Interface, Vol. 24, No. 1, 41-42. *Project 11*
7. Fenton, J. (2015). Home Energy Efficiency Retrofits and PV Provide Fuel for Our Cars. The Electrochemical Society Interface, Vol. 24, No. 1, 43-48. *Project 11*
8. Raustad, R. (2015). The Role of V2G in the Smart Grid of the Future. The Electrochemical Society Interface Magazine, Vol. 24, No. 1, 53-56. *Project 11.*
9. Qin, N., & Brooker, P. (2015). Numerical Analysis of Electric Bus Fast Charging Strategies for Demand Charge Reduction", submitted to Applied Energy. *Project 14*
10. McKenzie, K. (2015). The State of Electric Vehicles In Hawaii (HNEI Rep. No. HNEI-05-15). Honolulu, HI: University of Hawaii. *Project 17*
11. Onat, N., Kucukvar, M., Tatari, O., & Zheng, Q. (2015). Combined Application of Multi-Criteria Optimization and Life-Cycle Sustainability Assessment for Optimal Allocation of Alternative Passenger Vehicles in the U.S. *Journal of Cleaner Production, Elsevier. Project 18*
12. Onat, N., Kucukvar, M., & Tatari, O. (2015). Conventional, Hybrid, Plug-In Hybrid or Electric Vehicles? State-Based Comparative Carbon and Energy Footprint Analysis in the United States. *Applied Energy, Elsevier. Project 18*

13. Ercan, T., & Tatari, O. (2015). “A hybrid life cycle assessment of public transportation buses with alternative fuel options.” International Journal of Life Cycle Assessment, Springer, 20(9), 1213-1231, 2014 IF: 3.988, DOI: 10.1007/s11367-015-0927-2. *Project 18*
14. Ercan, T., Zhao, Y., & Tatari, O. (2015). Optimization of Transit Bus Fleet’s Environmental Life Cycle Assessment Impacts with Alternative Fuel Options (Accepted for publication). *Project 18*
15. Noori, M., Gardner, S., & Tatari, O. (2015). "Electric Vehicle Costs, Emissions, and Water Footprint in the United States: Development of a Regional Optimization Model", Energy, Science Direct, Elsevier. *Project 18*
16. Coffman, M., Bernstein, P., & Wee, S. (2015). Electric Vehicle Lifecycle Cost Assessment for Hawaii (HNEI Rep No. HNEI-07-15), Honolulu, HI: University of Hawaii. Project 19
17. Coffman, M., Bernstein , P., & Wee, S. (2015). Factors Affecting EV Adoption: A Literature Review and EV Forecast for Hawaii (HNEI Rep. No. HNEI-04-15). Honolulu, HI: University of Hawaii. *Project 19*
18. Hosani, M., Qu, Z., & Zeineldin, H. (2015). “A Transient Stiffness Measure for Islanding Detection of Multi-DG Systems,” IEEE Transactions on Power Delivery, Vol. 30, No. 2, 986-995. *Project 20*
19. Hosani, M., Qu, Z., & Zeineldin, H. (2015). “Scheduled Perturbation to Reduce Non-detection Zone for Low Gain Sandia Frequency Shift Method”, IEEE Transactions on Smart Grid. *Project 20*
20. Haghi, H., & Qu, Z. (2015). “Stochastic Distributed Optimization of Reactive Power Operations Using Conditional Prediction Intervals of V2G Capacity,” American Control Conference, Chicago, IL. *Project 20*
21. Harvey, R., &Qu, Z. (2015). “Cooperative Control and Networked Operation of Passivity-Short Systems,” Recent Advances and Future Directions on Adaptation and Control Workshop, Chicago, IL. *Project 20*
22. Gusrialdi, A., Qu, Z., & Simaan, M. (2015). “Game Theoretical Designs of Resilient Cooperative Systems,” European Control Conference, 699-1705, Linz, Austria. *Project 20*
23. Liu, Z., Qu, Z., Xin, H., & Gan, D. (2015). “A Distributed Solution to Real-Time Economic Dispatch Problem under Power Flow Congestion", IEEE PES General Meeting. PESGM2015-001658, Denver, CO. *Project 20*

Conferences/Workshops:

1. Electrochemical Society 227th Meeting, Chicago, IL, May 24-28, 2015. Attended by M. Dubarry.
2. Florida Department of Transportation Multimodal Transportation Planning Best Practices Workshop, Ocoee, FL, April 30-May 1, 2015. Attended by Doug Kettles.
3. Electric Drive Transportation Association, Dallas, TX, May 3-7, 2015. Attended by Colleen Kettles.
4. Florida Energy Systems Consortium Workshop, Orlando, FL, May 20-21, 2015. Attended by N. Qin.
5. Council of University Transportation Summer 2015 Meeting, Rutgers University, June 1-3, 2015. Attended by David Block and Kevin Schleith.
6. IEEE Transportation Electrification Conference, June 14-17, 2015. Attended by K. McKenzie.
7. American Control Conference, Chicago, IL, June, 2015. Attended by Zhihua Qu.
8. Recent Advances and Future Directions on Adaptation and Control Workshop, Chicago, IL, June 2015. Attended by Zhihua Qu.
9. Electric Vehicle Transportation Day, Tuskegee, AL, July 8-10, 2015. Attended by Kevin Schleith.
10. Space Coast Transportation Planning Organization, Viera, FL July 9, 2015. Attended by D. Kettles.
11. Transportation Innovation Series Forum, Department of Transportation Meeting, Washington, DC, July 14-15, 2015. Attended by James Fenton.
12. European Control Conference, Linz, Autstria, July 15-17, 2015. Attended by Zhihua Qu.
13. Hawaii Clean Energy Day, Hawaii Energy Policy Forum, July 16, 2015. Attended by R. Rocheleau.
14. USDOE’s “EV Infrastructure Corridor Development Workshop: Lessons Learned from the West Coast Experience” at the EVRoadmap 8 Conference, Portland Oregon, July 27, 2015. Attended by Doug Kettles and Colleen Kettles.

15. Electric Vehicle Roadmap 8 Conference, Portland, OR, July 27-31, 2015. Attended by Doug Kettles.
16. Big Data Analytics and Education Conference, Istanbul, Turkey, July, 2015. Attended by O. Tatari.
17. Asia Pacific Clean Energy Summit and Expo, Honolulu, HI, August 24-26, 2015. Attended by Richard Rocheleau and Katherine McKenzie.
18. Florida Department of Transportation's, "Florida Transportation Plan and Strategic Intermodal System Policy Plan meeting in Orlando, FL, August 25, 2015. Attended by Doug Kettles.
19. Modeling Hawaii's Clean Energy Future, Hawaii Clean Energy Initiative, Honolulu, HI, August 26, 2015. Attended by Richard Rocheleau, Makena Coffman, and Katherine McKenzie.
20. Space Coast Transportation and Planning Organization, Viera, FL, September 10, 2015. Attended by Doug Kettles.

What do you plan to do during the next reporting period to accomplish the goals?

The R&D program has been the primary focus. The research accomplishments for each of the 21 projects are presented in the Accomplishments Section. It is also noted that in all of the project accomplishments, future activities are presented and reference is made to these previous sections. As reported in the previous PPPRs, a detailed evaluation was conducted on all program activities and staff. The results have led to project upgrades and updates of the TRB RiP and TRID databases and EVTC website. New STEM activities are being planned.

II. Products

List of products resulting from the program during the reporting period.

The section on "How have results been disseminated?" has presented the information on results dissemination which is also applicable to this section. Thus, reference is made to the section. The other major product activity is the updated EVTC website and the TRB RiP and TRID databases. These websites and databases have been kept current with a web and data coordinator individual assigned to post all information. The EVTC web site includes a listing of the current research projects being conducted as well as educational information, technology transfer, news and events, publications, and resources applicable to the overall EVTC project. Note is also made that three EVTC Newsletters have been written and distributed by email. Additionally, senior level and graduate courses on EVs have been presented at the three partner institutions.

III. Participants & Collaborating Organizations

What organizations have been involved as partners?

The three universities of the EVTC are the University of Central Florida and the Florida Solar Energy Center**,** Civil, Environmental and Construction Engineering Department, Electrical Engineering and Computer Science Department, the University of Hawai'i at Manoa and the Hawai'i Natural Energy Institute (HNEI) and Tuskegee University.

Organizations up to this date that have supplied direct funding to the EVTC are Nissan Motors and NovaCharge which supplied equipment and funds for installation of a DC fast charging station at FSEC. General Electric Corporation completed computer analysis of Hawaii electrical grid and Alabama Power supported Tuskegee University EVTC day.

What organizations have been involved as collaborative partners?

Industry collaboration efforts have continued by all researchers. The collaborative partners are presented in the Industry Collaboration Accomplishments section.

IV. Changes/Impact

The project on federal and state highway taxes (#1) is considered completed. Due to the interest from both DOT and FLDOT a new project Automated and Connected Vehicle Implications and Analysis (#22) is being initiated. There are no other changes or problems.