EVTC
Electric Vehicle Transportation Center

Semi-annual Program Progress Performance Report for University Transportation Systems

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Program Director: Dr. David Block
Florida Solar Energy Center
block@fsec.ucf.edu
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Recipient Organization: University of Central Florida
12201 Research Parkway, Suite 501
Orlando, FL 32816

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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 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 notable events were the installation of a Nissan funded DC fast charger at FSEC (Project #3), EV sales data showing a 23% increase in sales in 2014 (#5), fuel cell mileage range extender results (#10), installation of EV chargers on the Florida Turnpike (#13), results comparing electric to diesel buses (#14), and equipment lists for battery labs in Hawaii and Tuskegee. Detailed industry interactions for the period included Nissan, NovaCharge, General Motors, Florida Power & Light, Eglin Air Force Base and Alabama and Florida DOTs. In the education and STEM area, seven new courses were developed and three STEM events were held. A special publication item was the writing and publication of six EV related articles (PV, EV and Your Home) in the March 2015 issue of "Interface" magazine of the Electrochemical Society.[1-6]

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 shown following the project title and objective (in italics). Reference for additional details of each project is made to the EVTC website at: http://evtc.fsec.ucf.edu/research/index.html. Note that the project results have produced 30 referenced publications. These 30 publications are presented by reference numbers in the R&D section with the formal citations and listing in the results dissemination section on pages 17-19.

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: Continued review of existing industry and government reports detailing EV sales and the current and future predicted fuel tax revenues for the federal highway programs. A preliminary report on EV implications on Gas Tax Revenues is being finalized and will be ready for review by FSEC staff. Additionally, current research results have been presented as a poster presentation at the Conference on Roads and Vehicles, Utah State University, February 9-10, 2015, and as a presentation at the 2015 Annual UTC Conference for the Southeast, Birmingham, AL., March 26-27, 2015.

***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: Several major developments in early 2015 will significantly alter the intended context of this analysis. On March 19th, President Obama signed an executive memorandum directing the federal government to increase its purchasing of zero-emission vehicles. The memorandum requires 50 percent of the federal fleet to be battery-electric or hydrogen vehicles by 2025. This is significant since the federal government maintains a fleet of 655,000 vehicles.

Another major development was the U.S. Postal Service's issuance of an RFI in February 2015 to begin the process of selecting a next-generation delivery vehicle. The USPS plans to replace the majority of its fleet of more than 200,000 vehicles, which includes 180,000 light-duty carrier route vehicles. As another part of President Obama' Executive Order, the U.S. Department of Energy will assist the U.S. Postal Service in evaluating and adding "the best alternative and advanced fuel technologies" for the USPS fleet.

***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.*

Accomplishments: The project output is a report on current and emerging EVSE technologies and an assessment of codes and standards, including safety standards for infrastructure, highway and vehicles.[7] The report also evaluates the barriers and challenges of deploying an expanded network of EV charging stations and makes recommendations to help standardize and expedite EVSE infrastructure deployment to support the accelerating growth of EVs. The study focuses on EVSE and the infrastructure for Battery-Electric Vehicles (BEVs) and Plug-In Hybrid Electric Vehicles (PHEVs) and the results are restricted to the standards, regulations and deployment of EVSE in the United States.

Figure 1. EV fast charger at Florida Solar Energy Center. (Charger donated by Nissan and NovaCharge)

Donation and Installation of DC Fast Charger—A significant effort on the part of the EVTC staff has resulted in the donation and installation of a DC Fast Charging station by Nissan and NovaCharge. The 50kW station is installed on Florida Solar Energy Center (FSEC) property and will be used for research and public use. The Signet Systems FC50K-CC charger has dual plugs and is equipped with both the CHAdeMO and SAE J1772 Combo connectors (one EV per charging session). The charger's location at FSEC provides the first fast-charge coastal location for PEV owners traveling between Orlando and Florida's Space Coast; including visitors to the Kennedy Space Center and Cocoa Beach.

***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: This project will identify and examine transportation infrastructure planning models and how they accommodate the deployment of Electric Vehicles (EVs) and Electric Vehicle Service Equipment (EVSE). The initial focus will be to identify existing transportation planning models and associated agencies in Florida and the EVTC partner states. Recommendations for planning and policy amendments to incorporate EVs and EVSE infrastructure will be provided. A significant contribution to planning is expected through the development of feasibility models for near-term and long-range EVSE infrastructure deployment. EV infrastructure planning feasibility models that utilize solar energy and/or energy storage as a complimentary power source will also be developed. The project will include an assessment of how transportation planning for EVSE infrastructure can support and enhance the growing acceptance of electric vehicles as a viable form of alternatively fueled transportation.

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. Provide predictions of sales through the year 2024 for the states of Florida, Hawaii, Alabama, Georgia, California and New York.*

Accomplishments: Predicted values of PEV yearly sales and cumulative sales have been presented based on 2014 data. The results for the U.S. show that the cumulative sales of EVs through 2014 are 286,390 vehicles with 118,773 sold in 2013. Depending upon the escalation rate selected, the 10 year future U.S. sales (2024) are predicted to be from 307,000 to 2.4 million per year and the cumulative vehicles on the roads would be from 2.4 to 9 million vehicles. Based on past sales, a growth rate of 20 to 25 % appears to be the most appropriate. A 20% growth rate will give U.S. sales of approximately 236,000 PEVs per year and cumulative sales of 4.0 million vehicles for 2024. 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 usage are vehicle cost, mileage between charging, perceived battery life, availability of charging stations, charging time, resale, infrastructure and public knowledge and education. State incentives and technical results from U.S. Department of Energy research are presented showing progress to overcome these barriers. (See the report at http://fsec.ucf.edu/en/publications/pdf/FSEC-CR-1996-15.pdf).

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: The project had three objectives: 1) develop a life cycle cost (LCC) model for automotive vehicles that accurately evaluates electric vehicle types, 2) allow for any user to download and use the developed LCC model, and 3) evaluate photovoltaics (PV) as a power option for electric vehicles. The most important part of the work was the LCC model that compares ownership costs, on a present value and an annual cost basis, of electric vehicles as compared to conventional internal combustion engine (ICE) vehicles for an average number of miles driven per year. The analysis uses actual cost values for 16 production vehicles all sold in the U. S. The LCC model includes the vehicle costs of purchase price with federal incentives, if any; salvage value; fuel consumption (electricity and liquid fuel); tires; insurance; maintenance; state tax; and financed interest payments. It is noted that the traction battery replacement costs for electric vehicles are difficult to ascertain, yet they are included in the analysis by replacing the batteries in the 11th year in order to investigate the battery impact on overall costs. Economic factors used in the LCC include differing rates for inflation, discount, and fuel escalation and battery degradation in the electric vehicles to account for battery energy depletion over time. The LCC is performed over a 5-, 10-, or 15-year lifetime period. For the specific case of 12,330 miles driven per year and for the selected economic factors, the LCC results show that even with higher first costs battery powered vehicles are lower in cost as compared conventional ICE vehicles. The project results were presented in a detailed report at: http://fsec.ucf.edu/en/publications/pdf/FSEC-CR-1984-14.pdf. This report was listed in PPPR#2.

7. Assess the SunGuide and STEWARD 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, outdated. An alternate Regional Integrated Transportation Information System (RITIS) database was used to provide current vehicle information on the Florida Turnpike for a transportation simulation model (See Project 13). Multiple measurement locations on the Florida Turnpike provide vehicle volume, speed, and direction which may be used as detailed input for transportation simulation models. Activities to date include review and formatting of RITIS vehicle transport data to provide inputs for a Florida Turnpike transportation model and coordination with UCF to revise vehicle transport data as needed for model development.

For purposes of transportation modeling, archived transit data for vehicle volume and speed were collected for specific locations on the Florida Turnpike. The data collected for use as input to the Florida Turnpike transportation model were organized according to zone ID and lane location. These data were initially non-chronological and required organizational post-processing. Other key metrics (e.g., vehicle volume per hour) also required post processing to calculate the desired value. Use of multiple zones on the Florida Turnpike provided a macroscopic view of vehicles traveling along this roadway. The RITIS data will be used to define these model inputs and to determine queuing information for optimally locating EV charging stations. Due to space limitations, examples of measured data, vehicle volume and speed information and roadway schematic drawings may be seen at the project web site: http://evtc.fsec.ucf.edu/research/project7.html.

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 have evaluated 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 temperature and voltage over several hundred cycles and/or several thousand hours. Research has also examined battery cost and range, the most critical technical factor to large scale EV deployment. From the U.S. Department of Energy research results, work has shown that over the past five years, the cost of batteries has dropped by 70% while the energy density has doubled. This is a result of research into novel anode and cathode electrode materials such as silicon nano-wires and high voltage electrolytes. This work will continue to advance toward the 2022 goals of $125/kWh and 400 Wh/L. Additional efforts aimed at increasing EV adoption include reducing vehicle weight through novel alloying and joining technologies, as well as reducing costs for the electric drive motor.[8]

Beyond the efforts on battery lifetimes and R&D, battery pack safety issues are being investigated. These efforts will be directed towards understanding battery pack operational safety, and how this safety may be impacted by degradation modes within the individual cells. Other considerations are chargers that may become obsolete causing concerns as to the ability of charging stations to accommodate larger battery packs, the relevance of home charging as battery capacity doubles, and other impacts due to high capacity batteries.

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: This research will determine the impact of EV use on battery life including charging cycles, G2V and V2G. To date, more than 100 papers have been reviewed. Data collection is now completed and the code necessary to easily display the results is operational. From the database, a peer–reviewed paper will be published and the database will be uploaded for easy access by any researcher online. A second literature survey was undertaken to assess the applicability of "design of experiment" methodology to electrochemical power sources testing. One important benefit of the methodology is to efficiently test the behavior of investigated systems as a function of various operating parameters while minimizing the experimental cost. Based on the survey result, the University of Hawaii is planning to use this methodology in future testing endeavors.

The experimental technology has been used to define a testing plan to assess cell degradation under electric utility grid operations.[9] The testing plan focuses on the understanding of the impact of vehicle to grid (V2G) and grid to vehicle (G2V) strategies on batteries comparable to the ones in EVs today. To fulfill these objectives, UH will devote a 40 channel battery tester for non-stop testing of the selected chemistries. In order to tackle the complexity of the number of variables to consider (charging time of day, V2G duration, G2V rate, G2V duration, temperature, SOC, etc.), the operational plan is to start the investigation with an "effect screening" design that will showcase the most instrumental factors to the battery degradation. Once complete, more complex plans will be designed to quantify the effect of the most relevant factors. Based on results, conditions to extend battery life will be identified.

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 will evaluate state-of-the-art of fuel cell (FC) vehicles technologies and current and future fuel station infrastructure roll-out for the deployment of large scale fuel cell vehicles. To date, project results are as follows:

Fuel Cell Vehicles -- Based on an analysis of over a hundred fuel cell vehicle concepts and models, the fuel cell/battery hybrid or the fuel cell/super capacitor hybrids were adopted in more models than a pure fuel cell power train. For pure fuel cell cars, the fuel cell sizes range from 80-100 kW, while for fuel cell/battery hybrid cars, the fuel cell sizes range from 20 to 100 kW. See: Qin, N., Raissi, A., & Brooker, P., (2014) Analysis of Fuel Cell Vehicle Developments (FSEC Report No. FSEC-CR-1987-14). Cocoa, FL: Florida Solar Energy Center. (Report listed in PPPR#2.)

FC as Range Extender — EVTC researchers performed modelling of a 2012 Chevy Volt with a fuel cell stack as a range extender using the FASTSim program. Modeling indicates that the fuel cell range extender significantly increases the fuel economy of the Chevy Volt. Additional range extension for a fuel cell does not result in a significant decrease in fuel economy, or a significant increase in cost. Thus, it is possible to achieve greater range more economically by utilizing a fuel cell rather than through additional batteries. Cold climate operation also benefits by the use of a fuel cell, as the waste heat from the fuel cell can be used to heat the vehicle cabin, thereby retaining battery energy for transportation.[10]

Hydrogen Fueling Stations -- The biggest obstacle to introducing fuel cell electric vehicles (FCEVs) to the market is the lack of a hydrogen fueling infrastructure. EVTC research has identified the most feasible types of hydrogen fueling stations as: 1) stations relying on hydrogen delivered via liquid hydrogen trucks, compressed hydrogen tube trailers, or pipelines and 2) stations with onsite hydrogen production from water electrolyzers or steam methane reformers. The onsite hydrogen production stations are most suitable for remote areas with smaller consumer concentration while delivered hydrogen stations are more suited for urban areas with higher demand. Smaller scale fueling stations (100-350kg/day) are likely to be installed to accommodate early markets. Larger stations with 1000+ kg/day capacity will be economically favored as more consumers adopt FCEV transportation. The hydrogen fueling station clusters with strategically placed fueling stations will serve as seeding elements to spur FCEV market growth. California is a leading state in implementing hydrogen fueling infrastructures. Sixty-eight stations are anticipated by the beginning of 2016, forty-five of which will be concentrated in the San Francisco and Los Angeles areas. The lessons learned during the station planning, building, and operation will be valuable for other states planning on constructing or expanding their hydrogen infrastructures.[11]

Continuing activities are: 1) evaluate FCEV technologies with regard to fuel cell system efficiency, range, durability, and lifespan, (2) compare the advantages and limitations of FCEVs and BEVs in different driving scenarios based on the National Household Travel survey, (3) investigate vehicle to building issues with FCEVs, and (4) model fuel cell range extender for battery electric vehicles using FastSim program.

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 measurement from different battery types and from electric vehicle chargers (type, rating, programmability). In the first phase, the task efforts have 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 has been selected for this analysis. Dedicated data recorders have been installed to monitor facility energy use. An inexpensive building management and information analysis program will be a project output.

Continued system development will couple the EMS system to the building energy profile, to the EV charging station demands, and to PV production output. These loads will then be brought together, with computers located at each of the three locations, by the EMS system that provides information to a central computer control system. The EMS system can then monitor building loads (primarily monthly peak loads) and make informed decisions on methods to reduce building peak demand for times when EVs are using the DC fast charger (3 ph., 480V, 60 amp) or other peak loads are occurring. A battery backup load reduction system is also under consideration and would be used to minimize the impact of workplace and public EV chargers on facility electric demand. An EMS control algorithm will be developed to control distributed equipment when the office building's energy use is approaching the monthly peak demand. This algorithm will attempt to limit or reduce building monthly demand by modulating or disabling other distributed resources while the building peak demand event occurs.

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: A literature review was conducted on the current state of EV charger technology, focusing on power ratings, control capabilities, embedded sensors, and international standards. The results of this study along with various categorizations of charging station standards are included in an EVTC report.[12] A literature review and report have also been completed on over-voltage mitigation at the sub circuit level of electricity grids with high photovoltaic (PV) to load ratios. 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 therefore increase grid reliability.[13]

The proposed over-voltage detection and prevention methodology is currently being verified for practicability with real data sets. A report and a journal publication will then be prepared featuring the outcomes of the modeling efforts, including EV charging, its integration into the grid at the sub circuit level, and TOV prevention. The objective is to find further potential solutions that EV charging offers while mitigating transient over-voltages at the sub circuit level and during normal operation.

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 proposed analytical model consists 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). Accordingly, a network-level protocol can be synthesized to optimize the performance (minimum waiting/charging time) of the overall system. In particular, the researchers have proposed a distributed scheduling algorithm for the overall charging network and a cooperative control algorithm for individual drivers to make their decisions. Synthetic data has been used to demonstrate effectiveness of the model and its three components.

Figure 2. EV charging on the Florida Turnpike. Photo: Doug Kettles

The Florida Turnpike network has been used as a test system for this project. Two meetings were held between the research team and Florida Turnpike engineers, and real-world data were collected and compiled from RITTS database (Project 7), and collaborative efforts are under way to use realistic data for model validation, analysis and projection of EV penetration level and its impact, and real-world application**.** Specifically, data of Florida Turnpike roadway traffic patterns will be used to study expected penetration and timing of EVs and in turn determine the requirements for electric vehicle supply equipment at turnpike plazas. The five year plan for the Turnpike has been carefully developed and is presented on the EVTC website for Project 13.

As a result of year-1 research efforts, two peer-refereed papers on the modeling have been published.[14,15] The on-going activities are to work with engineers at the Florida Turnpike Authority in identifying real-world data sets to be used for analysis and design. Upon having conducted several case studies, the researchers plan to pursue additional journal and conference publication(s).

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) are the newest addition to the alternative fuel transit bus arena. EBs use lithium batteries and electric motors as the energy storage and propulsion systems. This project will focus on the following areas: (1) Study the existing Tallahassee StarMetro five electric bus fleet. The implementing strategy, route distance and timing, charging times, fuel economy, impact of type of chargers, maintenance and operational characteristics of the electric bus will be analyzed and the results will be compared with a baseline diesel bus fleet. (2) Conduct modeling work on an electric public transportation system to determine optimized size of the electric bus fleet, routes, stop times, and charger locations in a selected city.

Figure 3. Tallahassee StarMetro bus (Proterra Bus Co.). Photo: FSEC Staff

The Tallahassee StarMetro has been operating five model EcoRideTM BE-35 battery EBs manufactured by Proterra since August 2013. These buses were equipped with Altairnano lithium titanate 72 kWh battery packs and a regenerative braking system. These EBs are fast-charged by way of a Proterra FastFill^{TM} charging station installed in designated locations in the route where the electric buses operate. The charging station is comprised of a 500 kW charger, a charger head, and a communication system. Typical charge time from 10% to 95% state of charge is about 10 minutes.

The EBs operational data such as mileages, energy consumption, electricity cost, maintenance record, and out of service causes have been collected and analyzed. The results show that between July 2013 and July 2014, the average monthly mileage for the EB and the baseline diesel buses were 980 miles and 3,495 miles, respectively. The average electricity-mileage of the electric buses was 2.5 kWh/mile, four times less than the diesel bus which was 9.6 kWh/mile. The average monthly maintenance cost for the electric buses during the July 2013 to March 2014 period was $979, which is lower than the monthly maintenance cost of the baseline diesel buses of $1,469. A simulation model was created using a MatLab/Simulink platform. The energy efficiency predicted by the model was within 6% accuracy compared to real world data. Future project activities are to use the electric bus model to optimize the routes, stops, passenger pick-up and drop-off schedule, and charging regiment to minimize the energy cost per mile, to identify secondary energy storage systems such as batteries and fuel cells to address the issues related to demand charge, and to investigate bus-to-building applications for emergency shelters.

15. Electric Vehicle and Wireless Charging Laboratory

Objective: *Furnish and equip 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 wireless chargers are evaluated.*

The EV laboratory was configured in August 2014. The laboratory has conducted experiments on an EV vehicle (presently a Nissan Leaf) electronically wired through its CHAdeMO charging port to an external electrical load with access controlled through a computer based communications network. The lab staff has also investigated wireless charging products and their respective manufacturers for developing purchase specifications. The lab is planning to purchase two EVs to be dedicated to interactions and storage experiments.

Future wireless test plans are to purchase wireless charging equipment that will be used to perform wireless experiments that include measuring system efficiency of transmitter/receiver pairs at various distances and offset. The results will document magnetic field strength according to standards and measurements. The EVTC researchers have also formed a partnership with the wireless charging research efforts at Utah State University.

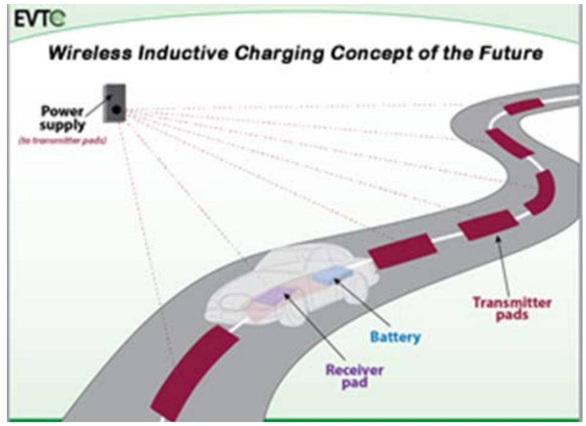

Figure 4. Wireless inductive charging concept of the future. Graphic: Shelli Keisling

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: Fleet vehicles offer an excellent opportunity for large scale deployment and resulting development of EVs. In fact, the U. S. federal government by itself could very easily be the deployment driving source. Data shows the U. S. government, including the military, operates more than 650,000 vehicles of every description. The Energy Policy Act (EPAct), and other federal statutes, require the U.S. Department of Energy to develop and manage alternative fuel programs. The goal of these programs is to reduce U.S. petroleum consumption through the use of alternative fuels, alternatively fueled vehicles and other methods.

Analysis will be conducted on the federal government fleets of the U. S. Postal Service and the U. S. Air Force in the Los Angeles, CA area. Another example of large government fleet vehicle users are state and municipal governments. In a 2008 Highway Statistics Report, the U. S. DOT stated that more than 4 million passenger cars, buses, medium and heavy-duty trucks, truck-trailers, and motorcycles were owned and operated by municipal or state fleet services. Three study examples of city governments are the Freedom Fleet in Indianapolis, IN, in partnership with Zipcar, Inc. in Houston, TX, and electric buses in Tallahassee, FL. In the commercial sector, selected case studies are UPS, Staples, and numerous rental car companies. Future 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 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: Grid-connected EVs were explored for their potential to take up the excess or "curtailed" energy when wind and solar resources exceeded the maximum that could be absorbed into the electricity grid system. This analysis was based on results from previous Hawaii Natural Energy Institute (HNEI) and General Electric International, Inc. (GE) high fidelity dispatch modeling efforts of the Oahu electricity transmission system, ("Oahu Electric Vehicle Charging Study", 2013). In order to balance the intermittent power generated by wind and solar resources, petroleum is typically used to fill the gap on Oahu. The additional petroleum use was quantified for the EV load in each future scenario.

With the current technology, it takes an especially high level of curtailed energy (23%) in the future scenario for EV mileage to exceed that of a 50 MPG gasoline-powered hybrid vehicle. Currently, EVs fueled by Oahu's electric power system achieve approximately 32 miles per gallon equivalent to gasoline (MPGe). Considering Oahu's entire passenger vehicle fleet, this represents an overall improvement of approximately 1 to 4 MPG to achieve the same gasoline savings realized by the very large fleets of EVs in these modeled future scenarios. However, significant reductions in curtailed energy can be made with operational changes to Oahu's power system, as explored in the next HNEI modeling effort with GE. Curtailment was found to range from a modest 1% to 8% with scenarios of up to 1000 MW of renewable energy (on a grid with ~ 1000 MW of demand), as summarized in the 2014 "Hawaii RPS Roadmap Study". With the scenarios modeled, Oahu can achieve delivered renewable energy approaching 34% with on-island resources. If the electric grids on the islands of Oahu and Maui are interconnected, this can increase the delivered renewable energy to 50% for both islands.

Figure 5. EVs at Hawaii charging station Photo: Katherine McKenzie

The next steps are to update estimates of the amount of curtailed energy that could be captured by strategically charging EVs, along with the impact of EV fleets on reducing petroleum imports, and a comparison with other alternate fuel vehicles and fuels. The comparison will include average and high mileage gasoline-powered vehicles, hydrogen and fuel cell vehicles. Further GE modeling is planned to fine tune past results, in order to explore and analyze the potential benefits that EVs offer. A literature review has been completed on the state of EV integration in Hawaii and the report will be posted on the EVTC website.

***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: The state specific carbon and energy footprint calculations of alternative passenger vehicles including hybrid, plug-in hybrid, and battery electric vehicles are completed. The results were submitted to the *Journal of Applied Energy*, and the manuscript was recently accepted. Additionally, a novel study quantifying social, economic, and environmental impacts of alternative vehicle technologies was recently published. As a continuation, optimum vehicle mix in the United States is estimated based on their socio-economic benefits versus environmental impacts. The trade-off among these bottom lines (macro-level economic, social, and environmental aspects) was analyzed. These results were submitted to the *Journal of Transportation Research Part A: Policy and Practice*, and the *International Journal of Cleaner production*. Both manuscripts are currently under review. In addition, other segments of alternative vehicle technologies such as commercial medium duty trucks and public buses are being analyzed. These studies aim to quantify the environmental impact reduction potentials of alternative vehicle options in these segments. Eight reports on the results are: Integrated Sustainability Model [16], Life

Cycle Assessment and Impact Model with Electricity Mix [17-21], Stochastic Cost Simulation Model for Electric Vehicles [22], and Dynamic Simulation Model of EV Adoption.[23]

Recently, a comprehensive system simulation model has been developed to assess macro-level socio-economic and environmental impacts of the U.S. transportation. This model is capable of capturing interdependencies among the system elements. This study has been submitted to the International Journal of Life Cycle Assessment. Currently, the developed model captures automobiles only. Similar models capturing other modes of transportation will be developed. Furthermore, the existing model will be improved to capture greater level of uncertainties in order to develop adaptive policies under deeply uncertain cases.

***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 examined likely levels of EV adoption based on a literature review looking at factors that affect EV adoption over time. Literature-based EV adoption rates are applied to a forecast for car ownership in Hawaii projecting to the year 2040. Factors that affect EV adoption are organized as internal and external, meaning characteristics of the EV vehicle itself and those that are out of the direct control of EV car manufacturers. Internal factors include battery costs, purchase price, driving range, and charging time. External factors include fuel prices, policy incentives, consumer characteristics, availability of charging stations, travel distance, public visibility, and vehicle diversity. The work also reviewed policy mechanisms available to support EV adoption, including subsidies and other incentives, supporting infrastructure build-up and raising awareness.

Researchers also reviewed studies that develop forecasts of EV adoption over time. Focusing on the literature for diffusion models, a set of forecasts that represent low, reference, and high EV adoption were selected. Diffusion models estimate rates of technology acceptance based on technology cost decline, marketing and other social factors. Applying these literature-based forecasts to Hawaii-specific EV and car sales data provides a preliminary forecast of potential EV adoption in Hawaii. Data are requested from the Hawaii Department of Transportation for existing registered vehicles (over a million vehicles) and the Hawaii Automobile Dealers Association. The forecast is based on growth in projected Gross State Product. 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. Further research is needed to better understand the uniqueness of Hawaii's economy and geography and how it affects EV ownership cost and likely EV adoption over time. Further work is now being done on the total cost of ownership of EVs in comparison to ICEs in Hawaii under a buy/lease scenario, as well as with the utility's existing time-of-use rates 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 electricity 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). As an 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.

This project has a very broad scope. As a result of year-1 research efforts, several peer-reviewed papers have been published or accepted for publication or submitted for publication. The subsequent efforts will be made to conduct research in the following areas in consultation with external partners: 1) develop a scalable model of large-scale EV and power grid systems, 2) investigate interactions between large-scale EVs and their power grid systems, 3) work on developing and optimizing both G2V charging and V2G feeding algorithms, and 4) working on optimizing both transportation network and electric power grid. The project team has formulated a detailed five year program of activities. The five year program is presented on the EVTC website under Project 20. Due to the year-1 efforts, seven refereed journal/conference papers were published. During this reporting period, seven additional technical papers have been prepared on power related issues. [24-30]

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: Having prepared an early working version of the SWITCH power system model for Oahu, all significant data sources have been identified and processed, and model run-time and qualitative results have been assessed. The model has been initialized with the data needed for analyzing future energy scenarios on Oahu. The model was also tested and performed as expected when the cost of fuels or access to various technologies were adjusted. The SWITCH model has been configured using Hawaii data, focusing on the datasets used to model hourly performance of potential wind and solar power systems and hourly electricity loads for non-vehicle applications. A report detailing this configuration and key datasets is in progress and will be made available on the EVTC website. Next steps will be to validate SWITCH against GE Maps, and later reports will discuss the configuration of SWITCH to match the inputs used for GE MAPS, validation of SWITCH against GE MAPS, and then the primary analysis listed above.

Industry Collaboration Accomplishments

PPPR#2 reported on nine industry collaborations. These activities are still being conducted, however, this report will concentrate on new and important collaborations which are:

1. Nissan North America, Inc. – The installation of a DC Fast Charger at FSEC was completed in December 2014. The EV fast charger was donated by Nissan and Nova Charge. The charging station was dedicated on March 20, 2015. The second Nissan project was with Russell Vare, Corporate

Planning, who has facilitated the purchase of two Nissan Leafs dedicated for EVTC lab use (March 13, 2015).

2. GM Powertrain Global Headquarters – Joseph F. Mercurio, Manager, New Business Development, GM Fuel Cell Activities at GM Headquarters, reviewed the EVTC report on using fuel cells as a range extenders for Chevy Volts. A possible demonstration project is under discussion.
3. Florida Power & Light (FPL) – Cory M. Ramsel, Director, Business Development, is partnering with FSEC on a micro-grid R&D project that uses EVs as the storage medium. A second FPL activity is a proposal from FPL to install 2 megawatts of PV at FSEC for power to include EV charging. It is noted that FPL sponsored the first ever electric Grand Prix event in downtown Miami on March 14, 2015.
4. Eglin Air Force Base – Discussions with Eglin have taken place as part of a PV, micro-grid and V2G project. Grid storage would be supplied by using up to 70 electric or plug-in vehicles as the storage media.
5. Alabama Department of Transportation – Tuskegee University has submitted a proposal on *Electric Vehicle and Vehicle Battery Technologies as Related to Alabama Department of Transportation Planning* to the Alabama DOT (March 6, 2015).
6. HEVO, Inc. – Jeremy McCool, Future Lab is working with EVTC to supply instrumentation for wireless charging stations and grid feedback.
7. Florida DOT – Telephone conferences with Darryll Dockstader, Research Center Manager at FDOT (January 7, 2015).
8. Utah State University – Discussions with faculty and cooperative efforts on wireless chargers have been initialized. EVTC faculty member has visited Utah State's wireless charging facility.
9. FleetCarma – Discussions regarding dynamic EV energy use monitoring and location tracking (February 19, 2015).

Education and Workforce Development Accomplishments

University of Central Florida

The UCF Department of Civil, Environmental, and Construction Engineering (CECE) offered the following course in the Fall 2014 semester: **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.

In the Spring 2015 semester, CECE is offering the following course that impacts sustainability and electric vehicles: **CCE 5220 --** *Green Design and Construction*. Introduction of sustainability concepts as they relate to construction design and delivery. Topics include Leadership in Energy and Environmental Design (LEED) categories, economic analysis, and integrated project management.

Within CECE, graduate students have completed specific carbon and energy footprint calculations of alternative passenger vehicles including hybrid, plug-in hybrid, and battery electric vehicles. These results have been submitted to peer publications and are presented in the results of Project 18.

Within the UCF Electrical Engineering Department, two new courses will be offered in spring 2015 as an undergraduate elective and an entry-level graduate course in electrical engineering as follows:

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.

University of Hawaii

The University of Hawaii at Manoa, College of Engineering's Department of Mechanical Engineering will offer in the spring 2015 the following two courses:

ME 492 -- *Special Topics in ME Electrochemical Power Sources Principles, Applications and Issues*. Course covers the usage of electrochemical power sources including principles, characterization, use and modeling for EV applications, fundamental knowledge on batteries, super capacitors and fuel cells.
ME 482 -- *Design Project II.* Students design and build a retrofit kit to cover conversion of an internal combustion engine (ICE) vehicle to an EV. The course covers extension of a conceptual design to final design and to a prototype. Included are analysis, materials and part selection, synthesis of working systems, computer-aided design, finite element modeling, manufacturing specifications, and shop drawings. Boeing is one of the sponsors.

The University of Hawaii System's Honolulu Community College offers an automotive technology curriculum, with hybrid and EV courses that cover basic electrical theory, wiring diagram and schematic use, and electrical system diagnosis. See http://www.honolulu.hawaii.edu/amt.

Tuskegee University

Future education and outreach activities from Tuskegee include; 1) Plans are to work with Alabama Power and Alabama Department of Transportation (AL-DOT) to enhance the STEM (Science, Technology, Engineering and Math) curriculum, education and research training on EVTC in the coming academic year (Fall 2014-Spring 2015), 2) Basic and applied research at the undergraduate level will be conducted in summer 2015, 3) The outreach activities will be continued and extended to middle schools, and 4) The summer workshop in 2015 will be organized for participants from local high school and university students.

Workforce Development

The EVTC has partnered with the Central Florida Clean Cities Coalition (CFCCC) and our regional workforce agency to provide two workforce related activities. The public safety workforce has been targeted for safety training and has been provided with opportunities for electric vehicle safety training courses, both online and live classroom sessions. As a result of this effort, the CFCCC was awarded a grant by the US Department of Energy to establish a Florida network of Alternative Fuel Vehicle Safety Training for First Responders. In addition, FSEC in conjunction with the workforce agency, has conducted surveys of the region's clean energy industry, including the clean transportation sector, to determine their employment and training needs for the near term. The results of the surveys will be used to inform the region's educational institutions about the gaps in current workforce training and post-secondary programs that cater to the clean energy industry.

Technology Transfer Accomplishments

As reported in the PPPR#2, UCF has established extensive business incubator types of programs including the new Innovative Corps NSF funded program which was attended by EVTC staff. UCF has also announced the Florida Advanced Manufacturing Research Center (FAMRC) which has a targeted completion date of spring 2016 and is part of a forward-thinking initiative led by the University of Central Florida (UCF), Osceola County, Florida High Tech Corridor Council, Orlando Economic Development Commission and Enterprise Florida. The 100,000-sq.ft. FAMRC facility being built in Osceola County will be used to pioneer manufacturing processes and materials designed to advance the production of smart sensors. An industry-led consortium, the International Consortium for Advance Manufacturing Research (ICAMR), is currently recruiting partners from industry, universities and government to utilize the facility and create the world's most advance open innovation programs and platforms focused on smart sensors and photonics devices. Another activity being planned by EVTC is to develop a program for students or other interested individuals to invent EV related projects that are then partnered with EVTC researchers.

Diversity Accomplishments

Two important components of the EVTC education activities are the development and implementation of STEM and K-12 programs.

STEM Activities

Three STEM related activities were accomplished – two at UCF and one at Tuskegee.

Figure 6. Mr. Cedric Daniels of Alabama Power provides hands-on demonstrations.

Figure 7. UCF STEM day, student discussions with two EVTC staffers.

University of Central Florida – The past year has seen an influx of EVTC-based activities that have joined the large STEM and diversity programs within UCF. One notable program was [STEM Day at UCF], held on January 30, 2015. This EVTC program featured three electric vehicles that were hosted by two very knowledgeable EVTC students who discussed the vehicles. In addition, faculty hosted a table with an Electric Vehicle Transportation Center display and student handout materials. The event also featured model solar-powered race cars that were used to stimulate student interest in science and engineering. The STEM program was located outdoors at the UCF electric vehicle charging area. More than 1,200 K-12 grade students from Orange County participated in the UCF STEM Day, with 310 students participating in the EVTC-specific activities. A second UCF event was the EVTC based one-day LEADS Scholar Academy Conference on women and EVs. This event was held on March 24, 2015.

A second UCF activity was the "Electric Vehicle Transportation STEM Day" held at the UCF Student Union on March 24, 2015. This four hour event for UCF students featured seven electric vehicle related speakers, a round table discussion, and an outdoor visit with students to the UCF charging station. The charging station provided a host for about two hours of Q & A.

Tuskegee University – The "Tuskegee University Electric Vehicle Day" was held on November 6, 2014, at the Kellogg Conference Center on the Tuskegee Campus. This event was hosted by the Tuskegee EVTC PI, Dr. Prakash Sharma and centered on over 150 students (from 3rd through 12th grade), and their teachers and parents who were invited to view and participate in daylong electric vehicle activities. The day started with lectures on electric vehicles by Mr. Keenan Kenny of Alabama Power and Mr. Thron

Crowe of the University of Central Florida/Florida Solar Energy Center. Students were informed about the history of electric vehicles, current and future technologies, charging capabilities and types of electric vehicles, both on the highways and raceways. They were also introduced to a variety of web sites that can be used to further educate themselves about electric vehicle technologies. They explored venues to participate in building and racing electric model cars.

The event concluded with a dinner hosted by Tuskegee at the Kellogg Hotel and Conference Center. Dignitary guests include the Tuskegee Provost, Dr. Cesar Fermin, the Tuskegee Dean of College and Arts, Dr. Lisa Hill, and the Superintendent of Public Schools for Macon County, Dr. Jacqueline Brooks. Also included were two keynote addresses by Mr. Cedric Daniels of Alabama Power and Mr. Kevin Schleith of the University of Central Florida.

University of Central Florida K-12 Program Activities

The EVTC program extends to the K-12 audience through the development and implementation of STEM-based curricula, professional development for teachers and public outreach events for students and their families. The EVTC is coordinating the Electrathon, a go-cart-based electric vehicle endurance race for high school and college students. Electrathon vehicles are custom, participant-designed and built, and powered by an electric motor and batteries. For more information visit: Electrathonoftampabay.org. See also UCF STEM day activities above that included K-12 students.

Metrics

Performance metrics for the EVTC project are designed to drive improvement and characterize progress and effectiveness. The metrics performance table for PPPR#3 with evaluation criteria is provided below.

Metric	Research Activities	Industry Collaboration	Educ. & Workforce Dev.	Tech. Transfer	Diversity
Productivity	EG	S	S	S	EG
Timeliness	S	S	S	S	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 and best practices was an extensive one-year project review by the EVTC Technical team. This review was started in December 2014 and took 2 months to complete. All projects were required to submit a project review covering description, past results, future plans, published results, external collaborations and suggestions for improvements. Discussions were also held with the project PIs. Upon completion of the review, the written material was used to update the projects and the TRB RiP UTC Research and EVTC websites. The updated websites were completed in March 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 section 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. Conference on Electric Roads and Vehicles, Park City, UT, February 8-11, 2015, Gas Tax results poster presented by Richard Raustad
2. University Transportation Center Conference for the Southeast Region, Birmingham, AL, March 25-27, 2015, Oral presentation by Kevin Schleith

Publications:

1. Fenton, J. (2015, Spring). PV, EV, and Your Home at Less Than $1 a Gallon. The Electrochemical Society Interface, Vol. 24, No. 1, 41-42.
2. Fenton, J. (2015, Spring). Home Energy Efficiency Retrofits and PV Provide Fuel for Our Cars. The Electrochemical Society Interface, Vol. 24, No. 1, 43-48.
3. Click, D. (2015, Spring). 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.
4. Raustad, R. (2015, Spring). The Role of V2G in the Smart Grid of the Future. The Electrochemical Society Interface Magazine, Vol. 24, No. 1, 53-56.
5. Brooker, P., Qin, N., & Mohajeri, N. (2015, Spring). Fuel Cell Vehicles as Back-Up Power Options. The Electrochemical Society Interface, Vol. 24, No. 1, 57-59.
6. Botsford, C. & Edwards, A. (2015, Spring). EV Fast Charging, an Enabling Technology. The Electrochemical Society Interface, Vol. 24, No. 1, 61-63.
7. Kettles, D. (2015). Electric Vehicle Charging Technology Analysis and Standards (FSEC Report No. FSEC-CR-1996-15). Cocoa, FL: University of Central Florida, Florida Solar Energy Center.
8. Block, D., & Harrison, J., & Brooker, P. (2015). Electric Vehicle Sales for 2014 and Future Projections (FSEC Report No. FSEC-CR-1998-15). Cocoa, FL: University of Central Florida, Florida Solar Energy Center.
9. Dubarry, M. (2015). Test Plan to Assess Electric Vehicle Cell Degradation under Electric Utility Grid Operations (FSEC Report No. HNEI-03-15). Honolulu, HI: University of Hawaii at Manoa, Hawaii Natural Energy Institute.
10. Brooker, P. (2015). Fuel Cells as Electric Vehicle Range Extenders (FSEC Report No. FSEC-CR-1995-14). Cocoa, FL: University of Central Florida, Florida Solar Energy Center.
11. Qin, N., Brooker, P., & Srinivasan, S. (2014). Hydrogen Fueling Stations Infrastructure (FSEC Report No. FSEC-RR-1986-14). Cocoa, FL: University of Central Florida, Florida Solar Energy Center.
12. Schwarzer, V., & Ghorbani, R. (2015). Current State-of-the-Art of EV Chargers (FSEC Report No. HNEI-01-15). Honolulu, HI: University of Hawaii at Manoa, Hawaii Natural Energy Institute.
13. Schwauzer, V. & Ghorbani, R. (2015). Transient Over-Voltage Mitigation and its Prevention in Secondary Distribution Networks with High PV-to-Load Ratio (FSEC Report No. HNEI-02-15). Honolulu, HI: University of Hawaii at Manoa, Hawaii Natural Energy Institute.
14. Gusrialdi, A. Qu, Z., & Simaan, M. (2014). Scheduling and Cooperative Control of Electric Vehicles' Charging at Highway Service Stations. Proceedings of the 53rd IEEE Conference on Decision and Control, USA, 6465-6471.
15. Haghi, H., & Qu, Z. (2015, July). Stochastic Distributed Optimization of Reactive Power Operations Using Conditional Prediction Intervals of V2G Capacity. To appear in the Proceedings of 2015 American Control Conference.
16. Onat, N., Kucukvar, M., & Tatari, O. (2014). Towards Life Cycle Sustainability Assessment of Alternative Passenger Vehicles. Sustainability, MDPI (Accepted for Publication).
17. Zhao, Y., Onat, N., and Tatari, O. (2015). Comprehensive Life Cycle Assessment of Electric Delivery Trucks (Working Paper).
18. Onat, N., Kucukvar, M., Tatari, O., Zheng, Q. D. (2014). 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 (Under Review).
19. Onat, N., Kucukvar, M., and Tatari, O. (2014). Electric Conventional, Hybrid, Plug-In Hybrid or Electric Vehicles? State-Based Comparative Carbon and Energy Footprint Analysis in the United States. Applied Energy, Elsevier (Under Review).

20. Ercan, T., and Tatari, O. (2015). Environmental Life Cycle Assessment of Public Transportation Buses with Alternative Fuel Options. International Journal of Life Cycle Assessment, Springer (Under Review).
21. Ercan, T., Zhao, Y. and Tatari, O. (2015). Optimization of Transit Bus Fleet's Environmental Life Cycle Assessment Impacts with Alternative Fuel Options (Working Paper).
22. Noori, M., Tatari, O. (2015). A Comprehensive Exploratory Stochastic Cost Simulation Model for Electric Vehicles (Working Paper).
23. Onat, N., and Tatari, O. (2016). Integration of System Dynamics Approach Towards Deeping the Life Cycle Sustainability Assessment Framework: A Case for Electric Vehicle Adoption (Working Paper).
24. Qu, Z., & Simaan, M. (2014, September). "Modularized Design for Cooperative Control and Plug-And-Play Operation of Networked Heterogeneous Systems," Automatica, vol. 50, no. 9, pp. 2405-2414.
25. Xin, H., Liu, Y., Qu, Z., & and Gan, D. (2014, December). "Distributed Estimation and Control for Optimal Dispatch of Photovoltaic Generations," IEEE Transactions on Energy Conversion, vol. 29, no. 4, pp. 988-996.
26. Hosani, M., Qu, Z., & Zeineldin, H. (2015, February). "Development of Current Dynamic Estimator for Islanding Detection of Inverter Based Distributed Generation," IEEE Transactions on Power Delivery, vol. 30, no. 1, pp. 428-438.
27. Hosani, M., Qu, Z., & Zeineldin, H., (2015, April). "A Transient Stiffness Measure for Islanding Detection of Multi-DG Systems," IEEE Transactions on Power Delivery, vol. 30, no. 2, pp.986-995.
28. Haghi, H., & Qu, Z. (2015, June). "Stochastic Distributed Optimization of Reactive Power Operations Using Conditional Prediction Intervals of V2G Capacity," American Control Conference, Chicago, IL.
29. Liu, Y., Qu, Z., Xin, H. & Gan, D. (2015, July). "A Distributed Solution to Real-Time Economic Dispatch Problem under Power Flow Congestion," 2015 IEEE PES General Meeting, Denver, CO.
30. Rahman, R., Liu, Y., Qu, Z., & Simaan, M. (2015). "An Integrated Optimization and Control Algorithm for Distributed Demand Responses in Smart Grid," submitted to the 54th IEEE Conference on Decision and Control, Osaka, Japan.

Conferences/Workshops:

1. Southeast Alternative Fuels Conference, Raleigh, NC, October 21-24, 2014, Attended by Doug Kettles
2. Tuskegee University Electric Vehicle Day, Tuskegee, AL, November 5-7, 2014, Attended by Kevin Schleith and Thron Crowe
3. Council of University Transportation Center Banquet and Business Meeting, Washington, DC, January 11-15, 2015, Attended by David Block, Kevin Schleith, and Thron Crowe
4. University of Central Florida Innovative Corps Kickoff Meeting, Orlando, FL, January 29, 2015, Attended by Richard Raustad
5. Florida Energy Systems Consortium Workshop, Orlando, FL, February 2-3, 2015, Attended by Richard Raustad, Doug Kettles, and William Wilson
6. Florida Utilities Coordination Committee Winter Meeting, Ocala, FL, February 4-6, 2015, Attended by Doug Kettles
7. Conference on Electric Roads and Vehicles, Park City, UT, February 8-11, 2015, Attended by Richard Raustad
8. University Transportation Center Conference for the Southeast Region, Birmingham, AL, March 25-27, 2015, Attended by Kevin Schleith
9. ESTN Fire Safety, Cocoa, FL, March 21, 2015, Attended by Richard Raustad

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 EVTC websites. 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 database. 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. The site can be accessed at http://evtc.fsec.ucf.edu.
Note is also made that the EVTC Newsletter, Volume 1, was written and sent on March 31, 2015. 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 centered on establishing partnerships in areas that have EVTC related projects. These projects and the collaborative partners are presented above and in the Industry Collaboration Accomplishments section.

IV. Changes/Impact

There are no anticipated problems or changes in the EVTC developed programs. One change has been done in the R&D program area. Projects #3 and #4 were combined into one project (#3) on charging technologies and standards. Project #4 was then established as a new project called Transportation Planning for Electric Vehicles and Associated Infrastructure.

V. Changes/Problems

There are no changes or problems.

VI. Special Reporting Requirements

New and updated reports were uploaded to DOT's RiP and TRID databases. Project reporting is also published on the EVTC website.