Electric Vehicle Transportation Center

Semi-annual Program Progress Performance Report for
University Transportation Center

U.S. Department of Transportation
University Transportation Centers (UTC) Program Office
Office of the Assistant Secretary for Research and Technology (OST-R)
1200 New Jersey Avenue, SE
Washington, DC 20590
Federal Grant Number: DTRT13-G-UTC51

Program Director:	Dr. David Block Director Emeritus Florida Solar Energy Center block@fsec.ucf.edu 321-638-1001 321-638-1010 (Fax)
Submission Date:	**April 18, 2016**
DUN Number:	150805653
EIN Number:	59-2924021
Recipient Organization:	University of Central Florida 12201 Research Parkway, Suite 501 Orlando, FL 32816
Recipient ID Number:	20126116
Project Grant Period:	October 1, 2013 – September 30, 2018
Reporting Period End Date:	**March 31, 2016**
Report Term or Frequency:	Semi-annual PPPR#5
Report No.:	FSEC-CR-2012-16
Signature:	

University of Central Florida

Semi-annual Program Progress Performance Report #5 for

Electric Vehicle Transportation Center

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 bridges the gap between deployment of electric vehicles and the traditional transportation system.

What was accomplished under these goals?

Summary: This reporting period the EVTC authored 17 publications and 9 presentations, attended 8 workshops and conferences, held or participated in 23 STEM events, and published 2 newsletters. Researchers in Hawaii also applied for a provisional patent (Project #9).

In the research area, FDOT accepted an EVTC/CUTR transportation planning research proposal (Project #4), Li-Ion battery performance in V2G applications was disseminated as a poster presentation at the 2016 International Battery Association meeting in Nantes, France, March 2016 (Project #9), the control algorithm for workplace chargers was improved to minimize or eliminate electricity demand charges (Project #11), data was collected on the magnetic field and efficiency of a wireless charger (Project #15) and a technology assessment of automated, autonomous and connected vehicles was completed (Project #22).

Collaborative efforts for the period included engagement with Florida DOT on automated vehicles, the University of South Florida on transportation planning to accommodate EVs, the City of Orlando on their Smart Cities and V2G applications and Idaho National Lab on assessing EV impacts. In the education and STEM area, twelve courses were offered, 23 STEM and K-12 education events were held, and 84 stakeholders registered for the EVTC's EV Transportation & Technology Summit in October 2015.

Research and Development Accomplishments

The EVTC R&D agenda identified 22 projects and respective teams have been conducting detailed research. A summary of results for each project are presented in the following sections. Referral for additional details of each project is made to the EVTC website. The project results for the period include 17 new 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 reviewed existing industry and government reports detailing current and future predicted fuel tax revenues for the federal highway programs. The research indicates shortfalls attributed to more fuel efficient internal combustion engine (ICE) vehicles and to the increased cost in highway construction and repairs. Results have also presented impacts and shortfalls to highway funding as a result of EV market penetration. EV penetration, although increasing, has not yet had 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. The passage and signing by the President of the FAST Act in December 2015 has given five years of highway trust fund support. Thus, Project 1 is considered completed with the publication of the research report.[1]

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 continues to monitor developments in EV policy. Project has reviewed activities done by U. S. DOE Clean Cities Alternative Fuel Data Center and Drive Electric Florida. Drive Electric Florida is conducting an April meeting to assess legislative results and identity future opportunities. Work has also identified an excellent publication on state led alternative fuel programs. (See “State Level Alternative Fuel Vehicle Incentive Programs, Virginia Clean Cities,” May 22, 2015.)

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. A 45 kW DC fast charger was installed on the Florida Solar Energy Center (FSEC) site in January 2015 and is used for both research and public charging. DC fast chargers can significantly increase commercial electric utility bills which creates a difficult business model for public charging stations. Data showed an electric peak demand increase of 23.4 kW for this DC fast charger in February, 2015 which equates to $234. This per month utility cost is significant when energy costs are typically $1-$2 to recharge an EV. One method to reduce or eliminate the commercial demand charge associated with DC fast chargers uses a low-cost energy management system (EMS) to reduce HVAC energy use for the short period of time when DC fast chargers are active.

4. Transportation Planning for Electric Vehicle and Associated Infrastructure

Objective: *Identify and examine 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 EV transportation planning models, to develop research partnerships and to evaluate planning activities occurring in Florida and the U.S. Current models do not provide considerations for deployment of EVs and other alternatively fueled vehicles. Project activities also included establishing a research partnerships with the Florida Department of Transportation (FDOT) and the Center for Urban Transportation Research (CUTR) at the University of South Florida. The FDOT Research Center has accepted a research proposal, “Integrating Electric Vehicles into Local and Regional Planning,” from EVTC and CUTR. Work is expected to begin in July of 2016. The goals of this research project are to identify national best practices for supporting electric vehicles through land use and transportation planning, and to provide guidelines for FDOT and other transportation planners to support electric vehicle integration efforts.

Another major activity was EVTC's *EV Transportation & Technology Summit*, a three day event for key EV stakeholders held October 20-22, 2015. The Summit provided an update on the current state of EV deployment, technology and planning. EVTC also conducted the EVTC Electric Vehicle Market & Technology Workshop as part of the EV Summit. The Summit and workshop provided an opportunity for transportation planners, electric utility service providers, students and other stakeholders to learn about EV and infrastructure technologies, issues and policies. PDFs of all Summit and workshop presentations can be viewed under the "About" tab at the Summit website, http://www.evsummit.org/. Response to the Summit was very positive and planning has been initiated for a second EV Summit scheduled for October 17-20, 2016.

Figure 1. EVTC's EV Transportation & Technology Summit

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 for 2015 show EV sales of 114,022, compared to a sales of 118,773 for 2014. Cumulatively, over 400,000 EVs have been sold since 2010. The two year period of 2013 to 2015 gives a yearly EV sales growth rate of 8.6%. Slower EV sales are attributed to a significant price drop for gasoline and the resulting increased sale of conventional autos, and also to customers waiting for soon to be available new model EVs with longer ranges. The U.S. EV fleet is the largest in the world, California is the largest market with about 47% of the total. The best-selling EV is the Nissan Leaf with 89,591 vehicles followed by the Chevrolet Volt with 88,750 and third is the Tesla Model S with 63,161 vehicles sold. The U.S. market now has over 26 EV models and 12,203 charging stations giving 30,669 public outlets for charging. 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. Work on overcoming EV barriers continues at both the federal and state levels.

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 previously presented as a paper and as a computer program of life cycle costs (LCC). This model was used to complete an LCC for Hawaii[14]. Project 6 is considered complete.

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 evaluated and used data from the Regional Integrated Transportation Information System (RITIS) database. The RITIS data was then used to provide vehicle travel data on the Florida Turnpike for a transportation simulation model (See Project 13). The measured data was vehicle volume and speed information and roadway schematic drawings. This data may be seen at the project web site. Project 7 is considered complete.

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: This period, research efforts focused on the use of plug-in electric vehicles (PEVs) in vehicle-to-grid (V2G) applications. In these applications, the vehicle is used to provide energy to the grid or building through power export from the battery. This is relevant for this task given the fact that V2G applications will increase the duty cycles on the battery, and could cause premature battery failure. Identifying the potential participation in V2G by the general public will assist in identifying reasonable V2G-related duty cycles, as well as identifying methods to incentivize PEV adoption.

Table 1 lists several grid ancillary services that were considered in this study, the number of vehicles needed to meet that service, and the approximate energy transferred per vehicle.

Table 1. Grid services impacts on vehicle energy transfer

Ancillary Service	Minimum Power	Required Interval	@ 6.6 kW charge rate		@ 14.4 kW charge rate	
			# Vehicles	kWh/vehicle	# Vehicles	kWh/vehicle
Frequency regulation	1 MW (primary) 2-3 MW (secondary) 10 MW (tertiary)	0 sec – 10 min 30 sec – 30 min 30 min – 6 hr	150 300 – 450 1500	Up to 1 kWh 0.05 – 3 kWh 3 – 40 kWh	70 140 – 210 700	Up to 2 kWh 0.1 – 7 kWh 7 – 86 kWh
Peak Shaving	50-500 kW	2 – 10 hr	8 – 75	13 – 60 kWh	4 – 35	25 – 150 kWh
Load shifting	100 kW-2 MW	20 min – 1.5 hr	15 – 300	2 – 10 kWh	7 – 140	5 – 20 kWh
Back-up Power	5kW (residential) 500kW (commercial)	5 hr – 5 days	1 75	25 – 600 kWh 33 – 800 kWh	1 35	25 – 600 kWh 70 – 1700 kWh

The ability of a vehicle to participate in select V2G services will depend on several factors: its location, the battery state of charge, and the dwell time at that location. The location and average battery state of charge of vehicles were determined previously and the average dwell time of these vehicles was analyzed to determine which locations are best suited for particular V2G activities. The results indicate that frequency regulation is feasible for vehicles at home, work, shopping and social destinations.[2] However, peak shaving, load shifting and back-up power applications require longer dwell times. As such, these services are likely to only occur at home and work locations. These results were shared with the Energy Storage and Transportation Systems group at Idaho National Lab, during a site visit this quarter.

In a recently published report, figures have shown that battery costs have decreased 35% between 2014 and 2015 which represents the largest drop since 2010. (From Global Trends in Renewable Energy Investment 2016 held at the Frankfurt School, Collaborating Centre for Climate & Sustainable Energy Finance in 2016), Currently, batteries are estimated to cost around $400/kWh, with expectations that these prices will continue falling. As battery prices decline, PEV sales will increase.

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 a function of several factors, such as electrode chemistries, operating temperatures, and usage profiles (i.e. vehicle-only vs. vehicle-to-grid applications). 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 V2G and G2V strategies have on commercial battery cell lifetime.

The new University of Hawaii Battery testing laboratory includes a temperature chamber, a battery tester and commercial "18650" Li-ion cells used for the tests. A test plan that uses the "design of experiment" methodology has been finalized, the 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. Thirty-six cells were selected to perform the cycling experiment and, as of March 31^{st}, 2016, the cells have cycled the equivalent of 500 driving days. Sixteen of the remaining 74 cells were selected for the calendar aging experiment and have now aged between 40 and 45 weeks at their target temperature and state of charge. Preliminary results shows that V2G strategies seem to induce additional capacity fading whereas G2V strategies do not seem to impact cell degradation. Results of the work have been a project progress report on Cell Emulation and Preliminary Results, November 2015 and poster presentation at the 2016 International Battery Association meeting in Nantes, France, March 2016.

Dr. Matthieu Dubarry and a team of researchers at the University of Hawaii have applied for a provisional patent entitled, "Apparatus & Method for Estimating the State of Health of a Battery via Updating the OCV and SOC relationship." The patent addresses issues with accurately determining the state-of-charge as batteries begin to age.

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) vehicle technologies, and fuel station infrastructure installations. As previously stated, three reports have been completed. Activity conducted during this reporting period included exploring innovative powertrain configurations that meet domestic travel patterns, which built upon a recently published paper.[2] (reported in Task 8). This task was conducted through literature research and Autonomie® computer modeling, a Matlab based software environment and framework for automotive control system design, simulation and analysis.

11. Electric Vehicle Grid Experiments and Analysis

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

Accomplishments: The project initially concentrated on laboratory measurements from different battery types and different electric vehicle chargers. The first phase efforts concentrated on developing a building energy management system (EMS) directed toward processes to reduce peak electrical demand for an office building. The FSEC office building and FSEC's DC fast charger were selected for this analysis. Dedicated data recorders were installed to monitor facility energy use.

The project is now focused on developing a low-cost building EMS that includes workplace chargers and allows commercial building operators to minimize electric utility bills while providing a benefit to employees through free or low-cost workplace chargers. Over eight months of data have been evaluated. This data shows that workplace chargers intermittently impose a monthly demand charge on the electric utility bill. This is dependent on the time the workplace chargers are utilized. Further analysis has determined that these costs can be minimized or eliminated with a predictive control algorithm. This algorithm will be implemented while further data is collected for verification.

The second phase of the project will instrument a Princeton Power System CA-30 bi-directional EV charger in a laboratory environment. Communications will be coupled with the existing building EMS system currently used to control Level 2 EV workplace and public charging stations. The VOLTTRON™ communications platform will be used to further develop EMS control algorithms. Initial experiments will use EV batteries to shift building peak demand, offset DC fast charger operation, and develop third party (i.e., utility companies) access protocols.

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 becoming better understood. A literature review has been conducted and reports are available on the EVTC project website. 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. A novel methodology for early detection of TOVs has been developed. The research has 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 and to increase the response time and reliability of inverter-based islanding detection, thus, increasing grid reliability. A report and a conference publication are being prepared on the results of the modeling efforts.

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 step of the project was 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 that 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 and coordination among service stations and individual drivers (using V2V and V2I communication).

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. The results demonstrated that the proposed strategy results in a uniform utilization of the charging equipment at the service stations. Two peer-refereed papers on the modeling have been published. Three journal articles on scheduling EVs on the Turnpike and on micro-grid operation have been submitted[3,4,5], an additional conference paper is being prepared[6]. Thus, Project 13 is considered completed with the pending publication of these research papers.

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. Route distance and timing, charging times, and other operational characteristics of the StarMetro EB fleet were analyzed and the results were compared with the StarMetro diesel bus fleet.

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 an additional utility fee based on the peak power used during a given billing cycle, normally one month. Due to the high demand charges, a research effort was undertaken to find means to reduce these charges.

A Matlab computer model was developed to simulate the energy consumption and charging behaviors of the EBs. The model was then used to study charging times and the scheduling of the buses for charging. 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 demand reduction can be achieved by requiring the electric buses to charge when the bus state of charge is below the 60%. By simply adopting an optimized charging strategy, the demand charges can be reduced up to 45%. This research is presented in a paper currently under review by Applied Energy.

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

Activities conducted during this reporting includes editing the paper "Numerical Analysis of Electric Bus Fast Charging Strategies for Demand Charge Reduction" for re-submission to Applied Energy, the edited version is ready for resubmission.

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 completed efficiency testing of a 3.3 kW Plugless Power wireless charging station. Power monitoring of the AC input and DC output have measured the efficiency to be greater than 88% at all heights, measured from finished floor, between 145 and 205 millimeters. A peak efficiency was measured at 93.6% at a height of 190 mm.

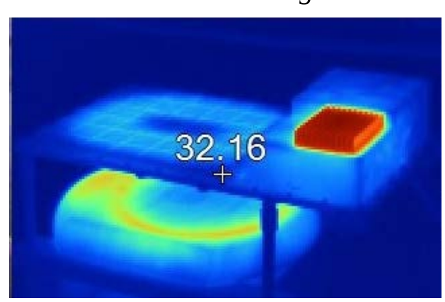

Figure 2. Thermal Imaging of Wireless Charger. Bottom: transmitter, Top: receiver (Photo: FSEC)

A Princeton Power System CA-30 bi-directional charger is ready for installation in the EV laboratory. This system is capable of charging the vehicle at up to 100 Amps at 28 kW and discharging the vehicle at up to 120 Amps at 32 kW. The DC rating is 280-500 VDC. The VOLTTRON™ open source software platform, developed and managed by the Pacific Northwest National Laboratory, will be used as the communication hub for subsequent laboratory testing of vehicle-to-grid (V2G) applications.

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. DOT, there are more that 11 million fleet cars and trucks in the U.S. 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. 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.

Ongoing project activities include the continued review of case studies and policies to evaluate the effectiveness of fleet electrification. Evaluations of the fleet electrification of taxis, transit buses, ride-sharing and other applications have been completed. A review of all applicable federal regulatory requirements has also been completed. EVTC will participate in a podium presentation on fleet electrification at the UTC Southeast Regional conference on March 31, 2016.

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: Analysis of EV integration in Hawaii has been built on high fidelity grid modeling of future Oahu renewable energy scenarios which produced quantified net petroleum and emissions savings. 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.

Figure 3. Hawaii's growing number of fast charging stations supported by the utility.

Hawaii's new Renewable Portfolio Standards (RPS) goal of 100% renewable generation by 2045 has increased the importance that EVs will play in balancing intermittent wind and solar resources on Oahu's power grids. Modeling scenarios to reach interim RPS goals were based on the utility's Power Supply Improvement Plan (PSIP). To assess future power growth in 30 years caused by EV charging, additional power loads of 5% and 10% were added to represent 122,000 and 244,000 EVs, respectively. Supplying this power by additional renewable energy will be increasingly challenging and will be addressed in future modeling. As expected, EVs in this PSIP study have lower carbon dioxide (CO_2) emissions as compared with gasoline vehicles running on E10. CO_2 emission savings for the fleet of EVs ranged from 528 up to 1,048 pounds of CO_2.

A second analysis, compared the US DOT average fuel economy for ICE passenger vehicles at 23.4 MPG and gasoline-powered hybrid vehicles at 50 MPG to EVs. These results showed that for each 23.4 MPG vehicle replaced with an EV, the net petroleum savings ranged from 197 to 224 gallons of gasoline per year which gives a savings of 8 to 18% of the total gasoline currently used on Oahu. EVs compared with 50 MPG hybrids showed the hybrids showed savings of 2 to 5% of the total gasoline currently used on Oahu.

The next phase of the EV analysis will build on grid modeling with increased wind and solar energy up to 70% renewable penetration levels, augmenting the significance of EVs in balancing these intermittent power sources.

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 first quarter of the year, the research team focused on the socio-economic and environmental implications applications of Vehicle to Grid (V2G) technology in sustainable transportation[7, 8, 9, 10, 11, 12, 13]. V2G systems are promising substitutes for traditional gas turbine generators, which are relatively inefficient and have high emissions impacts. Within this objective, three different vehicle types were studied: passenger vehicles, delivery trucks, and buses.

Passenger Vehicles: In this part of the research, the emissions savings and net revenue calculations are conducted with respect to five different Independent System Operator/Regional Transmission Organization regions. Future EV market penetration rates are predicted using an Agent-Based Model. Finally, the concept of Exploratory Modeling and Analysis is used to estimate the future net revenue and emissions savings of integrating V2G technology into the grid. The results indicate that, for a single vehicle, the net revenue of V2G services is highest for the New York region, which is approximately $42,000 per vehicle on average.

Delivery Trucks: The total cost of ownership and the life-cycle GHG emissions of electric trucks are also analyzed and compared to those of traditional diesel trucks. To account for uncertainties, possible ranges for key parameters are considered instead of only considering fixed single data values for each parameter. The results of this research indicate that providing V2G regulation services for electric trucks could yield considerable additional revenues ($20,000 to $50,000) and significant GHG emission savings (approximately 300 ton CO_2) compared to conventional diesel trucks.

Buses: Deployments of electric transit and school buses are expected to have large battery capacities, making them more feasible candidates for V2G service. The environmental benefits of using the V2G system are studied in place of traditional combustion power generation plants for the regulation services of each study region. Air emission externalities are another crucial issue for bus operations because buses are operated near highly populated areas. These externalities are also studied with the benefits of a V2G emission reduction potential taken into account. The analysis concluded that electric transit and school buses with V2G application have the potential to reduce electricity generation related GHGs by 1067 and 1420 tons of CO_2 equivalence (average), and eliminate $13,000 and $18,300 air pollution externalities (average), respectively.

Large-scale integration of wind power increases intermittency of the power grid; V2G technologies can provide ancillary services for wind energy and mitigate the fluctuation. However, the massive adoption of electric vehicles may also add burden to the grid and consume marginal electricity. The next objective is to evaluate the greenhouse gas emission savings by mitigating wind power intermittency through V2G technologies and to explore how marginal electricity generation due to EV fleet charging may weaken this environmental benefit.

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 have 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. Researchers have collected Hawaii data on vehicle adoption rates and practices as applied to Hawaii-specific vehicle ownership data. Researchers requested and received data from the Hawaii Department of Transportation on existing registered vehicles and 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. The vehicle adoption scenarios will be used to help determine impacts of EVs to Hawaii's electric sector and overall economy. To complement the Hawaii EV-adoption scenarios, lifecycle ownership costs of EVs were analyzed. The scenarios assess the impact of the federal tax credit for EVs, impacts of household solar photovoltaic and proposed time-of-use electricity rates for EV owners. Finally, a third report has been completed that estimates GHG emissions of EVs in Hawaii.[14] Comparisons are made to similar vehicles, including cost calculations for relative GHG abatement over the lifetime of a vehicle. Researchers are now working on developing and calibrating a model of Hawaii's economy and electric sector, including GHG emissions, including 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 vehicle-to-grid (G2V) charging and vehicle-to-grid (V2G) feeding development. 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. An optimization and control framework is needed to manage energy storage while using the remaining capacity of V2G to generate reactive power and cooperatively perform voltage control. This project has a very broad scope and implications. As a result of the year one to three research efforts, thirteen peer-reviewed papers were published, including seven in journals and six in international conferences. This period two reports were published[15-16].

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. The SWITCH model has been used to provide 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, and 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. 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. A presentation of these results called "Think Tech Hawaii, Getting 100% Renewables, December 2015" was presented to the Engineers and Architects of Hawaii in February 2016.

22. Automated and Connected Vehicle Implications and Analysis

Objective: *This project will evaluate the usage and implementation of automated and connected vehicles (AV/CV). The project evaluation will be done through case studies with the results being applied to determine appropriate vehicle applications and how EVs will participate in this new transportation future.*

Accomplishments: The U.S. DOT and almost every state DOT are showing extreme interest in the application of automated, autonomous and connected vehicles (ACV). This combined application can significantly reduce crashes, energy consumption, pollution and the costs of congestion which in turn will offer a disruptive change to the U.S. transportation network and system. This task has conducted an AVC study and has written a report that presents the technology assessment and the evaluation of the technologies, actions and the laws and policies that are in place. The results show the work being done by US DOT and the many states and that autonomous vehicles is the area that is receiving the most interest from the general public and the governing agencies. The report has also shown that electric vehicles will be a major participant in the new ACV transportation system.[17]

External Collaboration Accomplishments

Key collaborations are:

1. University of South Florida, Center for Urban Transportation Research (CUTR)—Collaboration to develop recommendations, policies and guidelines for EVs in the formal transportation and land use planning process. Project proposal submitted to FDOT Research Center, expect project to begin in July, 2016. (Project 4)
2. Florida Department of Transportation—Initial meeting with FDOT senior staff members on 9/28/15 to explore collaborations on transportation planning and advanced vehicle technologies. Doug Kettles, appointed to FDOT Florida Automated Vehicles Technology and Infrastructure Working Group in February, first meeting scheduled for April 2016. (Project 22)
3. City of Orlando, FL—Several EVTC and UCF staff members engaged in extensive collaboration with city administrators on their application submittal for the U.S. Department of Transportation's "Smart Cities Challenge" grant. Prepared documents and met with Charles Ramdatt, Chris Castro, and David Dunn. (Project 4)

4. GE Energy Management, Energy Consulting—Meeting with Derek Stenclik, Manager, Power Systems Strategy, monthly steering committee meetings for the HNEI-GE high fidelity grid modeling. (Project 17)
5. Hua Jin, Developing a platform to simulate the electric grid and communication, Powersim Inc., (Project 12*)*
6. Noriyasu Matsuno, Experiment on hardware platform for controlling the inverters (EV chargers), My Way Plus Inc., (Project 12*)*
7. Mark Lee, Developing smart gateway and smart measurement devices for smart electric vehicle charging stations, SmartGrid Corporation, (Project 12*)*
8. John Smart, Guest speaker at the EV Market & Technology Workshop, Cocoa, FL, Oct. 20, 2015. Idaho National Laboratory. (Project 4)
9. Tony Markel, NREL, Mark Burdge, VIA Motors, Inc., David Dunn, City of Orlando on development of a project on V2G experiments using VIA trucks. (Project 15)
10. Rocky Randels, City of Cape Canaveral, Florida. Consultation on installation of DC Fast Charge for new city hall. (Project 3)
11. Drive Electric Florida—On-going collaboration with Florida's largest and most influential EV stakeholder organization. Current emphasis is on Workplace Charging. (Project 2)
12. Clean Cities—On-going collaboration on a variety of projects and programs to support EV adoption

Education and Workforce Development Accomplishments

University of Central Florida

The UCF Department of Civil, Environmental, and Construction Engineering (CECE) offered one course that was taught by UTC project faculty:

CCE 3930H – Systems Analysis for Sustainability
Course Description: Introduction of the principles of sustainable engineering; the use of systems thinking and life-cycle thinking in understanding sustainable systems; the development of sustainability metrics; applications to sustainable transportation, energy-transportation nexus, and electric vehicles.

Within the UCF Electrical Engineering Department, five courses were offered in the fall of 2015 and three in spring 2016 as undergraduate electives and entry-level graduate courses.

Fall 2015

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

Spring 2016

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 Introduction to Smart Grid: Fundamentals of electric power systems, distributed generation and smart grid components, voltage control and VAR compensation, demand response, leader-follower optimization, resiliency.
EEL 6269 Advanced Topics in Power Engineering: Current research topics.

University of Hawaii

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

ME 610: Renewable Energy Engineering and Sustainability: This course covers the theoretical and technological background of renewable energy generation and distribution and its interactions with sustainability. Students from different disciplines are the general audience, a basic knowledge of physics, biology, dynamics and thermal science are required. The emphasis of the course is on solar, biomass, hydro, wind, wave, tidal, geothermal as well as smart grid, storage and electric vehicles. The goal of the course is to review both the scientific background and technological potential of renewable energy generation and distribution. Teamwork, communication and problem solving on class projects and discussions are required. Students may be involved in completing an industrial project on renewable energy in Hawaii.

ME 696: Innovations in Emerging Smart Electric Grid: This course covers the fundamentals of power electronics, inverters, converters, control systems, standards, and communication systems. Recent trends of patents and innovations in the field are reviewed. Students are expected to finish a major project on a specific topic. Examples of projects are given here but not limited to: control of a bi-directional charger for electric vehicles, universal Wi-Fi communication for smart building, smart appliances, and smart electric vehicle charging stations. Students can define project in consulting to the instructor.

Tuskegee University

Tuskegee has received TU Senate approval to offer the 3 credit hour course Physic 0570 --"Renewable Energy and Electric Vehicles" in the Fall 2016 and then on a regular basis every fall semester. The previous offering used a temporary course number. The course is for engineering, chemistry and physics majors.

Another major educational activity was the development and procurement of laboratory equipment for work on the characterization of Lithium-Ion polymer batteries by electrochemical impedance spectroscopy. Electrical impedance spectroscopy (EIS) is an indispensable tool to study the performance of batteries. This lab will support faculty and student lab experiments and student projects.

Workforce Development

As part of the STEM program and STEM presentations, staff has investigated career opportunities 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.

In addition, the EVTC has become a stakeholder with two of the five US DOT regional surface transportation workforce centers (TWC): Northeast TWC at the University of Vermont, and Southeast TWC at the University of Memphis. Each TWC will identify critical job needs by reviewing labor market intelligence and reaching out to stakeholders. Each center will also provide information about transportation careers, training and education, and best practices for transportation workforce development within their region. Together, the centers will contribute to a national strategy for transportation workforce development. Each center has a specific focus. The Northeast TWC focus includes climate change and alternative fuels. The Southeast TWC focus includes women in transportation and military/veteran transition to the workforce. The Northeast TWC interviewed EVTC staff member Colleen Kettles about the workforce needs of the electric vehicle industry as a result of our experience with workforce agency programs and the host agency's history of training. The Southeast TWC region covers Florida, and the EVTC will stay engaged with them as they review their draft "Job Needs and Priorities Report" recently released for our region.

Technology Transfer Accomplishments

As previously reported, UCF and the Central Florida region have established extensive business incubator style programs. These programs are: the Innovative Corps, an 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 to include workforce considerations.

Diversity Accomplishments

University of Central Florida

The primary components of the EVTC diversity program efforts are the STEM and K-12 activities. UCF events are presented by date and activity below. All professional development activities listed include information about the EVTC program and career awareness. Additionally, a major effort involving the Electrathon program (designing, building and racing electric go-carts) has been underway through collaborative efforts with the Electrathon of Tampa Bay group, the UCF EVTC Electrathon student team and the Seminole State College STEM Club.

The goal is to assess and adapt various approaches to the design and construction of Electrathon vehicles in order to develop appropriate hands-on lessons and activities that introduce electric vehicle technology and careers to high school students across a variety of platforms.

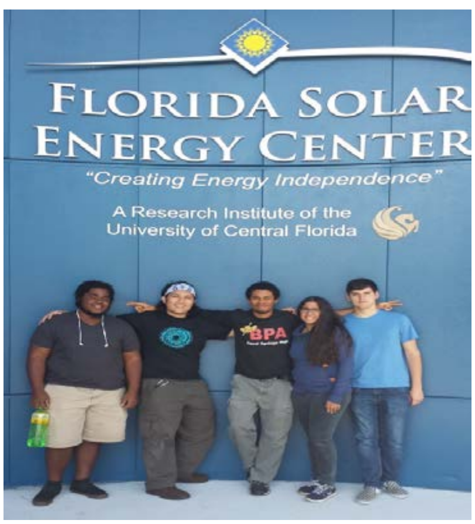

Figure 5. UCF EVTC Electrathon team

Figure 5. UCF team tests electric cart frame size

Activities include:

1. October 3, 2015 –SECME planning meeting at UCF. Orange County, FL – Featured Engineering Design – 80 participants
2. October 6, 2015 EVTC Day – Tuskegee University – Solar Electric Cars - 120 attended
3. October 9, 2015 – Melbourne Airport TechExpo
4. October 22- 24, 2015 – Florida Association of Science Teachers (FAST) Conference, Tallahassee, Florida – solar and hydrogen electric vehicle sessions – 60 attended
5. November 3, 2015 – Professional development session for 30 preservice teachers at UCF, Orlando - EVTC Information distributed

6. November 5, 2015 – Professional development session for 32 preservice teachers at UCF, Orlando, EVTC information distributed
7. November 10, 2015 – Professional development workshop for 15 teachers Solar & EV – Pasco County, FL
8. November 14, 2015 – Professional development for 50 teachers at SECME workshop at UCF
9. November 18, 2015 – EV and Solar Activities at Indian Trails Middle, Seminole County 25 students
10. January 4, 2016 – UCF students put forward plan to build Electrathon vehicle for EnergyWhiz
11. January 23, 2016 – Professional Development workshop for 12 teachers – Energy Innovations at FSEC, Cocoa, FL
12. February 6, 2016 – Professional Development Solar Workshop for 25 Teachers at FSEC, Cocoa
13. February 12, 2016 – Seminole State College STEM Club meeting/collaborate on Electrathon program.
14. February 13, 2016 – Coordinate Energy Transfer Machine competition at SECME, UCF in Orlando
15. February 18, 2016 – Provide presentation and tour for League of Women Voters group (12 attendees)
16. February 19, 2016 – Presentation on STEM & maker resources for 40 Brevard media specialists
17. February 20, 2016 – Attend Electrathon (EV event) at Engineering Expo at USF in Tampa
18. February 22, 2016 – Presentation on STEM & EVs to 30 Eastern Fl. State College students
19. March 5, 2016 – Host and coordinate Middle School Science Bowl for 85 Florida students at FSEC, Cocoa
20. March 7, 2016 – Meet with After School Program staff about training afterschool providers on energy and EV content necessary to implement specific projects with elementary students at Title one schools
21. March 8, 2016 – Meet with afterschool coordinator at Cambridge Elementary, Cocoa (Title) School - JSS
22. March 10, 2016 – Provide hands-on experience for 25 4-H students on solar and EV information at Oak Park Elementary, Titusville
23. March 17, 2016 – Presentation for Boy Scout Brevard County leaders about solar electric car (JSS & Electrathon) programs for boy scouts

Planning for future upcoming events include:

1. April 2, 2016 – Central Florida EnergyWhiz Expo – Solar Electric Cars
2. April 9, 2016 – North Florida Energy Whiz Expo – Solar Electric Cars
3. April 30, 2016 – West Central Energy Whiz Expo – Solar Electric Cars
4. April 22, 2016 – Florida Engineering Educator Conference - Hydrogen Fuel Cells
5. May 14, 2016 – EnergyWhiz at FSEC – Electrathon, Solar Electric Cars, EV demonstrations, EV exhibits and other STEM activities for students through college level.

Tuskegee University

Electric Vehicle Transportation Center (EVTC) Day, October 6, 2015 Tompkins Hall, Tuskegee University


Figure 6. October EVTC Day, presented by Tuskegee Physics Department.

Macon County School students, parents, teachers and administrators attended Tuskegee University's EVTC Day in October 2015. Special remarks were made by Tuskegee University President Brian L. Johnson and Chief of Staff Edward Brown. Academic presentations by Kevin Schleith and Susan Schleith from UCF, Danny Kings from

Alabama Power Company (APC), and Dr. Song-yul Choe from Auburn University, were included in the program; Dr. Zengjun Chen, Dr. A. Kumar, and Dr. Prakash Sharma from Tuskegee University also did presentations, along with Ms. Sarla Curry-Hillard, APC.

Tuskegee's Dean of the College of Arts and Sciences, Dr. Channa S. Prakash, also contributed to the program. Dr. Prakash C. Sharma, PI gave an overview of EVTC Project. Tuskegee University First Lady Mrs. Shemeka Barnes Johnson presented awards to elementary, middle and high school students who participated in the toy model motor making competition. Demonstrations of EV rides and renewable energy were presented by Alabama Power Company.

Spring 2016: Tuskegee University Faculty, Drs. Kumar, Sharma, Chen and physics EVTC students visited Tuskegee Middle school and Booker T. Washington High School discuss and demonstrate the importance of renewable energy sources. Students were able to get hands on experience with the models used in the demonstration.

Awards

Mr. Kumasi A. Salimu received EVTC's UTC Outstanding Student of the Year award at a banquet held in Washington D.C in January.

Mr. Davin Hicks, received second oral presentation prize for presenting his work in Alabama Academy of Science Annual Meeting held on February 18, 2016 in University of North Alabama, Florence.

Metrics

Performance metrics for the EVTC project are designed to drive improvement and characterize progress and effectiveness. The metrics performance table for PPPR#5 with evaluation criteria is provided below.

Metric	Research Activities	Industry Collaboration	Educ. & Workforce Dev.	Tech. Transfer	Diversity
Productivity	EG	S	EG	EG	EG
Timeliness	EG	S	EG	EG	EG
Quality	EG	EG	EG	EG	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 were 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. Schleith, K, “UCF EVTC Program Summary”, Tuskegee EVTC Summit, October 6, 2015.
2. Schleith, S, “EV’s, Photovoltaics and You”, Tuskegee EVTC Summit, October 6, 2015.
3. Kettles, D. EV Transportation and Technology Summit, Cocoa, FL, October 20-22, 2015. (84 registered attendees)
4. Raustad, R. “EV Charging Technology, Deployment and the Grid,” EV Technology & Transportation Summit, Cocoa, FL, October 20-22, 2015
5. Kettles, D. “EV Technology and Standards,” EV Technology & Transportation Summit, Cocoa, FL, October 20-22, 2015
6. Fenton, J. “PV, EV, and Your Home: How Transportation and Grid Infrastructure Work Together,” University of Connecticut Mechanical Engineering 2015 Seminar Series, October 2015.
7. Coffman, M. Association for the Collegiate Schools of Planning, Annual Conference, Houston, TX October 22-25, 2015.
8. Coffman, M. “Electric Vehicles and Solar PV: A Total Cost of Ownership Approach Western Regional Science Association,” Annual Conference, Kona, HI, February 14-17, 2016.
9. Kettles, D. “EV Fleets, Opportunities and Applications,” 2016 University Transportation Centers Conference for the Southeast Region, Knoxville, TN, March 2016.

Publications:

1. Schleith, K. (2015) Implications of Electric Vehicles on Gasoline Tax Revenues (FSEC Rep No. FSEC-CR-2011-15). Cocoa, FL: Florida Solar Energy Center *Project 1*
2. Brooker, P., & Qin, N. (2015). Identification of Potential Locations of Electric Vehicle Supply Equipment", Journal of Power Sources, Vol. 299, 76-84. *Project 8*
3. Gusrialdi, A., Zhihua, Q., & Simaan, M.A. (2016). “Distributed Scheduling and Cooperative Control for Charging of Electric Vehicles at Highway Service Stations," *IEEE Transactions on Intelligent Transportation Systems*, submitted. *Project 13*
4. Haghi, H., & Qu, Z. (2016). “A Stochastic Kernel-Based Predictive Model of V2G Capacity for Distributed Voltage Control and Demand Response," *IEEE Transactions on Smart Grid,* submitted. *Project 13*
5. Liu, Y., Qu, Z., Xin, H., & Gan, D. (2016). Distributed Real-Time Optimal Power Flow Control in Smart Grid," *IEEE Transactions on Power Systems*, submitted. *Project 13*
6. Gusrialdi, A., & Qu, Z. (2016). "Stability and Instability Analysis of Cooperative Systems with Time Delay: Application to Transportation Systems," Multi-Conference on Systems and Control, to be submitted. *Project 13*
7. Ercan, T., Noori, M., Zhao, Y., & Tatari, O. (2016). “On the Front Lines of a Sustainable Transportation Fleet: Applications of Vehicle-to-Grid Technology for Transit and School Buses.” *Energies, MDPI*. IF: 2.072. (Accepted) *Project 18*
8. Zhao, Y., Noori, M., & Tatari, O. (2016). “Vehicle to Grid regulation services of electric delivery trucks: Economic and environmental benefit analysis.” *Applied Energy, Elsevier,* 170(2016), 161-175, *IF: 5.261*. DOI: 10.1016/j.apenergy.2016.02.097 Feb 2016 *Project 18*
9. Onat, N., Kucukvar, M., Tatari, O., & Egilmez, G. (2016). “Integration of System Dynamics Approach towards Deepening and Broadening the Life Cycle Sustainability Assessment Framework: A Case for Electric Vehicles.” *International Journal of Life Cycle Assessment, Springer*. *IF: 4.844*, DOI: 10.1007/s11367-016-1070-4 Feb 2016 *Project 18*

10. Noori, M., Zhao, Y., Onat, N., Gardner, S., & Tatari, O. (2016). “Light-duty electric vehicles to improve the integrity of the electricity grid through vehicle-to-grid technology: Analysis of regional net revenue and emissions savings.” *Applied Energy, Elsevier*, 168(2016, 146-158, *IF: 5.261*. DOI: 10.1016/j.apenergy.2016.01.030 Jan 2016 *Project 18*
11. Ercan, T., Yang, Z., Tatari, O., & Pazour, J. (2015)." Optimization of transit bus fleet's life cycle assessment impacts with alternative fuel options." *Energy*, Elsevier. Nov 2015 Energy - *A hybrid life cycle assessment of the vehicle-to-grid application in light duty commercial fleet Project 18*
12. Onat, N. , Gumus, S., Kucukvar, M., & Tatari, O. (2016). "Application of the TOPSIS and intuitionistic fuzzy set approaches for ranking the life cycle sustainability performance of alternative vehicle technologies."*Sustainable Production and Consumption,* Elsevier. *Project 18*
13. Noori, M., & Tatari, O. (2016). "Development of an agent-based model for regional market penetration projections of electric vehicles in the United States." *Energy,* Elsevier. *Project 18*
14. 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*
15. Sarkar, R., Gusrialdi, A., & Qu, Z. (2016). "An Adaptive Restorative Method for Resilient Power Distribution Network," *2016 IEEE PES General Meeting*, 16PESGM2101, Boston MA, USA, July, 2016. *Project 20*
16. Xin, H., Liu, Y., Qu, Z., & Gan, D. (2016). “An Attack-Resilient Cooperative Control Strategy of Multiple Distributed Generators in Distribution Networks," *IEEE Transactions on Smart Grid*, to appear. *Project 20*
17. Block, D., Harrison, J., & Kettles, D. “Automated, Autonomous and Connected Vehicle Technology Assessment,” FSEC Research Report No. FSEC-CR-2020-16, March 2016. *Project 22*

Workshops/Conferences:

1. EV Market & Technology Workshop, Cocoa, FL, October 20, 215. This half-day workshop was developed and presented by Paul Brooker, and Nan Qin, with John Smart (Idaho National Labs) as a guest speaker. The PDF of the workshop presentations can be found on the EVTC website.
2. EVTC’s EV Transportation & Technology Summit -- The EV Summit was a three day event for key EV stakeholders that was held October 20-22, 2015. The Summit provided an update on the current state of EV deployment, technology and planning. The Summit and workshop provided an opportunity for transportation planners, electric utility service providers, students and other stakeholders to learn about EV and infrastructure technologies, issues and policies. Response to the Summit was very positive and planning is underway for a second EV Summit, which is scheduled for October 17-20, 2016.
3. Tuskegee University EVTC Day, Tuskegee University, October 6, 2015. Attended by Kevin Schleith and Susan Schleith
4. Florida Department of Transportation, Florida Automated Vehicles Summit, Jacksonville, FL. December 1-2, 2015. Attended by Doug Kettles and Colleen Kettles
5. University Transportation Centers Annual Business Meeting and Student Awards Ceremony, Washington, D.C. January 9-10, 2016. Attended by Dr. David Block and Doug Kettles
6. Transportation Research Board 95th Annual Meeting, Washington, D.C., January 10-14, 2016. Attended by Doug Kettles
7. 2016 University Transportation Centers Conference for the Southeast Region, Knoxville, TN, March 31-April 1, 2016. Attended by Doug Kettles
8. 2016 IEEE Transportation Electrification Conference and Expo, June 27-29, 2016, Dearborn, MI. Ms. Kathrine McKenzie organized and made assigned panel entitled “Electrified Transportation as a Power Source”. D. Block and R. Raustad helped in organizing and getting speakers.

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 22 projects are presented in the Accomplishments section. Also note 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.

Two EVTC Newsletters have been written and distributed by email during this 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 that 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. Finally, 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 partner universities of the EVTC are the University of Central Florida's Florida Solar Energy Center and UCF's Civil, Environmental and Construction Engineering, Electrical Engineering and Computer Science departments, and the University of Hawai'i at Manoa and the Hawai'i Natural Energy Institute (HNEI) and Tuskegee University.

Organizations that have supplied direct funding to the EVTC are Nissan Motors and NovaCharge, who 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 has supported four Tuskegee University EVTC days. EV Summit sponsors included, Florida Power and Light, Orlando Utilities Commission, Tampa Electric Company, Gulf Power, Charged Electric Vehicles Magazine, Delaware North Corporation (NASA/KSC) and VIA Motors.

What organizations have been involved as collaborative partners?

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

IV. Changes/Impact

Project 1 (Implications of Electric Vehicle Penetration on Federal and State Highway Revenues) is complete, as are Projects 6 (Electric Vehicle Life Cycle Cost Analysis), 7 (Assess Existing Software and Databases) and 13 (Optimal Charging Scheduler for Electric Vehicles on the Florida Turnpike). Due to the interest from DOT, the FAST Act, Beyond Traffic 2045, and FDOT, a new project Automated and Connected Vehicle Implications and Analysis (#22) has been initiated. There are no other changes or problems. A funding re-allocation request was sent to DOT in March 2016 due to re-prioritizing and ongoing evaluation of the R&D efforts. The request was approved.