U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Technology Integration

2019 Annual Progress Report

Vehicle Technologies Office

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Disclaimer

Acknowledgements

We would like to acknowledge the principal investigators and their teams from industry, academia, the national laboratories, and Clean Cities coalitions who prepared the project abstracts. In addition, we would like to thank the project managers at the National Energy Technology Laboratory for their continuing support in administering these projects.

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Acronyms

ACFC	Alabama Clean Fuels Coalition
ADAS	Advanced Driver Assistance Systems
AEO	Arkansas Energy Office
AFLEET Tool	Alternative Fuel Life-Cycle Environmental and Economic Transportation Tool
AFPR	Alternative Fuel Price Report
AFV	alternative fuel vehicle
AHJ	authority having jurisdiction
API	application programming interface
ATRI	American Transportation Research Institute
AV	autonomous vehicle
AVTC	Advanced Vehicle Technology Competition
BMS	Behavioral Micro-simulation
BMV	Bureau of Motor Vehicles
BTD	Bellevue Transportation Department
CACC	Chicago Area Clean Cities
CARB	California Air Resources Board
CARTA	Chattanooga Area Regional Transportation Authority
CATT Lab	Center for Advanced Transportation Technology Laboratory
CAV	Connected and Automated Vehicles
CC-G	Clean Cities - Georgia
CH2	compressed hydrogen
CMU	Carnegie Mellon University
CNG	compressed natural gas
CSU	Colorado State University
CTE	Center for Transportation and the Environment
CTS	Contract Transportation Services
CVEF	Clean Vehicle Education Foundation

CVLZ	Commercial Vehicle Loading Zone
DC	direct current
DCFC	direct current fast charger
DLI	Deterministic Linear Interpolation
DNL	Dynamic Network Loading
DOE	Department of Energy
DOT	Department of Transportation
EEL	energy efficient logistics
EEMS	energy efficient mobility systems
EERE	Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EISA	Energy Independence and Security Act of 2007
ELM	Electric Last Mile
EPA	Environmental Protection Agency
EPAct	Energy Policy Act of 1992
ERAU	Embry Riddle Aeronautical University
EV	electric vehicle
EVI-Pro	Electric Vehicle Infrastructure Projection
EVSE	electric vehicle supply equipment
FAST Act	Fixing America's Surface Transportation Act
FEI	Fuel Economy Information
FHWA	Federal Highway Administration
FOA	Funding Opportunity Announcement
FTG	Freight Trip Generation
FY	fiscal year
GAS	GPS Analysis Software
GHG	greenhouse gas
GIS	Geographic Information System

GLACC	Greater Lansing Area Clean Cities
GM	General Motors
GPS	Global Positioning System
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation
GT	Georgia Tech
GTI	Gas Technology Institute
H2	hydrogen
HDV	heavy duty vehicle
HEV	hybrid-electric vehicle
ICC	International Code Council
IDI	in-depth interview
IEEE	Institute of Electrical and Electronics Engineers
INCOG	Indian Nations Council of Governments
INL	Idaho National Laboratory
IO	Input-Output
IoT	Internet of Things
ITEM	Integrated Transport-Energy Model
KPI	Key performance indicator
kWh	kilowatt-hour
L2	level 2
LDV	light duty vehicle
LNG	liquefied natural gas
LPG	liquefied petroleum gas (propane)
M2M	Michigan to Montana
MaaS	Mobility as a Service
MAC	McMaster University
MAC-POST	Mobility Data Analytics Center – Prediction, Optimization and Simulation Toolkit
MEC	Metropolitan Energy Center

MEP	Mobility Energy Productivity
MMDUE	Multi-modal Dynamic User Equilibrium
MORPC	Mid-Ohio Regional Planning Commission
MOVES	Motor Vehicle Emission Simulator
MPG	miles per gallon
mph	miles per hour
MPO	metropolitan planning organization
MSU	Mississippi State University
MWCOG	Metropolitan Washington Council of Governments
MY	model year
NAICS	North American Industry Classification System
NASEO	National Association of State Energy Officials
NFPA	National Fire Protection Association
NGV	natural gas vehicle
NHTSA	National Highway Traffic Safety Administration
NOx	oxides of nitrogen
NREL	National Renewable Energy Laboratory
NTEA	National Truck Equipment Association
NYC	New York City
OEM	original equipment manufacturer
OHD	Off-Hour Deliveries
ORNL	Oak Ridge National Laboratory
OSU	Ohio State University
PBOT	Portland Bureau of Transportation
pdf	portable document format
PEV	plug-in electric vehicle
PHEV	plug-in hybrid electric vehicle
PNNL	Pacific Northwest National Laboratory

PSCFC	Palmetto State Clean Fuels Coalition
PY	project year
QoS	quality of service
R&D	research and development
RPC	Regional Planning Commission
RFP	request for proposals
RITIS	Regional Integrated Transportation Information System
RPI	Rensselaer Polytechnic Institute
SAE	Society of Automotive Engineers
SCL	Seattle City Light
SCOS	Smart Columbus Operating System
SDOT	Seattle Department of Transportation
SEAFDP	Southeast Alternative Fuel Deployment Program
SSCS	South Shore Clean Cities
TCO	total cost of ownership
TEAD	Transportation Energy Analytics Dashboard
TIC	Technologist in Cities
TNC	Transportation Network Company
TRB	Transportation Research Board
TRS	Technical Response Service
UA	University of Alabama
UCCC	Utah Clean Cities Coalition
UFL	Urban Freight Lab
UMD	University of Maryland
UPS	United Parcel Service
USU	Utah State University
UT	University of Tennessee, Knoxville
UU	University of Utah

UW	University of Washington
UWAFT	University of Waterloo Alternative Fuels Team
VT	Virginia Tech
VTO	Vehicle Technologies Office
VW	Volkswagen
WCC	Wisconsin Clean Cities
WVU	West Virginia University
WWCC	Western Washington Clean Cities

Executive Summary

The 2019 Technology Integration Annual Progress Report covers 30 multi-year projects funded by the Vehicle Technologies Office. The report includes information on 23 competitively awarded projects, ranging from safety training and design for maintenance facilities housing gaseous fuel vehicles, to electric vehicle community partner programs, to truck platooning with advanced driver assistance systems. It also includes seven projects conducted by several of VTO's National Laboratory partners, Argonne National Laboratory, Oak Ridge National Laboratory and the National Renewable Energy Laboratory. These projects range from a Technical Assistance project for business, industry, government and individuals, to the EcoCar Advanced Vehicle Technology Competition, and the Fuel Economy Information Project.

The projects involve partnerships between private industry, the public sector and, in many cases, non-profit organizations, and incorporate an educational component designed to enable the sharing of best practices and lessons learned. Data collected from these projects is used to inform the future direction of VTO-funded research.

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Vehicle Technologies Office Overview

Vehicles move our national economy. Annually, vehicles transport 11 billion tons of freight—about $35 billion worth of goods each day[1]—and move people more than 3 trillion vehicle-miles.[2] Growing our economy requires transportation and transportation requires energy. The transportation sector accounts for approximately 30% of total U.S. energy needs[3] and 70% of U.S. petroleum consumption.[4] The average U.S. household spends over 15% of its total family expenditures on transportation, making it the most expensive spending category after housing.[5]

The Vehicle Technologies Office (VTO) has a comprehensive portfolio of early-stage research to enable industry to accelerate the development and widespread use of a variety of promising sustainable transportation technologies. The research pathways focus on fuel diversification, vehicle efficiency, energy storage, and mobility energy productivity that can improve the overall energy efficiency and efficacy of the transportation or mobility system. VTO leverages the unique capabilities and world-class expertise of the National Laboratory system to develop innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures; and energy efficient mobility systems.

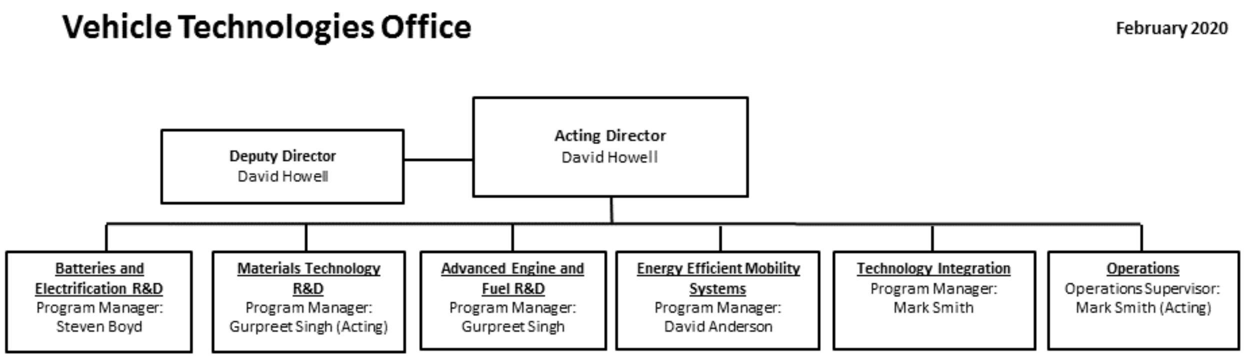
VTO is uniquely positioned to address early-stage challenges due to strategic public-private research partnerships with industry (e.g. U.S. DRIVE, 21st Century Truck Partnership) that leverage relevant expertise. These partnerships prevent duplication of effort, focus DOE research on critical R&D barriers, and accelerate progress. VTO focuses on research that industry does not have the technical capability to undertake on its own, usually due to a high degree of scientific or technical uncertainty, or that is too far from market realization to merit industry resources.

Annual Progress Report

As shown in the organization chart (below), VTO is organized by technology area: Batteries & Electrification R&D, Materials Technologies, Advanced Engine & Fuel R&D, Energy Efficient Mobility Systems, Technology Integration, and Analysis. Each year, VTO's technology areas prepare an Annual Progress Report (APR) that details progress and accomplishments during the fiscal year. VTO is pleased to submit this APR for Fiscal Year (FY) 2019. In this APR, each project active during FY 2019 describes work conducted in support of VTO's mission. Individual project descriptions in this APR detail funding, objectives, approach, results, and conclusions during FY 2019.

[1] Bureau of Transportation Statistics, Department of Transportation, Transportation Statistics Annual Report 2018, Table 4-1. https://www.bts.gov/tsar.
[2] Transportation Energy Data Book 37th Edition, Oak Ridge National Laboratory (ORNL), 2019. Table 3.8 Shares of Highway Vehicle-Miles Traveled by Vehicle Type, 1970-2017.
[3] Ibid. Table 2.1. U.S. Consumption of Total Energy by End-use Sector, 1950-2018.
[4] Ibid. Table 1.12. U.S. Transportation Petroleum Use as a Percent of U.S. Petroleum Production, 2018.
[5] Ibid. Table 10.1, Average Annual Expenditures of Households by Income, 2016.

Organization Chart



Technology Integration Program Overview

Introduction

VTO's Technology Integration Program supports a broad technology portfolio that includes alternative fuels, energy efficient mobility systems and technologies, and other efficient advanced technologies that can reduce transportation energy costs for businesses and consumers. The program provides objective, unbiased data and real-world lessons learned to inform future research needs and support local decision making. It also includes projects to disseminate data, information, and insight, as well as online tools and technology assistance to cities and regions working to implement alternative fuels and energy efficient mobility technologies and systems.

Goals

The Technology Integration Program's goals are to strengthen national security through fuel diversity and the use of domestic fuel sources, reduce transportation energy costs for businesses and consumers, and enable energy resiliency with affordable alternatives to conventional fuels that may face unusually high demand in emergency situations.

Program Organization Matrix

The Technology Integration Program's activities can be broken out into several distinct areas:

Technology Integration Tools and Resources

- The Alternative Fuels Data Center provides information, data and tools to help transportation decision makers find ways to reduce cost and improve energy efficiency.
- FuelEconomy.gov provides access to general information, widgets to help car buyers, and comprehensive fuel economy data.
- Energy Efficient Mobility Systems (EEMS) envisions an affordable, efficient, safe, and accessible transportation future in which mobility is decoupled from energy consumption.
- The Clean Cities Coalition Network supports the nation's energy and economic security by building partnerships to advance affordable, domestic transportation fuels and technologies. The Technology Integration Program assists this network of nearly 100 coalitions nationwide through its tools and resources.

Advanced Vehicle Technology Competitions

For more than 25 years, the Vehicle Technologies Office has sponsored advanced vehicle technology competitions (AVTCs) in partnership with the North American auto industry to educate and develop the next generation of automotive engineers. VTO's advanced vehicle technology competitions provide hands-on, real-world experience, and focus on science, technology, engineering, and math, to support the development of a workforce trained in advanced vehicle technologies.

Launched in 2018, the EcoCAR Mobility Challenge is the latest iteration of the advanced vehicle technology competitions. The EcoCAR Mobility Challenge challenges 12 teams from North American universities to redesign the Chevrolet Blazer, by integrating advanced propulsion systems to enable significant improvements in energy efficiency, while deploying connected and automated vehicle technologies, to meet Mobility as a Service market need.

These teams are tasked to incorporate innovative ideas, solve complex engineering challenges, and apply the latest cutting-edge technologies. Teams have four years (2018-2022) to harness those ideas into the ultimate energy-efficient, high performance vehicle. The Blazer will keep its familiar body design, while student teams develop and integrate energy innovations that maximize performance, while retaining the safety and high consumer standards of the Blazer.

Alternative Fuels Regulatory Activity

The Alternative Fuels Regulatory activity provides technical and analytical support for the implementation of federal legislation related to the deployment of alternative fuels and fuel-efficient fleet vehicles. Relevant legislation includes the Energy Policy Act (EPAct) of 1992, EPAct 2005, the Energy Conservation Reauthorization Act of 1998, the Energy Independence and Security Act (EISA) of 2007, and other amendments to EPAct.

EPAct regulated fleets include State & Alternative Fuel Provider Fleets and Federal Fleets (managed by the Federal Energy Management Program).

I Alternative Fuel Vehicle Initiatives

I.1 Northwest Electric Showcase Project (Forth, formerly Drive Oregon)

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Start Date: October 1, 2016 End Date: October 1, 2019
Project Funding: $2,290,240 DOE share: $993,450 Non-DOE share: $1,296,790

Project Introduction

Forth is a non-profit with the mission of advancing electric, smart and shared transportation in the Pacific Northwest and beyond, through innovation, demonstration projects, advocacy and engagement. The Northwest Electric Showcase Project sought to transform the market for plug-in electric vehicles (PEVs) in the Pacific Northwest from early adoption to early mainstream, putting Oregon and Washington on a sustainable path to increasing PEV sales more than tenfold, to at least 15% of all new cars sold by 2025. Forth led this effort through the creation of a physical vehicle showcase, mobile "pop up" showcases, and a "virtual" showcase online, as well as targeted multimedia outreach campaigns. The project also built a sustainable long-term model, which continues beyond the project period.

Objectives

The key project objective was to double PEV adoption rates in the Pacific Northwest by 2019, which translates to annual sales of 9,000 PEVs per year in Washington and 5,500 per year in Oregon. This would equate to total PEV sales of 33,000 in the two states over the three-year grant performance period. Secondary objectives included securing at least 5 million consumer impressions through direct interaction and marketing campaigns; potential PEV purchasers completing at least 5,000 test drives; at least 5,000 consumers subscribing to project emails; at least 12 new Northwest fleets taking the West Coast Electric Fleets pledge; and Forth securing at least $750,000 in cash or in-kind contributions to the Showcase Project over the project period.

Approach

The Showcase Project deployed a number of innovative tactics to engage consumers and drive PEV adoption. These included development of an electric vehicle showroom; long-term test drives facilitated through car sharing; mobile "pop-up" showcases; and focused programs and targeted campaigns aimed at low and moderate-income drivers. Forth developed a multimedia campaign in conjunction with Brink Communications that focused on well-defined market segments and used social media to generate traffic to the physical showcase.

A key project component was the coordination and staging of numerous ride and drive events throughout Oregon and Washington. Forth worked directly with a variety of community stakeholders, leveraging their relationships and expertise, to engage local consumers in cities around the Pacific Northwest. The region's electric utilities have been especially receptive to collaboration, and the project has emphasized working with them to communicate the benefits of PEVs to their customers. Other partners in the ride and drives included regional Clean Cities coalitions and electric vehicle owners' groups. While some utilities have well-defined transportation electrification plans, many do not; Forth's aim was to support any partner who was willing to participate, regardless of how new they were to these concepts.

Putting the Showcase Together

During the Northwest Electric Showcase application process, Forth (then Drive Oregon) was able to secure over 30 letters of support from various organizations across the Pacific Northwest. In addition to these commitments of support, Portland General Electric facilitated Forth securing the future site of the Showcase at 1 World Trade Center in downtown Portland.

Upon award of the grant, a short Request for Proposals was issued, and Brink Communications and Vizworks were chosen as the firms that would design and construct the Showcase. The design included installing several different charging units, also known as electric vehicle supply equipment (EVSE), for visitors to view and handle. In seeking EVSE unit displays for the showcase, Forth relied upon existing relationships with PEV manufacturers. The EVSE display also educates consumers about the benefits of 'smart,' network-enabled EVSE units. All of the EVSE were donated to the project.

Other elements of the Showcase design included a light up display of an unbranded BMW i3 to illustrate battery size and regenerative brakes; lettering on the walls describing levels of charging; a PlugShare display; and the EV DriveFinder, a fun survey that asks drivers about their car needs and recommends a new or used PEV based on their inputs. [1]

Staffing and Initial Reception

The Go Forth Electric Showcase opened in May 2017 with one full-time Program Manager and 2 part-time Program Associates. Using resources and allocations from other funding sources, Forth has been able to hire 11 additional full-time employees, and 2 part-time. Roughly half of these new hires regularly work at the Showcase, with other employees expected to do one shift there each quarter. The additional staff has allowed Forth to participate in more ride and drives and events at the Showcase.

Displays

The Showcase provided a number of rotating displays of various forms of new electric mobility, and tools for that mobility. Local bike stores loaned us a variety of electric bikes (e-bikes), including a collapsible model. We also had Zero electric motorcycles, which garnered a lot of attention from passersby; the electric Trikke, an interesting unit that mimicked skiing; and the Silver Eagle, a commercial e-bike with a cargo carriage.

Another display that received a lot of attention was the Chargeway beacon. Chargeway is a mobile app to locate EVSE using a system of colors and numbers instead of technical plug types, so that users don't get confused by energy levels or plug names.

As an additional service to the community, Forth installed a real-time public transportation display on a wall of the Showcase in the summer of 2019. This screen is visible from the outdoor sidewalk at all times.

Fleet

When the Showcase first opened there were three vehicles for visitors to test drive: a 2017 Chevy Bolt, a 2014 Nissan Leaf, and a 2017 Ford C-Max. Forth acquired a 2017 Chevy Volt a few months after opening. All four of these vehicles were purchased and financed by Forth. At that time, manufacturers were not yet willing to loan vehicles to the Showcase, but this quickly changed. In the winter of 2017, Forth received an all-electric

2017 Honda Clarity, and soon after a 2018 BMW i3. In 2018, Forth acquired a 2019 Toyota Prius Prime and a 2019 Mitsubishi Outlander. All of these later acquisitions were loans from the respective manufacturers.

Turo

To encourage consumers who need extra time in a car, Forth listed several of its fleet vehicles on the crowd-sourced car rental platform Turo. This peer-to-peer car share program allows vehicles to be rented for up to two days at a time and allows a consumer to make a road trip, and otherwise experience living with a PEV. Many Showcase visitors expressed interest in this program and the potential to test a car on their own for an extended period. The Turo platform requires no hardware to be installed, allows the vehicle rental rate to be set by the car owner, and provides insurance for the vehicle in exchange for a portion of the rental revenue. High quality images were also provided courtesy of a Turo hired photographer.

One initial difficulty with Turo was that drivers wanted to pick up and drop off the vehicles at times when the Showcase was not open and no Forth employee was able to meet them. We were able to improve upon this issue in January of 2019 with the hiring of several additional Program Associates, two of whom were dedicated to Turo rentals. Since then there has been a large increase in the number of rentals.

Results

Test Drives

From the beginning, Forth has believed that direct consumer experience is key to significantly increasing PEV sales. Economic and environmental cases can be made to consumers, but the experience of actually driving a PEV goes far in convincing potential PEV owners that driving electric is very feasible with their lifestyles.

The Northwest Electric Showcase project initially set a goal of giving 5,000 test drives over the 3-year grant period. By the end of October 2019, Forth had facilitated 1,687 test drives. Notably, the Showcase logged over 6,000 visitors in that same time period. In hindsight, there were several contributing factors to not reaching the test drive goal.

- Location: The Go Forth Electric Showcase is located on a highly visible street corner in Downtown Portland. Most of the foot traffic, however, is from office workers during the week, without time to test drive. Initially, visitors to the Showcase were not sure of its purpose. Seeing the fleet vehicles with Forth branding, they often assumed we were a car sharing organization, thus involving some kind of payment. This situation was improved by putting lettering on our windows which read “Learn about Electric & Smart Mobility here.”
- Parking: Downtown Portland is also notorious for having difficult parking with expensive, and often aggressive, parking enforcement. At times, Forth was able to offer parking garage vouchers to test drivers, offsetting the cost.
- Construction and Traffic: A month after opening the Showcase, construction began on an entire city block behind the Showcase. This particular construction involved extensive demolition and street closures. Many Portlanders do not drive Downtown, and many choose to use public transportation regardless of any construction, but this particular project, combined with large, newly available fleets of scooters and other types of micromobility, unfortunately discouraged potential would-be test drivers. They did not want to focus on learning the features of a vehicle while navigating other distractions.

Ride and Drives

As part of the Northwest Electric Showcase project, Forth participated in over 60 ride and drives throughout Oregon and Washington: 11 in 2017, 18 in 2018 and 32 in 2019. Ride and drives have typically relied on one or more community partners, often a utility, and whenever possible we have tried to engage nearby dealerships. The most successful events have encompassed multiple partners, a variety of dealerships, and the local city as well. The City of Seattle National Drive Electric Event is a good example of this. Forth collaborated with Western Washington Clean Cities, the City of Seattle, and the Seattle Electric Vehicle Owners Group to pull off an event that attracted more than 1000 consumers.

In addition, Forth also partnered with local organizations to host ride and drives for their employees and customers. Forth relied heavily on utility partners to co-host existing local events that would attract foot traffic and maximize marketing dollars. The locations of the venues varied, from public parks and farmer's markets to classic car shows.

The Forth team provided planning and onsite support staff and fleet vehicles for test drives. There were some challenges in getting participation from local car dealerships to provide test drive vehicles and navigating service territories, so it was extremely important for the Forth team to have its own vehicles available. The attendees were requesting information regarding available models, charging options and available state and federal incentives. Most attendees were in the process or committed to buying a PEV as their next car. Overall, the project partners saw great value in hosting ride and drive events and were eager to participate in planning future events.

Funding from the U.S. Department of Energy (DOE) enabled the Showcase to both purchase vehicles and foster relationships with manufacturers who subsequently loaned us vehicles, enabling Forth to gain lucrative ride and drive contracts with PG&E and Pacific Power. Proceeds from these contracts will help fund the Showcase in subsequent years.

Electric Scooters

In the summer of 2018 electric scooters (e-scooters) made their debut on the streets of Portland. Several e-scooter companies received permits from the Portland Bureau of Transportation (PBOT) for a pilot program lasting seven months. Survey results from PBOT that were released the following month indicated that 70% of the e-scooter riders in Portland had never ridden a bicycle before - which is perhaps an indicator of why there were a large number of e-scooter accidents. When permits were renewed in 2019, e-scooter companies were required to provide some form of education for riders, and for this they turned to Forth. The Showcase has now had 5 e-scooter safety workshops paid for by various e-scooter companies. This service has now been requested by other cities through Forth's work with the American Cities Climate Challenge.

Conclusions

Northwest Electric Showcase achieved its overall mission of providing a physical, brand-neutral Showcase where over 6,000 visitors came to learn about electric vehicles in a sales-free environment. Through Forth's adaptive management style, goals of the project were met, evolved, and were exceeded.

References

1. EV DriveFinder, https://forthmobility.org/drive-finder

I.2 Safety Training and Design, Permitting and Operational Guidance for Garage Facilities Maintaining and Parking Natural Gas, Propane and Hydrogen Vehicles (Marathon Technical Services USA, Inc.)

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Start Date: September 1, 2016 End Date: August 31, 2019
Project Funding: $940,912 DOE share: $750,000 Non-DOE share: $190,912

Project Introduction

This project is focused on vehicle maintenance and storage facilities for gaseous fuel vehicles. The gaseous fuel types include compressed natural gas (CNG), liquefied natural gas (LNG), liquefied petroleum gas (propane or LPG) and compressed hydrogen (CH_2).

Design codes for stations that dispense gaseous fuels are mature and provide relatively clear, understandable, and constructible standards; however, this is not the case with the codes that are commonly referenced for design and upgrade of vehicle maintenance and storage garages. There are gaps and discrepancies between codes, resulting in facilities that are either unsafe or over-designed and prohibitively expensive. This weakness in code guidance results in a heavy dependence on local engineering judgment and limited knowledge of best practices. Often, consultants hired by maintenance facility or garage owners have little or no experience with facilities designed for gaseous fuel vehicles, so implementation issues persist. Similarly, local code officials may have little firsthand experience with designing facilities for gaseous fuel vehicles and may be uncomfortable reviewing and approving plans related to these projects.

There is a current lack of easily understood and applied facility design resources. Lay people and even code officials need a reference document and training to assist them in understanding what is the best industry practice to provide safe upgrades to facilities, why these upgrades are done, and how upgrades may differ depending on regions and fleet types.

Objectives

The objective of this project is to provide safety training and guidance related to garage facility upgrades and building modifications that will support the use of commercially available natural gas, propane, and hydrogen alternative fuel vehicles (AFVs), as defined by the Energy Policy Act of 1992 (EPAct).

There have been several efforts to alleviate problems in interpreting codes that apply to gaseous fuel facilities, and to support the dissemination of best practices. These efforts have included a code review and summary by the Clean Vehicle Education Foundation (CVEF) and the publication of project case studies in trade magazines. Technical training that is focused on end users and code officials is also available, from Marathon

Technical Services USA, Inc. (Marathon), and others. While these efforts have been beneficial, there is a need for a more evolved and widely promoted program to organize and disseminate this information. There is limited benefit to simple regurgitation of current code requirements. Instead, this project provides a more interactive and hands on approach to interpreting codes, by way of picture rich manuals, classroom instruction, case studies of various facilities and on-line instruction, to guide fleets and safety officials through current and future gaseous fuel facility development.

This project is focused on facility owners, consulting engineers, fire marshals and code officials, to increase their general knowledge of gaseous fuel risks, which differ from conventional fuel risks; raise stakeholder awareness of code requirements; and provide a wide variety of case studies for various gaseous fuels in differing climates and fleet types. This approach provides practical knowledge and industry experience for stakeholders with no first-hand experience with gaseous fuels.

Overall, the goal of this project is to enhance the safety of gaseous fuel vehicle garages, while controlling the cost of facility upgrades. The project will address perceived and real problems of gaseous fuel safety and affordability.

Approach

For this project, Marathon has teamed with Clean Fuels Ohio and seven other Clean Cities coalition partners: Kansas City Regional Clean Cities, Long Beach Clean Cities, Sacramento Clean Cities, Tucson Clean Cities, Virginia Clean Cities, Clean Communities of Western New York (Buffalo), and Western Washington Clean Cities (Seattle). These partners provided the local connections, knowledge and support to identify and interact with fleets, and to support the local training sessions that were completed in year two.

As planned in the first year and extending into the second year, the training manuals were developed in-house then subjected to a peer review and a beta trial, with subsequent edits and a final outside polishing of the four training manuals before use in the remaining training sessions. The final product consists of one easy-to-read manual for each fuel type that provides users with the background theoretical and code knowledge to understand why upgrades are required, how the upgrades add safety, which upgrades are code mandated and which are best practice, and why certain new operating procedures have been implemented. Manuals also include fuel specific case studies.

In the second year, the team finalized the development of training materials and successfully completed approximately half of the classroom training sessions, with strong reviews by attendees. The remaining training sessions were completed early in the third year. Marathon continued to execute the plan developed in the first year and added coverage of additional fuels to three of the local training sessions, to address local demand.

These training manuals are the basis for the on-site training sessions that took place over 15 days in the cities represented by our Clean Cities partners. These training sessions included classroom time supported by tours of selected local garages that showcase best practice upgrades and operating procedures. Ohio and New York were selected as the locations for the beta training, due to the proximity to core team members.

In year three of this three-year project, training and best practice materials were converted to an online narrated webinar format that is available on-demand in module format from the project website.

It should be noted that DOE awarded two projects under this Funding Opportunity Announcement (FOA) topic, one being managed by Marathon Technical Services and one managed by the Gas Technology Institute (GTI). Although the overall goals, objectives, and approaches are somewhat similar, they have formed different teams of subject matter experts and will be focusing on different geographic regions for their training workshops and site tours. However, Marathon and GTI are actively collaborating to share technical information and coordinate workshop scheduling and site tours, to avoid overlap and duplication and to assure consistency with regard to technical content and recommended best practices for facility upgrades.

Results

The team has completed its original plan and met its goals.

Marathon has invested significant time to author and produce training materials that are interesting, well-illustrated and useful to personnel from a wide variety of backgrounds. These materials were peer reviewed by several industry experts, then published as beta versions that were used in the Ohio and New York training sessions in June 2018. Based on further user and expert feedback, the manuals were edited again for content, as well as grammar and spelling. In the midst of this effort, three of the major reference codes were revised to 2018 versions that introduced significant changes to the code treatment of these projects; this required a significant rewrite to update the manuals.

Clean Fuels Ohio located and contracted with a graphic arts company to assist in polishing the edited manuals to a final professional state – resulting in the four training manuals that are listed in the publications section below. Marathon produced the manuals in a format that will allow us to easily and inexpensively perform further revisions to address future code or best practice changes.

Clean Fuels Ohio also created a website, SafeGasGarage.com, which will continue to operate for the near future as a resource, to allow users to download pdf manuals and to view the webinar training modules.

By the end of fiscal year (FY) 2018, Marathon had completed 7 of 15 total days of training and the remaining classroom training sessions were completed in the first quarter of FY 2019. Marathon developed a two-page course evaluation that students completed in class at the end of each training session. This evaluation system consists of a “poor” to “excellent” scale that allows attendees to rate and comment on all aspects of the training, including registration, the training facility, food, training materials, the trainer, the sponsor presentation, the tour(s) and what could be improved. Scores recorded have generally been in the “above average” to “excellent” range, with the lowest scores being “average”. Marathon and Clean Fuels Ohio have converted these evaluations into a 5-point numerical scale; the average score was typically greater than 4.5.

It was the team’s goal to provide training and food at no cost to all attendees, to minimize barriers to users interested in attending. One element in this effort was the use of sponsors who paid for breakfast, coffee and lunch. These sponsors were then given an opportunity to provide a presentation of their goods and services to the attendees. Sponsors were typically gas detection manufacturers, contractors or consultants, all of whom brought their own gaseous fuel garage upgrade knowledge and experience to the attendees. Marathon found that having different voices describing their approaches was beneficial to the attendees.

Conclusions

This project has now been completed. The list below summarizes our findings. In addition, we have noted challenges that the project team identified and addressed along the way.

- The project achieved its initial goals. The team adapted the schedule to shift more training to the fall of calendar year 2018 to address delays experienced in FY 2017. Other than the shift in training schedule, the approach and project schedule originally proposed were applied.
- Marathon and Clean Fuels Ohio developed a “new from the ground up” training manual for each of the four fuels. This manual was written as a training manual rather than a technical paper and is rich in pictures and diagrams to explain concepts and applications. The training materials were very well-received by attendees at the training sessions, as noted by comments and scores taken from the training evaluations.
- As noted in previous years’ reports, Marathon encountered strong support for this program from government fleets, but private fleets were less open to hosting tours of their facilities, citing protection of trade secrets as the primary concern. This being the case, Marathon built the training and tours plan around primarily public fleets that continue to be very receptive and welcoming to this initiative.

- At the outset of this project, the team expected that there would be an abundance of existing CNG garage upgrades, and this indeed proved to be the case. Additionally, there has been a transition in the industry away from LNG in transit and garbage fleets, and even in the day-tractor Class 8 truck fleets, so there was a very limited number of LNG garages available for study. Marathon located a new garage built for LNG in the Seattle area, so the training for that city was expanded to include LNG, bringing the total number of LNG training sessions to three.

- Hydrogen fleets are still few, so the team knew that it would be a challenge to locate a significant facility that was already upgraded for hydrogen; however, the team located one such facility and promoted this training session nationally, and not just regionally. Marathon received significant feedback from the California partners that they needed more training in hydrogen garages due to the push locally toward hydrogen as a transportation fuel. Although code sources differ, hydrogen and CNG upgrades are very similar, so Marathon was able to add hydrogen to the two California CNG/LNG training sessions, which helped to increase the number of attendees.

- LPG garages are plentiful; however, these garages have consistently had no LPG-specific upgrades, although several garages had LPG-specific operating procedures. There was interest in LPG training, but typically at a lower level than for CNG. Marathon has adapted to this by promoting the LPG training as providing a strong background for training for conventional fuels, since the code requirements are the same. Having a compliant conventional fuel garage is a positive first step when upgrading for other fuels.

- The manuals and presentation materials used in years two and three were converted to narrated, modular training webinars to simulate the classroom experience while allowing users to consume the material at their own pace in the location of their choice. These webinars are available from the project specific website, SafeGasGarage.com, as links to a private YouTube channel.

Key Publications

The published documentation for this project was completed in beta form in the second quarter and in final form in the fourth quarter of FY 2018, timed to coincide with the beta training in June and regular training sessions in the fall of calendar year 2018. The published documentation is distributed electronically in pdf form to training session attendees in advance of each training session, and will be posted to the project website SafeGasGarage.com in December 2018, after the final training session. The training manuals include:

1. Adams, Rob, September, 2018. Compressed Natural Gas (CNG) Vehicle Maintenance and Storage Garage Modifications: Requirements and Best Practices.

2. Adams, Rob, September, 2018. Liquefied Natural Gas (LNG) Vehicle Maintenance and Storage Garage Modifications: Requirements and Best Practices.

3. Adams, Rob, September, 2018. Gaseous Hydrogen (GH_2) Vehicle Maintenance and Storage Garage Modifications: Requirements and Best Practices.

4. Adams, Rob, September, 2018. Liquefied Petroleum Gas (LPG, LP-Gas or Propane) Vehicle Maintenance and Storage Garage Modifications: Requirements and Best Practices.

5. Adams, Rob, September, 2019. YouTube training webinar modules addressing the four gaseous fuels for Vehicle Maintenance and Storage Garage Modifications: Requirements and Best Practices.

I.3 Training For Cost-Effective, Code-Compliant, Maintenance Facilities for Gaseous Fuel Vehicles (Gas Technology Institute)

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Start Date: October 1, 2016 End Date: September 30, 2019
Project Funding: $834,782 DOE share: $749,965 Non-DOE share: $84,817

Project Introduction

As the commercial introduction of alternative fuel vehicles continues to grow, and businesses consider investing in large fleets of alternative fuel vehicles, the capital cost and regulatory requirements of needed modifications to maintenance facilities can influence a company's decision and timeframe to purchase alternative fuel vehicles.

Up to now, the alternative fuel vehicle industry stakeholders have largely focused their efforts on the development and deployment of certified vehicles and fueling infrastructure. As a result, the fleet owners and operators have had to rely upon internal staff and consultants as they search for best practices and determine applicable code requirements for designing upgrades to maintenance facilities for these vehicles. All designs for new or upgraded maintenance facilities for alternative fuel vehicles ultimately have to be approved by the local authority having jurisdiction (AHJ). This can be a difficult and time-consuming process, as the codes are performance documents, with little design guidance. The codes also use language and phrasing that may require expert interpretation to properly evaluate and remedy any potentially hazardous conditions and associated risks.

Additionally, many engineering and design firms are inexperienced with requirements and best practices for maintenance facilities that service alternative fuel vehicles. This can lead to designs that are overly conservative and result in unnecessarily high construction costs to modify or build a maintenance facility. Due to a lack of knowledge regarding safe practices for facilities servicing vehicles operated on gaseous fuels, some AHJs may go as far as to deny construction permits for these upgrades.

Objectives

The objective of this project is to present guidance and cost-effective, practical solutions to facility owners, AHJs, designers, fire officials, and other stakeholders, that will facilitate the permitting of maintenance or repair facilities for alternative fuel vehicles. This will be done by describing how codes are interpreted and applied in "real world" cases. The project team will develop guidance documents that include an explanation of the intent of the code committee that drafted the language, so that the requirements resulting from the codes may be appropriately and cost-effectively incorporated into the design of maintenance facilities.

Approach

The project accomplished these objectives through the use of multiple outreach and training activities and resources that include on-site training seminars, facility tours of code-compliant maintenance garages, best practices reports, and a dedicated website. This project covered three gaseous fuels currently being used in heavy duty vehicles: natural gas, hydrogen, and propane. It also included the preparation of in-depth reports on applicable codes and standards for maintenance facilities that service alternative fuel vehicles operated on each of these fuels. Each report addressed issues with current or proposed codes and included best practices that a facility can implement to be "code-compliant".

For on-site training, the project team developed and presented materials at workshops at locations across the United States that are at the forefront of alternative fuel vehicle deployment. The workshops included a half-day classroom session to review applicable codes and compliance strategies, and a half-day tour of an upgraded "code-compliant" maintenance facility. The reports, workshop materials, and educational tools are available to the public on a dedicated website developed for the project. Gas Technology Institute (GTI) worked with project partners and fuels subject matter experts Clean Energy (natural gas), Frontier Energy (hydrogen) and Superior Energy Systems (propane). To maximize outreach impact, the workshops were planned and coordinated with involvement from representatives of local Department of Energy (DOE) Clean Cities coalitions.

It is noteworthy that DOE awarded two projects under the Funding Opportunity Announcement (FOA) topic. One award was managed by Marathon Technical Services and the one for this project was managed by GTI. While the overall goals, objectives, and approaches were somewhat similar, they formed different teams of subject matter experts and focused on different geographic regions for their training workshops and site tours. Nevertheless, Marathon and GTI collaborated to share technical information and coordinate workshop scheduling and site tours. This collaboration avoided overlap and duplication of effort and provided for consistency with regard to the technical content of reports dealing with codes and recommended best practices for facility upgrades.

Results

During the first year of the project (FY 2018), GTI met with industry experts, garage owners, and safety officials to gather information on the key technical areas that present issues for fleet owners during garage upgrades. The team of subject matter experts aided GTI during development of in-depth reports on code compliance for natural gas, hydrogen, and propane. These reports cover both current and recent versions of the following codes from the International Code Council (ICC) and the National Fire Protection Association (NFPA):

- International Fire Code
- NFPA 30A: Code for Motor Fuel Dispensing Facilities and Repair Garages
- NFPA 2: Hydrogen Technologies Code
- NFPA 58: Liquefied Petroleum Gas Code

Key topic areas discussed in these reports include gas detection, ventilation, electrical classification compliance, heating devices, alarm system configuration, and the behavior of lighter-than-air fuels.

Through conversations and visits with industry experts, equipment suppliers, design firms, and garage owners, GTI collected industry best practices, and incorporated key findings into a series of reports and workshop training material specific to each of the three gaseous fuels. These best practices represent methods and strategies that can be implemented to cost-effectively meet the code requirements by incorporating proven techniques and equipment. By reducing uncertainty and complexity of designs, it is reasonable to expect that this will result in lower capital and operating costs for facility upgrades. These best practices reports have been written as standalone resources to provide the reader with a quick introduction to individual topic areas.

During FY 2018, GTI's education team also designed a workshop structure that would encourage presentation of material in different formats to encourage participation by attendees. The education team helped develop consistent presentation of the key issues for maintenance garage modification in simple, easy to understand language. Topics (e.g., codes) that are important to one audience segment (e.g., AHJ) may not necessarily be relevant to or of interest to another (garage managers). The education team's contributions led to the definition of learning tools and strategies that cater to a broad audience. GTI's education team conducted early information-sharing with the Chicago Area Clean Cities Coalition and worked with other Clean Cities coalitions in the cities where the remaining workshops were held.

GTI also worked with web and graphic designers at Frontier Energy to allow public access to the developed educational materials and online resources via the project's dedicated website. [1] All of the reports, best practices, and workshop presentation material made available during the first year were uploaded to the website. Additionally, the team began design of a graphic model. This graphic model presents a digitized image of a typical garage and provides information about the key issues of facility modification via a rollover feature.

In December 2018, Fleet Maintenance Magazine published an article highlighting some of the requirements in establishing a fleet maintenance facility for NGVs. Team members from GTI were interviewed and quoted in the article, and DOE's involvement was highlighted. (Wartgow, Gregg 2018: pages 34-37).

During FY 2018, GTI and project partners conducted four workshops: Chicago, Emeryville (California Bay Area), Los Angeles, and Pittsburgh. All workshops included a natural gas educational module. The Emeryville workshop also included the hydrogen module, and the Pittsburgh workshop included the propane module. All of the workshops included a morning of classroom education, lunch, and then a tour of an upgraded facility.

During FY 2019, the project team organized and conducted an additional four workshops, for a total of eight, as described below:

GTI and Clean Energy performed the fifth workshop at the NTEA Work Truck Show in Indianapolis, March 5-8, 2019. (Figure I.3.1). The session began with NGV America's panel on "Five Ways Natural Gas Can Advance Your Fleet Goals". A project team member from Clean Energy presented on maintenance facilities. Representatives from GTI and Clean Energy then conducted a workshop on alternative fuel maintenance garages.

Figure I.3-1 NTEA Work Truck Show

GTI and Clean Energy performed the sixth workshop at the HD Repair Forum held April 2-3, 2019 in Dallas-Fort Worth, TX (Figure I.3.2). There were over 300 attendees at the forum and the presentation was given on the main stage. The attendees were executives from all of the industry stakeholders, including insurance companies, Original Equipment Manufacturers, collision repairers, dealerships, independent appraisal firms, parts providers, tool and equipment manufacturers, national training organizations, and vocational education schools.

Figure I.3-2 Workshop Attendees at HD Repair Forum

GTI performed the seventh workshop at the Green Drives Conference and Expo, sponsored by Chicago Area Clean Cities and held in Naperville, IL on May 16, 2019 (Figure I.3.3). Details about the event can be found on the conference website. [2]

Figure I.3-3 Workshop at Green Drives

GTI, Clean Energy, Texas NGVA, and four Clean Cities Coalitions (Houston-Galveston Clean Cities, Dallas-Fort Worth Clean Cities, Lone Star Clean Fuels Alliance, and Alamo Area Clean Cities) planned and/or attended the eighth and final workshop. The workshop was held at the Hilton Garden Inn, Houston NW

American Plaza, Houston, TX, on August 7, 2019 (Figure I.3.4). It was followed by transportation to, and a tour of, the Rush Truck Center Garage.

Figure I.3-4 Attendees at August 7, 2019 Workshop

The project team typically provided attendees with a complimentary thumb drive that contained Best Practices white papers and reports prepared to date through DOE project funding. The presentation material and selected photographs from the workshop were subsequently uploaded to the project website.

As with previous workshops, outreach prior to each FY 2019 workshop included LinkedIn and Twitter campaigns that began roughly two months prior to the workshop date, continuing every five to ten days until the date of the event. GTI published information on its own company LinkedIn site and Twitter feed, and leveraged those of Frontier Energy, the California Fuel Cell Partnership, and Clean Energy, as well as individual LinkedIn accounts.

In addition to online outreach, GTI engaged Clean Cities coordinators in or adjacent to the regions in which the workshops were held so that they could distribute an e-mail based notification about the training to their distribution lists. The same e-mail based notification was sent through the distribution lists at Frontier Energy, the California Fuel Cell partnership, Sierra Monitor Corporation, Superior Energy, and Clean Energy. GTI estimates that news of each workshop reached over 2,000 individual stakeholders.

GTI also worked to obtain lists of contact information for fleets, fire marshals, city permitting officials, and suppliers of equipment to the natural gas and maintenance facility industries. GTI reached out through phone and email channels to over 300 individuals with more personalized messaging, based on the type of individual contacted.

The AltFuelGarage.org website continued to collect data on the number of website visits and downloads of reports, best practices documents, and workshop presentation material – reaching well over 1,000 unique visitors and downloads. The team developed a digitized schematic of a maintenance garage (Figure I.3.5), that is now available on the website.

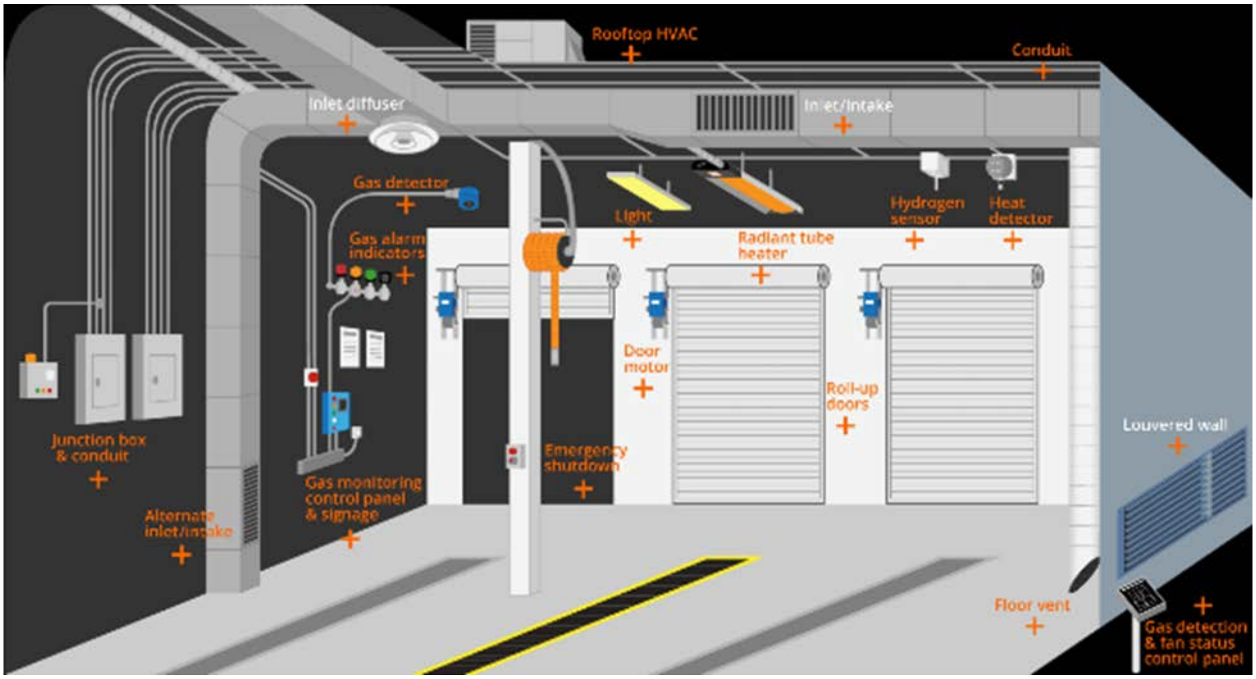

Figure I.3-5 Alternate Fuel Maintenance Facility General Diagram-Natural Gas, Propane, and Hydrogen fuels

Conclusions

This project ended September 30, 2019. The most current versions of code reports, best practices, and workshop curriculum material are available via the project website, AltFuelGarage.org. The website will continue to be available to the public past the end of the project period.

DOE funding provided through this project made it possible for the team to create training that covers three alternative fuels (CNG, propane and hydrogen); targets audiences in several major markets for alternative fueled vehicles (California, Texas, the Midwest, and Pennsylvania); and was designed to reach the broadest possible audience of stakeholders. As a direct result of this project, repair and maintenance facilities for alternative fueled vehicles should face fewer roadblocks in construction and permitting of cost-effective, code-compliant garages. These code-compliant garages will ensure that alternative fuel vehicles are safely maintained throughout their deployment.

Key Publications

1. Wartgow, Gregg. “Setting up a Fleet Maintenance Facility to Service Natural Gas Vehicles.” Fleet Maintenance Magazine, December 2018: pages 34-37. http://epub.southcomm.com/fms/2018/FleetMaintenance_NovemberDecember_2018/#/1/

References

1. All project materials are available on the project website: www.AltFuelGarage.org
2. Green Drives Conference and Expo: https://chicagocleancities.org/green-drives/

I.4 U.S. Fuels Across America's Highways - Michigan to Montana (Gas Technology Institute)

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Start Date: January 19, 2017 End Date: June 27, 2021
Project Funding: $ 10,479,623 DOE share: $ 4,999,983 Non-DOE share: $ 5,479,640

Project Introduction

The Fixing America's Surface Transportation (FAST) Act of 2015 required the Secretary of Transportation to identify the need for, and location of, EV charging infrastructure and natural gas, propane and hydrogen fueling infrastructure along designated interstate highway corridors, to improve the mobility of passenger and commercial vehicles that employ these technologies.

Interstate 94 is an east–west Interstate Highway connecting the Great Lakes and northern Great Plains regions of the United States. It traverses the northern tier of the United States between Billings, Montana and Port Huron, Michigan. With a strategically placed network of DC fast chargers, compressed natural gas (CNG) and propane fueling stations, travel along I-94 could be accomplished seamlessly using the respective alternative fuel vehicles that are commercially available today. To establish a Michigan to Montana (M2M) Alternative Fuel Corridor, however, the project goal is not to install infrastructure in every identified gap; rather, it is to create the necessary team to guide the creation of a planning and implementation framework to provide outreach, commission additional charging and fueling stations, deploy alternative fuel vehicles, and provide the education and training necessary to establish a sustainable market for alternative fuel vehicles. This will allow the M2M Corridor to continue growing well beyond the end of the project term. Significantly increasing the availability and use of alternative fuels and advanced vehicles in key markets such as along I-94 is critical for the long-term growth of these technologies.

A critical success factor for the project will be the ability of the team members and community partners to provide leadership, and to guide the organization and implementation of project elements, to ensure project sustainability beyond the project term. As prime, the Gas Technology Institute (GTI) brings over 75 years of research, development, and technology integration experience, including several large projects to increase adoption of alternative fuel vehicles and the installation of fueling stations. The project team members include several of the most motivated and active U.S. Department of Energy Clean Cities coalitions, as well as key industry leaders in adopting alternative fuel vehicles (AFVs) and building required fueling/charging infrastructure. These team members include: Greater Lansing Area Clean Cities, South Shore Clean Cities, Chicago Area Clean Cities, Wisconsin Clean Cities, Twin Cities Clean Cities, North Dakota Clean Cities, ZEF Energy, Ozinga Ready Mix, and Contract Transportation Services (CTS).

Objectives

The objectives of the project are to establish community-based partnerships, accelerate the adoption of AFVs, and develop related fueling infrastructure needed to support those vehicles along I-94 from Port Huron, Michigan to Billings, Montana. The project focuses on alternative fuels and vehicles including electric drive, CNG, and propane. Tactical objectives include:

- Establish a successful and sustainable alternative fuel corridor
- Deploy approximately 12 electric vehicle (EV) DC fast chargers, 5 publicly accessible CNG fueling stations, 1 propane station, and 60 CNG long-haul trucks along the corridor
- Identify and deploy aforementioned chargers/stations/vehicles to fill gaps along the corridor that will create the consistent demand necessary for sustainability
- Provide outreach, education, and training to critical stakeholders, i.e., fleets, communities, utilities, permitting officials, first responders, and fire marshals
- Create a model built upon case studies and best practices that can be used to establish future alternative fuel corridors across the country
- To the extent practicable, leverage and expand existing Smart Mobility programs along the corridor by implementing new “smart infrastructure” initiatives that increase connectivity.

Approach

A performance measure of the project’s success will be the degree to which AFVs have sufficient access to applicable fueling options. Providing this access will remove range anxiety and allow light-duty plug-in electric vehicle (PEV) owners to travel longer distances, while also expanding commercial fleets’ abilities to utilize PEVs and AFVs for regional and long-haul applications. To the extent possible, the project will leverage results and experience from past projects to prepare for and to accelerate adoption of alternative fuel infrastructure and vehicles along the corridor.

The project team will collaborate with several community-based stakeholders in all phases of this project. To achieve our objectives, the team will include direct input from partners at State Energy Offices, state and municipal departments of transportation (DOTs), metropolitan planning organizations (MPOs), utilities, and the private sector. To support the long-term growth of alternative fuels along the corridor, the project team will also provide appropriate outreach, education, and training to our community-based partners.

Results

FY 2019

Needs Analysis

The M2M Team analyzed the current strengths and resources along the corridor, as well as the greatest needs. To identify gaps in the EV charging and alternative fueling infrastructure along the corridor, the team analyzed various studies and established maximum acceptable separation distances between charging or fueling stations to provide sustainable infrastructure and reduce driver’s range anxiety.

The M2M Team decided to follow the Federal Highway Administration (FHWA) suggested distances because their analysis overlaps with many of the goals of the M2M project. FHWA considered maximum acceptable separation distances for a corridor to be considered “corridor-ready” and determined that they were fuel specific: no greater than 50 miles for DC Fast Chargers (DCFC), no greater than 150 miles for CNG and propane, no greater than 200 miles for liquefied natural gas (LNG), and no greater than 100 miles for hydrogen. The M2M team then created a map of the existing infrastructure along the corridor and identified the gaps in the locations of fueling infrastructure (Figure I.4.1).

Figure I.4-1 Infrastructure Gap Analysis and Station Locations (Blue – DCFC, Red – Propane, Green – CNG); Note: Red ovals denote major gaps in fueling infrastructure on I-94.

This analysis highlighted several gaps in infrastructure availability. At a high level, these gaps include western Michigan, central Wisconsin, and areas along I-94 west of Minnesota, including most of North Dakota and Montana. There are currently 42 public DCFCs (11 of which are maintained by M2M team members), 36 public CNG stations (14 owned by M2M team members), and 23 public propane stations along I-94. The M2M team is also assessing additional strengths and needs, including information on existing anchor fleets, station providers, and stakeholders that will be key to creating a sustainable corridor.

In Fiscal Year (FY) 2018, ZEF Energy installed DCFCs in Tomah, WI and Moorhead, MN, key locations denoted in the red ovals in Figure I.4.1. Independent of this project, a propane station was added in Kalamazoo, MI. This filled an identified gap.

Beyond the gaps identified in the map above, the project determined that there are unique needs in different regions of the country. While a distance of 150 miles between CNG stations on a highway may be sufficient, the critical distance needed between fueling stations in urban areas is significantly shorter. Urban fleets tend to stay closer to a home base and must contend with traffic that increases the time needed (and fuel consumed) to travel shorter distances, compared to highway driving. Accordingly, it is very difficult to establish a specific critical distance for urban environments because those distances are unique to the given locations. Therefore, the team is concentrating on identifying and eliminating gaps to reduce barriers to adoption of AFVs, and not recommending urban-specific critical distances.

Infrastructure redundancy is a critical attribute of a robust and sustainable fuel corridor, because lack of access to fuel, caused by downtime at a single station, can cost companies millions of dollars in lost business. End-users, particularly large fleets that utilize vast amounts of fuel, will not switch to alternative fuels if they cannot rely on the fueling station network. It was decided that charging and fueling station locations will not be limited to "filling gaps" but will also consider the impact on the probability of adoption by end-users.

Sustainable Corridor Planning

The M2M team members began work on creating a model for a sustainable I-94 Alternative Fuel Corridor that can subsequently be used to guide other communities with future corridor development. Once adequate access to charging or fueling stations is available along an interstate highway corridor, the next step is to ensure that travelers/users are made aware of the availability of this infrastructure. One means is through signage.

The FAST Act established a process for nominating alternative fuel corridors for designation as either "corridor ready" or "corridor pending". The FHWA is implementing the designation program. The type of designation depends on the distance between available refueling or recharging stations, and differs for electric charging, propane, and CNG. FHWA has designated several sections of I-94, and through the efforts of project team members, Michigan DOT has installed Alternative Fuel Corridor signage along I-94 in Michigan. See Figure I.4.2.

Figure I.4-2 Corridor Signage on I-94 in Michigan

Outreach and Coordination

In FY 2018, members of the project team held outreach meetings with dozens of potential stakeholders (i.e., fleets, station site owners, government entities, utilities) and also presented at several auto shows, conferences, and workshops to promote the M2M project and alternative fuel corridors.

Deployment Activities

In FY 2018, CTS provided match funding to place an additional 10 CNG trucks (2018 Kenworth Model T680) into service, for a total of 30 CNG trucks. The CTS trucks traveled well over 5,000,000 cumulative miles on CNG, displacing over 1,000,000 gallons of diesel. ZEF Energy installed a DCFC site in Tomah, Wisconsin and initiated site work in Moorhead, Minnesota.

FY 2019

Outreach and Coordination

Project team members from Wisconsin Clean Cities (WCC), South Shore Clean Cities (SSCC), and Chicago Area Clean Cities (CACC) held workshops and roundtable discussions with stakeholders to support permitting and construction activities along the M2M Corridor. Work began to develop and implement regionally focused marketing and social media campaigns, to promote the region-wide stations and increase interest and understanding of alternative fuel vehicles. The project team began investigating operating policies and procedures that can be implemented by key stakeholders along the corridor. This included working with state DOTs to identify signage requirements to create consistent and recognizable Alternative Fuel Corridor branding. Examples of activities by team members from the Clean Cities Coalitions include the following:

- SSCC held meetings with government and industrial stakeholders to discuss potential sites for fueling charging stations along the M2M corridor in Indiana.

- Greater Lansing Area Clean Cities (GLACC) presented on the M2M Project at the Clean Cities North Central Regional Meeting in October 2018 and the Clean Cities National Peer Exchange in November

2018. They also held meetings with stakeholders to discuss potential sites for fueling stations along the M2M corridor. GLACC also took the lead to plan a Roadshow across the M2M Corridor, tentatively scheduled for 2020.

- CACC contracted with a local trainer to hold a First Responders Awareness Program in Chicago. The classroom and hands-on training focused on requirements for dealing with potential fires from alternative fuel and electric vehicles. CACC also began working with the State of Illinois on alternative fuel corridors.
- WCC worked with NREL to prepare a letter to the Clean Cities Clean Fleet National Partners summarizing the implementation of the I-94 M2M Alternative Fuel Corridor and requesting their support. This communication was distributed through NREL. WCC also hosted the Electric Zone at the Milwaukee Auto Show. The Electric Zone exhibited all-electric and plug-in hybrid electric vehicles. WCC created and displayed a poster map with locations of the electric, natural gas and propane stations along the I-94 corridor. (Figure I.4.3.)

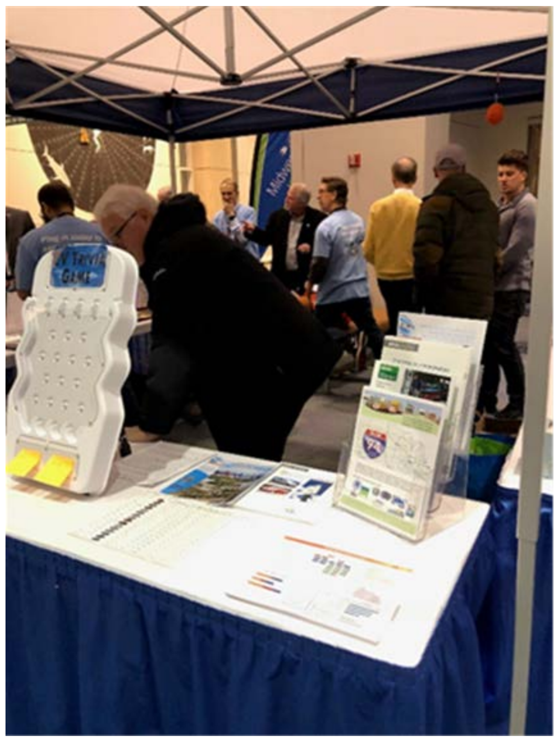

Figure I.4-3 M2M Brochure at Chicago Auto Show, February 2019

Deployment Activities

ZEF continued to focus on finding locations for DCFC stations in Minnesota, Wisconsin and Michigan to eliminate gaps that have been identified in those states, and held several meetings with utilities. Specific locations of interest include: Eau Claire, WI; Wisconsin Dells, WI; Kalamazoo, MI; Benton Harbor, MI; Jackson, MI; and Port Huron, MI.

The 30 CTS trucks from this project have traveled well over 9,000,000 cumulative miles and displaced almost 2,000,000 gallons of diesel.

In December 2018, the Fargo Moorhead West Fargo Chamber of Commerce held a ribbon-cutting ceremony, attended by the public and project partners, to celebrate the second DCFC site installed with support from the

M2M Project. (Figure I.4.4.) The DCFC and Level 2 station is located near a Starbucks and Qdoba in Moorhead, MN. This location filled a key gap west of Minneapolis and on the border with North Dakota and will support efforts to continue corridor expansion to the west.

With assistance from SSCC, GTI secured financial participation from Ozinga Ready Mix in the M2M project. Ozinga will purchase equipment and design, permit, deploy, install, commission, operate, maintain, and manage three (3) publicly accessible, compressed natural gas (CNG) fueling stations at the following locations:

- 2555 E. 15th Ave., Gary, Indiana
- 825 S. Whittaker St., New Buffalo, Michigan
- 6445 S. State St., Chicago, Illinois.

Figure I.4-4 ZEF Energy DCFC Moorhead Site – Ribbon Cutting Held December 2018

Conclusions

The M2M Corridor Project continues to be on track to accomplish all of its goals and objectives within the planned schedule. The project focus on organization and planning involving team members from the Clean Cities Coalition, industry and community partners is providing a pathway to establishing a sustainable alternative fuel corridor along I-94.

I.5 WestSmart EV: Western Smart Plug-in Electric Vehicle Community Partnership (PacifiCorp)

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Start Date: January 19, 2017 End Date: January 18, 2020
Project Funding: $11,548,617 DOE share: $3,532,333 Non-DOE share: $8,061,287

Project Introduction

The WestSmart EV Project is designed to accelerate adoption of plug-in electric vehicles (PEVs) in communities located within PacifiCorp's electric service territory across the Intermountain West. This will be accomplished by developing a large-scale, sustainable PEV charging infrastructure network, coupled with PEV adoption programs. The program is led by PacifiCorp, a locally managed, wholly-owned subsidiary of Berkshire Hathaway Energy Company. PacifiCorp is one of the leading electric utilities in the western United States, with service territory in six states: Utah, Wyoming, Idaho, California, Oregon, and Washington.

PacifiCorp has built a first-class Project Team of strategic partners and leading experts to successfully execute the program. Team members include the Idaho National Laboratory (INL), Salt Lake City, Utah Clean Cities Coalition (UCCC), Breathe Utah, Park City, Utah State University (USU), and University of Utah (UU). Additional community partners include Yellowstone-Teton Clean Cities and Forth Mobility. The program also has committed partnerships with key private businesses including ChargePoint, and Maverik gas stations, the largest independent fuel retailer in the Intermountain West.

Objectives

The primary objective of WestSmart EV is to increase the adoption rate of PEVs across the intermountain multi-state region covering Utah, Idaho, and Wyoming. A secondary objective of WestSmart EV is to spur additional growth of PEVs among the broader western states, including Washington, Oregon, California, Nevada, and Colorado.

The overall target is to double the growth rate for PEVs in communities in PacifiCorp's electric service territory, from 20% to 40%, leading to more than 50,000 PEVs within 10 years. This three-year project will launch a multi-pronged approach to help meet these targets.

Approach

To accomplish the primary project objective of increasing PEV adoption across the intermountain multi-state region, this project has implemented a three-year, strategically phased, directed, and coordinated implementation plan, as shown in Figure I.5.1.

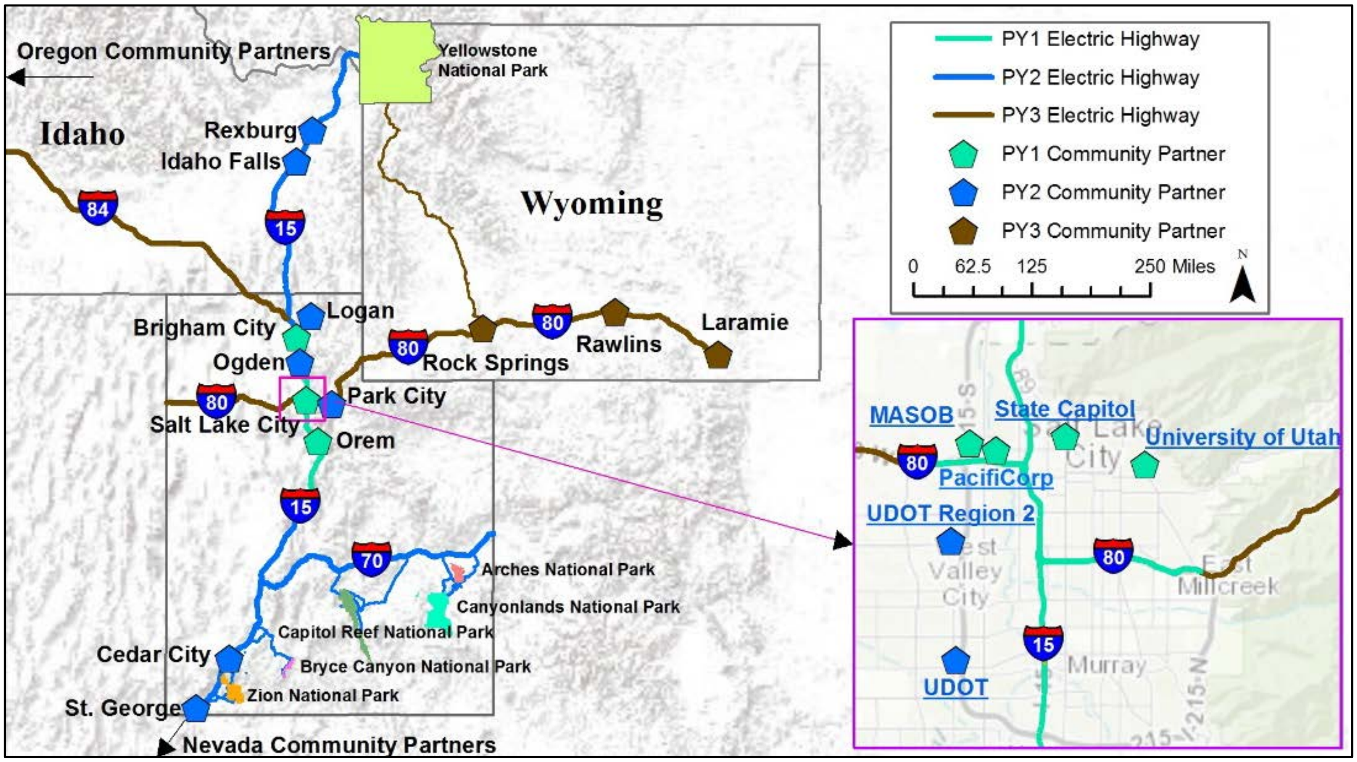

Figure I.5-1 WestSmart EV Three-year Project Implementation Plan

The three annual phases for all project tasks include the following:

- Project Year 1 (PY1): Pilot year for initial implementation and initiation of data collection
- Project Year 2 (PY2): Expansion year for ramping up efforts and beginning strategic flow of data results back into project components
- Project Year 3 (PY3): Rollout year to reach full project capacity and incorporate lessons learned while disseminating best practice. The phased approach to building PEV growth through the WestSmart EV project includes 6 major tasks, as depicted in Figure I.5.2. They include (1) developing over 1,500 miles of electric highway corridors along I-15, I-80, I-70, and I-84 in Utah, Idaho, and Wyoming; (2) advancing Workplace Charging within the corridors; (3) targeting fleet operators and incentivizing conversion of fleet vehicles to PEVs within the corridors; (4) building community partnerships and incorporating Smart Mobility programs to align efforts with long-term transportation planning; (5) collecting, processing, and applying data from across all activities through the WestSmart EV Central task to inform project reporting, develop new tools for utility integration of charging infrastructure, and detail lessons learned and best practices, and (6) coordinating outreach, education and dissemination of best practices through a series of workshops across seven states, and one-on-one meetings with business leaders though community partners.

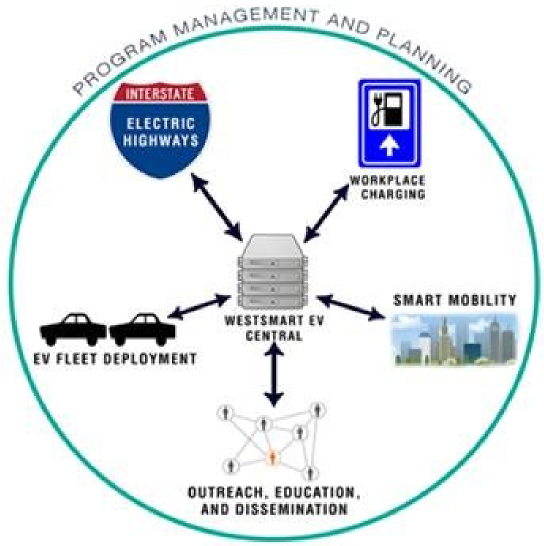

Figure I.5-2 WestSmart EV Major Task Diagram

Task 1 - Electric Highways

WestSmart EV will electrify over 1,500 miles of interstate highways in three states, with DC fast chargers every 50-100 miles along the corridors and AC level 2 (L2) chargers covering every major community across the region. The project will create two primary electric interstate highway corridors along I-15 and I-80. In addition, the project will include portions of I-70 running east from I-15 in southern Utah to the Colorado border, I-84 from Utah to western Idaho, along with off-corridor highways leading to the national parks.

Task 2 - Workplace Charging

With the strong support of local air quality managers, municipalities, state agencies, business groups, and public interest advocates, WestSmart EV will aggressively push workplace charging through a combination of public events, workshops, and awareness campaigns. The project will incentivize installation of over 600 AC L2 chargers at workplace locations.

Task 3 – EV Fleet Deployment

The program will strategically target fleet operators with incentives to convert fleets to PEVs. All vehicles will use data loggers that enable data sharing and development of lessons learned and best practices. In all, the program will incentivize the purchase of over 200 PEVs.

Task 4 – Smart Mobility

WestSmart EV will pilot, expand, and roll out innovative concepts for zero local emission smart mobility in urban living along the Wasatch Front (a 100-mile segment of the I-15 corridor running north and south of Salt Lake City) and at university campuses throughout the region. This task focuses on eliminating the need for personal vehicles and providing all-electric solutions in the first-mile and last-mile trips for commuters. The lead pilot program in Park City will include electric buses (ebuses), electric bikes (ebikes), micro transit programs, and an electric vehicle (EV) ride hailing program with 200 EV conversations between mobility service drivers and potential EV owners.

Task 5 – WestSmart EV Central

This task involves centralized data collection, analysis, modeling, and tool development, to inform investment and policy decisions. INL will lead efforts on data collection for vehicles and chargers; USU will lead the collection of behavioral data; and UU will lead the collection of utility infrastructure data.

Task 6 - Outreach and Education

In this task, partners develop education and outreach materials, including a website, and conduct workshops throughout seven western states.

Results

Overall Project Results for fiscal year (FY) 2019:

The budget period 3 continuation application and revised budget were approved March 21, 2019.

Successfully published two research papers regarding dynamic charging, EV charging installation, and residential utility utilization.

Successfully launched a social media campaign and www.liveelectric.org website.

Task 1 - Electric Highways Results:

- Installed 24 DC Fast Chargers (DCFC) in FY 2019:
    - Nine at Rocky Mountain Power service centers statewide
    - One at West Jordan City, Utah
    - Eight at Park City, Utah
    - Two at Curtubus Audi car dealership in Layton, Utah
    - Three at Sandy City, Utah
    - One at Summit County, Utah

Task 2 - Workplace Charging Results:

- Installed 388 workplace L2 chargers in FY 2019

Task 3 – EV Fleet Deployment Results:

- Purchased 7 EVs in FY 2019
    - All seven EVs were sold using the program's EV buy-down program.

Task 4 – Smart Mobility Results:

- Launched the EV ride hailing program with Lyft, supported by Forth Mobility utilizing data collection by FlexCharging App

Task 5 – WestSmartEV Central Results:

- Coordinated data collection consensus with ChargePoint, EVgo, BTCPower, and GreenLots
- Utility Integration – released study results from residential study
- Enhanced EV Adoption Model formulation/data collection

Task 6 – Outreach and Education Results:

- Awareness and branding campaign continues, led by Doglatin Media
- www.liveelectric.org website is online; social media and public relation plans established
- Conducted multiple EV workplace challenge workshops in the region.

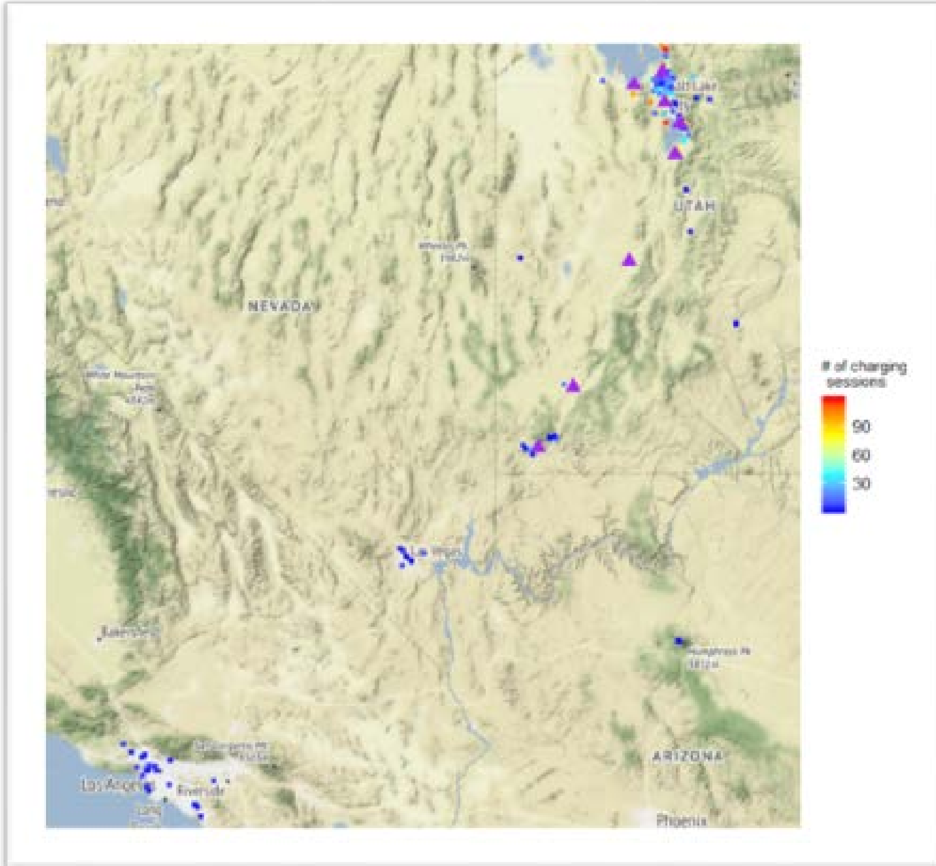

Figure I.5-3 WestSmart EV Major Task Diagram

Based on user zip codes, DCFC deployed along I-15 by WSEV have successfully enabled EV travels from Los Angeles through the State of Utah. A high number of drivers from Las Vegas and Los Angeles are using the corridor's DCFC.

Conclusions

The project team continued to implement the key activities associated with all primary objectives of the WestSmart EV project's third year. The team successfully installed DC Fast Chargers (DCFCs) across the project territory and collected data from the chargers. This data indicate that the DCFCs have created an effective EV highway corridor (Figure I.5.3). The Team continues to install workplace chargers and has exceeded the milestones for this task. For Task 4, Smart Mobility, the team has expanded electric bus operations into Salt Lake City, while leveraging lessons learned from Park City. Further, the team has successfully launched a ride hailing EV program with Lyft drivers. The participating drivers are providing information on transportation network companies' activities, including an App that can be downloaded that tracks the charging characteristics and telematics of the vehicle. The project team has also launched an electric car share program at an affordable housing complex. The WestSmart EV project has been successful, and the team anticipates achieving all program objectives.

Key Publications

1. Liu, Z and Song, Z. 2017. "Robust Planning of Dynamic Wireless Charging Infrastructure for Battery Electric Buses." *Transportation Research Part C: Emerging Technologies*, vol. 83, 77-103.

2. Liu, Z., Song, Z., and He, Y. 2017. "Optimal Deployment of Dynamic Wireless Charging Facilities for an Electric Bus System." *Transportation Research Record: Journal of the Transportation Research Board, vol. 2647, 100-108.*
3. Palomino, A and Masood P. 2018. "Probabilistic Impact Analysis of Residential Electric Vehicle Charging on Distribution Transformers." *2018 North American Power Symposium*
4. Liu, Z., and Song, Z. 2018. "Dynamic Charging Infrastructure Deployment for Plug-in Hybrid Electric Trucks." *Transportation Research Part C: Emerging Technologies, vol. 95, 748-772.*
5. Liu, Z., and Song, Z. 2018. "Network User Equilibrium of Battery Electric Vehicles Considering Flow-dependent Electricity Consumption." *Transportation Research Part C: Emerging Technologies, vol. 95, 516-544.*
6. Liu, Z., Song, Z., and He, Y. 2018. "Planning of Fast-charging Stations for a Battery Electric Bus System under Energy Consumption Uncertainty." *Transportation Research Record: Journal of the Transportation Research Board, DOI:10.1177/0361198118772953.*
7. He, Y., Song, Z., Liu, Z., and Sze, N. 2019. "Factors Influencing Electric Bike Share Ridership: Analysis of Park City, Utah." *Transportation Research Record: Journal of the Transportation Research Board, in press.*
8. Liu, Z., Song, Z., and He, Y. 2019. "Economic Analysis of On-route Fast Charging for Battery Electric Buses: A Case Study in Utah." *Transportation Research Record: Journal of the Transportation Research Board, in press.*
9. Palomino, A., and Parvania M. 2019. "Advanced Charging Infrastructure for Enabling Electrified Transportation." *The Electricity Journal Vol 32, 21-26*
10. Palomino, A., and Parvania M. 2019. "Data-Driven Risk Analysis of Joint Electric Vehicle and Solar Operation in Distribution Networks" *IEEE Power & Energy Technology Systems Journal (Under Review)*

I.6 Electric Last Mile (Pecan Street, Inc.)

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Start Date: October 1, 2017 End Date: June 30, 2020
Project Funding: $2,000,000 DOE share: $1,000,000 Non-DOE share: $1,000,000

Project Introduction

Electric Last Mile (ELM) is a research and demonstration project managed by Pecan Street Inc., carried out in partnership with Austin's transit agency, Capital Metro, and funded by a grant from the Department of Energy's Vehicle Technologies Office. The goal of the Electric Last Mile project is to study public transit ridership in pilot neighborhoods using electric shuttles (eShuttles) that reduce greenhouse gas emissions and traffic congestion. This will be done via cost-effective public-private partnerships that provide opportunities to demonstrate and evaluate technology solutions to transit problems.

Objectives

Pecan Street will pursue this goal through the following five objectives:

- Conduct pilot tests of a last-mile transit solution using all-electric, six-person shuttles from a private vendor, Electric Cab of North America, in three Austin neighborhoods, for eight months each
- Collect data on consumer engagement, vehicle performance, traffic impacts, and feasibility of new technologies through surveys, community charrettes, and hardware installed on the vehicles
- Pilot a fully autonomous eShuttle for neighborhood circulator service, to demonstrate the benefits and challenges of applying this technology to local connections
- Develop best practices for public-private partnerships for first- and last-mile transit solutions that achieve the following:
    - Reduce reliance on personal vehicles for daily trips
    - Increase the appeal of using a public transit option by reducing transit time and overcoming the well-documented stigma of riding buses and shuttles
    - Quantify the community value of various options and weigh theme against the costs of each tested model
- Assist other communities in replicating the successful aspects of this program through lessons learned and case studies.

Approach

The project team established three ELM pilot routes in Austin neighborhoods. Maps of the three neighborhood service areas can be found in Figure I.6.1 through Figure I.6.3. These neighborhoods were selected to test applicability of the ELM model to different neighborhood types and varying transit needs. Specifically, the

Kramer/Domain route tested the ELM model as a solution for first- and last-mile connectivity to a major shopping, restaurant, and entertainment destination. The Downtown route tested the ELM model as a solution for commuter transit. The Mueller route tested the ELM model as a solution for neighborhood connectivity between residences, public transit stops, medical facilities, and local retail. The Kramer/Domain route began on November 24, 2017, the Downtown route began on January 8, 2018, and the Mueller route began on May 21, 2018. The project utilized two shuttles in each neighborhood.

The project team selected the neighborhoods based upon several factors:

- High rates of traffic congestion
- Lack of available parking
- Proximity to major transit points
- Proximity to major retail, employment, medical, dining, and employment centers
- Potential for business sponsorship to ensure sustainability beyond a subsidized pilot period.

The team designed the routes in each neighborhood based on several factors:

- Identification of desired drop-off/pick-up points in each area
- Keeping the routes to under 3 miles, to ensure shuttle frequency of at least every 15 minutes
- Ensuring the eShuttles would be on streets where the speed limit is no higher than 35 miles per hour (mph).

Results

In Fiscal Year 2019, the project team evaluated vendors for the autonomous vehicle (AV) demonstration and, working in partnership with Capital Metro and the City of Austin, selected the Mueller neighborhood for the AV demonstration route. The primary constraints were the temporary timeline for a route; finding a route that connected public transit on roads with speeds at 35 mph or below and 4-way stop signs at any intersections where speed limits on the roads to be crossed are higher than 25 mph; and finding a location nearby to park and charge the vehicle at night. Pecan Street signed a contract with EasyMile on May 6, 2019 to utilize their EZ10 vehicle for the demonstration project and EasyMile applied to NHTSA (National Highway Traffic Safety Administration) on May 10, 2019 for approval to conduct the autonomous demonstration. NHTSA notified Pecan Street on June 7, 2019 that the application was under review. On June 28, 2019, NHTSA notified Pecan Street that the application was not approved. NHSTA returned the application with requests for significant modifications to the route. Pecan Street is working to design an AV route and demonstration around several constraints:

- The AV cannot operate on roads with speed limits higher than 30 mph
- The AV operates at 3 mph when not in autonomous mode and vehicle cannot be in autonomous mode when moving from storage to selected route
- The AV has difficulties operating alongside large amounts of undeveloped property or properties under active development
- The AV cannot operate on congested roads with parked vehicles.

Kramer/Domain

Between April 2 and August 31, 2018, the eShuttles traveled 3,367 miles with passengers in the vehicles in the Kramer-Domain Service Area. (See Figure I.6.1.) Extrapolated to one year, that would be 10,101 miles driven. If 45% of these trips replaced trips that would have been taken in a gas-powered car, it would equate to 4,545 gas-powered vehicle miles being averted through the eShuttle program. This translates to 3.6 "well-to-wheels" barrels of petroleum and 2.1 short-tons of greenhouse gases (GHGs) saved per year. About 9.3 pounds of direct vehicle operation GHGs would have been averted over this period. If 100% of eShuttle trips replaced personal vehicle trips, 8 "well-to-wheels" barrels of petroleum, 4.6 short-tons of GHGs, and 20.8 pounds of direct vehicle operation GHGs would be saved per year.

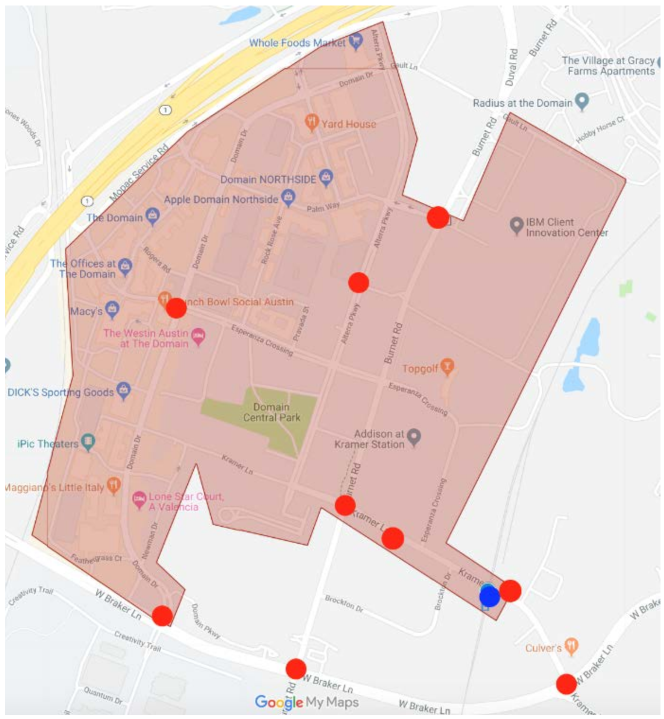

Figure I.6-1 Kramer-Domain Service Area. Red Dots = Bus Stops

Mueller

Between July 1 and September 30, 2018, the eShuttles traveled 2,664 miles with passengers in the vehicles in the Mueller Service Area. (See Figure I.6.2.) Extrapolated to one year, that would be 10,656 miles driven. If 45% of these trips replaced trips that would have been taken in a gas-powered car, it would equate to 4,795 gas-powered vehicle miles being averted through the eShuttle program. This translates to 3.8 "well-to-wheels" barrels of petroleum and 2.2 short-tons of GHGs saved per year. About 9.9 pounds of direct vehicle operation GHGs would have be averted over this period. If 100% of eShuttle trips replaced personal vehicle trips, 8.5 "well-to-wheels" barrels of petroleum, 4.9 short-tons of GHGs, and 18.7 pounds of direct vehicle operation GHGs would be saved per year.

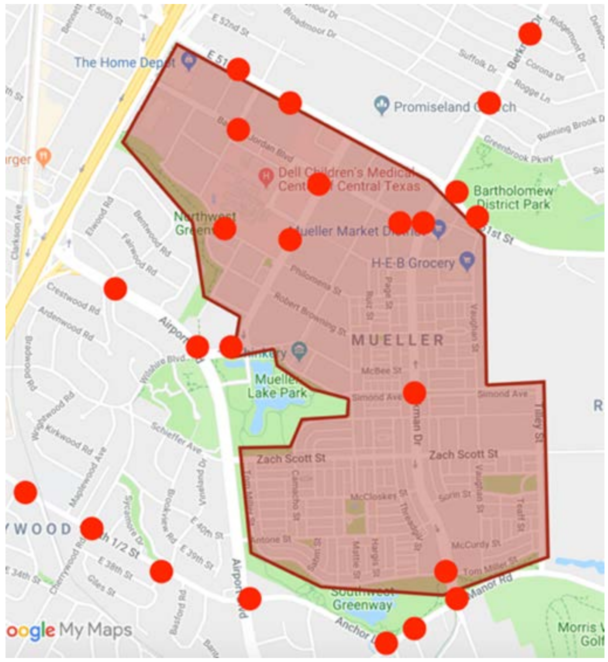

Figure I.6-2 Mueller Service Area. Red Dots = Bus Stops, Blue Dot = Train Stop

Downtown

Between April 2 and August 31, 2018, the eShuttles traveled 2,276 miles with passengers in the vehicles in the Downtown Service Area. (Figure I.6.3.) Extrapolated to one year, that would be 5,462 miles driven. If 45% of these trips replaced trips that would have been taken in a gas-powered car, it would equate to 2,458 gas-powered vehicle miles being averted through the eShuttle program. This translates to 2 "well-to-wheels" barrels of petroleum and 1.1 short-tons of GHGs saved per year. About 5.1 pounds of direct vehicle operation GHGs would be averted over this period. If 100% of eShuttle trips replaced personal vehicle trips, 4.4 "well-to-wheels" barrels of petroleum, 2.5 short-tons of GHGs, and 11.2 pounds of direct vehicle operation GHGs would be saved per year.

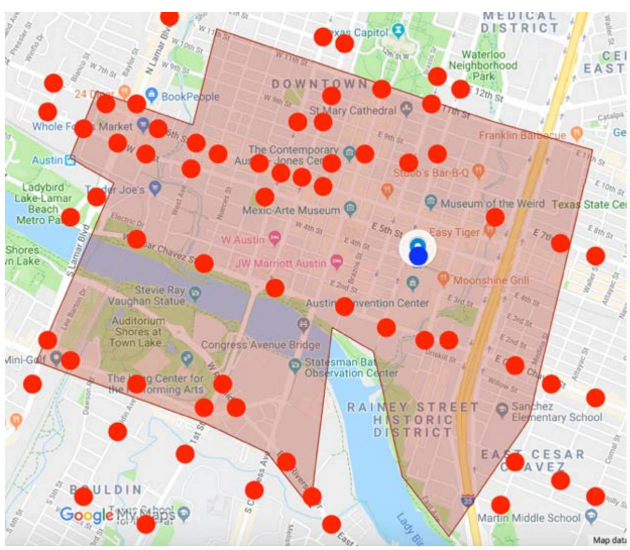

Figure I.6-3 Downtown Service area. Red dots indicate Capital Metro stops. Blue dot indicates train stop.

Conclusions

Pecan Street has identified many obstacles to the AV demonstration and continues to identify mitigating strategies to complete a successful AV demonstration.

All three pilot eShuttle routes have concluded for this program. Taking lessons learned from ridership on the three routes reveals some best practices that can be transferred to other areas considering a similar program. Understanding the needs of each community with first- and last-mile transit gaps will help identify the appropriate solution. The categorization chart shown in Table I.6.1, developed through discussions with Capital Metro, is a useful tool for solutions planning:

Table I.6.1 Matrix of Last-mile and Micro-transit Solutions for Community Needs

Neighborhood Category	Solution Description	Challenges
High-density residential and mixed-use	15-person capacity vehicles; electric neighborhood circulator and public transit connection; operate on high-frequency fixed route; cross-subsidized by advertising revenue, public transit and/or area businesses; vehicles can charge overnight in business parking spaces using standard outlets or charging stations.	Cost barriers to procure large electric vehicles; ensuring appropriate charging infrastructure
Low-density residential	6 to 15-person capacity vehicles; fixed route; provided by private operator that costs up to $35/hour; contracted by public transit agency through bulk purchase of service; personal entry and exit doors on both sides of vehicle; runs every 15 minutes; electric vehicle ideal if distances traveled are within range.	Long ranges make many electric vehicles unfeasible; lack of available vehicles on market
Market districts	6 to 12-person vehicles that circulate locally and connect to public transit; electric shuttles; low-speed (up to 30 mph); can charge overnight at market district using standard outlet or charging stations.	More small vehicles require more drivers, increasing cost
Para-transit	Small to mid-size vehicles; on-demand service that can be hailed via a mobile app or by phone; operated by transit agency; long-range electric vehicles would be suitable if cost-competitive with gas-powered shuttles.	Lack of cost-competitive long-range, ADA-compliant EVs
Suburban business campuses	Small to mid-size shuttles; private operator; run on high-frequency fixed route to connect employees with public transit stops; subsidized by employers.	Convincing employees to use public transit w/o parking shortages

Acknowledgements

Pecan Street would like to acknowledge the funding and support from the U.S. Department of Energy, as well as participation, information, guidance, and data from Austin Capital Metro.

I.7 Collaborative Approaches to Foster Energy-Efficient Logistics in the Albany - New York City Corridor (Rensselaer Polytechnic Institute)

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Start Date: October 1, 2017 End Date: September 30, 2020
Project Funding: $4,000,342 DOE share: $1,999,999 Non-DOE share: $2,000,343

Project Introduction

The goal of the Collaborative Approaches to Foster Energy-Efficient Logistics in the Albany - New York City Corridor project is to foster adoption of Energy Efficient Logistics (EEL) along the supply chains operating in this corridor, in a way that benefits the range of stakeholders and agents involved in, and affected by, those supply chains, i.e., shippers, carriers, and receivers. The project aims to exploit the potential of collaborative approaches to induce carriers to adopt energy efficient Technologies and Operations (Tech/Ops), and induce shippers and receivers to change demand patterns to exploit the synergies with Tech/Ops, to achieving EELs.

Objectives

Reaching this goal will require achieving a number of objectives, as outlined below:

- To conduct research and develop behavioral models, to understand the most effective methods to foster changes in the behavioral patterns of shippers, carriers, and receivers towards greater energy efficiency, by adopting energy efficient Tech/Ops, and implementing changes in their demand patterns
- To broaden the focus when assessing energy scenarios, to consider both demand and supply, and the roles played by all participants in supply chains (shippers, carriers, and receivers)
- To exploit the synergies and mutually reinforcing effects among EEL initiatives
- To provide public-sector decision makers with the procedures and analytical tools they need to determine the best ways to reduce freight energy use in their jurisdictions.
- To gain insight into the potential, and the real-life barriers to implementation, of EEL initiatives, using advanced modeling techniques and pilot testing.

Approach

The team's chosen approach to meet these objectives combines novel supply-side Tech/Ops with freight demand management techniques that will induce energy efficient freight demand changes. A selected group of EEL initiatives will be pilot-tested in the Albany-New York City (NYC) corridor, the project's living lab, to: (1) gain insight into the barriers and obstacles for EELs; (2) identify ways to overcome those barriers; and (3) demonstrate the real-life benefits of EEL initiatives to stakeholders.

The key outcomes of the project will be an energy management guidebook with actionable information and a practice-ready approach to fostering EEL initiatives at the city, Metropolitan Planning Organization (MPO), and state levels; and an Integrated Transport-Energy Model (ITEM) to estimate the impacts of collaborative measures on adoption of Tech/Ops and demand changes.

The project consists of four major thrusts, as follows:

- Thrust 1: The team will develop a catalog of EEL initiatives to be considered, and conceptually design the initiatives and collaborative measures to be piloted.
- Thrust 2: The team will develop tools and algorithms to assess the initiatives, and develop an energy management guidebook.
- Thrust 3: The team will assess the impacts of collaborative measures on initiative adoption, assess the initiatives' effectiveness, and design pilot tests.
- Thrust 4: The team will conduct and assess the pilot tests.

Thrusts 1, 3 and 4 roughly correspond to the first, second and third years of the project respectively, while Thrust 2 is expected to be completed across the duration of the project.

Results

During the past year, the team worked to develop tools and algorithms that aim to model the echelons of the supply chain. In addition, the team worked on the characterization of the baseline conditions in terms of supply chain practices and energy use in the Albany - New York City Corridor. Lastly, the team started working to assess the effectiveness of possible initiatives that would increase the EEL in the corridor.

Enhanced Behavioral Micro-Simulation

A major component of the project is the development of the enhanced Behavioral Micro-Simulation (BMS). The original BMS was developed by RPI in 2009, to identify the optimal set of policy initiatives to foster Off-Hour Deliveries (OHD), and was successfully used in the NYC OHD project (Silas and Holguín-Veras 2009; Holguín-Veras and Aros-Vera 2014) [1], [2]. Since the original BMS (BMS-OHD) was developed to support the design and implementation of the NYC OHD project, it had to be redesigned to support the formulation of EELs. The enhanced BMS (BMS-EEL) incorporates Freight Trip Generation (FTG) patterns for major gateways and commercial establishments, allowing a more effective assessment of the impacts of policy interventions, and a more complete representation of all truck vehicle trips generated in the study area.

As part of this redesign, the team re-wrote the code of the BMS so that it considers four interactions of the supply chain: (1) from gateways to large establishments, (2) from large establishments to large establishments, (3) from large establishments to small establishments, and (4) from small establishments to small establishments. See Figure I.7.1. The output of the BMS-EEL is a set of pick-up and delivery tours (or *freight activity* tours); each of them comprised of ZIP code and North American Industry Classification System (NAICS) of the shipper, and ZIP codes and NAICS of the receivers. The freight activity tours represent how the logistics industry arranges its operations to meet customer needs. Based on the delivery tours, it is possible to estimate emissions from freight activity and assess impacts of energy efficiency measures in different scenarios. In the base conditions, these tours are very inefficient in terms of energy consumption, due in part to deliveries during the congested hours of the day, and increases in the number of deliveries due to low shipment sizes. Inducing changes in demand patterns will change freight activity tours for the better. The intent is to use the BMS to simulate the base case, as well as the new freight activity tours that will arise from the changes in the demand patterns. The resulting tours will be the input to the Polaris, SVtrip and Autonomie simulation tools.

In terms of input data, the BMS-EEL uses Freight Trip Generation (FTG) by ZIP code and industry sector, and the Use Table, that specifies the interaction matrix between industry sectors. The Use Table comes from the analysis of the Input-Output (IO) account from the U.S. Bureau of Economic Analysis. The IO account provides the monetary value of the supplies and services that are consumed by a given economic sector.

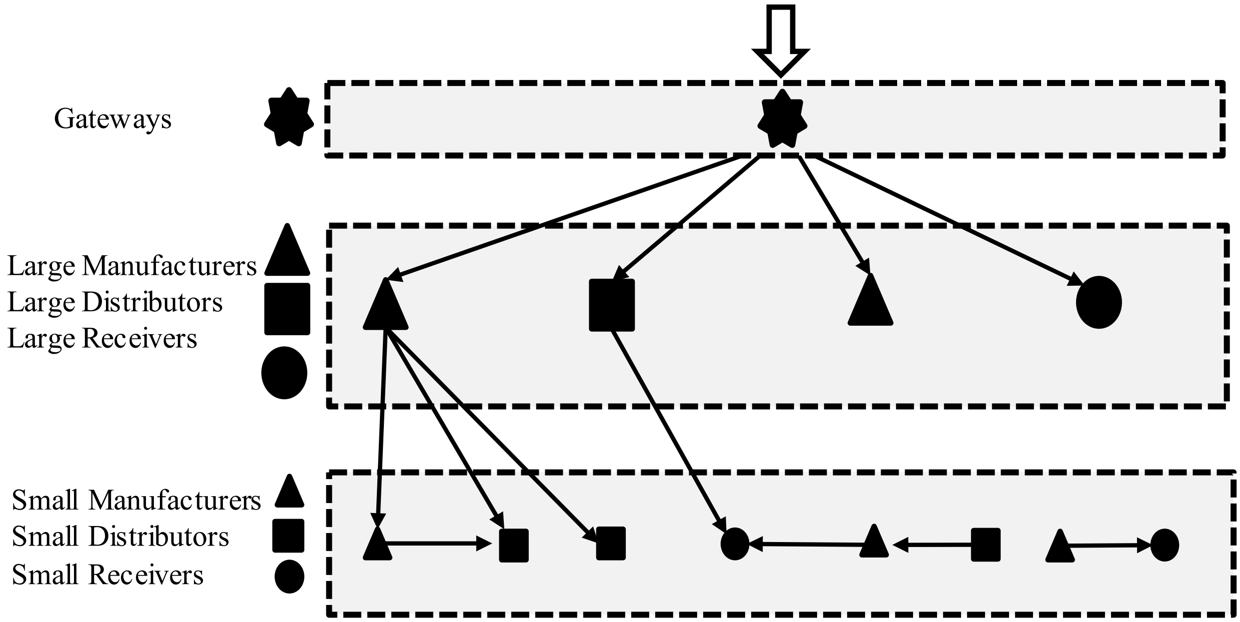

Figure I.7-1 Supply Chain Interactions considered by the BMS-EEL

Integrated Transport-Energy Model

The BMS will be part of the Integrated Transport-Energy Model. The team will develop procedures to use the BMS outputs as inputs to SVTrip and Polaris. The BMS infers the changes in supply chains that would take place in response to initiatives to reduce freight energy use. Polaris predicts the paths and generates the information that will be used for SVTrip, to estimate the corresponding speed profiles with the initiatives' effects. Finally, Autonomie uses SVTrip speed profiles, along with vehicle classes, to predict energy consumption.

SVTrip requires high resolution Global Positioning System (GPS) data (a second or less between consecutive GPS readings) to calibrate truck emission models, but the GPS data available for purchase from data aggregators do not have the level of detail needed. The team has been discussing collecting data using GPS data loggers with Anheuser-Busch, Price Chopper and the Trucking Association of New York. All entities have expressed willingness to collaborate with the team; however, there were major delays when purchasing the GPS data loggers. The loggers needed were expected to be available in the summer of 2018; however, the loggers' vendor had production delay issues and the new units arrived in mid-March 2019. Additionally, the team is currently waiting for United Parcel Service's (UPS') legal team to review the formal request for obtaining their GPS data. The response from their legal team is taking longer than anticipated.

The delays in acquiring the GPS data also impacted the characterization of baseline conditions. The goal of this task is to develop a basic quantitative idea about the current patterns of energy use, emissions, delivery costs, and other similar indicators of performance in the Albany-New York City corridor. The analyses will use the methodology developed by the RPI team to assess the impacts of congestion on supply chains. The first step of the methodology was to identify the areas of interest. The second step is to get GPS data for two or three weeks in the corridor. The team contacted the American Transportation Research Institute (ATRI), which routinely collects data from trucking companies. ATRI expressed interest in becoming a partner in the project. As part of this collaboration, the team will acquire two weeks of GPS data from ATRI. The team is currently negotiating the geographic and temporal scope of the GPS data. In addition, the data service agreement is currently under review by the ATRI's and RPI's legal counsels.

The GPS data from ATRI are typically collected at time intervals of one to five minutes. The problem is that the data required by ANL and George Mason University should correspond to shorter intervals, of one second or less. To take advantage of the massive GPS data archive maintained by ATRI, the team decided to study the feasibility and accuracy of techniques to impute second-by-second GPS data using data collected at one to five minute intervals. Although the imputed data cannot replace GPS data directly collected from the field, the availability of reasonably accurate imputation techniques would enable the use of archival data to produce estimates of energy consumption.

To this effect, the team designed and tested a number of procedures to input speeds, on a second-by-second basis, using the real-life speeds collected by GPS devices at one to five minute intervals. Although a number of procedures were considered, the team settled on a *deterministic linear interpolation* (DLI) of speeds, where the second-by-second speeds change at a constant acceleration in between the known GPS measured speeds; and a *randomized linear interpolation* (RLI), where the estimates from the DLI are randomized using the statistical distributions of the differences between actual observations and the estimates of the DLI obtained from previous data.

Figure I.7.2 outlines the differences between the DLI and RLI. In the DLI, the speeds every second are linearly interpolated between the values observed at longer intervals of times (the stars); the resulting interpolation is shown as the solid line connecting the stars, with white triangles that represent the estimate for each second. In the RLI, the results from the DLI are randomized with the addition of error terms, ε_i, resulting in random variations with respect to the straight line, and shown in dashed lines. These error terms are obtained from the statistical distribution calibrated by RPI using the archival GPS data already owned by RPI.

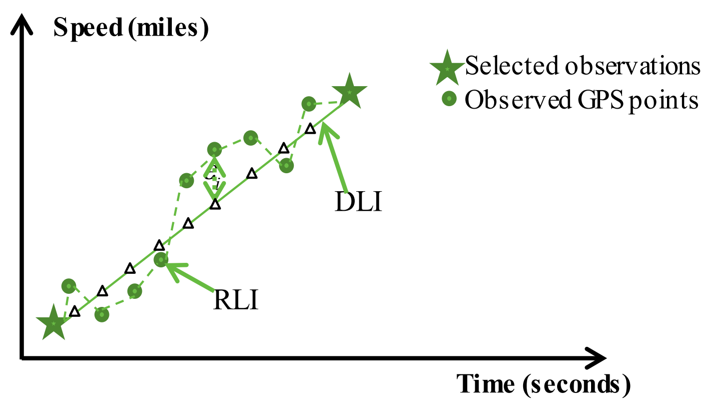

Figure I.7-2 Schematic of the differences between DLI and RLI

The process to compute the statistical distributions for the random component in the RLI (not shown in the figure) starts with the analysis of the second-by-second GPS data available to the team. The first step is to select the GPS observations that correspond to the desired interpolation interval (i.e., 60, 120, 300 seconds). The second step is to conduct the DLI and compute the errors, ε_i, with respect to the DLI. These errors are used to obtain the parameters of the statistical distributions at the core of the RLI.

To test these procedures, the team used second-by-second real-life GPS data previously collected by RPI to create two different datasets, the *test* and the *control* dataset. The test dataset is a subset of the control dataset, where the only data are those for the selected interpolation interval (i.e., 60, 120, 300 seconds). The control dataset contains the complete set of second-by-second GPS observations. The test data set is used to assess how well the procedures designed by the team are able to estimate speeds, and ultimately, energy consumption.

To estimate energy consumption, the team used the second-by-second fuel consumption parameters from the EMFAC database (California Environmental Protection Agency 2016), incorporated into the web-software developed by RPI, to estimate the "true" values of fuel consumption. Then, the team used the output files from the imputation procedures—using one, two, and three minutes— to estimate the fuel consumption. The results, shown in Figure I.7.3, indicate that the DLI is able to estimate fuel consumption within 2.5% of the "real" values obtained using the actual GPS data. As shown, the RLI did not do as well and, for that reason it is being improved. The team expects to produce a revised version of the RLI in the coming year.

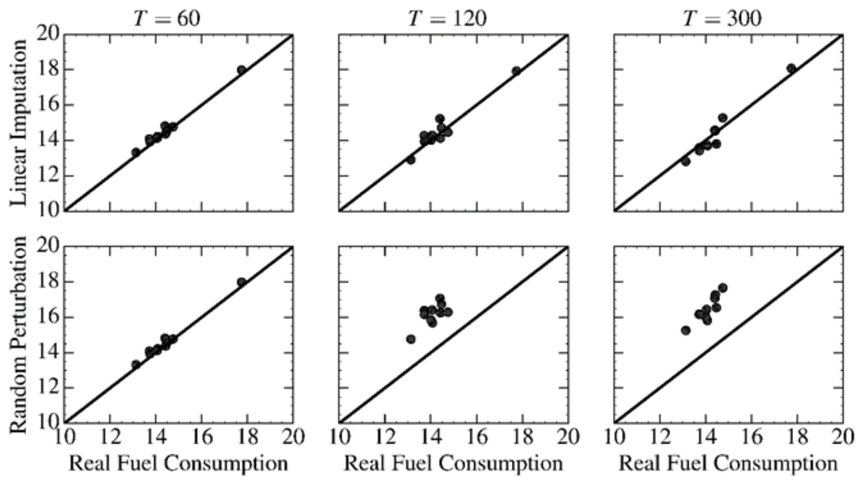

Figure I.7-3 Estimation errors Using GPS imputation procedures

All signs indicate that that the imputation procedures could indeed be used to estimate energy consumption for the entire corridor, using archival data. The imputed second–by-second GPS data will be used as an input to the GPS Analysis Software (GAS), produced by the team, to make estimations of patterns of energy use, emissions, and freight transportation costs. An important feature of the GAS is that it estimates its outputs—fuel consumption, emissions, and transportation costs—for both real-life conditions captured in the dataset and the free-flow travel conditions. The free-flow results provide a benchmark for what could be attainable if congestion diminishes.

Home Delivery Survey

During the past year, the team also worked on a survey to gain insight into Americans' opinions on freight demand management strategies for internet deliveries. The survey allowed the team to learn which of the proposed strategies to reduce the congestion and pollution produced by internet deliveries has the highest probability of being successful. Respondents were presented with a brief overview of several proposed freight demand management strategies. After reading about each of these strategies, respondents were asked to provide any opinions they had and to rate how likely they would be to utilize each strategy. The survey was organized into five general sections:

1. Internet Use and Screening Question: Respondents were asked how often they were able to utilize the internet in a manner that allowed them to shop online, and were provided with a screening question that asked if they had ever purchased an item online. A response of "yes" directed participants to the next round of the survey, while a response of "no" directed participants to provide a list of reasons why they do not shop online, before skipping ahead to Section 5 ("Demographic Information").

2. Online Shopping Activity: Respondents were asked a series of questions regarding their typical online shopping activity, such as the reasons why they purchase items online, the number of items purchased online or restaurant orders made online in a given month, the categories of items they purchase online, and if they ever order items online from a local retailer.

3. Last Online Purchase: Respondents were asked about the last item they bought online, and the importance of delivery cost, shipment time, and reliability of the promised delivery time window, along with the level of urgency of the shipment and whether or not the respondent would pay extra to either reduce delivery time or obtain a guaranteed delivery time window.

4. Home Delivery Schemes: This section assessed the receptiveness of respondents towards five different freight demand management strategies: delivery lockers, workplace delivery, delivery consolidation (delivering multiple orders at the same time), night delivery, and crowd delivery (delivering items using a crowdsourcing service). For each strategy, respondents were shown a short definition of the strategy and a stock image illustrating the process, along with an optional comment box, for any opinions they had regarding a strategy. Finally, respondents were asked to rate how likely they were to use each strategy, on a scale of "extremely unlikely" to "extremely likely". The question was then repeated, with respondents asked to assume that the strategies could reduce congestion and pollution in their neighborhoods.

5. Demographic Information: This section asked questions about age, gender, household size and income, education level, and ZIP Code. At the end of this section, respondents were asked for their views regarding climate change and whether or not several external factors, particularly the opinions of friends and family, and the social positions of companies, affect their purchasing decisions.

To maximize the reach of the survey at a minimal cost, the team used Amazon's Mechanical Turk (MTurk) platform to recruit and compensate participants. MTurk is a crowdsourcing marketplace for recruiting participants across the world. MTurk has the advantage of relatively low cost compared to traditional recruiting methods, and it safeguards the privacy of users, as the research team receives no information about respondents other than their MTurk identification number and what is provided in the survey. Each respondent who provided a complete and valid response received $5.00. The survey was activated at approximately 11:00 a.m. on June 14, 2019, with the target number of recipients (500) reached before 10:00 p.m. on the same day. In total, the team received nearly 550 responses, of which 507 were complete and qualified for payment. Survey respondents were located throughout the United States, and most states were represented. Generally, the number of respondents by state were correlated to the state's population.

About 83% of respondents stated that they were able to shop online at any time of day. Nearly 90% of respondents stated that they shop online because it saves time, while three-quarters shop online because it saves money. The ability to read reviews from other shoppers and the ability to choose from a larger inventory than is available at local stores were also cited as reasons for shopping online by a majority of respondents. The mean respondent had 10.26 online shopping orders per month and 5.25 online shopping deliveries per month, both excluding food orders. This corresponds to slightly more than 1 delivery per week. For online restaurant orders, the mean respondent had 3.90 orders/month and 3.14 deliveries/month. Within the month before the survey, three-quarters of respondents purchased clothing and electronics online, and two-thirds of respondents purchased health and beauty items online. Slightly less than half of respondents purchased groceries and cleaning supplies online.

With regard to demographics, two-thirds of respondents were male. There was a strong bias toward younger respondents. Slightly over half of respondents were under the age of 35, with the 25 to 34 age range containing roughly 47% of respondents. Slightly over two-thirds of respondents had a college degree of some form, with over 55% having a bachelor's degree or graduate degree. Respondents were overwhelmingly low- and middle-income, with more than two-thirds having an annual household income below $70,000. Respondents overwhelmingly believed that climate change is a serious issue, with nearly half selecting the highest response of "a major threat to humanity". Respondents tended to base their purchasing decisions on the suggestions of friends/family, the social positions of companies, and reviews made by other customers.

A key purpose of the home delivery survey was to learn which of the many proposed freight management strategies are most likely to be used by consumers. While governments and companies could promote any strategy they desire, it is most effective to promote the strategies that consumers are most likely to use. Figure I.7.4 illustrates the willingness of acceptance of the five demand management strategies. Delivery lockers and delivery consolidation strategies were the initiatives with the highest willingness to accept.

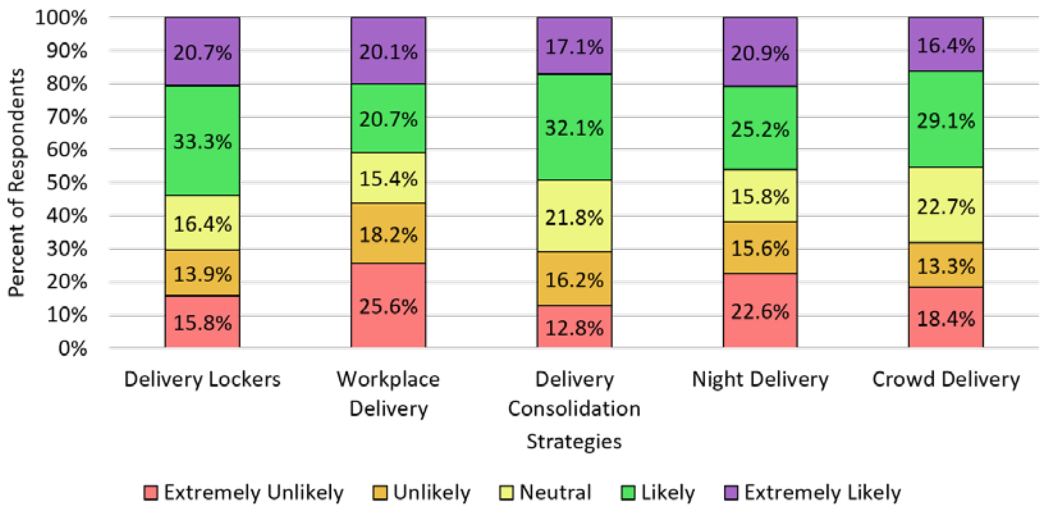

Figure I.7-4 Acceptance of freight demand management strategies

In addition to the home delivery survey, the team is working on a survey for carriers and receivers, and on in-depth interviews (IDIs) for large traffic generators, to gain insight into the freight activity of businesses. At this point, the team is designing the survey for carriers and receivers. The team has developed a questionnaire for the IDIs and started interviews. At this early stage, there are not sufficient respondents to report.

Conclusions

The team has made substantial progress on the project and is on track for achieving the objectives. The team has been working on the activities of tasks 1.3 "Develop draft tools and algorithms" of thrust 2, and task 2.1 "Characterization of baseline conditions" and task 2.2 "Assess initiatives' effectiveness", both of thrust 3.

For the task "develop draft tools and algorithms." the team has done a major redesign of the BMS-EEL. In addition, companies such as UPS, Price Chopper and Anheuser-Busch have agreed to work with the team. Regarding the task "Characterization of baseline condition," the team will have a collaboration with ATRI to obtain the necessary data to assess the baseline energy consumption scenario in the Albany-NYC corridor. The team has also developed data algorithms to simulate second by second speed data. Lastly, for the task "Assess initiatives' effectiveness," the team developed and administered a household survey on freight demand management strategies regarding internet deliveries.

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I.8 Southeast Alternative Fuel Deployment Partnership (Center for Transportation and the Environment)

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Start Date: October 1, 2017 End Date: March 31, 2021
Total Project Cost: $10,881,211 DOE Share: $4,621,781 Non-DOE Share: $6,259,430

Project Introduction

The Center for Transportation and the Environment (CTE) has assembled a team of local and regional organizations throughout the Southeastern states of Georgia, Alabama, and South Carolina to create the Southeast Alternative Fuel Deployment Partnership (SEAFDP). Project team members represent entities from private, public, and non-profit sectors that are engaged in and actively support the deployment of alternative fuel vehicles (AFVs) and infrastructure. SEAFDP members include: Clean Cities – Georgia (CC-G), Alabama Clean Fuels Coalition (ACFC), Palmetto State Clean Fuels Coalition (PSCFC), Southern Company, UPS, Waste Management, DeKalb County, City of Atlanta, McAbee Trucking, and Clean Energy.

Alternative fuel vehicles can provide multiple operational benefits, including lower fuel costs, lower or no emissions, and positive public image; however, the up-front capital costs are still often significantly higher than gasoline and diesel vehicles, especially for all-electric vehicles and medium- and heavy-duty vehicles. Infrastructure is costly, and often times the lack of it is what prevents fleet owners from adopting AFVs into their fleets, so providing access to fueling infrastructure through incentives is key to ensuring successful and meaningful adoption of AFVs. This project is essential to offset the capital cost of new fueling and charging stations and the incremental cost of AFVs, as compared to equivalent diesel or gasoline vehicles, as these costs are often the last barrier to AFV adoption.

This program also encourages partnerships and promotes collaboration within the AFV industry. CTE will study a mix of fleets that are experienced with AFV adoption, along with fleets that are new to alternative fuels. This will provide the opportunity to develop relationships and share best practices and data, which may otherwise not occur under normal circumstances. The team has the opportunity to leverage peer-to-peer exchanges to help educate and mentor fleets new to AFV acquisition and operation. Veteran fleets that are expanding their alternative fuel adoption will also have the chance to explore the opportunities and challenges associated with scale-up.

Finally, there are several risks associated with the adoption of AFVs. In particular, electric vehicles (EVs) in the medium- and heavy-duty markets have unique charging profiles. It is important for fleets considering these vehicles to understand their operational characteristics, as well as the relevant utility rate structures, to ensure the most efficient and cost-effective operation. Additionally, AFV adoption requires that operators, technicians, and first responders be properly educated and trained on these new vehicle systems, which takes time, money, and expertise. The SEAFDP project makes it possible for CTE to consult with project partners on these activities and better prepare them for successful outcomes.

Successful adoption of these vehicles and refueling/recharging infrastructure will do the following:

- Demonstrate the viability of these technologies, compared to other fleets
- Develop the technical skills and expertise of operators, integrators, and component providers, and
- Increase the size of the AFV market, increasing volume of sales, adding competition, and driving down costs.

Objectives

The objective of the project is to accelerate the deployment of commercially available alternative fuel fleet vehicles and infrastructure in niche markets throughout the Southeast. To accomplish this objective, CTE will work with SEAFDP members to develop a case study, to strategically identify best practices, policies, and procedures resulting from three major activities:

- Purchase of Alternative Fuel Vehicle (AFV) Fleets and Infrastructure
- Development of Alternative Fuel Corridors
- Development of Strategic AFV Fleet Partnerships.

Approach

The SEAFDP will purchase a mix of commercially available AFVs, including compressed natural gas (CNG), plug-in hybrid electric (PHEV), and 100% battery electric vehicles (EVs), in various fleet applications, including package delivery, waste/recycling haulers (both public and private), freight haulers, and municipal/county fleets. U.S. Department of Energy (DOE) funding will pay for 40% of the incremental costs of purchasing AFVs, as well as a portion of refueling or recharging infrastructure costs. The project will accelerate the growth in these niche AFV fleet markets by championing the efforts of fleets already committed to AFVs in their daily operations, as well as fleets new to the industry. CTE will rely on the enthusiasm of its fleet partners to utilize and study these vehicles in different operating environments, evaluate an AFV fleet's ability to perform at the same level of operation as similarly sized gasoline and diesel fleets, and calculate reductions in vehicle emissions and petroleum consumption, based on actual operation.

Participating partners represent a diverse group of organizations at different stages of the AFV adoption cycle. Through a comprehensive analysis of the best practices, policies, procedures, and scalability of each of these unique applications, the project team plans to draw conclusions that will prove relevant for organizations of all types, sizes, and experience levels, which will increase the likelihood of replication throughout the Southeast and the U.S.

Specifically, CTE and SEAFDP members will:

- Reduce emissions and petroleum consumption in the Southeast by putting into service approximately 300 AFV fleet vehicles in niche fleet markets in Georgia, Alabama, and South Carolina
- Collect AFV operational and maintenance data during an approximate 12-month evaluation period
- Educate fleet owners on the technical and financial feasibility of various AFV technologies and applications, and how they compare to their gasoline and diesel counterparts
- Identify infrastructure gaps for CNG fueling stations and electric vehicle supply equipment (EVSE), to support creation of alternative fuel corridors and extended range AFV travel throughout the Southeast
- Facilitate local and regional partnerships between AFV market players throughout the supply chain, to alleviate barriers to AFV adoption and provide consultation for organizations as they enter the market, and

- Using findings from project activities, develop a best practices, policies, and procedures case study, to accelerate the deployment of commercially available AFVs and infrastructure in niche fleet markets across the United States.

Results

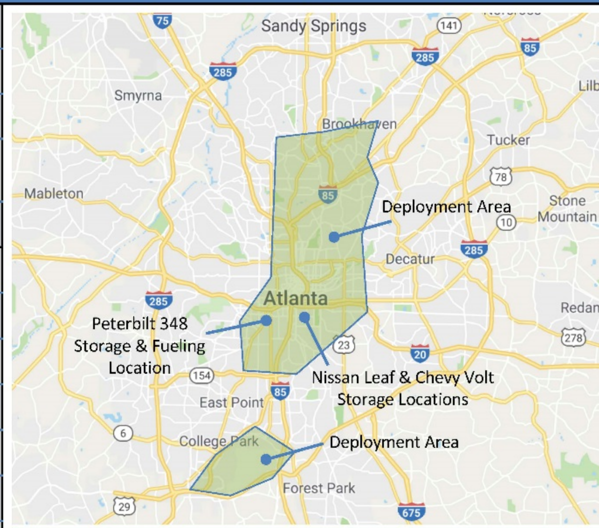
Deployment of AFV Fleets and Infrastructure

During fiscal year (FY) 2019, CTE conducted the following key activities towards the completion of this objective:

- Completed pre-deployment planning and key performance indicator (KPI) reporting workshops for participating fleet owners, which allowed CTE to estimate fuel economy, fueling requirements, and operating costs for each partner, to help ensure that expectations are clear and realistic, and to provide a baseline for KPI reporting. This information also helped ensure that vehicle and infrastructure deployment, training, and data collection plans were in place. Figure I.8.1, below, represents an example of the summarized pre-deployment planning results.

CITY OF ATLANTA — SEAFDP ROUTE EVALUATION

① Vehicle Attributes	**Vehicle Make**	Chevrolet	Peterbilt	Nissan
	Vehicle Model	Volt	348	Leaf
	Fuel Type	PHEV	CNG	Electric
	Onboard Fuel Storage	18.4 kWh 8.9 gal gas	10,448 scf (75 DGE)	40 kWh
	Expected Range	420 miles	150-200 miles	151 miles
② Deployment Plan	**Service Type**	Daily Ops	Refuse	Daily Ops
	Hours Driven per Day	9 hours	10 hours	9 hours
	Miles Driven per Day	45-60 mi.	60 mi.	45-60 mi.
	Fuel Consumed per Day	14-18 kWh 2 gal gas	2,090-2,786 scf (15-20 DGE)	14-18 kWh
	Est. Fuel Cost per Day	$5.10*	$41	$1.54-$1.98*
	Fueling Station Location	Various	City Facility	Various
	Fueling Station Owner	Private	City of Atlanta	Private
	Time Required to Fuel	5 hours/ 10 minutes	10 hours	8 hours
	Time of Day for Fueling	Varies	Varies	Overnight
	Vehicle Storage Location	Various	Various	Various
③ Deployment Risks	**Driving Range**	Low	Low	Low
	Fueling Strategy	Low	Low	Med



Annual Impact

CO_2 Emissions reduced each year by operating the alt-fuel vehicles: **176 tons CO2**

Annual fuel cost savings by operating the alt-fuel vehicles in place of traditional diesel and gasoline vehicles: **$269,715**

④ Comments

- The alt-fuel vehicles will not be deployed on fixed routes. Instead, the vehicles will be used to transport City staff and perform city services (e.g. park refuse and construction material transport) within City limits.
- The City has matched each alt-fuel vehicle with an appropriate duty cycle. The risk of an alt-fuel vehicle running out of fuel while in service is low.
- The new CNG vehicles will utilize existing CNG fueling stations owned and operated by the City, which limits fueling risks. The electric vehicles do outnumber the charging infrastructure and the City will need to develop a charging management strategy.
- The City has prior experience with both electric and CNG vehicles. Overall deployment risk is low.
- *Cost based on commercial average electricity cost in GA.

Figure I.8-1 Example of pre-deployment planning results: City of Atlanta alternative fuel vehicle deployment

- Through a competitive selection process, welcomed two new project partners for CNG fueling station deployment in Birmingham, Alabama
- Participated in alternative fuel vehicle training for maintenance personnel at UPS
- Conducted site visits to confirm delivery and deployment of 194 alternative fuel vehicles, as outlined in Table I.8.1, below.

Table I.8.1 Fleet Partner Vehicles Delivered To Date

SEAFDP Partner	Expected # of Vehicles	Vehicles Delivered to Date	% of Vehicle Share Delivered	Completion Date
City of Atlanta	58	5	3%	3Q20
DeKalb County	32	32	100%	2Q19
McAbee Trucking	4	0	0%	4Q19
UPS	150	150	100%	3Q19
Waste Management	25	7	28%	2Q20
SEAFDP Project	269	194	72%	3Q20

- Submitted quarterly reports to DOE and attended the 2019 Annual Merit Review in Washington, DC.
- Continued to coordinate vehicle and fueling infrastructure equipment purchase orders, vehicle deliveries, infrastructure installation, and data collection and reporting activities, as outlined below:

City of Atlanta

In 2019, the City of Atlanta's Department of Watershed Management (DWM) took delivery of three (3) Nissan LEAFs. Previously, the City took delivery of two (2) CNG refuse trucks, for a total of five (5) project vehicles to date. The City also placed an order for an additional three (3) LEAFs and (1) Chevrolet Bolt. The City has faced procurement challenges with respect to electric vehicle charging infrastructure, which is necessary to support a larger scale deployment of electric vehicles, and will use existing chargers until new chargers can be purchased. To further support infrastructure planning and procurement efforts, the City is coordinating with Georgia Power to conduct a detailed fleet charging assessment under its Will-It-Work program, which is scheduled to begin early 2020.

DeKalb County

DeKalb County has taken delivery of all 32 project vehicles and placed them into routine service. CTE and DeKalb County continue to collect operational data for the CNG refuse trucks to support a 12-month KPI study (expected completion 1Q20).

McAbee Trucking

Freightliner completed production on McAbee's four (4) Class 8 CNG trucks in September 2019. Next steps include CNG fuel system integration at Quantum Fuels; pre-delivery testing; delivery; and acceptance testing onsite at McAbee. McAbee expects delivery and acceptance testing to occur in 4Q2019. CTE provided McAbee with a data collection and reporting template to track KPIs during deployment.

UPS

UPS has received all 20 Workhorse PHEV and all 130 Ford CNG delivery trucks. UPS continues to work with Workhorse on the engineering and design changes for the next generation electric vehicle, which the group hopes to study as part of the project. Please note that UPS is not using project funds to purchase the electric vehicles. CTE continued to collect operational data from UPS to support a 12-month KPI study (expected completion 1Q20).

Waste Management – Hardeeville, South Carolina

In FY 2019, Waste Management completed the installation and commissioning of its CNG fueling station in Hardeeville, South Carolina. Waste Management also took delivery of seven (7) CNG refuse trucks. CTE and Waste Management finalized the data collection and reporting plan and began collecting operational data to support a 12-month KPI study (expected completion 1Q20). Waste Management placed an order for the remaining 18 project vehicles in August 2019, with delivery expected in summer 2020.

Clean Energy and Waste Management – Birmingham, Alabama

In August 2019, DOE executed Amendment 0001, which approved the addition of Clean Energy and Waste Management – Birmingham as project partners. CTE resumed contract negotiations with these new partners and expects to begin work in January 2020. Clean Energy currently owns and operates a liquefied natural gas (LNG) station that is situated in a signage-ready location off the I-65 corridor in Birmingham, AL, and plans to integrate CNG equipment into the existing station. Waste Management plans to install CNG fueling infrastructure for their private fleet at an existing facility located at 700 Clow Road in Birmingham. Waste Management's CNG station will be located near the Birmingham-Shuttlesworth International Airport; thus, this project will reduce emissions in an area that has a disproportionate share of the state's emissions from high traffic volumes.

Development of Alternative Fuel Corridors and Strategic AFV Fleet Partnerships

For this objective, CTE tasked the Clean Cities Coalitions in Georgia, Alabama, and South Carolina with developing a scope of work to identify gaps for CNG and EVSE infrastructure, and support creation of alternative fuel corridors and extended range AFV travel throughout the Southeast. The project team completed the final scope of work in June 2019. As a first step, the team obtained spatial data on current and planned EV (DC fast charge), CNG, and LNG fueling stations located in Alabama, Georgia, and South Carolina, as well as adjacent areas of surrounding states. CTE obtained spatial data on Federal Highway Administration (FHWA)-designated Alternative Fuel Corridors in Alabama, Georgia, and South Carolina, as well as highways and exits along these corridors. The team also utilized ArcGIS Online to select fueling stations located along FHWA-designated Alternative Fuel Corridors, and to perform drive-time area analyses around these fueling stations, to determine areas of the corridor located within the FHWA-mandated distances of fueling locations (50 miles for EV, 150 miles for CNG, and 200 miles for LNG). Finally, the team identified gaps in the FHWA-designated corridors not served by any existing fueling stations, for each of the three types of alternative fuel. As a next step, CTE will identify particular locations that may be candidates for EV, CNG, and LNG stations that would fill in the identified gaps in the corridors. For this objective, the project team is maintaining a living methodology document. Upon completion of the deliverable, the project team will create and publish a final draft as part of the project case study, along with results of the study.

Figure I.8.2 represents the completed drive-time area function at a 50-mile separation distance between EVSE stations along corridors. Areas that are covered within the 50-mile station distance are overlaid with purple, while gaps in the corridors fall outside the purple areas. CTE also incorporated exit data, which will allow users to identify where to site EVSE infrastructure to eliminate gaps.

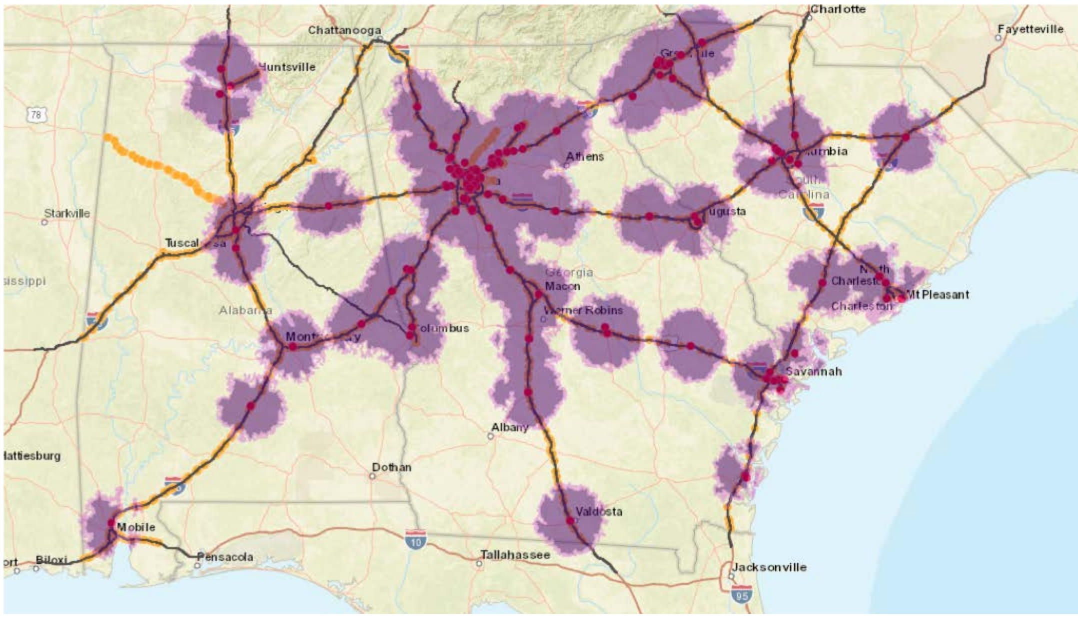


Figure I.8-2 EVSE drive-time area function

Conclusions

The three-year project began on October 1, 2017, and after a six-month no-cost extension, is scheduled for completion in March 2021. The majority of the tasks in Year 1 were dedicated to contracting, project planning, and finalizing purchase orders for alternative fuel vehicles and associated infrastructure. Year 2 focused on planning for data collection and reporting; delivery of project vehicles; commissioning infrastructure; and finalizing purchase orders for the remaining project vehicles. To date, the project team has documented the following lessons learned from project activities:

- Federal funding assistance greatly increases an organization's willingness and ability to purchase and deploy AFVs and infrastructure, due to higher capital costs, compared to diesel or gasoline equivalents. This is especially true for small to medium size organizations and municipalities, where local funding may be scarce, and budgets are based on historic, conventional vehicle prices.

- While federal funding assistance greatly increases participation in AFV programs, maintaining project partner commitments throughout the project life can be a challenge, primarily due to time constraints and federal contract requirements. Specifically, the limited time provided during the initial application process sometimes makes it difficult to engage all relevant parties/departments within an organization, and obtain the necessary sign-offs from councils or boards. This was especially a challenge with the project's municipal partners that must follow a lengthy process for formal commitment to the project scope of work, and allocation of local funds. In addition, timing associated with administrative and contract requirements may take too long, or the required federal contract terms and conditions may not align with team member or legal expectations, causing partners to withdraw from the project.

- Proper and accurate budgeting for infrastructure construction and installation work is necessary for a successful deployment. The project team recommends conducting these activities prior to proposal development to increase the level of readiness for a project. If not conducted prior, proper planning for these activities should be included in the project work plan, and project budgets adjusted accordingly.

- Allocating proper funding or general planning to support the use of technology (e.g., telematics systems) in data collection and reporting activities will help streamline processes and increase the reliability of data.

I.9 Making the Business Case for Smart, Shared, and Sustainable Mobility Services (Seattle Department of Transportation)

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Start Date: October 1, 2017 End Date: September 30, 2020
Project Funding: $8,196,377 DOE share: $1,982,068 Non-DOE share: $6,214,309

Project Introduction

The transportation sector is expected to undergo more change in the next decade than in the three previous decades combined. The automotive and energy industries are actively investing in zero emission vehicles and alternative fueling infrastructure in response to public policy, new technologies, and market forces. New companies in the mobility arena are also transforming the way we look at personal transportation and vehicle ownership, shifting the mobility marketplace from an ownership model to a shared transportation model that will be driven largely by electric vehicles (EVs).

With urban populations projected to rise throughout the United States in the coming decades, the challenges associated with mitigating transportation impacts on air quality, the environment, and urban livability could intensify without concerted action.

This project, led by the City of Seattle, brings together the U.S. Department of Energy and major industry stakeholders with the City and County of Denver, City of New York, Forth, and Atlas Public Policy to test different electric shared mobility interventions. Project teams in each city will focus on one type of market intervention and analyze the impact on EV adoption and electric vehicle miles traveled by car share and ride hail services. The project will serve as a replicable blueprint, highlighting intervention results, and providing pathways for other cities to electrify shared fleets across the country.

The shared mobility environment is rapidly evolving and has changed significantly since the launch of this project in October 2017. Fiscal Year (FY) 2019 brought the unexpected loss of three project partners – Eluminocity, Reachnow, and Maven – who were responsible for deploying Electric Vehicle Supply Equipment (EVSE) and EVs. In June 2019, partners submitted a project amendment (A002) that would continue tracking toward project goals under a revised budget and extended schedule, to account for recent changes. This report is based on the project as currently approved and includes A002 proposed changes when relevant.

Objectives

The objective of this project is to accelerate the adoption of plug-in EVs in shared mobility applications throughout several major U.S. markets, and to establish best practices for all U.S. metropolitan regions. By piloting a series of programs in several widely varied urban environments, the project will develop, test, and prove market-viable techniques for EV adoption. This will be achieved through:

- Facilitating the deployment of new EVs [1] and EVSE in several U.S. cities
- Defining the business case for the use of EVs in shared mobility applications
- Deploying and evaluating tools for addressing many of the barriers to EV adoption

- Developing an EV Shared Mobility Playbook, which will summarize the project's findings by providing a comparative analysis of each city's program and identifying factors that affect the success of shared mobility electrification programs.

Approach

Each regional partner is applying unique interventions, in partnership with local car share and/or ride hailing services and other regional partners, as described below and shown in Table I.9.1. Each intervention will be evaluated and compared throughout the course of the project and in the EV Shared Mobility Playbook (Playbook). Actions and Key Partners have been adjusted to account for project partnership changes in FY 2019.

Table I.9.1 Interventions by Regional Lead, Including Region, Strategy, Action, and Key Partners

Regional Lead	Region	Strategy	Action	Key Partners
Seattle Department of Transportation (SDOT)	Seattle, WA	Increase EVSE access by strategically siting new infrastructure to serve shared mobility, including deployment at or near Shared Mobility Hubs	Identify priority locations for EVSE. Install EVSE, conduct outreach and engagement, and partner with local shared mobility companies to support implementation, utilization, and evaluation.	Seattle City Light, Seattle Office of Sustainability & Environment, Western Washington Clean Cities Coalition
City of New York (NYC)	New York, NY	Provide EVs and supportive charging infrastructure to ride hail drivers.	Deploy 4-8 new DC Fast Chargers and supportive pilot programming, including outreach and engagement, to support the electrification of shared mobility.	EVgo, NYC Mayor's Office of Sustainabiliy, NYC Department of Transportation, NYC Taxi & Limousine Commission, Empire Clean Cities
City and County of Denver (Denver)	Denver, CO	Provide EVs directly to ride hail drivers, and supply charging infrastructure.	Deploy 4-6 DC Fast Chargers and supportive pilot programming, including outreach and engagement, to support the electrificaiton of shared mobility.	EVgo, Denver Metro Clean Cities Coalition
Forth	Portland, OR	Promote and support EV use by ride hail drivers, coupled with access to free, unlimited charging.	Partner with ride hail service provider to pilot a program that systemically encourages drivers to use EVs; work with local utilities and ride share companies to educate and train ride hail drivers to promote plug-in vehicles to consumers.	Uber, Portland General Electric, Brink Communications

Results

In FY 2019, project partners developed portions of the EV Shared Mobility Playbook, made progress on EVSE deployment, and provided supportive programming for EV use in ride hail services. Preliminary results and lessons learned by Task are provided below.

Task 1 - EV Shared Mobility Playbook Development

Throughout the project period, partners are compiling reports and other deliverables into the Shared Mobility Playbook, hosted on the project's website, http://evsharedmobility.org/, and broadcasting this information via the project list serve, webinars, and public presentations. New content added to the Shared Mobility Playbook in FY 2019 includes a variety of documentation and tools described below. In addition, partners continue to engage with external stakeholders to share information about the project and lessons learned, and identify information gaps. In 2019, the project team shared its work via five webinars and ten public speaking engagements, reaching an estimated 900 interested individuals.

Documents published in FY 2019

- Seattle Department of Transportation's (SDOT) EVSE Roadmap for Shared Mobility Hubs - This guidance was published by SDOT, and developed with Seattle-area project partners to provide improved connections to public transit via electrically-powered shared mobility services. The document outlines an initial regional strategy for deploying EVSE at or near Shared Mobility Hubs (places where transportation connections, travel information, and community amenities are aggregated). This document will be updated as necessary throughout the project period.

- National Overview of TNC Electrification - This report, by Atlas Public Policy, provides an overview of the growing transportation network company (TNC) market in the United States in the context of an expanding electric vehicle (EV) market. The largest TNC companies –Uber and Lyft—have established electrification targets, creating a significant opportunity to accelerate transportation electrification generally, with the expansion of EV offerings and charging infrastructure, along with supportive public policy development.

- Electrifying Ride Hailing in Seattle - This report, by Western Washington Clean Cities Coalition (WWCC), provides a brief overview of the existing state of electrifying ride hailing services, along with policies and incentives local governments and utilities are pursuing to encourage ride hail electrification. It reviews lessons learned from relevant studies and WWCC's initial outreach to ride hailing drivers, and provides recommendations for future engagement and action in the Seattle area.

Tools developed in FY 2019

- The EV Shared Mobility Analysis Tool (BETA) analyzes the business case for electrifying ride hail services. It allows users to understand the income potential of providing ride hail services through various means of acquiring a vehicle, including owning, renting, and leasing. It is designed to make it easy to compare two scenarios side-by-side, such as an EV purchase and an EV rental. It populates most inputs with reasonable default values, but users can overwrite any input.

- Seattle's Dynamic Electric Vehicle Supply Equipment Siting Model (PROTOTYPE) is a Geographic Information System (GIS)-based tool to guide EVSE deployments that align with Seattle's priorities and the project's objectives. This model includes a variety of different data sources that are nearly all publicly available. It was designed so that other organizations could create similar tools for their own purposes and unique geographies. (See Figure I.9.1.)

- Data dashboards - Atlas Public Policy developed two data dashboards; one on "Indicators for EV Adoption" in shared mobility services, and a second mock dashboard for EV charging station data. The dashboards are publicly accessible and will be developed and updated as more project data is collected, or other relevant data is identified.

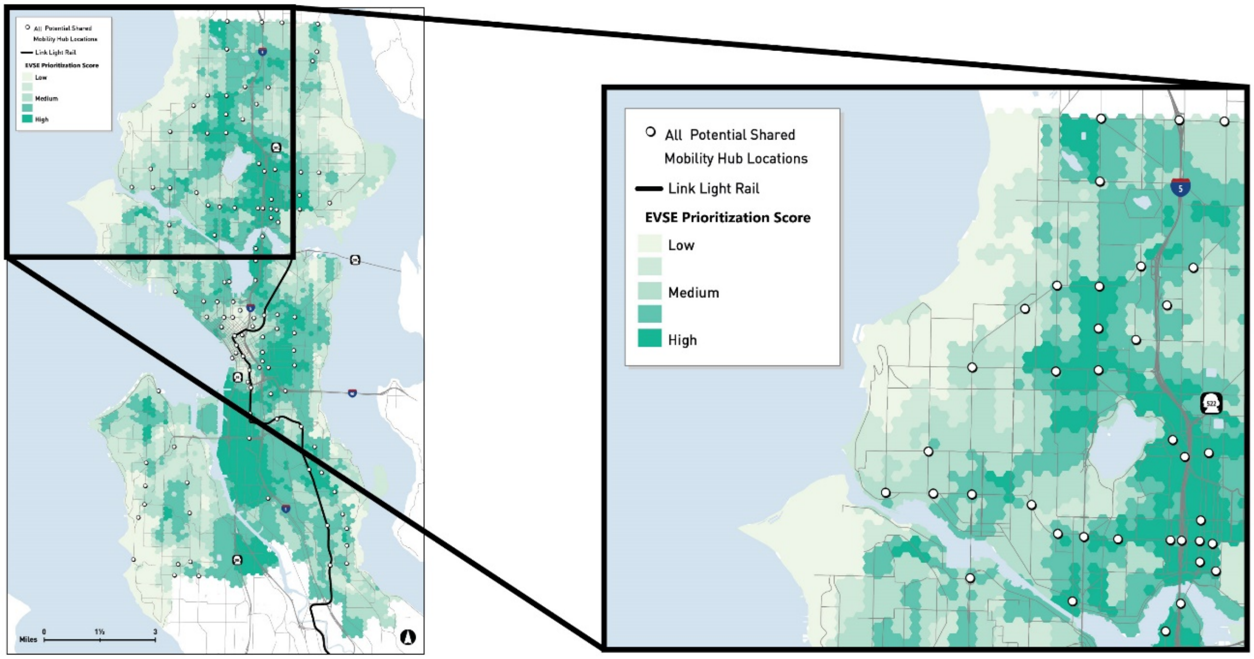

Figure I.9-1 An example of results from Seattle's Dynamic EVSE Siting Model. The adjustable GIS-based model provides an EVSE prioritization score for different areas across the City by shared mobility hub, zip code, and neighborhood.

Task 2 - EV Charging Station Deployment

The Cities of Denver, New York, and Seattle are deploying EVSE as a part of this project. Deployments in Denver and New York will be done through EVgo, beginning in FY 2020. Seattle City Light (SCL) will deploy a total of 20 Direct Current Fast Chargers in Seattle, two of which are already operational and four more that should be operational by the end of November 2019. Preliminary session-level data from SCL's two deployed chargers near the Beacon Hill Light Rail Station reveal fluctuating usage since January 2018, with the highest usage in December 2018. (See Figure I.9.2.)

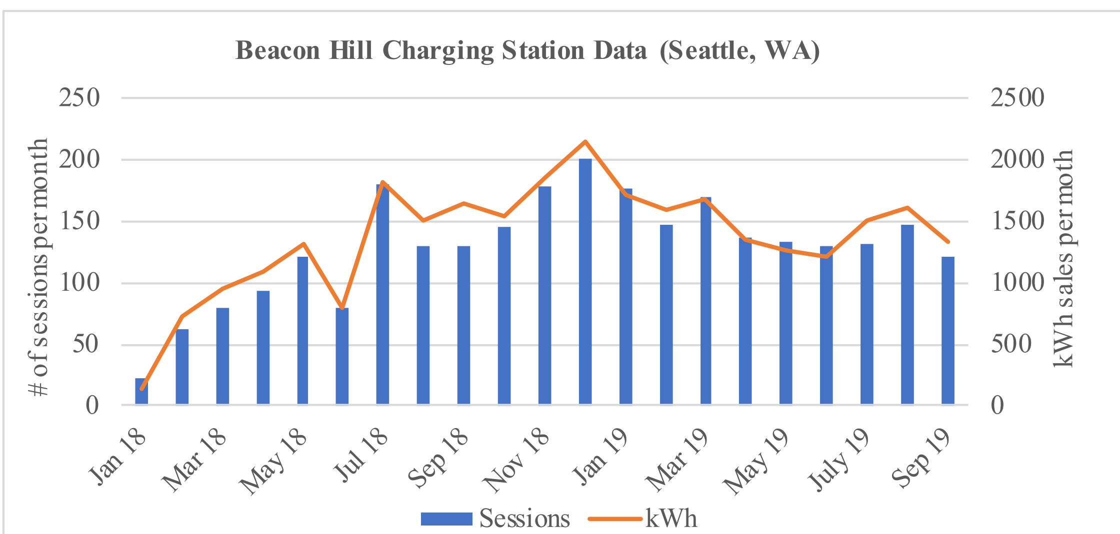

Figure I.9-2 Number of sessions and electricity provided (kWh) by month for Seattle City Light's two DC Fast Chargers near the Beacon Hill Light Station in Seattle, WA. This station became operational in January 2018.

Since August 2018, the average daily sale at the station is 47.1 kWh and the average daily use is 4.5 sessions. Analysis supports that some drivers have used this station as their primary charging location, charging more than 20 times in a month.

Task 3 - Launch Operations for Initial EV Deployment [2]

Due to the loss of EV car share partners Reachnow and Maven, amendment A002 removes the project's plan to deploy EVs and adjusts it to focus on operations to facilitate EV deployment. These operations began 2019, with the launch of marketing campaigns, online information for rideshare drivers [3], rideshare driver outreach, and a fair financing pilot. These efforts focused on the ride hailing industry and drivers. Partners are coordinating data collection and metrics tracking from these efforts.

Outreach conducted through Forth, in Portland, and Western Washington Clean Cities, in Seattle, produced key findings that will guide future outreach and project implementation. The project team synthesized these findings from data collection at a variety of engagements, including tabling events at airports and a service center for ride hail drivers. Partners are developing an Attitudinal Study Questionnaire for driver engagements, to collect comparable feedback across all regions, and assess the impact of outreach and engagement activities. This will be finalized in 2020. Key findings from outreach in FY 2019 include:

- Rideshare drivers are interested in EVs with longer driving ranges, more space, and a luxury car feel. Many available EVs are too small for passengers and luggage.
- There is strong interest in EVs, but many people do not know where to find more information about them.
- Fuel and maintenance cost savings seem to be the most appealing aspects of driving an EV.

In August 2019, the City of New York instituted a cap on new for-hire vehicle licenses, with an exemption for full battery electric vehicles, and will be assessing the resulting impact on EV adoption in its for-hire vehicle fleets. Before drivers purchase or lease an EV, they are encouraged to look at factors that include how far the vehicle can travel on one charge, how long it takes to charge the vehicle, and where a vehicle can be charged. Prior to the recent exemption changes, only a handful of the over 120,000 licensed for-hire vehicles were EVs. Since the exemption went into effect, 75 new EVs are now licensed by the Taxi and Limousine Commission. These for-hire vehicles include a range of models, such as the Tesla Model 3, Nissan LEAF EV, the Chevrolet Bolt EV, and the Hyundai KONA Electric.

Conclusions

Due to unanticipated project changes in FY 2019, partners moved forward significant portions of the EV Shared Mobility Playbook (Task 1), EVSE Deployment (Task 2), and Operations to Facilitate EV Deployment (Task 3 as amended in A002). EVSE deployed may help drivers feel more comfortable with shifting to an EV, particularly if they lack at-home charging. While many are aware of the potential benefits of driving an EV, these benefits are not always clearly conveyed or accessible, and current EV models may not suit some ride hail driver's requirements for space and driving range. In 2020, partners look forward to deploying additional EVSE, continuing outreach and engagement and other supportive programming, and compiling data to evaluate the impacts of different implementation strategies across the four regions.

Key Publications

1. Seattle Department of Transportation. 2018. "EVSE Roadmap for Shared Mobility Hubs." http://evsharedmobility.org/resource/evse-roadmap-for-shared-mobility-hubs/.

2. Seki, Stephanie and Nick Nigro. 2018. "Electrifying Carshare Services: A Case Study on car2go's All Electric Fleet in San Diego." http://evsharedmobility.org/resource/electrifying-carshare-services/.

3. Atlas Public Policy. 2019 "EV Shared Mobility Analysis Tool (BETA)." http://evsharedmobility.org/resource/ev-shared-mobility-analysis-tool-beta/.

4. Connor Smith. 2019. "National Overview of TNC Electrification." http://evsharedmobility.org/resource/national-overview-of-tnc-electrification/.

5. Puget Sound Clean Air Agency. 2019. "Electrifying Ride-hailing in Seattle." http://evsharedmobility.org/resource/electrifying-ride-hailing-in-seattle/.

6. Seattle Department of Transportation. 2019. "Seattle's Dynamic Electric Vehicle Supply Equipment Siting Model." http://evsharedmobility.org/resource/seattle-evse-siting-model/.

References

1. This objective is altered in proposed project amendment A002 to remove EVs and instead "deploy charging infrastructure and supportive pilot programming."
2. In amendment A002, this is adjusted to "Operations to Facilitate EV Deployment."
3. Forth's Rideshare Drivers webpage can be viewed at: https://forthmobility.org/why-electric/rideshare-drivers.

I.10 Accelerating Alternative Fuel Adoption in Mid-America (Metropolitan Energy Center, Inc.)

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Start Date: October 1, 2017 End Date: September 30, 2021
Project Funding : $7,630,417 DOE share: $3,803,793 Non-DOE share: $3,826,624

Project Introduction

There are significant gaps in the I-70, I-29, and Highway 54 compressed natural gas fueling corridors in Kansas. I-70 and I-29 are major shipping corridors, and Highway 54 is in the middle of the Beef Belt. Insufficient fueling infrastructure is inhibiting alternative fuel adoption throughout the Midwest. The goal of this project is to expand the use of alternative fuels and fueling infrastructure in Kansas and Missouri.

Objectives

Our objectives are to establish compressed natural gas (CNG) corridors through the state of Kansas, expand access to gaseous fuels and electric vehicle infrastructure in Kansas and Missouri, and reduce greenhouse gas emissions by converting diesel and gasoline-powered vehicles to alternative fuels.

Approach

Metropolitan Energy Center (MEC) facilitates partnerships between local governments, fleets and other local stakeholders; assists project stakeholders with resource development and change management; provides training and technical support; and creates accountability and rapport among our stakeholders and project partners. Grant subrecipients include the cities of Kansas City, Missouri, Garden City and El Dorado, Kansas; the Grain Valley and Blue Springs School Districts in Missouri; Kansas City International Airport; Stirk CNG and 24/7 Travel Stores. DOE funding covers 45% of the costs of purchasing alternative fuel vehicles and purchasing and installing refueling infrastructure; the remaining 55% is paid for by the grant subrecipients.

Our relationship management approach involves project coordinators working directly with assigned subrecipients as single points of contact, organizing monthly status calls (which serve a secondary purpose of facilitating relationships and a shared informational record among subrecipients), and fostering a consultative relationship that allows us to connect subrecipients with resources and prospective vendors, and generate public-private partnerships.

Using our guidance and their internal guidelines and policies, subrecipients are responsible for sourcing and implementing their own alternative fuel projects with comprehensive reporting and tracking to MEC. Through the course of project implementation, each subrecipient also hosts an alternative fuel workshop, which serves many functions. Workshops educate myriad stakeholders, build community support for the projects, and provide opportunities to develop relationships and engender additional AFV adoption projects.

Results

At this stage in the project, the project partners have deployed 2 fueling stations (one propane and one 12-stall electric); conducted 4 informational/networking workshops (Figure I.10.1); converted 5 gasoline vehicles to CNG; and replaced 18 diesel trucks and 4 diesel shuttles with natural gas equivalents (Figure I.10.2). Our subrecipients in Grain Valley Public Schools erected propane fueling infrastructure and have seen a complete return on investment in less than one calendar year (Figure I.10.3). This was due to creative use of funding opportunities and wide use of the infrastructure by vehicles with high mileage accrual (vehicle miles traveled, or VMTs). Grain Valley acquired their propane school buses using another funding source.

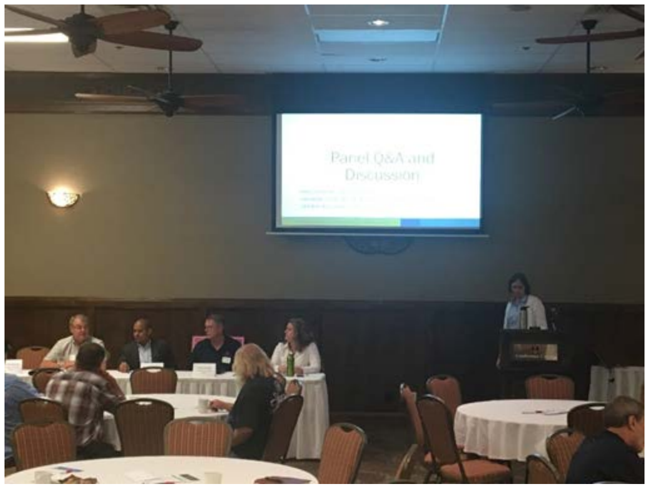

Figure I.10-1 Panel discussion at a workshop in Garden City, KS. (Photo Credit: Natalie Phillips)

Figure I.10-2 A CNG bus from Kansas City International Airport's fleet. (Photo credit: Kelly Gilbert)

MEC conducted four alternative fuel workshops and reached an audience of approximately 100 diverse stakeholder companies and agencies. Each of these workshops generated follow-on activities related to alternative fuels. For example, the Wakeeney, Kansas, workshop on CNG led to conversations with Dodge City on the conversion of city vehicles to CNG, as well as the prospect of building the CNG fueling infrastructure to support fleet adoption. This new project is already in the works and partially funded using a separate funding source. Additional follow-ons include pursuit of Mid-America Green Fleets analyses for City of Overland Park, Kansas, Topeka Metro, and City of Olathe, Kansas. These analyses examine fleet composition and duty cycles, and the project team uses this information to identify and prioritize vehicles that can be converted to alternative fuels. Such analyses can be used to help build support and consensus for alternative fuel projects, strategize funding pursuits and potential partners, and facilitate a smoother application process when funding opportunities arise.

Figure I.10-3 Tour of Grain Valley School District's propane fueling infrastructure. (Photo Credit: Kelly Gilbert)

Three of five subrecipients assigned to install new, or augment capacity at existing, CNG stations have backed out of that task. Two of these subrecipients were augmenting existing capacity, so the net effect is minimal. The third—which was tasked with installing new infrastructure on corridor gaps on I-70—was removed from the project for nonperformance. MEC is working with a fourth subrecipient to re-set expectations and re-assess opportunities, and has released a request for proposals to replace one or more of the planned public-access CNG station subrecipients. The fifth is requesting a re-scope to instead install DC Fast Chargers at several convenience stores, for interstate electric vehicle travel.

Conclusions

Our approach is seeing anticipated results, both in planned deployments and in new project development; however, we have seen delays for CNG fuel station development and for heavy-duty vehicle deliveries, either of which could delay an on-time delivery of the final project. Project staff are monitoring opportunities to lessen these delays and are preparing mitigating actions as necessary.

Lessons Learned:

- Public fast-fill infrastructure projects are vulnerable to the competitive price of diesel. Such projects have faced challenges retaining anchor fleets that are necessary for a reasonable return on investment.
- Vehicle replacement projects are subject to manufacturing delays resulting from supply chain interruptions, some of which may be due to fluctuations in trade policies and their effects on the price and availability of components.
- Fleet managers are heavily influenced by the experiences and testimonies of their peers. Word of mouth and peer networking have been great assets in promoting the adoption of alternative fuels beyond the scope of this project.

I.11 Technology Integration to Gain Commercial Efficiency for the Urban Goods Delivery System, Meet Future Demand for City Passenger and Delivery Load/Unload Spaces, and Reduce Energy Consumption

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Start Date: October 1, 2018 End Date: December 31, 2021
Project Funding: $2,140,200 DOE share: $1,500,000 Non-DOE share: $640,200

Project Introduction

We are living at the convergence of the rise of e-commerce, ride-hailing services, connected and autonomous vehicle technologies, and fast-growing cities. Many online shoppers want the goods delivery system to bring them whatever they want, where they want it, in one to two hours. At the same time, many cities are replacing goods delivery load/unload spaces with transit and bike lanes. Cities need new load/unload space concepts that are supported by technology to make the leap to autonomous cars and trucks in the street, and autonomous freight vehicles in the final 50 feet of the goods delivery system. The final 50 foot segment starts when a truck parks in a load/unload space, and includes delivery persons' activities as they maneuver goods along sidewalks and into urban towers to make their deliveries.

In this project, the Urban Freight Lab (UFL), part of the Supply Chain Transportation and Logistics Center at the University of Washington; the Pacific Northwest National Laboratory (PNNL), and project partners will develop, pilot test, and (using a learn/do approach) improve upon technologies supporting new operational strategies to optimize use of urban load/unload space, as well as business efficiencies, in the final 50 feet of the goods delivery system.

Objectives

The objectives of this project are to develop and implement a technology solution to support research, development, and demonstration of data processing techniques, models, simulations, a smart phone application, and a visual-confirmation system to:

1) Reduce delivery vehicle parking seeking behavior by approximately 20% in the pilot test area, by returning current and predicted load/unload space occupancy information to users on a web-based and/or mobile platform, to inform real-time parking decisions

2) Reduce parcel truck dwell time in pilot test areas in Seattle and Bellevue, Washington, by approximately 30%, thereby increasing productivity of load/unload spaces near common carrier locker systems

3) Improve the transportation network (which includes roads, intersections, warehouses, fulfillment centers, etc.) and commercial firms' efficiency by increasing curb occupancy rates to roughly 80%, and alley space occupancy rates from 46% to 60% during peak hours, and increasing private loading bay occupancy rates in the afternoon peak times, in the pilot test area.

Approach

The project team has designed a 3-year plan, as follows, to achieve the objectives of this project.

In Year 1, the team will develop integrated technologies and finalize the pilot test parameters. This involves finalizing the plan for placing sensory devices and common locker systems on public and private property; issuing the request for proposals; selecting vendors; and gaining approvals necessary to execute the plan. The team will also develop techniques to preprocess the data streams from the sensor devices, and begin to design the prototype smart phone parking app to display real-time load/unload space availability, as well as the truck load/unload space behavior model.

In Year 2, the team will execute the initial implementation, which includes overseeing installation of the sensors, and collecting and processing data. The team will also manage installation, marketing and operations of common locker systems in the pilot test site; test the prototype smart phone parking app with initial data streams; and write a code to simulate truck parking behavior in the model.

In Year 3, the project team will expand and improve upon project implementation. We will continue to measure results against project goals and make improvements; develop a visual-confirmation system to alert drivers if they overstay their authorized time in the space (inducing improved compliance); and run the behavior model to evaluate demand and other scenarios.

Results

The project team identified a list of site selection criteria to choose the pilot test areas for this study. After lengthy negotiations with Seattle Department of Transportation (SDOT) and Bellevue Transportation Department (BTD), and facilitation to ensure that the two involved transit agencies' (Sound Transit and King County Metro Transit) needs were also part of the final agreement, the team selected an 8-block pilot site in Greater Downtown Seattle, Washington, and another site in downtown Bellevue, Washington. The selected sites balance the project's need for high-demand delivery locations and agencies' interests. All project partners toured the pilot test areas in July 2019.

Key accomplishments of the project over the past fiscal year (October 1, 2018 through September 30, 2019) are summarized below, in terms of each project objective:

Objective 1 - Reduce parking seeking behavior by approximately 20% in the pilot test areas

Accomplishment #1

More and more, city privacy and/or surveillance ordinances preclude use of advanced technologies such as computer vision to track parking seeking behavior in public rights of way. As this is the case in Seattle, the project team developed a new, rigorous data collection protocol to gain quantitative insights into commercial vehicle drivers' operations – based on observations taken aboard delivery vehicles (ride-alongs), and highly granular private data (GPS route traces) provided by delivery firms, as explained below. The project team will use them to evaluate the parking app's effectiveness in reducing parking seeking, by comparing the 'before' data, collected in Years 1-2, with 'after' data, collected in Years 2-3.

1) *Delivery vehicle ride-alongs* - The team developed and tested a data collection protocol to collect real-time data from riding with delivery vehicle drivers. This data will inform the design of the parking app and selection of key variables for the development of the parking decision model. The collected data will include vehicle route, parking location alternatives, parking location choice, dwell time, pick-up and delivery activities, and parking inefficiencies (queueing for load/unload spaces, re-routing, parking cruising, or unauthorized parking).

2) *GPS route traces* - The team developed a methodology to analyze historical GPS traces data obtained from delivery companies, to identify and quantify parking inefficiencies. For each delivery trip, the team calculated the difference between the real trip time (the time between the end of one delivery event and the start of the next delivery) and the estimated travel time from Google API. This difference could be related to time spent searching for parking (parking cruising time) or other parking inefficiencies. This

data will also enable the team to better understand commercial vehicle drivers' parking behaviors, and which types of information they use to make routing and parking decisions.

Accomplishment #2

The team arranged for and conducted 9 ride-alongs with delivery companies. Researchers rode with delivery vehicle drivers during their shifts and collected data by observing the drivers' parking behavior and delivery operations in downtown Seattle. Based on these observations, the team created four categories of parking behavior that will be used to inform development of a driver parking choice model in Years 2-3:

1) *Pre-parking-arrival plan* - Experienced drivers often have a pre-determined load/unload space in mind long before they approach the delivery location. They do not 'seek a parking space', but rather see if their preferred space at a given location is available or not.
2) *Re-routing* - When drivers cannot find a load/unload space near their delivery location, some will go across town to make another delivery before returning to that location.
3) *Unauthorized parking* - In addition to Commercial Vehicle Load Zones (CVLZs), drivers also consider other parking zones, including paid parking, no-cost passenger load zones, no-parking zones, and even travel lanes, as potential parking locations.
4) *Invisible queueing* - Some drivers are willing to wait in nearby non-CVLZ parking spaces until a desired CVLZ is available.

Accomplishment #3

The team started cleaning and processing data collected from the ride-alongs and created four main delivery datasets, listed below:

1) *Ride-along dataset* - Contains information about the ride-along, including vehicle type, company, number of stops, total travel distance, and total travel time
2) *Stop dataset* - Contains information on the delivery parking events (a commercial vehicle parking and performing one or more deliveries/pick-ups), including start and end timestamps; dwell time; latitude and longitude of the parking location; parking choice; whether any waiting or re-routing was experienced; number and type (delivery/pick-up) of activities performed; number and types of goods handled
3) *Segment dataset* - Contains information on each "activity segment". Activity segments are classified into two types:
   a. Delivery segment starts with the driver parking the vehicle and ends with the driver leaving the parking spot
   b. Driving segment (a vehicle trip between two stops). For each segment, the recorded data includes start/end timestamps; total time and distance; latitude and longitude of start and end location; segment type; average speed; and altitude
4) *GPS dataset* - Contains all the GPS traces obtained for all segments. The traces show the routes taken by the drivers both while driving the vehicle and while walking to perform the deliveries/pick-ups.

Accomplishment #4

The project team used paper prototypes to facilitate post-observation interviews with delivery drivers about a potential parking occupancy app, to develop a better understanding of app requirements from drivers' perspectives, as well as the factors an app would need to accommodate drivers' ease of use. After the ride-alongs, PNNL refined paper prototypes into wireframes and storyboards to describe app interactions in greater detail. PNNL started app development using the data obtained from mapping the study area and the simulated parking data. App development efforts included establishing the development environment and creating the full front end and back end server, and the general architecture and design. The design is somewhere in between prototype and production. Since parcel and big/heavy delivery firms represent a significant share of the urban delivery market, the mobile parking app will be targeted to those user groups.

***Accomplishment** #5*

The team obtained GPS data from two delivery companies (a parcel delivery firm and a big/heavy delivery firm). Using the developed GPS traces methodology, the team estimated the parking cruising time, i.e., the difference between real trip time and estimated travel time, and analyzed (1) the empirical distribution of parking cruising time and (2) the factors that affect these differences. The team found that 70% of the trips showed a longer trip time than the estimated travel time, with a mean difference of 9 minutes. Furthermore, using regression modelling, we showed that the variability in trip time deviations can be explained by the characteristics of the parking infrastructure at destination. These results can help city authorities to detect “hot spots”, urban areas that experience heavy congestion, and understand how to best allocate parking infrastructure to improve the final 50 feet of the urban logistics system.

Accomplishment #6

The SDOT Curbside Management team developed criteria for selecting a parking occupancy sensor vendor and drafted a request for proposal (RFP) based on those criteria. The BTD installed and tested a sensor technology with processing capabilities to detect parking occupancy in the Bellevue pilot test area. The sensor reported on parking occupancy for a single commercial vehicle loading zone, and on through traffic, and has now been discontinued. BTD is planning to install and test more sensor technologies during Year 2 of the project.

Objective 2 - Reduce parcel truck dwell time in pilot test area locations by approximately 30%, by increasing productivity of load/unload spaces near common locker systems

Accomplishment #7

The project cost-share partners and UFL members did a walkthrough of the downtown Seattle pilot test area in July, to recommend potential locations for common lockers. The team also noted considerations for locker system installation associated with certain locations, including transit stations, alleys, private parking lots, curbside locations, sidewalks, and indoor locations.

The team compiled an extensive list of potential common locker vendors and their service offerings for the RFP. The team designed the RFP; the University of Washington’s procurement services, risk management and capital projects offices reviewed it and sent it out in September.

Objective 3 - Increase network and commercial firms' efficiency by increasing curb occupancy rates to approximately 80%, and alley space occupancy rates from 46% to 60% during peak hours, as well as underutilized private loading bay occupancy in the afternoon peak times, in the pilot test area.

***Accomplishment** #8*

On the July walk-through of the Seattle pilot test area, the team observed and described commercial vehicle parking issues in the area and recommended that potential metered/paid parking spaces be reclassified to CVLZs. Following the walkthrough, the Curbside Management team at SDOT decided to move CVLZs in the Seattle pilot test area, based on their long-standing expertise in curb management and their observations during the walkthrough. Those observations led to design principles listed in Table I.11.1 that the research team will evaluate in the CVLZ reallocation. SDOT also decided to increase the minimum length of CVLZs to 35 feet.

Table I.11.1 Draft Design Principles and Measurable Goals for CVLZ Reallocation

Design Principle	Decision Basis	Measureable Goals
Group CVLZs at the beginning of the block, instead of interspersed along the curb.	Historically, SDOT has placed CVLZs along the block in response to requests from business/property managers. This has led to a checkerboard pattern of CVLZs alternating with passenger parking spaces and other uses, which causes many delivery drivers to back into CVLZs to serve the block. During the July walkthrough, the project cost-share partners, UFL members and delivery drivers interviewed on the spot recommended that the CVLZs be consolidated at the beginning of the block to allow drivers room to pull into the space. Moreover, grouping multiple CVLZs at the beginning of the block allows longer trucks to safely park in authorized spaces.	1: Eliminate/reduce time-consuming maneuvers into mid-block spaces.
Don't place CVLZs between a bike lane and a travel lane.	If drivers have to move goods (via hand truck) across a bike lane to get from a CVLZ to the sidewalk, they may create an obstacle for bicyclists, and walking in the bike lane they may not be safe themselves. Walking in a through lane to get to the corner is also a safety problem for the delivery drivers.	2: Move CVLZs adjacent to the bike lane on 2nd Ave to the other side of the street or to nearby cross streets.
Place some CVLZs by common locker locations.	Common lockers create delivery density, which has private and public benefits.	3: Reduce delivery time in the final 50 feet at these locations

Conclusions

This project will significantly improve three important aspects of urban freight systems:

1. It will provide new and deep knowledge of urban good delivery system operations.

There are significant gaps in the current understanding of urban goods systems at an operational level. This project integrates and analyzes real-time data (when vehicles are occupying load/unload spaces, as well as how long each of the spaces are occupied) collected via multiple sensory technologies, with a new network-use-concept for city load/unload spaces. Data from the sensors will develop knowledge of curb, loading zone, and alley usage, and parking cruising behavior, including which vehicles use which infrastructure features; how dwell times vary across these parking locations; and how usage of these features is differentiated over the course of a typical day. Answering these questions is essential to developing improved city infrastructure planning and policy development.

In addition to benefiting city officials and professional staff responsible for planning and managing public assets, this information can benefit delivery firms' dispatchers and drivers, once it is shared with them. Drivers can better plan their routes to schedule visits when parking is more likely to be available, and carriers can compare their average dwell times to the status quo, and identify drivers who spend longer/less time than average at locations. Municipalities can use this information to inform pricing and enforcement strategies that will best achieve desired outcomes.

2. It will enable active management of the comprehensive urban load/unload space network.

Real-time information about dwell times and infrastructure usage allows cities to implement active management strategies. The proposed integrated data systems will enable evaluations of alternative management approaches. In many cities, curb space is allocated to specific vehicle types: transit, passenger, or freight vehicles. With comprehensive sensor systems, alternative approaches to curb management could be tested by comparing results to the status quo. These could include sections of the curb dedicated to vehicles with certain stop durations (e.g. 15 minutes or less), or to vehicles of certain size (e.g. motorcycles, cars, etc.) and dynamically allocating usage by time of day. In the future, sensor data could be incorporated into a separately considered permitting upgrade where the sensors play a role in vehicle recognition, payment and enforcement. This could scale beyond loading, to cover digital permitting for many very short-term curb uses such as ride-hailing. Moreover, the sensor data could support strategies such as time-of-day pricing, where the prices can be set based on evidence and knowledge of existing usage patterns.

3. It will produce commercial benefits.

Real-time information about infrastructure usage and parking availability may make dramatic improvements for drivers and carriers possible. This information could be provided on mobile devices available in vehicles, and/or at fixed locations around the city, and could reduce the amount of vehicle circulation and the amount of time required per stop. When integrated into mobile device applications, driver routing tools can direct vehicles to the route that minimizes parking or cruising time. In the future, these apps could also automatically reserve spaces so that parking will be guaranteed to be available upon arrival. Of course, parking reservations could also be made independent of the routing algorithm.

A final application of the proposed sensing, information, and communications systems is specific to driver stop times. The common carrier lockers systems can cut truck dwell times, leading to higher turnover and increased productivity of load/unload spaces.

The project team is on schedule for achieving the project objectives. The main achievements to date are:

- Formed and staffed the project’s advisory and technical work groups
- Determined study pilot and control locations
- Secured permission to execute the project in the pilot areas
- Drafted the RFP to select a parking occupancy sensor vendor and sensor data collection plan
- Designed and released the RFP to select a common locker system vendor
- Identified two new data sources (ride-alongs and GPS route traces), developed data collection protocol for gathering data from ride-alongs and a new methodology to analyze GPS traces data to quantify parking cruising
- Performed multiple ride-alongs, and identified several sources of parking inefficiencies that affect the performance and operations of commercial vehicles in urban areas
- Developed a decision model for commercial driver parking choice
- Held a walkthrough at the Seattle pilot test area, leading to identification of potential locations for common lockers and SDOT’s plan to modify CVLZs in the pilot test area
- Translated user preferences to features and functionality, and designed skeleton code and wire-framing of the mobile parking app.

Key Publications

1. G. Dalla Chiara, and A. Goodchild. 2020.“A Method to Empirically Investigate the Effects of Parking Availability on Commercial Vehicles Travel Times in Urban Areas.” In Transportation Research Board Annual Meeting, Washington, DC. (Accepted).

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- King County Metro Transit
- Kroger Company
- Pepsi Co.
- Puget Sound Clean Air Agency
- Seattle Department of Transportation
- Sound Transit
- UPS
- USPS

I.12 Drones, Delivery Robots, Driverless Cars, and Intelligent Curbs for Increasing Energy Productivity of First/Last Mile Goods Movement (Carnegie Mellon University)

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Project Introduction

Achieving large improvements in the energy productivity of the freight transportation sector is challenging. In the largely petroleum-powered U.S. transport sector, truck transport comprises 23% of transportation energy use, and is responsible for 24% of transportation-related greenhouse gas (GHG) emissions, while light-duty vehicles comprise 60% of transportation GHG emissions and 64% of transportation energy use. [1] In addition, transportation remains a large source of nitrogen oxides (NOx) and other air pollutants. The way the U.S. moves goods is changing, however, and this will affect changes in energy productivity over the coming decades. As more Americans are buying their goods online, retail employment has shifted away from department stores and toward electronic shopping firms. [2]

With the continued growth of e-commerce, the use of Autonomous Aerial Vehicles (or “drones”) and sidewalk-based autonomous ground delivery vehicles (or “delivery robots”) for package delivery has become more attractive, and several companies have announced development programs for package delivery using these vehicles. Widespread adoption of drones and delivery robots to replace a portion of first/last mile truck pickups and deliveries could reshape the transportation sector by changing demand patterns and by shifting a portion of the demand for fuel, from diesel used by trucks, to electricity used by drones, for example. At the same time, both on-road electric vehicle (EV) and driverless automated vehicle (AV) technologies are advancing rapidly and highly automated passenger vehicles could be on streets and highways within the next decade. These AVs could carry goods as well as passengers, and intelligently managed curb spaces could optimize first/last mile exchanges. Drones, delivery robots, and vehicle automation are coming to the transportation sector, but how these vehicles and systems could be designed to maximize energy productivity is less clear. This research project evaluates pathways for improving the energy productivity of first/last mile mobility for goods movement, using drones, delivery robots, and automated vehicles, with and without the use of optimal routing and intelligently managed curb spaces.

Objectives

The objective of the project is to use empirical testing, life cycle assessment, and systems analysis to research and demonstrate an improvement of at least 20%, compared to a baseline network, in energy productivity of goods delivery using drones, ground delivery robots and automated vehicles. The research will also develop proof-of-concept testing, a model, and simulation for a smart curb space as an intelligently-managed urban delivery zone, with a goal of demonstrating at least an additional 10% improvement in energy productivity.

Approach

The team's hypothesis is that both an urban flight environment and on-board autonomous capabilities affect the energy use of delivery drones across a range of vehicle types and payloads, and this needs to be considered and optimized. Researchers, firms, and stakeholders also need an understanding of the comparative advantages of a range of ground delivery robots, vehicles, and system designs to maximize overall energy productivity and potential. The team has designed and executed an experimental protocol to empirically measure the energy use of drones of various designs (See Figure I.12-1 and Figure I.12-2) and sizes, carrying a range of payloads through various campaigns and altitudes. The team recorded testing environment conditions of wind speed, temperature, and other factors, and on-board sensors recorded voltage and current, GPS location, speed, wind speed, and drone movement characteristics for each flight. This enabled the team to estimate the energy used for each flight at a high resolution.

Figure I.12-1 Package delivery drone during testing (Photo: CMU Team)

Figure I.12-2 Package delivery drone during testing with payload (Photo: CMU Team)

Similar to aerial drones, ground delivery robots will navigate urban conditions with collision avoidance sensing, computer vision, and on-board autonomous software—changing transport patterns and energy requirements. The team's hypothesis is that energy use per package delivered increases non-linearly as a function of payload and additional people and obstacles these vehicles have to navigate on urban sidewalks. Thus, there is a tradeoff between vehicle size, payload mass, battery size, delivery range, and energy use, all of which affect energy productivity estimates. The team has designed and executed an experimental protocol to empirically measure the energy use of ground delivery robots carrying a range of payloads through various scenarios (See Figure I.12-3). The team also estimated the theoretical propulsion energy use of electric, rubbertired delivery vehicles of various masses, and assessed the energy tradeoffs between vehicle, battery, and payload mass across a range of existing and potential battery specific energy values.

Figure I.12-3 Automated ground delivery robot used for testing (Photo: CMU Team)

In Fiscal Year (FY) 2019, the team also collected existing traffic data for the Pittsburgh, Pennsylvania region and initiated development of a goods delivery network model with intelligent curb spaces. This data, and the results from the ground and air vehicle empirical testing and simulations, will enable the team to simulate, evaluate, and optimize energy productivity of goods delivery. The combined empirical, simulation, and modeling methods enable identification of pathways to improve the energy productivity of goods delivery.

Results

The team completed more than 200 successful tests of a drone with various payloads, and more than 50 successful tests of a delivery robot. Using the test results, the team characterized differences from the theoretical minimum power needed, and how conditions, vehicle design, and payloads affect energy use. Understanding these differences will enable engineers, firms, and stakeholders to make decisions to optimize delivery energy use and maximize energy productivity. The team collected high resolution data across a range of variables for each test, and analyzed the data for trends and outliers. For example, Figure I.12-4 shows how power consumption changes over flight duration. The team separately analyzed three distinct regimes of flight operations: ascent (seen on the left of Figure I.12-4), cruising, and descent (seen on the right of Figure I.12-4). By using machine learning to separate the data into these three regimes for all of the flights, the team can better assess the conditions that enable energy productivity improvements.

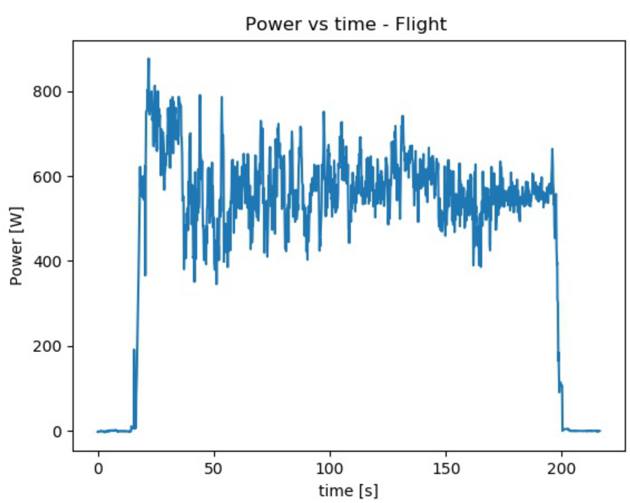

Figure I.12-4 Example of data collected from one unmanned drone flight

The team's hypothesis is that wind speed and direction can affect the energy use and optimal routing of delivery drones, but little data exist about wind speeds and drone energy use. Hence, the team used an on-board anemometer to measure and quantify the impacts of wind speed on drone energy use. The results can enable optimal design routing of drones to maximize energy productivity of delivery. Figure I.12.5 shows an example of wind magnitude and direction data collected during an unmanned aerial vehicle test flight.

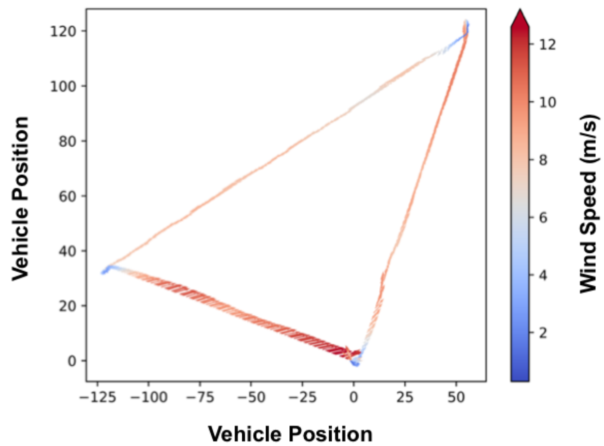

Figure I.12-5 Illustrative chart of wind magnitude and direction during a drone test flight

In comparing the initial data from the test flights, the team found an association between higher speeds and lower trip total energy consumption, due to a shorter overall flight duration. (See Figure I.12-6) There are limits to this relationship, and additional analysis is ongoing. If confirmed with additional testing, this has implications for route planning and energy productivity.

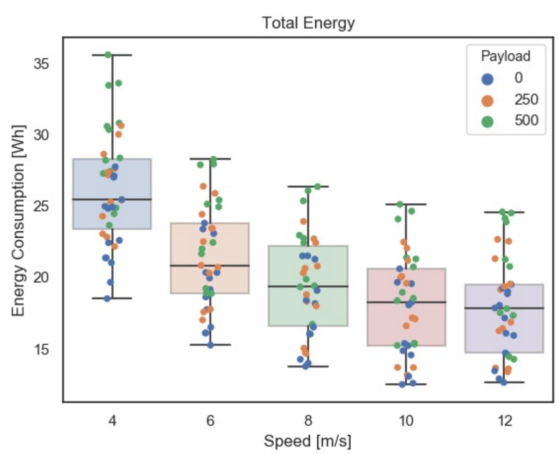

Figure I.12-6 Initial results of drone energy use for various speeds and payloads

Finally, the team filed a patent in FY 2019 titled, “System, Method, and Computer Program Product for Transporting an Unmanned Vehicle”. The patent involves a method for optimizing vehicle parking space use and unmanned vehicles, and provides a method for transporting an unmanned vehicle in a smart city environment. In addition, the PI co-authored a paper about Internet of Things (IoT) devices and automated vehicles in a smart city context for *IEEE Internet of Things Magazine.* The PI also discussed the approach and initial results at the Society of Automotive Engineers (SAE) Government Industry Conference in April 2019 in Washington, D.C. in a presentation titled “Improving Energy Productivity of Delivery.”

Conclusions

In FY 2019, the team made substantial progress on the project, and the results from the initial year align with achieving the project objectives. Publicly available real-world data on drone energy use is extremely limited, and the team generated novel vehicle energy use data and delivered it to DOE. The team is continuing vehicle testing and simulation of the pathways to improve the energy productivity of delivery with several variants and scenarios, which will provide insights to entrepreneurs, researchers, designers, and decision-makers. One publication and one patent application resulted from the project in the initial year, and the team is finalizing several more research publications for submittal to peer-reviewed journals.

Key Publications

Bergés, M., Samaras, C. 2019. “A Path Forward For Smart Cities and IoT Devices”. *IEEE Internet of Things Magazine.*

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Acknowledgements

The team is grateful to DOE Project Manager Darren Stevenson for valuable feedback and advice that improved the project. The team is also grateful to Ellen Bourbon for valuable feedback on this report summary.

I.13 Integrating Microtransit with Public Transit for Coordinated Multi-Modal Movement of People (Ford Motor Company)

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Project Funding: $2.500,000 DOE share: $2,000,000 Non-DOE share: $500,000

Project Introduction

The growing presence of on-demand transportation services provides a unique opportunity to influence the urban mobility status quo, shifting from personally owned and operated vehicles to the Mobility as a Service (MaaS) paradigm. To be successful, microtransit, (i.e., on-demand shuttles), service providers will need to be able to offer services that are seamlessly integrated with public transit, and do so with a high degree of efficiency to make the service operationally, financially and behaviorally viable. In this project, the focus is on the potential benefits of mobility service providers and transit agencies cooperating to offer fully integrated and seamless multi-modal mobility services for commuters. In particular, the project team is interested in the potential for energy savings via the adoption of MaaS, by reducing the number of personal vehicle trips, and encouraging higher occupancy transportation modes. While there has been considerable recent interest in using on-demand services as a solution to first/last mile connectivity, this is a challenging problem that is far from solved. There is not a clear indication that such solutions can be i) operationally efficient, ii) financially viable for operators and/or transit agencies, and iii) a convenient and compelling option for users.

Objectives

The objective of the project is to research, develop, and demonstrate that a first/last mile mobility service, integrated with transit agencies' real-time transit and user data, works seamlessly in a simulation environment and a real-world pilot. The major expected outcomes of this project are:

1. A simulation environment for planning and optimizing a first/last mile mobility service that is seamlessly integrated with public transit (i.e., has access to real-time transit data)

2. Calibration of the behavioral components of the system via user surveys and field tests

3. A comprehensive field experiment that shuttles riders to one of the three major park and ride stations in Seattle in collaboration with King County Metro, and a second pilot that will take place in a different city

4. A quantification of the potential for energy efficiency and mobility gains from implementing such a system (one that is also economically viable)

Approach

A number of transit agencies have launched pilot projects in which microtransit provides first/last mile connectivity to transit stations. While these vehicle sharing services offer accessibility benefits, meaning that more people can access and use the transit system, they can lead to other systemic inefficiencies. For example, there may be a need to rebalance vehicles to avoid deadheading (empty vehicles traveling the routes), to ensure the supply of vehicles remains aligned with the demand for transport (i.e., deadhead miles) [1]. This rebalancing has the fundamental side effect of potentially increasing the total vehicle mileage driven in the system, compared to the traditional methods of transport. The viability of microtransit is also unclear from both an operational and behavioral sense. For example, riders are typically anxious about missing scheduled transfers to public transit, and these worries only increase with a microtransit system. Therefore, the solution must integrate seamlessly with public transit systems (using real-time information) and provide systemic guarantees on transfers, with contingencies for missed connections. Also, riders who are currently using personal vehicles could worry about their ability to secure a viable return trip once reaching a destination, since they are unable to fall back on their personal vehicles at this point. Any successful system will have to account for these and other behavioral considerations of the riders. Long-term financial viability is also a question, as microtransit pilots are also typically heavily subsidized. Microtransit as a feeder system presents an opportunity to overcome challenges related to energy efficiency and financial viability.

The research team of experts in on-demand service operations, online optimization, heuristics, real-time network control, behavioral economics, simulation, market and mechanism design, and transit operations will address the operational, behavioral and economic challenges of realizing the maximum benefits of first/last mile connectivity. Furthermore, the team comprises an on the ground microtransit service provider (Ford, with its subsidiary Transloc), a pioneering transit agency in microtransit (King County Metro) and a university that has significant research capabilities in this area (Cornell), which allows for multiple complementary perspectives for solving this real-world problem.

Mitigating Negative Effects of Fleet Rebalancing

There are two obvious approaches for mitigating the negative effects of rebalancing. The first entails the construction of vehicle dispatch systems capable of pooling ride requests to take advantage of the multi-passenger capacity of most vehicles, thus encouraging ride-sharing. The second option entails a better integration of these systems with high-capacity public transit services such as commuter rail, bus rapid transit, and subway systems. The team believes that integration between new forms of microtransit and existing public transit systems is crucial to their net scaling and energy efficiency impacts.

While there has been significant recent progress in resolving the core technical challenges of on-demand ride-hailing and dispatch systems [2, 3] the associated results rarely extend to services that enable high-capacity microtransit. Existing results for microtransit have been largely limited to heuristic methods [4, 5], or static analysis for low-capacity sharing [6]. A solution strategy for high-capacity microtransit must satisfy the ability to: (1) compute optimal user-vehicle assignment and routes in real-time; (2) strategically (dynamically) route empty and partially full vehicles to capture future demand; and (3) identify efficient ridesharing corridors by means of trip chaining (i.e., assigning passengers to an already full vehicle as the vehicle regains capacity). This project utilizes a model whereby passenger requests arrive online and require real-time assignment to a vehicle (i.e., within 30 seconds). Each microtransit passenger has a maximum time he or she is willing to wait prior to pick up, and a maximum in-trip delay due to detours relative to a direct door-to-door car or taxi ride.

There is a fixed fleet of on-demand vehicles, with each vehicle having a corresponding vehicle capacity. The model assumes that a door-to-door service will require that no riders switch between vehicles (except for at the transfer to public transit), as transfers induce a negative perception in riders. In 2017, one of this project's co-PIs and collaborators proposed a new framework for solving this problem at the urban scale, as shown in Figure I.13-1. [7] The system was experimentally validated for New York City (NYC) with a fleet of 3,000 vehicles and over 400,000 requests per day, computing solutions every 30 seconds. The preliminary results obtained from this study show that 98% of the demand served by 14,000 NYC taxis can be served by 2,000 ten-passenger shuttles, assuming a fixed capacity for every vehicle in the fleet. In this project, we will extend this model to incorporate the seamless integration with public transit systems.

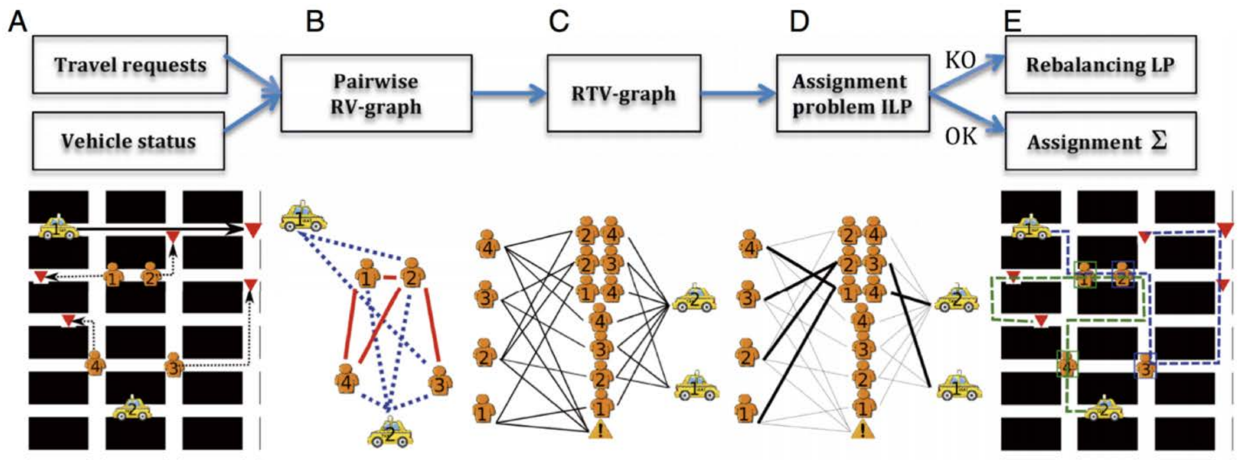

Figure I.13-1 An illustration of the optimization framework for simultaneous passenger assignment and vehicle routing. (Source: Alonso Mora et al. 2017 [7])

Integration of Microtransit and Public Transit

The primary operational challenge is the seamless integration of real-time transit data to the microtransit fleet management problem. A major deterrent to first/last mile solutions (and multi-modal travel in general) is the limited availability of information for planning multi-modal trips. For example, most commuters are sensitive to travel time uncertainty [9], and in particular availability and timing during inter-mode transfers [8, 10]. While there is limited quantitative research on the topic [11], transit ride planning tools such as Google Maps have made it much easier for riders to identify transit options that best fit their needs. Most services do not address the uncertainty in travel times and resulting disutilities, including the risk of missed transfers during an inter-modal trip. To improve commuter confidence in multi-modal trips, there is a need to develop route planning tools that capture the inherent uncertainty of travel times and transit schedules. In the context of first/last mile solutions, it is critically important that the feeder system accounts for these uncertainties and integrates directly with the transit system using both schedules and real-time updates.

The key differences between a stand-alone microtransit system and one that is part of a multi-modal feeder system are the breakdown of the original trip into multiple trip components, and coordinating the transfer between the two systems. The team's approach to achieve this will be two-fold: i) provide a robust multi-modal route planner that accounts for travel time and transit schedule uncertainty, and ii) a fleet manager that optimizes the microtransit system, subject to the constraints imposed by the transit schedule and system uncertainty. Integrating the route planner with the fleet manager allows for the system to better utilize its resources and provide a higher level of service.

First/last Mile Microtransit

In this project, once a route has been planned for each commuter, the trip component to be served through the first/last mile service for all of the requests is sent to the microtransit system for batch processing. For each request, the trip deadline is specified by the departure time of the transit service to which the route planner assigns it. The framework of the fleet manager described above can then be customized to specify user specific quality of service (QoS) constraints, such as the transfer deadline, maximum walking distance for pickup, departure time flexibility etc. These additional constraints can be easily incorporated into the fleet manager due to its decomposition of the vehicle routing and passenger assignment components. This framework also allows the system to accommodate both advanced reservations and on-demand requests.

In a fully coordinated setting, all the microtransit shuttles and public transit vehicles will stream their real-time locations to the route planning and fleet management systems continuously (e.g. every 10 seconds). This information can be used by both the route planning and fleet management algorithms to improve their solutions and reduce systemic uncertainty. For example, the fleet management framework can update its internal simulation state of the shuttle and transit locations to re-optimize the fleet routing and matching. More precisely, if a shuttle is stuck in heavy traffic and its expected schedule is no longer accurate, future pickups allocated to that vehicle may be reassigned to another vehicle.

Behavior Modeling

The team's approach will also seek to develop a deep understanding of user behavior. Despite heterogeneity in customer demand, microtransit service is generally designed for a fixed and exogenous demand, (i.e. observed trips), but designers fail to quantify the impact of endogenous demand (i.e. new trips induced by improved service) on the urban transportation system, and the implications for transit ridership. From a business perspective, microtransit is a service that responds to demand, and the level of demand needed to make the service viable depends on the behavior of commuters and whether they are willing to adopt microtransit. From a modeling perspective, behavioral models which represent heterogeneous mobility preferences and patterns must be integrated so that the system optimizer accounts for endogeneity (i.e. changing demand) and microtransit operations are designed accordingly. [12]

To make demand endogenous and construct an operational model that integrates behavioral response, the team will adopt discrete choice analysis. There is a long tradition of using discrete choice models to forecast demand of traditional mobility patterns, from mode choice (driving vs. using transit) to route choice, and to make inference on behavioral estimates that are relevant for the design and management of the transportation system. The team will draw upon an extensive literature in transportation engineering and economics devoted to estimates of the subjective valuation of in-vehicle travel time savings, which is the maximum willingness to pay to reduce in-vehicle travel time by one minute [13]. However, the introduction of microtransit in the mobility ecosystem may impact how in-vehicle time is valued, and the tradeoff between travel time and cost will need to be revisited. When considering last-mile service design, users' response to pricing, backtracking, QoS constraints, willingness to share the ride (as a function of vehicle capacity), and willingness to wait are critical. The team's discrete choice models of demand for these services will consider all of these attributes in the construction of the compensatory utility function that users maximize to make economic decisions.

The team's approach is two-fold: 1) deploy a survey to collect customer data to specify a discrete choice model for microtransit, and 2) collect revealed-preference data from direct observation during field tests. The customer survey will also gather broader information about preferences, travel patterns, environmental and energy considerations, attitudinal response to Mobility on Demand and traditional transit services, and behavioral responses to hypothetical first/last mile service conditions presented in a discrete choice experiment.

Alignment of Incentives across Stakeholders

An obstacle to the long-term viability of microtransit is financial and economic viability for the multiple stakeholders who are involved in its provision, including: 1) the on-demand microtransit provider (mobility provider), 2) the public transit agency (mobility provider), 3) the users/commuters (mobility consumers), and 4) the city (regulatory oversight and subsidy/incentive manager). Today, the status quo involves the mobility providers operating individually in a fully decentralized market, offering their own separate mobility solutions to the users, without any coordination. This lack of coordination between providers can lead to severe operational inefficiencies [14], and to this end, many cities have started exploring more coordinated schemes.

A threshold question that must be answered is whether there exists a feasible trio of pricing, revenue-sharing, and subsidy schemes that satisfies all the stakeholders. Microeconomic theory suggests that this is a difficult question to answer; moreover, it is further complicated by the concern that some stakeholders may not willingly share the required information with the system (e.g., user-specific parameters that determine their valuations, operating costs of providers) or share false information in an attempt to "game the system". [15] Thus, the pricing, revenue-sharing, and subsidy schemes must also induce truthful reporting of the required privately held information from all stakeholders. The question of finding the "best" such trio depends on who owns and runs the system, e.g., the city might be interested in maximizing social welfare, whereas the on-demand provider might want to maximize profits.

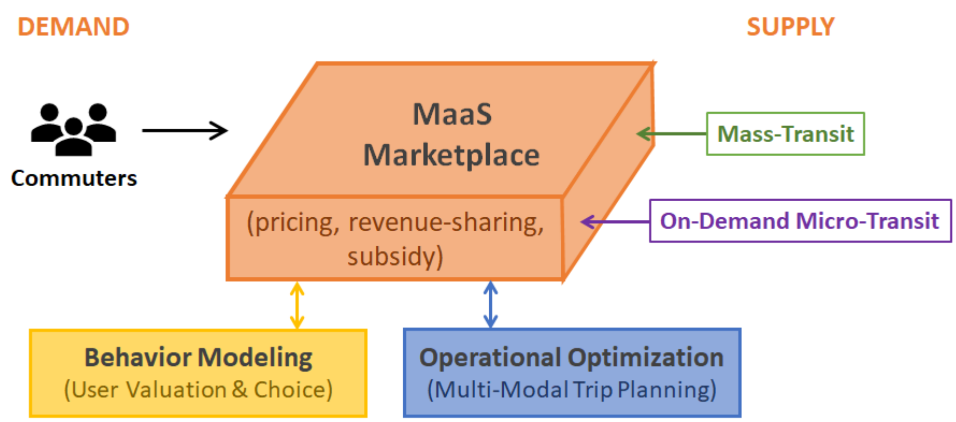

Figure I.13-2 A schematic of a "MaaS Marketplace" that involves various stakeholders (Source: Banerjee 2019)

The team's approach to this issue is to study the design of a MaaS marketplace (see Figure I.13-2), both from the perspective of microeconomic theory, as well as using a simulator for multi-modal transit. Some potential outcomes of such a study will be to compare and contrast different market-structures; understand the design of revenue-sharing schemes between public agencies and private firms; and quantify the overall welfare effects of such a marketplace, and the tradeoff curve between government subsidies and passenger utility. The team's short-term aim will be to use these studies to identify appropriate comparative statistics which can then be tested based on data from real-world pilot schemes. Longer term, the team hopes this research can be used to shape public policy and regulations around the urban MaaS marketplace of the future.

This project is expected to generate both fundamental insights and practical expertise on coordinated multi-modal transit systems, thereby increasing the potential for successful implementations in cities across the United States. The project team is cognizant of the importance of generalizable and reproducible research and considers this to be a primary objective of this work, even though the field experiments will rely on specific transit agencies and microtransit service providers. If the project can successfully resolve the inefficiencies and adoption pain points in existing first/last mile solutions, more people will be encouraged to use public transit and the corresponding trips can be served more efficiently (from an energy perspective).

To highlight this potential, the team provides the following high-level estimate of the potential energy savings that could result from this project:

> According to 2015 U.S. census data, there were a total 1,326,014 jobs around the Seattle (King County) area with an average commute distance from home to work of 36 miles a day. Based on the assumptions of a 20 miles/gallon fuel economy rate, $3/gallon cost of fuel and traveling to work 250 days/year, if 10% of the commuters switch from a private vehicle to public transportation, the resulting VMT savings is 4,773,650 miles per day and 1.93 billion miles per year. Correspondingly, nearly 60 million gallons of fuel could be saved per year. Even accounting for the VMT and fuel consumption of the first/last mile service (which would be reduced with microtransit compared to current single passenger feeders), these savings are significant.

Results

This project experienced a delayed start in Year 1 due to a change of one of the original project partners, the microtransit provider called Chariot. In January 2019, Ford announced the closure of Chariot and notified DOE that its role on this project would most likely be taken over by another Ford microtransit subsidiary, Transloc. However, it took some time for Transloc to evaluate the project and their ability to participate, and to formally join it in August. This change also resulted in delays in the subcontracting process with Cornell, which was also concluded in August. The Cornell team started work on the project at a reduced effort level (focusing on the simulator) during the summer of 2019, but research progress on other elements of the project did not get substantially underway until the fall semester. The post-doc has yet to be hired, due to the delayed project start and additional lead time required for hiring high quality post-docs.

This project was originally proposed with one transit agency partner, King County Metro, but when it was awarded, DOE required that Ford work with a second agency to conduct a second real-world microtransit pilot. The Ford team identified two requirements for selection of the second city: 1) the availability of the type of real-time transit data that is required for the routing and dispatch algorithm (i.e. a GTFS-RT feed), and 2) a mature market for high-capacity transit with demand for first/last mile service (e.g. not starting from scratch). In September, Ford's City Solutions team joined the project to help with outreach to potential cities and identifying appropriate transit agency partners. A further criteria that emerged from these efforts was the availability of a transit agency staff person dedicated to working with third-party service providers and shepherding the pilot through internal contracting and procurement processes. A project kick-off meeting with the whole team is planned for October at King County Metro headquarters in Seattle.

A lesson learned to date is that the funding budgeted for the real-world microtransit pilot in this project was not sufficient. In the original proposal, the two real-world pilots were proposed to run for a 3 to 6 month period. Subsequent discussions with King County Metro and other transit agencies have revealed that they are not willing to introduce a new service to their ridership for a period of less than one year, due in part to high procedural and marketing costs of introducing a new service, and in part to a political reluctance to risk cancelling the service if the pilot fails and associated negative public perceptions. To address this issue, the team plans to work with King County Metro to use the DOE funds to leverage matching funds from other sources to enable a one-year timeframe for the microtransit pilot. This means implementation will depend upon King County Metro's 2021 budget approval process. The situation with the second pilot city is likely to be similar.

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I.14 Transportation Energy Analytics Dashboard (TEAD) (Center for Advanced Transportation Technology Laboratory and National Renewable Energy Laboratory)

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Project Funding: $1,250,000 DOE share: $1,000,000 Non-DOE share: $250,000

Project Introduction

The investment decisions within the nation's transportation sector have traditionally been prioritized and measured against safety and travel efficiency goals. Increasingly, federal, state, and local policies are requiring consideration of energy use and emissions in the design of our transportation infrastructure. Yet the processes, analytics, and knowledge to include these new metrics in transportation decisions are lacking. Although targeted studies and before and after analysis are performed from time to time, no comprehensive real-time monitoring systems provide energy and emissions analysis to the same level as congestion and safety. To address this gap, the Center for Advanced Transportation Technology Laboratory (CATT Lab) at the University of Maryland (UMD), in partnership with the National Renewable Energy Laboratory (NREL), is creating a Transportation Energy Analytics Dashboard, or TEAD, to raise awareness of the energy and emission impacts to the same level of observability as that of safety and mobility concerns.

The overall goal of this project will be to develop an online tool to monitor transportation energy use and emissions in real-time and to archive this data for retrospective analysis. While this project will develop the roadway component of TEAD, the framework for a complete surface transportation energy use and emission analysis tool will be developed. The development of TEAD is being guided by a stakeholder group led by the Mid-Ohio Regional Planning Commission (MORPC) and the Metropolitan Washington Council of Governments (MWCOG) that is identifying real-world use cases for demonstrating the applications of TEAD.

Objectives

While several vehicular energy and emissions models exist, such as the Environmental Protection Agency (EPA) Motor Vehicle Emissions Simulator (MOVES), none are responsive to the rapidly evolving environment of energy and emissions impacts arising from adoption of automated, connected, electrified, and mobility as a service options. The need for a real-time highway energy and emission estimation tool capable of adapting to a rapidly changing environment has never been greater.

To address this critical need, the TEAD project team is developing a state-of-the-art online tool guided by the following objectives and goals:

- Discover and validate needs for urban transportation energy use and emissions analysis from stakeholders
- Enhance and customize methodology framework to calculate dynamic transportation energy use, emission production, and mobility benefits for the surface transportation system at the facility, local, state, regional, and national levels
- Identify data requirements, availability, and sufficiency to enable the real-time comprehensive TEAD and acquire needed data sources
- Create an online platform for TEAD users that makes data accessible through interactive data visualizations
- Integrate real-time data and the energy, emissions, and benefits calculations into an interactive, web-based analysis tool using best of industry congestion analysis as a point of departure
- Build an archive for the energy and emission estimates that can be used for planning, performance measures, and research; just as real-time traffic data is archived to provide a rich R&D environment, so also the energy dimension can complement such work.
- Develop an Application Programming Interface (API) that allows for 3rd party access to real-time and archived energy use data—thus enabling technology transfer for core energy/emissions calculations and analytical graphics
- Demonstrate the TEAD contribution via pilot studies with MORPC and/or MWCOG
- Promote technology transfer and widespread TEAD adoption by documenting methodology, online tool development, and use cases.

Approach

TEAD is being designed to estimate energy use and emissions using traditional roadway data sources such as traffic sensors, vehicle probe data, trajectory/trips data, vehicle registrations data, etc., for real-time, short-term predictive, and historical analysis. Figure I.4-1 shows a conceptual information flow diagram of the TEAD framework.

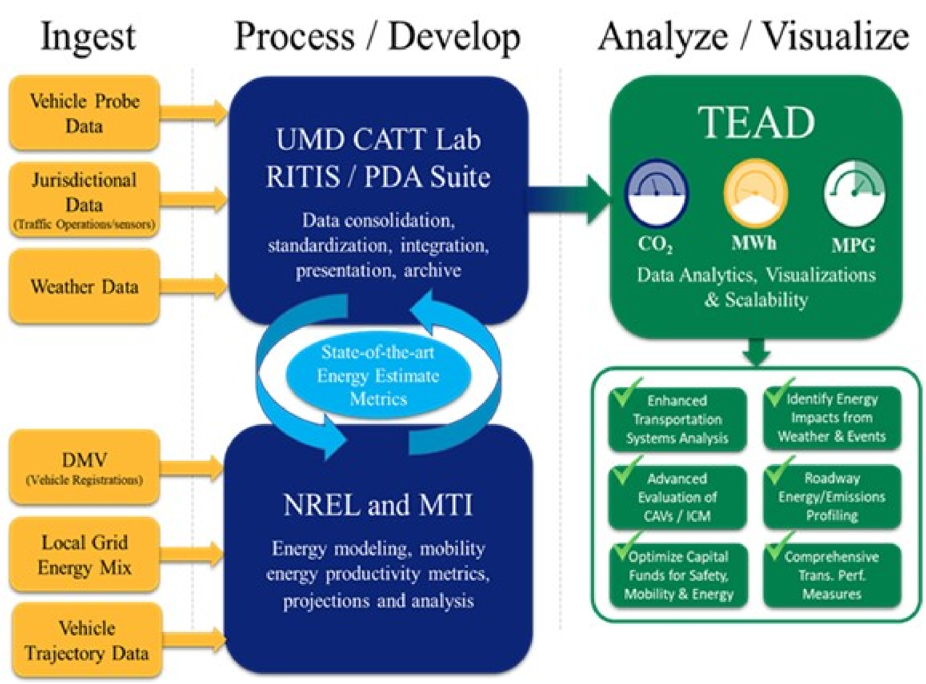

Figure I.14-1 TEAD dataflow framework

A critical task for the development of TEAD was to down select and test energy use and emissions methodologies for real-time, short-term predictive, and historical analysis. Table I.14.1 summarizes the methods selected.

Table I.14.1 Short-list of TEAD Energy Use and Emissions Methods

Analysis Type	Energy Use	Emissions
Predictive	MovesLite + Bayesian Recalibration or RATE-C	MovesLite + Bayesian Recalibration
Real-time	MovesLite + Bayesian Recalibration or RATE-C	MovesLite + Bayesian Recalibration
Historical	RouteE Application of Transportation Energy Consumption (RATE-C)	MovesLite

Results

The team applied the RATE-C energy use model to test scenarios in Columbus, Ohio. The preliminary results presented in Figure I.14-2 show the modeled energy use by speed and engine type (conventional, plug-in hybrid electric, and hybrid electric).

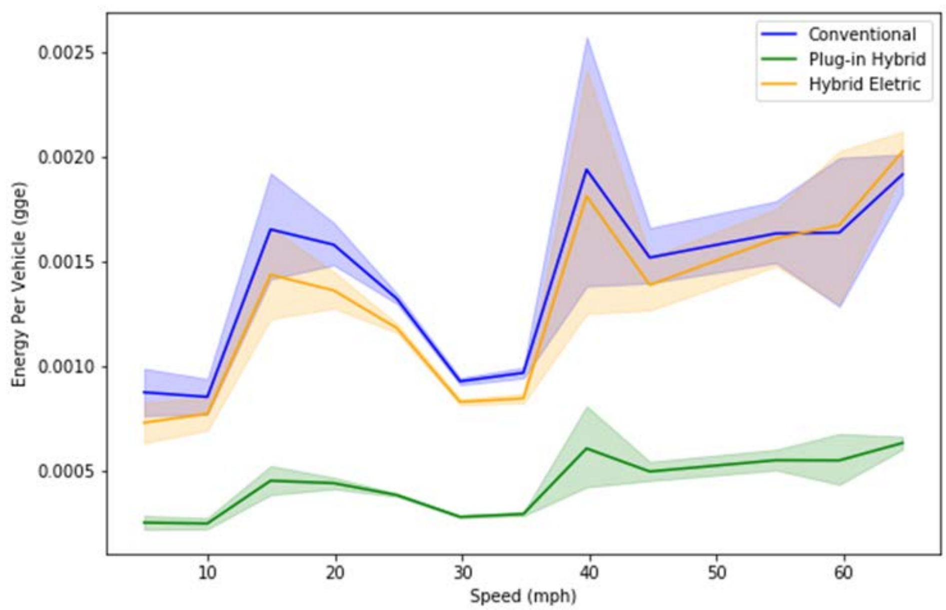

Figure I.14-2 RATE-C preliminary results (energy use by speed and engine type)

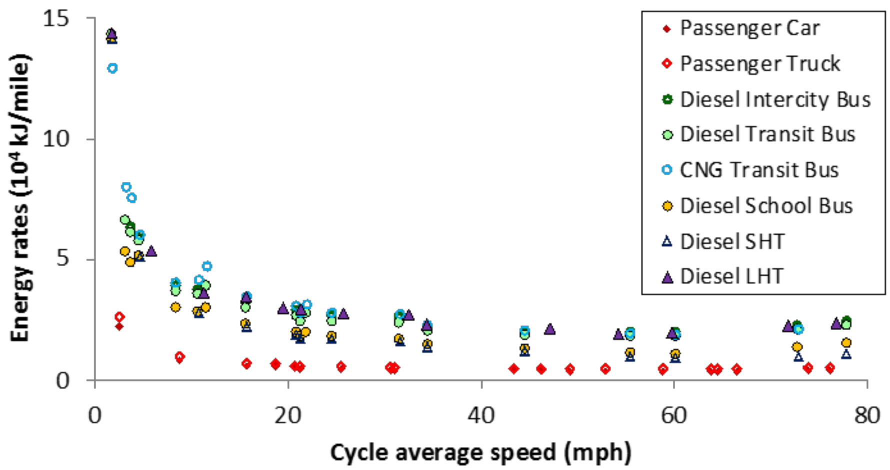

Figure I.14-3 Preliminary results for Bayesian re-Calibration energy model (energy use by cycle speed and vehicle type)

In a similar fashion, the team applied the Bayesian re-calibration energy use model to the Washington, DC test scenario. Figure I.14-3 shows the preliminary results of energy use by vehicle speed for various vehicle and engine types.

In parallel to the methodologies discussed above, the NREL team is continuing to refine its Mobility Energy Productivity (MEP) metric, which will eventually be integrated into the TEAD platform. The MEP metric, as originally conceived, quantifies the mobility potential of a location. NREL is in the process of enhancing the MEP calculation to be more responsive, such that an individual can customize the metric for a location, with his/her mode, activity, and time-of-day preferences. Building on the existing methodology, the proposed dynamic MEP metric will also be updated using a continuous stream of data pertaining to traffic states and vehicle efficiencies relayed through the TEAD platform. These enhancements to MEP will allow it to be used to assess the real-time, customized mobility potential of a location.

Conclusions

The preliminary results of the proposed energy use and emission models show promise for enabling transportation stakeholders to estimate energy use and emissions from historical, real-time, and predictive perspectives. As this project progresses, these methods will be validated against real-world on-board diagnostic data loggers. The final methods will be integrated into an online analysis tool within the Regional Integrated Transportation Information System (RITIS) framework.

I.15 Understanding and Improving Energy Efficiency of Regional Mobility Systems Leveraging System Level Data (Carnegie Mellon University)

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Start Date: January 1, 2019 End Date: December 31, 2021
Project Funding: $1,304,699 DOE share: $1,000,000 Non-DOE share: $304,699

Project Introduction

In 2017, rising traffic congestion levels added 8.8 billion hours of travel time and the need to purchase 3.3 billion more gallons of fuel for urban-dwelling Americans—a total congestion cost of $166 billion in 2017—according to this year's Urban Mobility Report [1]. Faced with this situation, and unprecedented access to massive amounts of system-level transportation data, public agencies across the country are being tasked with the mounting challenge of effectively managing their regional mobility systems while also improving their energy efficiency. To meet this need, Carnegie Mellon University (CMU) and National Renewable Energy Laboratory (NREL) researchers are developing comprehensive data-friendly models at the system level, which can be used by public agencies to evaluate the inefficiencies of their mobility systems and understand where new energy efficiency opportunities may exist.

Despite urban congestion, travel time, energy efficiency, and cost trends heading in the wrong direction, recent years have also witnessed the availability of massive multi-jurisdictional, multi-modal, system-level data from various sources, which provides an unprecedented opportunity to improve the mobility system and its energy efficiency. However, implications of system-level data for mobility and energy efficiency are unclear. Those system-level data sets are siloed, spatially and temporally sparse, biased, not unified, and lacking in insights for system management. Consequently, there is a real need to acquire, fuse, mine and learn from multi-source system-level data to prepare public agencies to deal more effectively with large-scale energy efficiency modeling, management and planning.

Mobility systems consist of three main components: infrastructure, vehicles and passengers. The inefficiency of mobility and energy stems from each of the three components. There exist bottlenecks of infrastructure that result in substantial energy inefficiency. Energy is wasted directly by vehicles, partially attributed to inefficient driving, unnecessary trips, congestion, and the use of gasoline engines. Driving and cruising for parking, as a part of the characteristics of travel demand, generate negative externalities associated with energy use and congestion. The three components of mobility systems are interdependent, and thus the solution to improving the energy inefficiency of mobility systems is likely to be comprehensive. It will require a holistic approach to identify, integrate, and demonstrate multiple innovative strategies; underutilized commercial technologies; data; and modeling partnerships, to advance planning, operations, and management on all three components, simultaneously. Therefore, it is essential to understand how the three components are linked in a mobility system and what the impacts are from one to the others. Multi-source, system-level data reveal the complex interplay among the three components, and is crucial to understanding and managing mobility systems.

Objectives

This project proposes to intensively review inexpensive, replicable and openly-accessible data from multi-modal systems; develop a data-driven system-level modeling framework enabled and validated by data; identify the energy inefficiencies of mobility systems from infrastructure, vehicles, and passenger systems; and quantify the benefits of system-level strategies to improve mobility/energy efficiency. Philadelphia and Pittsburgh, Pennsylvania each are struggling with providing high-quality, energy-efficient mobility for citizens in the face of core growth and aging infrastructure. The project will demonstrate the effectiveness and replicability of those data-driven analytical methods with two case studies in Philadelphia and Pittsburgh.

The team considers a regional mobility system with a focus on solo driving, ride sharing and parking in this project. Parking availability, accessibility and prices are central to travel behavior. The search for parking can result in substantial use of energy and travel time from unnecessary cruising. Additionally, emerging ride-sharing brings in revolutionary changes in how, when and where trips are made. Shared mobility is likely to drastically impact solo driving, parking, and ultimately the resultant energy use patterns. To have a better understanding of the linkage among driving, ride sharing and parking in high spatial and temporal resolutions, the team proposes to establish a novel modeling framework to encapsulate both passenger and vehicular flow in a roadway-parking transportation network. The analytical model takes input of data collected from various sources (such as roadway traffic, parking, and vehicle registration), and models demand trips and behavior in the mobility system. Three types of system-level management strategies will be examined, each corresponding to one source of energy efficiency: vehicle electrification; demand management through incentives and information provision for both ride-sharing and parking; and roadway/parking expansion. The system performance is measured in terms of travel time, vehicle-miles traveled, energy use, emissions, accessibility, and mobility energy productivity (MEP). MEP is an emerging energy and user cost weighted accessibility metric under development at NREL that provides a mobility benefit per unit of energy performance, from which to assess impacts on transportation energy use. Finally, a management strategy optimization framework will be developed to improve the system efficiency and MEP in both the Philadelphia and Pittsburgh regions.

Approach

Regional mobility systems consist of three main systems: infrastructure, vehicles and passenger systems. The passenger system represents the travel demand, the infrastructure system represents the traffic supply, and the vehicle system is the ultimate energy consumer. Over the last few decades, the regional mobility model has been studied intensively with a single travel mode in one single system, e.g. solo driving. Travelers' behavior in choosing different traffic modes, such as parking choices and shared rides, were not the focus of the conventional network mobility models. The impact of the traffic demand and travelers' behavior on multi-modal multi-class systems remains understudied. On the other hand, simulation-based mobility models on large-scale networks requires dynamic network loading/simulation (DNL) models to obtain travel costs/time. Most of the existing DNL models assume homogeneous traffic flow, in the form of standard passenger cars. Multiple vehicle classes such as buses, trucks versus cars, electrified cars versus gasoline cars, can be explicitly modeled in DNL, but are usually not explicitly considered when augmenting the DNL with system-level travel behavior. Another challenge for the network mobility model is that, despite the availability of spatio-temporal data on all modes of transportation systems, there is a lack of understanding of the causes of various travel patterns across those modes in high spatio-temporal resolutions. This project involves formulating and solving for spatio-temporal passenger and vehicular flows in a roadway-parking network explicitly considering solo driving, parking and ride-sharing with multiple vehicle characteristics/classes. Vehicular flows, namely vehicles in different classifications, are integrated in a holistic DNL model. The team further proposes a general formulation of a multi-modal dynamic user equilibrium (MMDUE) problem considering both behavior of travel demand and heterogeneous (multi-class) flow in multi-modal networks. This general framework that holistically models mobility systems would enable further validation by emerging real-world data collected from roadways, vehicles and parking systems.

Parking spots play the roles of the trip origins/destinations of travelers. Choices of parking spots and park-and-ride stations are dependent on parking fares and parking cruising time. Thus the parking system has a profound impact on the mobility system. In previous studies, the parking system was often viewed as an isolated system, and its influence on energy efficiency was overlooked. This project explicitly considers the parking choices of locations over time in a roadway-parking network with respect to the parking cruise time and parking fares, and further examines the impact of parking systems on energy efficiency, through the proposed holistic multi-modal mobility system.

In addition, the team has built a novel data-friendly calibration framework that incorporates multi-source datasets with the developed MMDUE as the underlying behavior model. The calibrated mobility model simulates the traffic demand of millions of travelers and those travelers' behavior, and reproduces traffic flow as observed from multi-source system-level data. In this data-driven framework of network simulation and calibration, the whole optimization problem is decomposed into small computation steps which can be encapsulated in a computational graph, where the state-of-the-art computational frameworks in the machine-learning field become applicable for solving this large-scale and challenging mathematical problem.

The team is leading the development of a multi-modal multi-class network model and its data-friendly framework, which is based on Mobility Data Analytics Center - Prediction, Optimization, and Simulation Toolkit for Transportation Systems (MAC-POSTS). MAC-POSTS is not only a mesoscopic traffic simulation software in the road network, but also a passenger/vehicle modeling package in the general roadway-parking network. MAC-POSTS is capable of modeling a comprehensive real-world mobility network with multi-class traffic flow, multi-modal network, heterogeneous travelers route choice and infrastructure modeling (such as parking facilities). The mobility model can be calibrated with multi-source datasets.

Results

In the first three quarters of Budget Period 1, the team obtained, processed and stored a variety of data needed for this project. All data sets are summarized in Figure I.15.1.

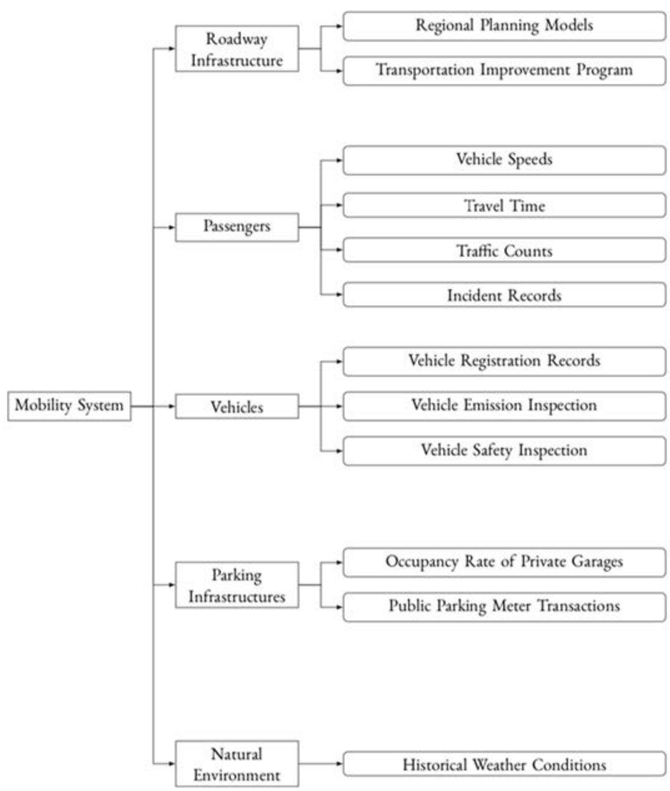

Figure I.15-1 A summary of all system-level data sets in this project

In addition, the team developed a system-level data guide to provide insights for researchers and practitioners. The data guide discusses the following aspects of the data:

- A brief summary of the data
  - What information the data provide and how that is relevant to our interests;
  - How the data are collected
- How to obtain the data files
  - How to access the data files
  - Size of the data and solutions for storing the data
- How to use the data
  - Spatial and temporal resolutions
  - Variables in the data and possible values for each variable
  - General procedures for preprocessing the data
- Suggestions and caveats
  - Main issues to consider when working with the data
  - Alternative data sets

For this project, the team chose the Pittsburgh and Philadelphia Metropolitan Areas as the research regions for developing models and demonstrating the effectiveness of those models. The system-level data are collected and reviewed for those two regions only, but most of those data or similar data should be generally available for other regions, as well. Note that to make the work reproducible, the programs and scripts for collecting and processing those data sets are publicly available.

The team completed a generalized database for the system-level data storage in view of regional mobility modeling and energy-efficient strategies, based on the features of each data set. We also completed and launched the web-based user interfaces of the database such that both public agencies and researchers can conveniently access the database and query any dataset in desired formats, as shown in Figure I.15-2.

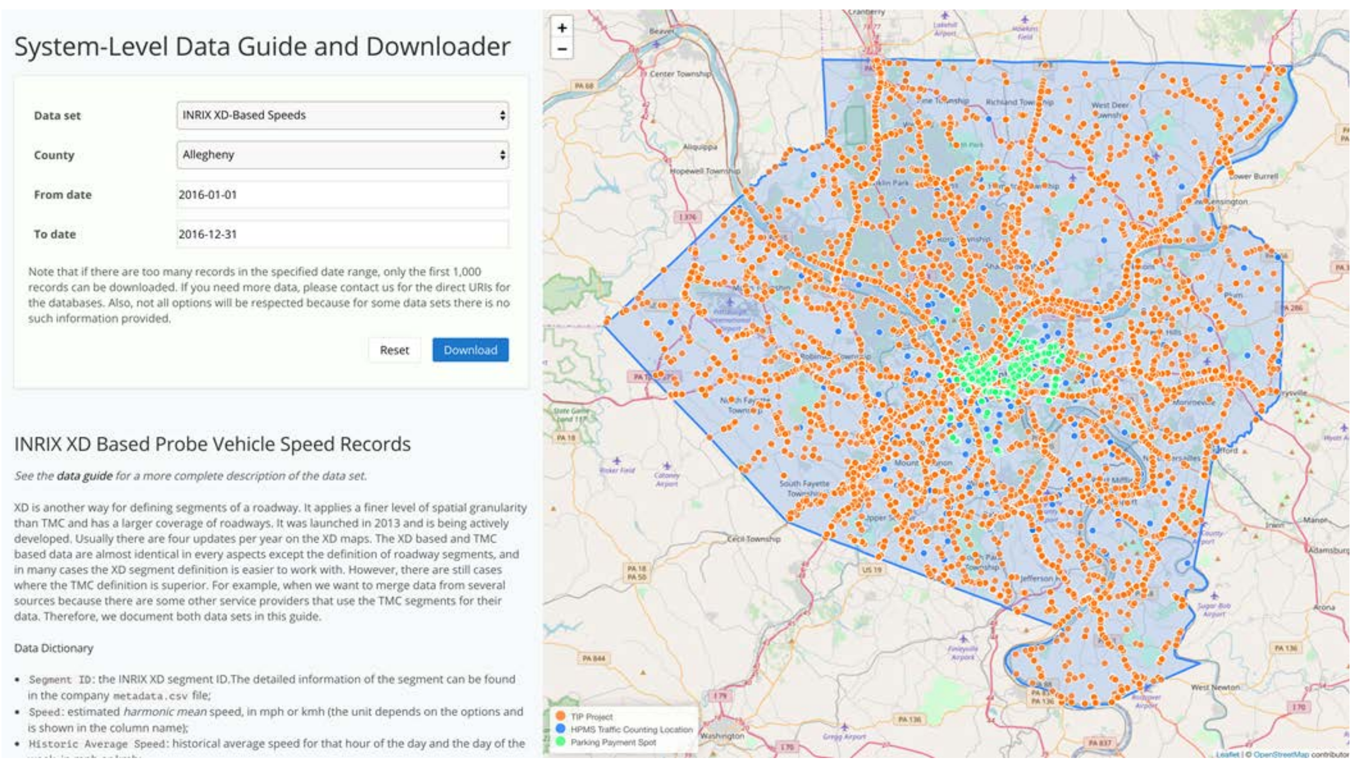

Figure I.15-2 A screenshot of web-based system-level data guide and user interfaces

We further extended the data-driven network modeling framework [2], [3] to enable the integration of any system-level data in general. We proposed a computational-graph based formulation and algorithm to use a set of system-level data to estimate multi-class dynamic origin-destination demands, as well as the resultant network system performance. The formulation of computational-graph essentially decomposes the network calibration process into small sub-problems that can be efficiently solved, which makes it possible to inject more information into the model without significantly impacting the performance of the algorithm. In particular, we developed methods to incorporate time-varying parking data and vehicle registration data into the network simulation and calibration process.

In addition, we propose a way to bridge the gap between the data desired for the subsequent policy analysis and the outputs from the large-scale network models, by working with general vehicle classifications of users' interest. Conventionally the outputs of network models are time-dependent demands among Origin-Destination pairs. However, these types of outputs, without specifying vehicle classes or characteristics, would make it challenging to accurately estimate the emissions and energy use implications. For example, we want to know the vehicle class distribution of the demands, to analyze the influence of vehicle electrification. To fill this gap, we designed two methods: one universal method for general vehicle classes and one ad-hoc method for cases with very limited data sources. In addition, models of emissions and fuel consumptions for each vehicle class are developed in this framework to quantify the system-level performance metrics, including MEP.

Conclusions

This project re-positions energy analysis within regional mobility planning/operation so that it is inherently merged with system-level mobility modeling, and not simply scaled attributes of total vehicle miles traveled. Traditional transportation planning/operation, though data intensive, does not leverage existing big data sources in an efficient or productive manner. Current DOE funding has supported dynamic network simulations, such as POLARIS and BEAM, to understand energy use in mobility systems, but how to utilize large-scale multi-source system-level data for model development and calibration remains a big challenge. The utilization of open-accessible multi-modal data will allow public agencies (including DOE and other relevant agencies) a better understanding of mobility system dynamics, and replication of the methods and processes to most regions. This project advances the knowledge regarding travel behavior across different modes and vehicle classifications, by incorporating ride-hailing impacts, the cost and availability of parking, vehicle electrifications, and infrastructure improvement projects. All those components, in the large-scale multi-class network framework, combined with appropriate metrics, such as the holistic MEP being developed by NREL, provide a robust and replicable methodology for assessing energy implications of current and future transportation scenarios and for developing policies and tools to manage mobility and energy systems.

Key Publications

Pengji Zhang, Sean Qian, System-Level Data Guide for Modeling Regional Mobility Systems, 2019

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3. Ma, Wei, Xidong Pi, and Sean Qian. "Estimating multi-class dynamic origin-destination demand through a forward-backward algorithm on computational graphs." arXiv preprint arXiv:1903.04681 (2019).

I.16 High-Dimensional Data-Driven Energy Optimization for Multi-Modal Transit Agencies (Chattanooga Area Regional Transportation Authority)

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Start Date: October 1, 2018 End Date: December 31, 2020
Project Funding: $951,745 DOE share: $760,868 Non-DOE share: $190,877

Project Introduction

The goal of the project is to develop high resolution context-sensitive energy consumption predictors for the Chattanooga Area Regional Transportation Authority (CARTA), and then use those predictors in optimizing service routes and operations. Through development of this model and integration of data across multi-modal transportation systems, this project will provide a real-time operation and network guidance system to enhance the energy efficiency of transportation and create a transferable model for other cities.

Project collaborators include Vanderbilt University, the University of Houston, the University of South Carolina, Chattanooga Department of Transportation, the Enterprise Center, and the East Tennessee Clean Fuels Coalition.

Objectives

The objective of the project for the first year was to develop and demonstrate a replicable data collection and model-training framework that supports system-wide energy consumption analysis and prediction across mixed-fleet transit vehicles with differing fuel sources, vehicle sizes, and type. This is crucial for understanding and developing mechanisms that will reduce the overall impact of energy usage in the transportation sector. Toward this goal, we have developed a framework for capturing high-resolution multi-modal data from the transit fleet in Chattanooga and are now developing analysis, prediction and optimization tools for CARTA. These tools are transferable to other cities and will be crucial in providing insights into policies that can promote energy efficiency within a mobility-as-a-service transportation model.

Approach

The team's approach is to use continuous monitoring sensors on the complete mix of CARTA transit buses and to develop predictors and optimization mechanisms using the data. The specific activities covered as part of this effort in this annual reporting period are:

1. Develop a project code repository and website
2. Conduct a detailed study of existing energy prediction models in use for transit vehicles
3. Acquire high-resolution (updated every minute) spatio-temporal telemetry data from CARTA vehicles and exogenous data sources, such as traffic and weather
4. Develop an efficient framework to store and process the operational data and external data, including street and elevation maps
5. Create macro-level energy predictor using route information and general fleet parameters
6. Create a higher-resolution micro model that is tuned to specific vehicle parameters
7. Create an optimization framework to select the optimal assignment of vehicles to trips with the goal of reducing overall energy consumption
8. Develop a visualization framework to analyze the data
9. Submit papers to academic conferences to ensure transferability of our work.

Develop Project Code Repository and Website

To ensure outreach and encourage collaboration, we have set up a project source code repository and a website available at https://github.com/hdemma and https://hdemma.github.io, respectively. Currently, the project repository is available only to project partners, but the team is working on making it open, including making the datasets (described below) available to the public.

Literature Review on Energy Consumption Estimation Models

During our review we found that most research work is focused on energy analysis of electric vehicles. These models can be classified from two primary perspectives: modeling scale and modeling methodology. The modeling scale refers to the spatial-temporal resolution of energy estimation results, which can be as detailed as energy consumption rate (e.g., kWh per second), or averaged at the individual road link or trip level (e.g., kWh per mile). In literature, modeling scale is determined based on both the purpose of the study and data availability. Methodologies of existing models can be roughly classified into rule-based and data-driven. Rule-based models adopt a "white-box" approach that follows some fundamental physics laws and mimics the dynamics and interactions of various vehicle/powertrain components to estimate energy consumption. Data-driven models draw on a "black-box" approach so that users do not need to understand the physical process of electricity generation and consumption, or even the principles governing vehicle dynamics and powertrain operation, but rely on the exploration of statistical relationship between inputs and energy outputs with certain assumptions or statistical technique. Among the data-driven approaches, regular linear or multiple linear regression models are the most common approaches in electric passenger car energy prediction models. Limited studies have adopted machine-learning based methods, e.g. ANN, etc. (As indicated by our results, we have found that neural networks are better suited for learning these models). The results of this review indicate areas that require attention from the research community are:

1) Energy estimation for vehicles other than passenger cars and other than EVs: Much of the up-to-date literature on energy estimation models has been focused on passenger EV cars. For electric passenger car energy prediction models, about half of the literature looks at energy estimation of every second that can be used in applications such as energy-oriented vehicle routing, transportation operation, etc. This is what is referred to as a micro-level model. Another half of the literature looks at estimating energy consumption of electric passenger cars averaged at each trip or on each road link. Recently, some progress has been seen in the development of freight and transit electrification. However, as trucks consume more than 20% of total transportation energy and public transit is deemed a viable solution for transportation in many developing countries or populated areas, more research should be conducted for modeling the energy consumption of electric trucks and buses.

2) Application for vehicle-to-grid integration: The vehicle-to-grid technology is considered as an emerging and cost-effective solution to optimizing both EV usage and power grid operation in a cooperative manner. One challenge in vehicle-to-grid integration systems is to find a computationally efficient algorithm that can handle real-time EV energy consumption analysis and large-scale charging facility scheduling optimization. Specifically, the embedded EV energy consumption model should be capable of estimating and comparing EV energy consumption over different candidate driving scenarios.

3) Development of multi-scale EV energy estimation model: Multi-scale models are able to simultaneously cover important features at different resolutions of time and/or space. Such integrated modeling approaches may preserve the information at different levels, from individual components to traffic in a collective manner. All existing studies have been focused on either microscale or macroscale EV energy estimation. It will be useful to develop multi-scale EV energy estimation models which can provide consistent information for energy estimation across different scales. However, one major challenge would be to develop algorithms or methodologies to find accurate and efficient solutions to multiscale modeling problems.

Our work in this project is related to all three of these categories. We discuss these activities below.

Acquire High-resolution Spatio-temporal Telemetry Data from CARTA Vehicles

CARTA operates a mix of vehicle types, including gasoline powered vans, diesel and diesel-hybrid buses, battery-electric shuttles, and battery-electric buses, with production dates ranging from 1998 to 2016. CARTA provides service with 17 fixed routes, 3 neighborhood demand-response routes, 2 downtown circulator routes, and a complementary ADA paratransit service. The team configured operating data associated with vehicle routes, passenger counts, bus operators, and baseline performance for analysis. CARTA selected and installed a telematics kit produced by ViriCiti LLC (the DataHub – see Figure I.16.1) on each CARTA fleet vehicle, to provide a real-time data stream at a minimum 1 Hz resolution of all available vehicle operating parameters, as well as GPS positioning for each record.

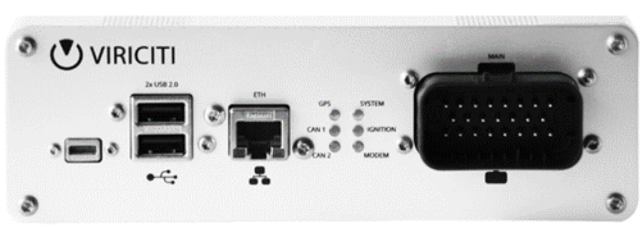

Figure I.16-1 ViriCiti DataHub

Develop an Efficient Framework to Store and Process Operational Data

Maintaining data and computation integrity is one of the fundamental problems that any team handling multimodal data at this rate will face. To ensure that we resolve this problem, the team has implemented a novel cloud-centric data collection and processing framework hosted at Vanderbilt University's Institute for Software Integrated Systems.

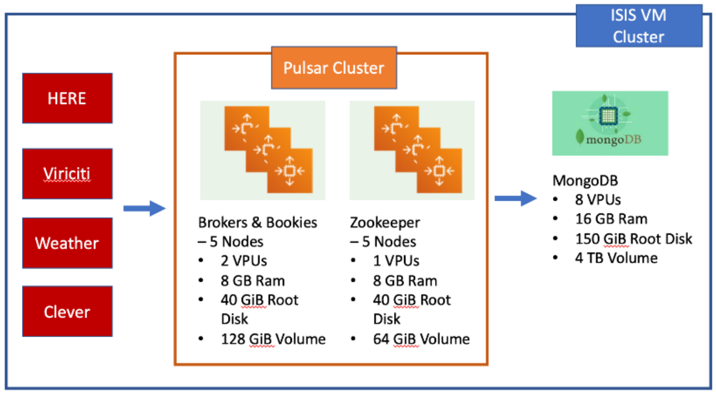

Figure I.16-2 HD-EMMA data collection and storage framework

An overview of the data collection architecture is provided in Figure I.16-2. We designed the architecture to optimize the storage and processing demands of our analysis and modeling. Data from the various sources is first published to an Apache Pulsar cluster [1] and stored persistently as a distributed log in its raw format. The benefit of this framework is that data is replicated and shared across multiple nodes that can be distributed geographically, ensuring resilience and better throughput – more machines mean more computation power.

Another advantage of this framework is that it allows client applications (one who wants to read the data in real-time for analysis) to attach directly to various data streams, providing near real-time access to each data source. This setup minimizes latency for running the team's trained models in production in real-time use cases. Additionally, we deployed a software layer that synchronizes the data in Pulsar with a MongoDB database running in our cluster. The MongoDB instance provides geospatial and temporal indexing for historical queries and easy data transfer between teams and is mostly used for model building and visualization.

In addition, we have built a graph database interface that will enable fast access to data based on graphical queries. As shown in Table I.16.1, different database engines are required for different kinds of spatio-temporal queries, such as energy consumption queries that need to access data across time and across geographical region.

Table I.16.1 The Choice of Data Access Engine Depends on the Kind of Queries to be Executed

Goal	Data Sources Needed	Queries Needed	Optimal Access Engine
All buses in a region	- bus locations - bus route	- buses within polygon - aggregation across time	- spatial indexed data store (mongodb)
Identify bottlenecks on bus routes	- bus route - bus speed - surrounding traffic - road network infrastructure	- road network shape along route - traffic per road segment - bus route ID - bus speed - weather	- graph data store - spatial indexed data store (graph database- neo4j)

The list of data recorded includes traffic and weather; speed, current, voltage and state of charge for all electrical vehicles; speed (km/h), fuel level, and engine fuel rate for ICEVs; various engine and driver parameters, including "accelerator pedal position"; GPS position; route; trip updates and patterns for all vehicles. All data is available from August 2019 onwards.

Create Macro-level Energy Predictor Using Route Information

Using telemetry from the ViriCiti DataHub and external data sources, including weather, elevation, street-level maps, and traffic, the team trained and evaluated models for predicting energy, as illustrated in Figure I.16-3.

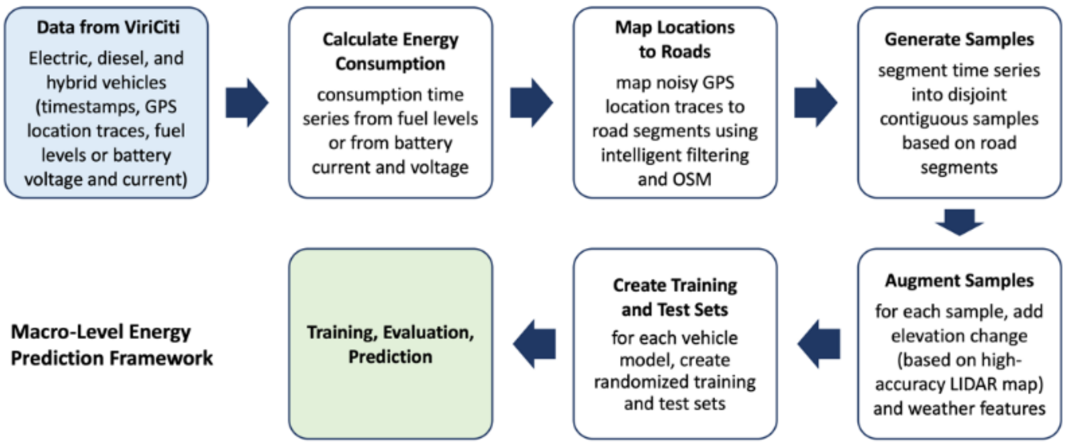

Figure I.16-3 Energy prediction workflow

For EVs, the team collected the following features: timestamp, GPS-based position (latitude and longitude), battery current (A), battery voltage (V), battery state of charge (%), and charging cable status (0 or 1). For diesel and hybrid vehicles, instead of battery data, the team collected fuel level (%) and fuel used, in gallons.

For energy usage prediction, the team completed the following steps:

1. **Data Cleansing:** Based on the GPS positions, the team first removed all data points that were acquired when a vehicle was in the garage, and considered a vehicle leaving the garage to be the starting point for calculating energy consumption. For EVs, based on the charging cable status, the team also removed all data points that were acquired when a vehicle was charging.

2. **Calculating and Verifying Energy Consumption:** Next, the team computed the energy consumed between consecutive data points. For EVs, the team converted changes in the state of charge (%) values to energy consumption, in Joules, based on the total capacity of the battery (1.8×10^9 Joule for the CARTA vehicles). The team also computed energy consumption by integrating the product of the measured current and voltage values and verified that these consumption values coincided with changes in state of charge. Since the current and voltage-based values are more accurate than state of charge-based values, the team used the former in subsequent steps. For diesel and hybrid vehicles, the team performed similar steps with fuel level and fuel used.

3. **Cleansing Locations and Mapping to Roads:** The GPS based locations collected from the ViriCiti portal are inherently noisy, meaning some of the locations reported fall onto side-streets, where vehicles do not travel, onto parking lots, and even inside buildings. To remove noise, the team used a street-level map from OpenStreetMap. The team developed an algorithm that filters data and maps a GPS based location onto a street, considering previous and subsequent location measurements and various characteristics of nearby streets, and determines how likely it is that a vehicle travels on them.

4. **Sample Generation:** Given the data points with street-level data, the team segmented time series into disjoint contiguous samples based on contiguous road segments, and, again, performed outlier detection and removal.

5. **Augmenting Samples with Elevation and Weather Data:** For each sample, the team added features corresponding to elevation changes within the samples, and weathers features, such as temperature.

6. **Training and Test Sets:** For each type of vehicle, the team created training and test sets by dividing samples randomly. For each vehicle type, the entire dataset spans more than 3 months of data, collected at 1 Hz.

The prediction models used the following sample features: distance traveled, travel time, road types (e.g., motorway, residential), elevation change, weather features, and energy (fuel or electricity) consumed.

The team applied three different approaches for creating prediction models: *linear regression*, *deep feed-forward neural-network learning*, and *decision-tree regression*. The team compared the performance of these approaches based on their mean prediction errors for the test datasets and found that decision tree regression results in the most accurate prediction. Figure I.16-4 shows the results for tree regression-based prediction for 50 test samples of an EV. We also found that including weather information improves the energy prediction models.

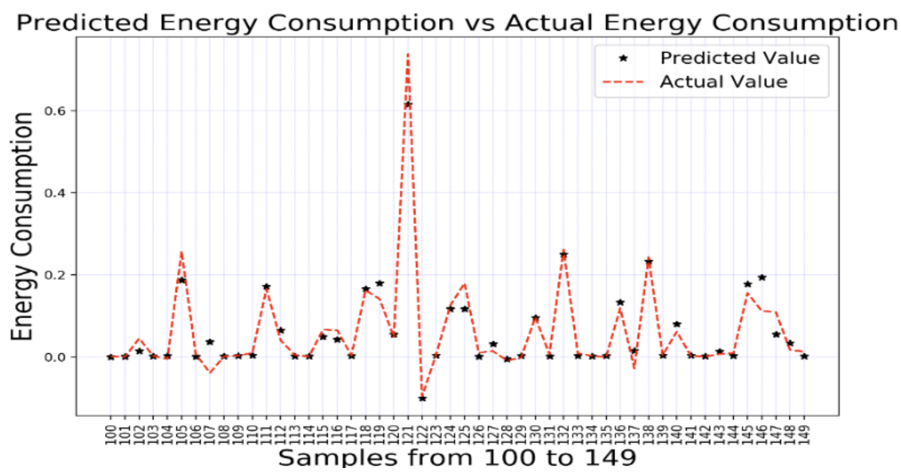

Figure I.16-4 Energy prediction using a macro model

Create a Higher Resolution Micro Model That is Tuned to Specific Vehicle Parameters

In addition to the macro energy models which are applicable for route specific analysis, we also worked on developing micro models that are finely tuned to individual vehicles. These models are essential to estimate energy consumption under various traffic control and operational strategies. Thus, they are widely used by researchers and transportation practitioners in evaluating benefits and comparing traffic control and operational strategies. Based on a comprehensive literature review of energy consumption models of EVs (described earlier), we can conclude that there is a knowledge gap for electric bus energy prediction models.

In this task, the team developed an ensemble of neural network-based EV bus prediction models (see Figure I.16-5) that achieves better accuracy performance compared with regular regression models, and accuracy performance comparable to physical based models.

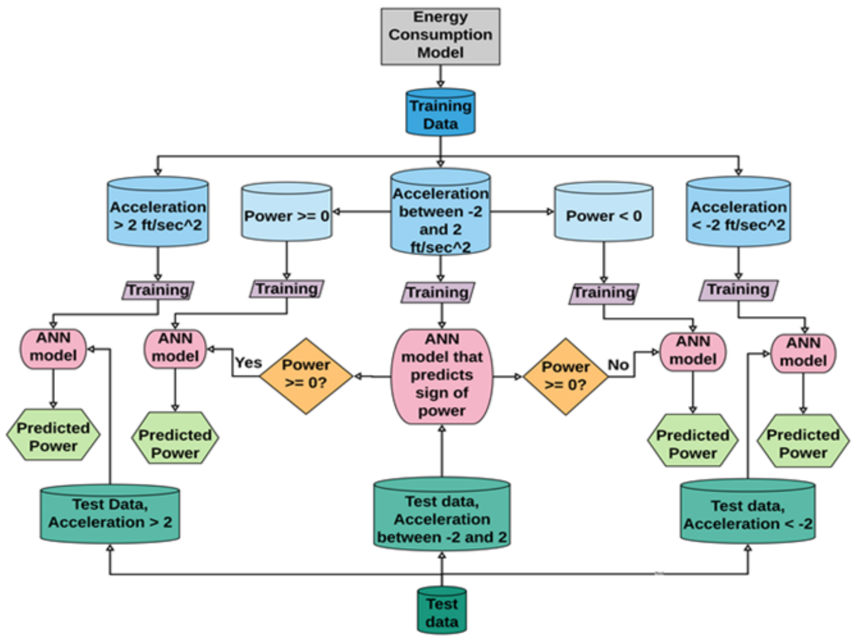

Figure I.16-5 Decision tree of the ensemble of micro models

The models cover three different driving situations: regenerative braking (acceleration < -2 ft/s^2); aggressive acceleration (acceleration > 2 ft/s^2); and cruising (acceleration between -2 and 2 ft/s^2). The accuracy of the three models outperforms the single model for predicting all driving conditions. This is primarily because these three different scenarios are effectively three different modes, and energy consumption dynamics vary significantly between them. The predicted versus actual cumulative energy consumption of one trip from CARTA's EV bus driving dataset is illustrated in Figure I.16-6. The cumulative energy consumption is calculated based on energy consumption at each second. The figure shows high accuracy in prediction of electric bus energy consumption.

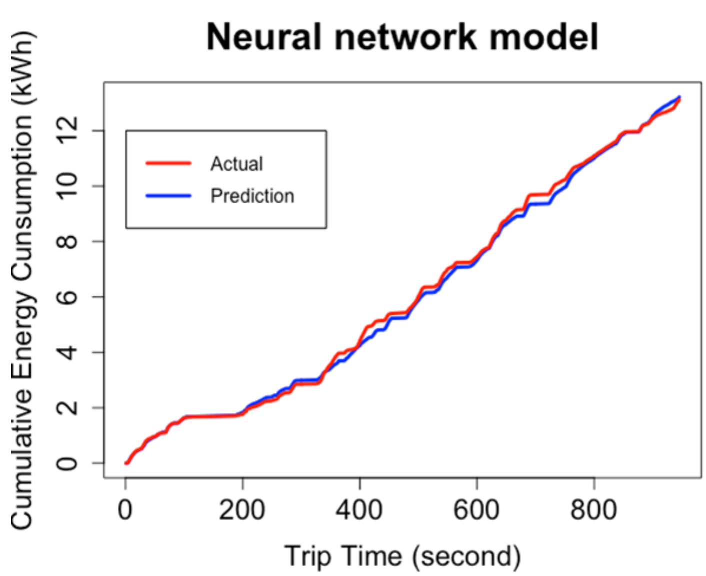

Figure I.16-6 Micro model test

Optimization Framework to Select the Optimal Assignment of Vehicles to Trips with the Goal of Reducing Overall Energy Consumption

EVs incur lower energy costs and environmental impact during operation than comparable ICEVs; however, their upfront costs are much higher. As a result, many public transit agencies can afford only mixed fleets of EVs and ICEVs. Making the best use of such a mixed fleet of vehicles presents a challenging optimization problem. First, agencies need to decide which vehicles are assigned to serving which transit trips. Since the advantage of EVs over ICEVs varies depending on the route and time of day (e.g., the advantage of EVs is higher in slower traffic with frequent stops, and lower on highways), the assignment can have a significant effect on energy use and costs. Second, agencies need to schedule when to charge EVs with limited battery capacity and driving range that are not enough for an entire day of transit service. Scheduling must also consider charging infrastructure limitations, e.g., limited number of charging poles, or limited peak load on the electric grid.

The team introduced a novel problem formulation and algorithms for assigning a mixed fleet of transit vehicles to transit trips and for scheduling EV charging. The problem formulation is general and applies to any transit agency that must provide fixed-route transit service using a mixed fleet. The objective is to minimize energy use (i.e., fuel and electric power use), which can be used to model minimizing operating costs and/or environmental impact with the appropriate cost factors. To solve the problem, the team introduced an integer program, as well as domain specific heuristic and genetic algorithms. The team evaluated the algorithms on CARTA's transit routes using the macro-level energy predictors to evaluate the objective. The results show that the heuristic and genetic algorithms are scalable in terms of computation time, and they provide near-optimal results.

Develop a Visualization Framework to Analyze the Data

The team is currently developing a visualization framework for the various data sources. The framework works for both real time visualization of the current state of the system, as well as visualization of historical patterns in the data. The framework is designed for visualizing historical trends in the data as well as real-time monitoring of the system and uses open source data visualization technologies from Uber. The team has implemented visualization of historical traffic data with bus locations as shown in Figure I.16-7 and is working on energy consumption visualizations as shown in Figure I.16.8. Current visualizations are accessible through Jupyter notebooks [2].

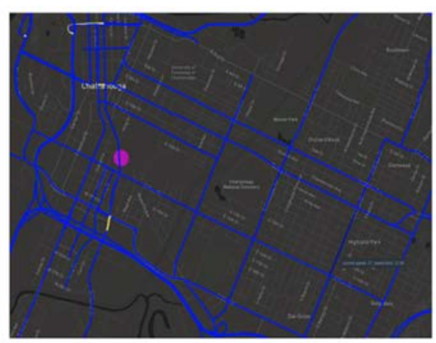

Figure I.16-7 (a) Traffic and bus locations during morning rush hour and (b) Traffic and bus locations late evening

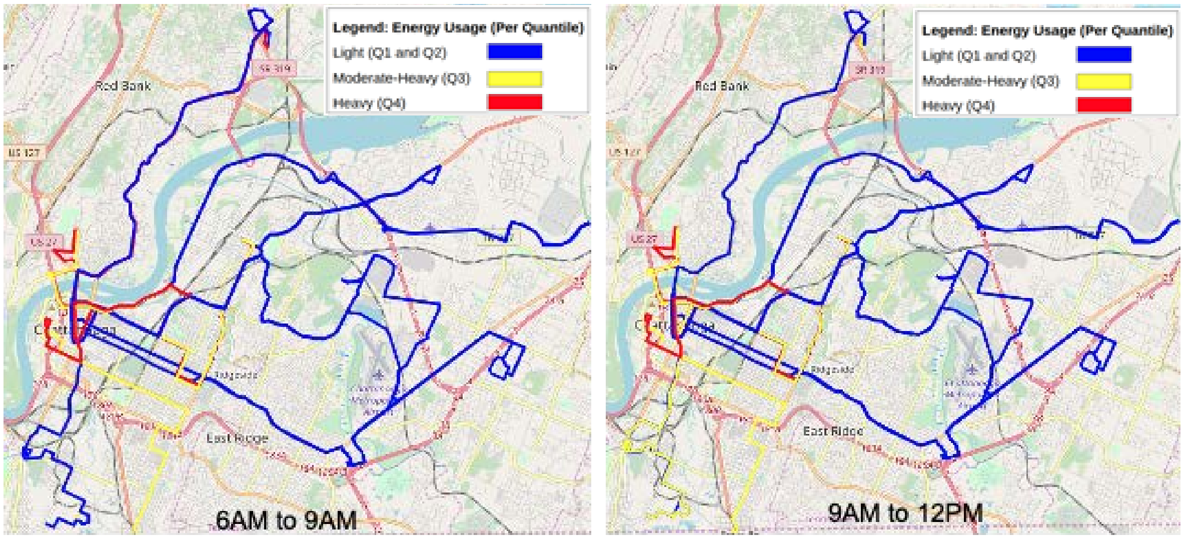

Figure I.16-8 Energy consumption visualizations for electric buses

Results

As noted above, the team has completed the tasks associated with this phase of the project, with the development of the vehicle telemetry system, data store and analysis framework, and initial testing of macro and micro level prediction models. Initial tests of prediction models have been promising and second-year project efforts will be directed toward optimization of CARTA's energy consumption.

Conclusions

In general, the deployment of a vehicle telemetry system across legacy transit vehicles of various ages and powertrain systems was more challenging than anticipated. Additional development was necessary to convert older SAE J1708 communications to SAE J1939 format represented on newer vehicles and obtaining unique and proprietary data protocols from vehicle manufacturers often proved difficult.

Key Publications

Poster presentation at the 2019 Tennessee Sustainable Transportation Forum.

References

1. http://pulsar.apache.org/docs/en/concepts-architecture-overview/#persistent-storage
2. https://jupyter.org/

I.17 Mobility and Energy Improvements Realized through Prediction-based Vehicle Powertrain Control and Traffic Management (Colorado State University)

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Project Funding: $1,035,831 DOE share: $828,663 Non-DOE share: $207,168

Project Introduction

This project proposes a set of hypotheses for improving novel metrics of Mobility Energy Productivity (MEP) through improved system level traffic management and data sharing, as well as vehicle-level prediction and optimal control. Colorado State University has teamed with the City of Fort Collins, Colorado (FtC) Traffic Operations to collect a specific set of coordinated traffic, vehicle, and infrastructure data inputs, using well-established connected vehicle probe data collection techniques. The project's subsequent tasks are:

- Develop microscopic traffic models of the City of Fort Collins
- Develop vehicle-level models of the fuel economy and emissions of connected and automated vehicles (CAVs)
- Test scenarios demonstrating the synergistic benefits of system-level data sharing, infrastructure management and CAV controls optimization.

The team will then communicate the results of these studies through the continued development of MEP metrics, and then test them for their extensibility through a partnership with the City and County of Denver, Colorado (CCoD).

Objectives

The project level goals are:

1) Quantify the costs of problems using novel mobility metrics applied to validated microscopic simulations of the traffic in FtC

2) Use vehicle identification data and emissions and fuel economy (FE) modeling of high-impact vehicles (buses and class 8 trucks), along with optimization of both traffic management systems and connected vehicle energy management, to improve the mobility and energy of the FtC transportation system, as measured using the proposed mobility metrics, and

3) Transmit these findings to other municipalities including CCoD and beyond.

By solving these problems locally, this research project can exemplify the technologies that can enable the use of novel data streams and actuation techniques to solve these common, modern transportation problems throughout the United States.

Approach

To enable this type of dynamic and quantifiable interaction between infrastructure, vehicles, and the social/economic/environmental aspects of transportation, this research project requires the development and integration of 4 key technologies and their associated and supporting datasets. These technologies are:

1) A transportation network model and optimal traffic management strategy (*Optimal TMS*)
2) An individual vehicle optimal energy management strategy (*Optimal EMS*)
3) Optimizable vehicle class-specific models of fuel consumption and emissions that can be used to quantify the effects of these strategies, and
4) Novel models and metrics to quantify the broad impacts through MEP.

Optimal TMS

An Optimal TMS seeks to provide energy and mobility improvements to the transportation network. This research will build the Optimal TMS through development and optimization of a microscopic traffic simulation to inform an energy and travel time model of the transportation network. For this research, the Optimal TMS includes vehicle-class specific (truck, bus, light-duty vehicle) energy consumption, travel time variance, and emissions in these considerations and cost functions, to optimize these individual vehicles' trajectories by traffic signal control algorithms.

Optimal EMS

An Optimal EMS provides energy improvements for a fixed drive cycle through improved powertrain operation. Note that an Optimal EMS is sometimes referred to as optimal powertrain control. The team will derive an Optimal EMS by formulating an optimal control problem that maximizes FE (or other benefit function) by explicitly or implicitly modeling future vehicle operation (enabled by modern CAVs technology) and controlling the vehicle powertrain (e.g. downshifting before an upcoming hill or turning off the engine when approaching a red light). An Optimal EMS does not require a change in driver behavior; thus, this FE improvement technique has an advantage, in terms of consumer acceptance and realizability, over fuel efficient driving behaviors (Eco-driving), or taking alternate routes that typically increase travel time (Eco-routing) [1].

Vehicle Class-specific Models of Fuel Consumption and Emissions

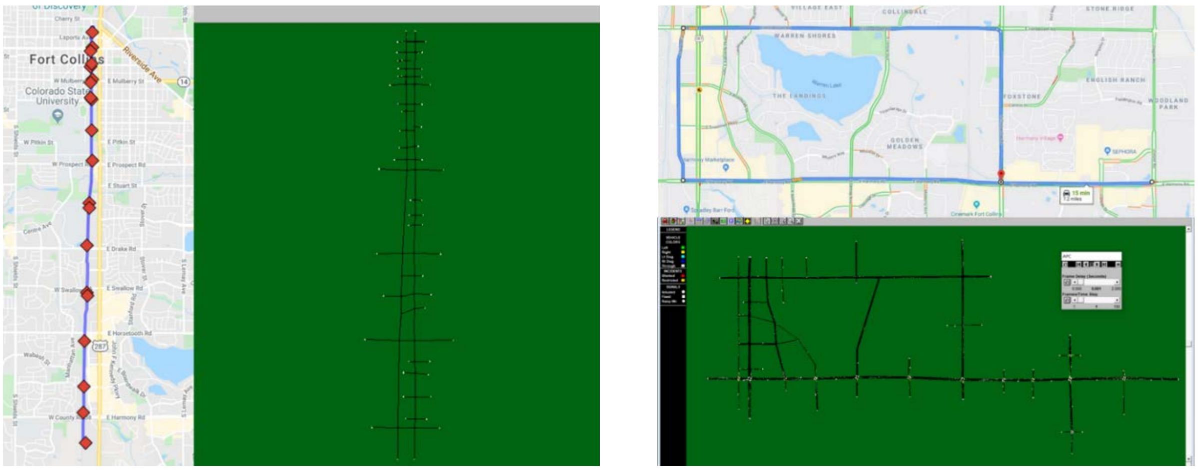
To answer the hypotheses proposed for this research requires an understanding and prioritization of the impact of high emissions or low FE vehicles as they pass through the transportation network. Conventional modeling of FE and emissions effects during traffic signal phase and duration design, using EPA MOVES data or "g/mi type" regressions, does not capture acceleration transients, or the diversity of vehicle types.

Novel Metrics

In considering the impact of the transportation system improvements that can result from system level data, from infrastructure and vehicle optimization, and from prioritization of high-impact vehicles (trucks and buses), the metrics by which we quantify these effects become critical. For example, by reducing vehicle miles traveled, a municipality can reduce the energy and environmental impact of transportation, but at the cost of the productivity/equity/social benefits that mobility provides. At the same time, increasing mobility is beneficial, but a municipality must consider energy consumption to be able to meet its sustainability and environmental quality goals. For this study, NREL will engage with the universities and municipal stakeholders to define a MEP metric that can quantify the tradeoffs between mobility and energy consumption, with the objective of developing integrated transportation systems that "maximize mobility, while not using too much energy." In practice, this metric will be a combination of a mode-weighted accessibility score for transportation, normalized by system-level energy consumption. The accessibility score will be based on statistically-relevant travel time isochrones, so that the movement of goods and people through the transportation system at higher rate realizes productivity and mobility gains.

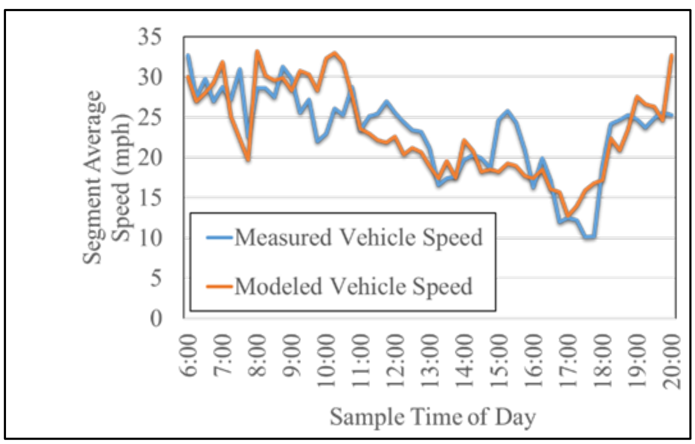
Results

To date, the results of this research have been promising and constructive in validating the approach to each of these technology developments. For TMS optimization, the team has been able to validate traffic microsimulations against traffic data for an extended network of the City of Fort Collins, by constructing traffic simulations (Figure I.17.1) for both the conventional road system, as well as for the bus rapid transit (BRT) network. Validation efforts have demonstrated that the simulations have average transit time through the traffic simulation network comparable to the measured transit time through the actual street network (Figure I.17.2).



(a) (b)

Figure I.17-1 Map and CORSIM simulation models for a) BRT routes in Fort Collins, CO, and b) traffic network under study for this research



Time	Average Speed (mph)
AM	35.1
Midday	35

Figure I.17-2 Example validation case for a segment of the CORSIM simulation

For the EMS simulations, the team has demonstrated both the validation of the fuel economy and emissions modeling, through previous work, published this year [1]. The EMS optimization efforts have demonstrated the effectiveness of the approach initially through the effort to use predictive optimal EMS, the first step of which is to assemble synthesized vehicle and traffic management system datasets. The team measured the set of data using probe vehicles, and assembled it into a large-coherent dataset, as shown in Table I.17.1 and

Figure I.17.3. Probe vehicle velocity measurements while moving through the traffic network under study for this research.

Table I.17.1 Data Streams Now Successfully Measured via Probe Vehicles and Assembled into a Coherent Dataset

Relevance Area	Data Treatment	Description	Data Stream
EGO	Driver Inputs	Steering, accelerator and brake pedal traces, drive mode selection, turn signal, etc.	VEH
	Vehicle Performance	Vehicle speed, engine load and speed, transmission gear, accelerations, etc.	VEH
	Vehicle Position and Motion	GNSS position and motion information	COMM
VIS	Object Tracks	Relative locations and classifications of detected and tracked objects	ADAS, COMM
	Lane Information	Information about vehicle position and trajectory relative to the vehicle's current lane	ADAS, COMM
	Condition Information	Lighting and weather conditions in the vehicle environment	ADAS, COMM
FPI	Signal Phase and Timing	Phase and timing information for traffic signals	COMM
	Segment Speeds	Average vehicle speeds for segments of road	COMM
	Lead Vehicle	Relative position and motion of the vehicle most immediately in front of the ego vehicle	ADAS, COMM
	Historical Speeds	Speeds which vehicles have historically travelled at specific locations	VEH, COMM

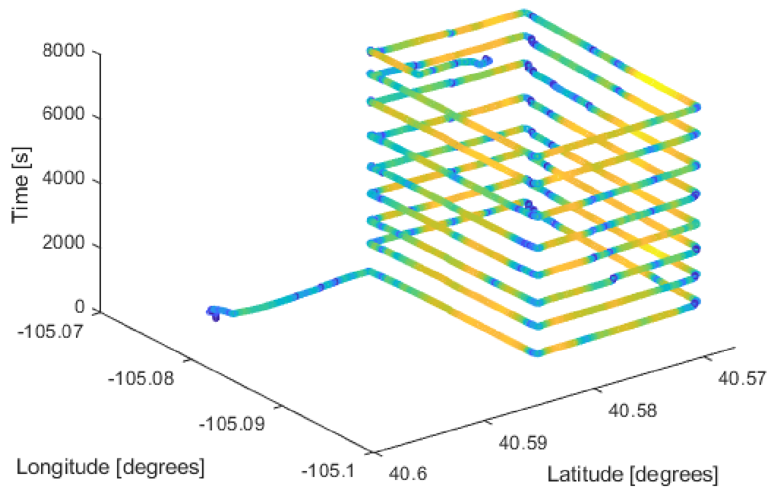


Figure I.17-3 Probe vehicle velocity measurements while moving through the traffic network under study for this research

Finally, this research seeks to put these advancements into TMS and EMS into the context of the MEP. The team has now exercised these metrics for CCoD, one of the cities that is the subject of this research. The baseline, all modes MEP map for CCoD is illustrated in Figure I.17.4.

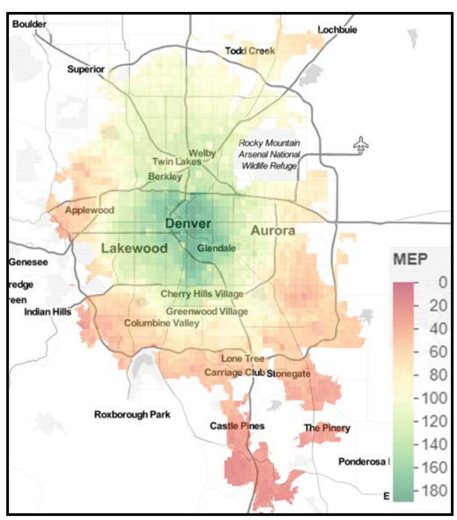


Figure I.17-4 MEP maps by mode for Denver, CO

Conclusions

This research project is designed to develop solutions to a set of transportation problems, based on the availability of advanced infrastructure and vehicle datasets. The team will seek to understand the value of integrating the datasets available from transportation system infrastructure into the control of CAVs. The results of this combination of simulation and experimental study will gather real-world data to populate optimizable simulations of traffic and vehicle-level control, so as to understand the implications of these datasets for improving transportation system emissions and fuel economy.

Key Publications

1. Rabinowitz, A,. Gaikwad, T., White, S,. Bradley, T., Asher, Z. 2019. "Synchronous and Open, Real World, Vehicle, ADAS, and Infrastructure Data Streams for Automotive Machine Learning Algorithms Research" Society of Automotive Engineers (SAE) Technical Paper 2019-01-0258 (in review)

2. Gaikwad, T,. Rabinowitz, A,. Hanson, L, Asher, Z,. Motallebiaraghi, F., Fong, A. 2019. "Vehicle Velocity Prediction Using Artificial Neural Network and Effect of Real World Signals on Prediction Window.," SAE Technical Paper 2019-01-0266 (in review)

3. Motallebiaraghi, F., Bradley, T., Fong, A., Asher, Z., Chenna, S., Jathar, S., Gaikwad, T. 2019. "Vehicle Emissions Modeling Improvements Realized through Deep Neural Networks," SAE Technical Paper 2019-01-0882 (in review)

References

1. Tarun, S., Asher, Z., Bradley, T., Johnston, B., Anderson, C., and Jathar, S., "Artificial Neural Networks for Emissions Modeling and Environmental Routing for Light-Duty Passenger Vehicles," CARTEEH — February 18-20, 2019 — Austin, TX

Acknowledgements

The PI would like to acknowledge the project team, including Eric Wood, Venu Garikapati, Jacob Holdner, Zach Asher, Suren Chen, Diego Garcia, and Bonnie Trowbridge.

I.18 Advancing Platooning with Advanced Driver-Assistance Systems Control Integration and Assessment

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Start Date: October 1, 2018 End Date: December 31, 2021
Project Funding: $1,869,145 DOE share: $934,572 Non-DOE share: $934,573

Project Introduction

User acceptance is of fundamental importance for truck manufacturers to achieve rapid market penetration and widespread use of platooning or Cooperative Adaptive Cruise Control (CACC) technology. Understanding the implications and limitations of platooning technology in real-world driving scenarios is also of great importance to truck and powertrain manufacturers, as they design, integrate and calibrate the platooning control system accordingly. The objective of this project is to assess real-world fuel savings and identify barriers to platooning. To do this, the Cummins team proposes a comprehensive approach, including:

- Analysis of the impact of existing platooning technology on fuel consumption; emissions; engine, aftertreatment and transmission operation; and customer requirements
- Integration of ADAS (Advanced Driver-Assistance Systems) control features with platooning control
- Integration of tire connectivity to assess the effect of tires on platooning, e.g., knowledge of tire conditions and braking capabilities
- Assessment of the integrated technologies under real-world driving scenarios with two and three trucks in platoon operation
- Analysis of the impact of variations in vehicle specifications, routes, and traffic
- Identification of barriers and issues, with proposed solutions, if applicable.

Objectives

This project will assess the benefits of platooning for fuel consumption reduction under real-world driving scenarios for two and three trucks platooning. The project objectives are:

Objective 1: Assess baseline platooning control integration for class 8 line-haul truck applications under real-world driving scenarios, and identify barriers and issues through analyzing data from vehicle, engine, transmission, aftertreatment, control software, connected tires, braking system, and fuel economy test sensors

Objective 2: Assess technology integration with platooning control, including fuel economy control features in cruise and throttle operation, and tire connectivity technology to monitor tire condition and braking capabilities under different tire/road conditions

Objective 3: Develop and demonstrate solutions to overcome barriers and issues for advancing platooning/CACC with technology integration if applicable

Approach

Analysis of data collected from trucks tested under characterized real-world driving scenarios is the main approach in this project to assess the fuel saving of platooning trucks under real-world driving conditions and to identify barriers and issues with this technology. The project will be conducted in 3 budget periods:

- Budget Period 1
  - Integration of CACC for baseline
  - Tuning, instrumentation and data collection of two-truck baseline platoon
- Budget Period 2
  - Assessment of the baseline performance for two-truck platoon and identification of barriers and solutions
- Budget Period 3
  - Tuning, instrumentation and data collection of three-truck baseline platoon and proof of concept of the proposed solutions for advanced platooning/CACC system
  - Tire connectivity impact on platooning performance to be assessed and reported
  - Results.

In this first budget period, the main goal was to acquire and instrument the trucks with platooning/CACC baseline control, data loggers, fuel flowmeters, and other test related sensors. The team selected truck specifications based on line-haul class 8 trucking applications. Three trucks were acquired for the two-truck platooning tests (two trucks to operate in platooning as the test trucks and one truck used as a baseline control truck). The team instrumented the data loggers and configured them to collect data from vehicle, engine, aftertreatment, transmission, tires and added sensors.

Table I.18.1 Truck Specifications

	Control Vehicle	Lead & Follow Vehicles
Truck Model	INTERNATIONAL 2020 LT625 6X4 (LT62F)	
Application	General Freight Long Haul Sleeper	
GVW	67000 lb	
Engine	Cummins X15 Efficiency Series, EPA 2017, 430HP @ 1800 RPM, 1450/1650 lb-ft	
Transmission	Eaton Endurant 12-Speed Fully Automated Manual Overdrive	
Rear Axle Ratio	2.79	
Steer Tire	Bridgestone R283A ECOPIA 295/75R22.5	Michelin X Line Energy 275/80R22.5
Drive Tire	Bridgestone M710 ECOPIA 295/75R22.5	Michelin XDA Energy 275/80R22.5
Trailer Tire	Bridgestone R283A ECOPIA 295/75R22.5 (need to confirm)	Michelin X Line Energy 275/80R22.5
Trailer Model	2020 Great Dane 53' Van	
Trailer Aerodynamic Features	Underbody skirts	

The logged data from the trucks are automatically sent to Cummins' cloud network and are analyzed to assess the performance of the trucks in detail. The specifications of the acquired trucks are shown in Table I.18.1. A picture of one of the trucks is shown in Figure I.18.1.

Figure I.18-1 A picture of the control truck

To verify the baseline platooning control integration and tuning, the team conducts a fuel economy test based on SAE J1321 fuel economy test procedure on a test track. The results indicated about 7% fuel savings for the trailing truck and about 1.5% fuel savings for the lead truck at a time gap of 0.6 sec, speed of 65 mph, vehicle weights of 67,000 lbs. and the trailer with side-skirts without boat-tail. At this time gap, about 3% additional fuel savings can be gained on the trailing truck with platooning/CACC, compared to operation in the baseline adaptive cruise control mode. In the next phase of the project, the baseline platooning control will be assessed under real-world driving test factors. The results are presented in Table I.18.2.

Table I.18.2 Fuel Saving Results of Two-truck Platooning to Verify Integration

	Fuel Saved (%)	
	Lead Truck	Trailing Truck
CACC at 0.6 sec	1.26% +/- 0.86% *1.70% +/- 0.96%	5.90% +/- 0.80% *7.07% +/- 0.78%
CACC at 1.0 sec	-0.06% +/- 0.96% *0.23% +/- 0.98%	5.49% +/- 0.74% *6.52% +/- 0.66%
ACC at 2.3 sec	N/A	3.76% +/- 0.71% *4.01% +/- 0.96% (w.r.t Lead)

The results with an asterisk (*) represent the fuel savings after initial transient due to engagement is removed.

Conclusions

The project is proceeding on schedule and the first year go/no-go milestone to integrate baseline platooning control or CACC along with the data loggers and fuel economy test sensors is completed. The performance of the integrated system has been verified on test track conditions and the team is ready to test the characterized real-world test scenarios. During the next year of the project, the team will assess platooning control under real-world driving scenarios and identify issues and barriers with this technology, using collected data from the vehicles.

I.19 Fuel-Efficient Platooning in Mixed Traffic Highway Environments (American Center for Mobility)

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Start Date: October 1, 2018 End Date: December 31, 2020
Project Funding: $4,922,146 DOE share: $2,447,271 Non-DOE share: $2,474,875

Project Introduction

The American Center for Mobility (ACM) and its project partners – Auburn University, University of Michigan-Dearborn, the National Renewable Energy Laboratory, U.S. Army Combat Capabilities Development Command Ground Vehicle Systems Center (formerly TARDEC), and Michigan Department of Transportation – are engaged in an SAE Automation Level 2 connected-autonomous semi-truck platooning project with measurable fuel-efficiency savings. The project comprises research, modeling, and simulation, as well as proving ground and public road testing and demonstration, with up to four vehicles and trailers. Both steady-state and transient effects are studied in terms of platooning efficacy. This report documents the progress made in Year 1 of this two-year project.

Objectives

The objective of this project is to improve multi-vehicle heavy-duty truck platooning efficiency and safety using automated controls, advanced communications, real-world testing, data analysis, and computer modeling and simulation.

Approach

The project team designed fuel economy testing in the spirit of SAE Type II. The trucks are first warmed up via a full hour of operation, ensuring the engine fluids and vehicle tires have obtained nominal operating temperature. The team then weighs fuel consumption at the end of each test within a window of 30 minutes, to ensure these operating temperatures are maintained. The team conducts each test over a full hour of 45 mph operation at both the National Center for Asphalt Technology (NCAT) and ACM test tracks. This speed was selected from a safety perspective based on the track corner radii. On-road testing is conducted at 65 mph.

Each vehicle's fuel economy is first quantified in isolation ('single vehicle baseline') for a basis of comparison to platooning fuel consumption. The team obtains fuel quantification from multiple sources on each vehicle. Two Auburn Peterbilt trucks, denoted A1 and A2, utilize weighable auxiliary fuel tanks to which the engine fuel send and return pathways are switched at the onset of each test, via electronically controlled valves. In this way, the team isolates consumption measurements to just the testing duration, rather than from key-on to key-off. Simultaneously, the team records the commanded fuel rate from the Controller Area Network (CAN) system and measures the fuel flowrate via AVL KMA flow meters for quantified fuel consumption during transient events, such as vehicles cutting in and out of the platoon formation. The weighed fuel consumption is utilized as an absolute quantification check for both the cumulative CAN fuel rate and cumulative KMA flow meter measurements. Two Ground Vehicle Systems Center M915 line haul tractors, denoted T13 and T14, also record CAN fuel rate. Additionally, T14 utilizes a KMA flow meter while T13 is fitted with a weighable auxiliary tank, for secondary fuel consumption quantification.

The team designed a matrix of tests to assess the fuel economy performance of multiple platoon configurations relative to each vehicle's consumption during standalone operation at the NCAT. See Table I.19.1.

Table I.19.1 Test Matrix to Establish Baseline Vehicle Performance during Various Platoon Configurations at NCAT – Absent the Impacts of Vertical Curvature and V2V Disturbances

Testing Matrix for NCAT					
Test #	**Test Description**	**Vehicle Order**	**Following Distance [ft]**	**Speed [mph]**	**Objective**
1	Single Vehicle Baseline	A1	NA	45	Non-platooning baseline fuel economy
2	Single Vehicle Baseline	A2	NA	45	Non-platooning baseline fuel economy
3	Single Vehicle Baseline	T13	NA	45	Non-platooning baseline fuel economy
4	Single Vehicle Baseline	T14	NA	45	Non-platooning baseline fuel economy
5	Two-truck platoon Baseline for A1 & T14	A1, T14	50	45	Establish 2 truck platoon FE benefit - optimal solution to 4 truck platoon disturbances may be to establish two, 2-truck platoons rather than rejoin 4-truck
6	Two-truck platoon Baseline for A1 & T14	A1, T14	100	45	Establish 2 truck platoon FE benefit - optimal solution to 4 truck platoon disturbances may be to establish two, 2-truck platoons rather than rejoin 4-truck
7	Two-truck platoon - Baseline for T13 & A2	T13, A2	50	45	Establish 2 truck platoon FE benefit - armored T13 leading due to its strategic location in the four truck platoon (looking for the maximum platoon disturbance during merge testing)
8	Two-truck platoon - Baseline for T13 & A2	T13, A2	100	45	Establish 2 truck platoon FE benefit - armored T13 leading due to its strategic location in the four truck platoon (looking for the maximum platoon disturbance during merge testing)
9	Four-truck platoon - Baseline	A1, T14, T13, A2	35	45	4-truck platoon efficiency baseline with fully instrumented fuel economy in locations 1, 2 and 3 - correlated fuel economy in location 4
10	Four-truck platoon - Baseline	A1, T14, T13, A2	100	45	4-truck platoon efficiency baseline with fully instrumented fuel economy in locations 1, 2 and 3 - correlated fuel economy in location 4
11	Four-truck platoon with isolated merging distrubance	A1, T14 - Merge -T13, A2	50	45	Merge disturbance between 2 fully FE instrumented T14 &T13. NCAT merge is on a flat straigthaway, isolating it from the impact of curvature/grade. Armored T13 trailing to maximize the effect of the merge disturbance

Testing Matrix for NCAT					
Test #	**Test Description**	**Vehicle Order**	**Following Distance [ft]**	**Speed [mph]**	**Objective**
12	Four-truck platoon with isolated merging distrubance	A1, T14 - Merge - T13, A2	100	45	Merge disturbance between 2 fully FE instrumented T14 &T13. NCAT merge is on a flat straigthaway, isolating it from the impact of curvature/grade. Armored T13 trailing to maximize the effect of the merge disturbance
13	Radio network reliability	Four vehicles, any order	Various	45	Verify the reliability of the radio network under various clutter conditions @NCAT
14	Four-truck platoon - Baseline	A1, T14, T13, A2	50	45	4-truck platoon efficiency baseline with fully instrumented fuel economy in locations 1, 2 and 3 - correlated fuel economy in location 4

NCAT testing serves as a baseline for fuel economy performance, as the track is absent vertical curvature and features that may interfere with the vehicle-to-vehicle (V2V) truck communication. Conducting the same battery of tests at ACM's track will quantify the impacts of vertical curvature on a relative basis. See Table I.19.2.

Table I.19.2 Test Matrix to Establish Baseline Vehicle Performance during Various Platoon Configurations at ACM – Including the Impacts of Vertical Curvature and V2V Disturbances

Testing matrix for ACM					
Test #	**Test Description**	**Vehicle Order**	**Following Distance [ft]**	**Speed [mph]**	**Objective**
1	Single Vehicle + Curvature	A1	NA	45	Non-platooning fuel economy with curvature
2	Single Vehicle + Curvature	A2	NA	45	Non-platooning fuel economy with curvature
3	Single Vehicle + Curvature	T13	NA	45	Non-platooning fuel economy with curvature
4	Single Vehicle + Curvature	T14	NA	45	Non-platooning fuel economy with curvature
5	Two-truck platoon + curvature: A1 & T14	A1, T14	50	45	Establish 2 truck platoon FE benefit with curvature- optimal solution to 4 truck platoon disturbances may be to establish two, 2-truck platoons rather than rejoin 4-truck
6	Two-truck platoon + curvature A1 & T14	A1, T14	100	45	Establish 2 truck platoon FE benefit with curvature- optimal solution to 4 truck platoon disturbances may be to establish two, 2-truck platoons rather than rejoin 4-truck

Testing matrix for ACM					
Test #	**Test Description**	**Vehicle Order**	**Following Distance [ft]**	**Speed [mph]**	**Objective**
7	Two-truck platoon + curvature T13 & A2	T13, A2	50	45	Establish 2 truck platoon FE benefit with curvature effects - armored T13 leading due to its strategic location in the four-truck platoon (looking for the maximum platoon disturbance during merge testing)
8	Two-truck platoon + curvature for T13 & A2	T13, A2	100	45	Establish 2 truck platoon FE benefit with curvature effects - armored T13 leading due to its strategic location in the four-truck platoon (looking for the maximum platoon disturbance during merge testing)
9	Four-truck platoon + curvature	A1, T14, T13, A2	50	45	4-truck platoon efficiency baseline with fully instrumented fuel economy in locations 1, 2 and 3 - correlated fuel economy in location 4
10	Four-truck platoon + curvature	A1, T14, T13, A2	100	45	4-truck platoon efficiency baseline with fully instrumented fuel economy in locations 1, 2 and 3 - correlated fuel economy in location 4
11	Four-truck platoon	A1, T14 - Merge - T13, A2	50	45	Curvature and merge disturbances. Merge between 2 fully FE instrumented T14 &T13. ACM merge combines the effect of curvature/grade with the merge. Armored T13 trailing to maximize the effect of the merge disturbance
12	Four-truck platoon	A1, T14 - Merge - T13, A2	100	45	Curvature and merge disturbances. Merge between 2 fully FE instrumented T14 &T13. ACM merge combines the effect of curvature/grade with the merge. Armored T13 trailing to maximize the effect of the merge disturbance
13	Radio network reliability	Four vehicles, any order	Various	45	Verify the reliability of the radio network under various ACM clutter conditions
14*	Impact of rain	Any formation	75	45	Experimental characterization of rain impact on platooning sensor set and controls
15	Four-truck platoon + curvature	A1, T14, T13, A2	35	45	4-truck platoon efficiency baseline with fully instrumented fuel economy in locations 1, 2 and 3 - correlated fuel economy in location 4

The team conducted platoon disturbance tests to quantify the fuel economy impact of transient events such as non-platooning vehicles merging into the formation. The order of the four-truck platoon was strategically designed so that the impacts of a merging vehicle maximally disrupted the platoon formation. This was accomplished by merging before the heavily armored T13 vehicle.

The team also designed two-truck platoon fuel economy tests for independent assessment of 50 and 100-ft headway distance (physical gap between leading and following vehicles) and collected these results. Independent assessment of the two-truck platoon data, in conjunction with the four-truck merging fuel economy data, facilitates critical decision making for the platoon as a system. Namely, should the vehicles consume additional fuel to reform the four-truck platoon after the departure of a merged vehicle, or would two independent two-truck platoons provide the greater overall fuel economy benefit to the system?

The project team created a high-fidelity model of the two-truck platoon using PreScan [1]. The model consists of the following elements: map of the ACM highway loop, vehicle dynamics of the semi-trucks, the connected autonomous cruise controller, and the on-board sensors, i.e., GPS, dual-beam radar, and DSRC radio.

Several crucial "What if?" scenarios are examined and, using the model, quantitative answers obtained [2]. We present two such scenarios in this report:

1. What is the effect of weather on safety margins of two-truck platoons?

   ANS: *When there is rain, the follower vehicle must double its headway time (driving duration of following vehicle to reach current location of leading vehicle), compared to dry weather. When there is snow, the headway time of the follower vehicle should triple that of dry weather. Headway time can be increased by increasing headway distance. See Figure I.19.1.*

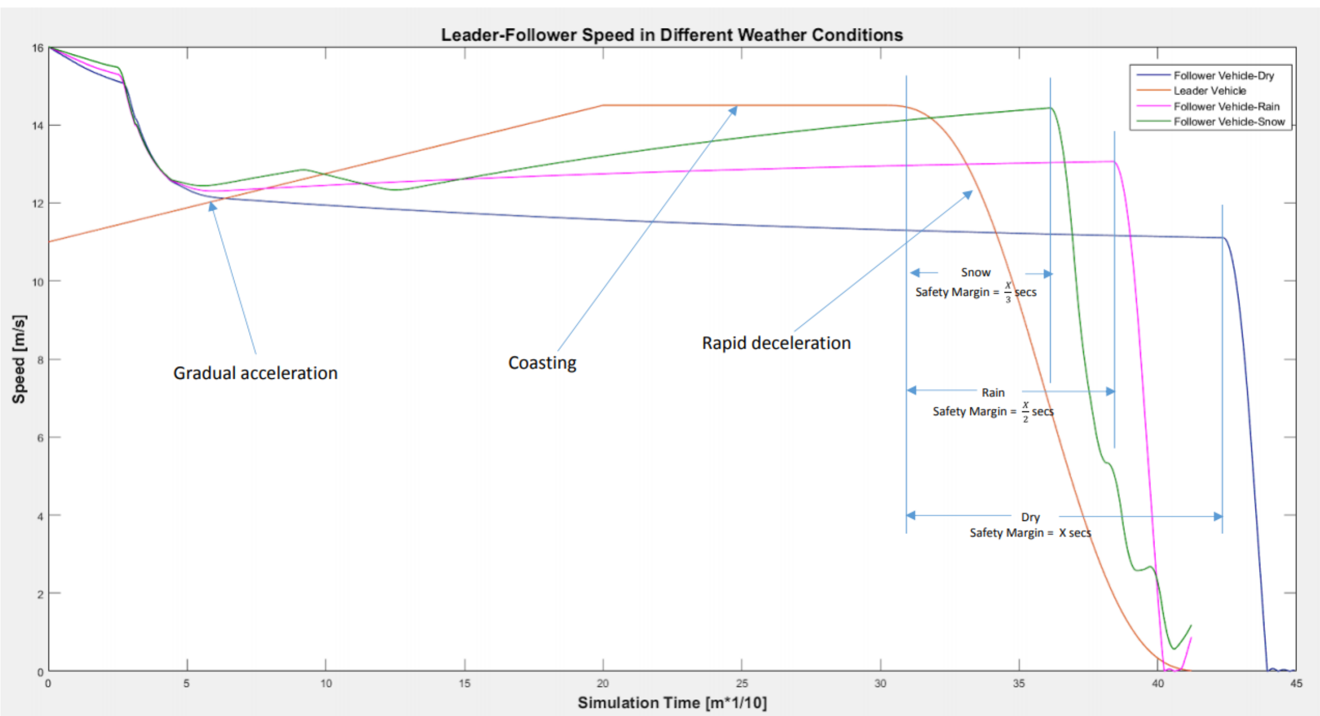

Figure I.19-1 Simulation results – effects of weather on the safety margin of a two-truck platoon

2. What is the effect of road curvature on sensor reliability in two-truck platoons?

   ANS: *When the radius of the road curvature is less than 200 feet and the follower vehicle is at 150 feet, neither the short- nor the long-range radar beam in the follower vehicle detects the leader. Therefore, the platooning system entirely relies on the V2V communication. See Figure I.19.2.*

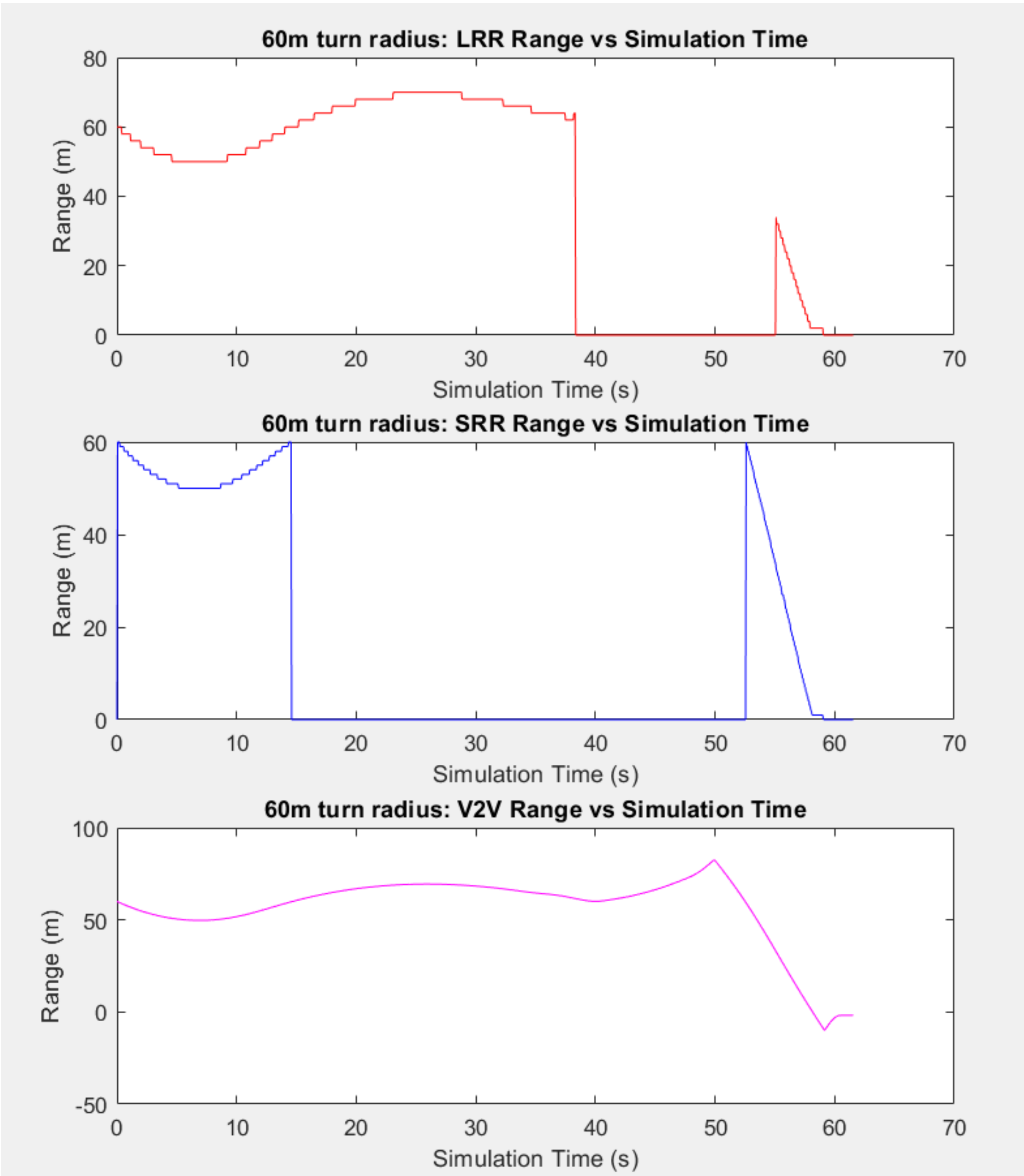

Figure I.19-2 Simulation results – effects of road curvature on two-vehicle platoon

Results

The team completed at least three iterations of each test in Table I.19.1 (tests 1-14) at the NCAT test track, and is currently analyzing the data. Four-truck platoons were operated with 35, 50, and 100-ft headway distances as shown in Figure I.19.3. Previous results at 65 mph indicated a peak aerodynamic fuel economy benefit at approximately 50 feet for following vehicles, and diminishing benefits at closer following distances [3]. These results also indicated that the leading vehicle fuel economy benefits continued to rise when the following vehicle platoons more closely to it. Preliminary four-truck platoon results, based on only the percent change in consumed fuel weight relative to individual truck operation, are shown in Figure I.19.3. Note that gravimetric fuel measurement was not conducted on T14 as per the original testing plan. Gravimetric fuel economy analysis was planned for the Auburn Peterbilt trucks (A1 and A2) and was added to the scope for T13 due to persistent KMA operational issues during testing. The T14 KMA data has not yet been analyzed; thus, only data from three trucks is displayed in Figure I.19.3.

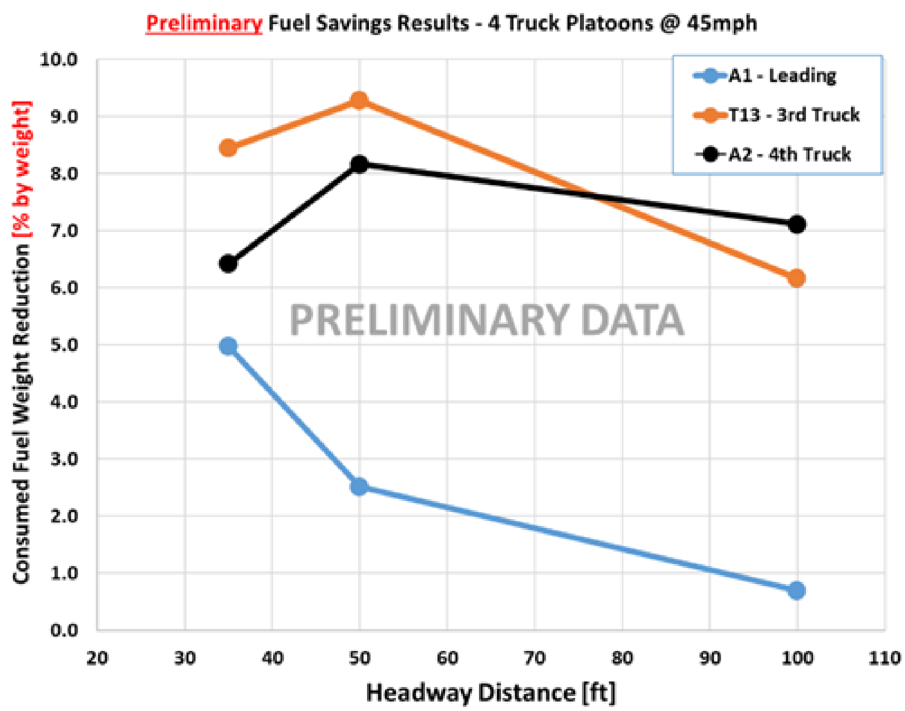

Figure I.19-3 Preliminary results illustrating the reduction in consumed fuel by weight during 4-truck platooning at various headway distances (following distances)

These preliminary results agree with prior testing experience, as the following trucks experience a reduction in fuel savings during close following (under 50 feet). The team is currently investigating this phenomenon. Furthermore, given the chosen operational speed (45 mph) and the fact that the trailers were unloaded, the preliminary fuel consumption savings (by weight alone) align with expectations. Disparate slopes for T13 and A2 are not surprising, given the vast differences in both vehicle weights (T13 is armored) and the baseline fuel consumption of each.

Further analysis of the fuel economy data requires parsing of the vehicle CAN and KMA data. The team is currently undertaking this process for all KMA and vehicle fuel rate data. The consumed fuel weights are available for a preliminary examination of platoon performance; however, caution is recommended when examining the consumed fuel weights as a measure of efficiency gain. The Dynamic-Base Real Time Kinematic (DRTK) position system data for the two Auburn Peterbilt trucks (A1 and A2) must be simultaneously analyzed to accurately assess the distance traveled by each vehicle during testing. The DRTK system utilizes dual frequency antennas and Novatel flex packs on each vehicle to obtain differential GPS position estimates with a 2-centimeter accuracy. Only with this combined analysis can the results be confidently expressed as fuel economy improvements.

With these considerations in mind, and depending on platoon headway distance and configuration, preliminary analysis of differential fuel consumption by mass alone reveals platooning consumption reductions of 1-5% for the leading vehicle, and 6-9% for following vehicles. The values are in line with expectations for baseline system performance, considering the limited speed (45 mph) and the fact that the trucks are tested unloaded. Further results will be released as the analysis progresses.

The semi-truck platooning system relies crucially on the radio network, including its packet latency (data transmission and receipt time delay). [4] The performance of the radio network is assessed as part of the fuel-efficiency testing. Table I.19.3 summarizes the preliminary results.

Table I.19.3 Performance of the DSRC Radio Network

Key Performance Indicator	Target Result	Actual Result
Received Signal Strength Indicator	Between -50 dBm (high) and -90 dBm (low)	-47 dBm (avg.) Better than target
Packet Latency	< 10 msec	~4 msec Well within target
Network Utilization	< 10%	3-5% Well within target

ACM baseline platooning assessments are currently underway and scheduled for completion Oct. 14, 2019 – Nov 2, 2019. See Figure I.19.4.

Figure I.19-4 Four-vehicle platoon testing in progress at the American Center for Mobility

Conclusions

The project team successfully tested four-truck platoons operating at 35, 50, and 100-ft following distances at NCAT. Preliminary results indicate 1-5% and 6-9% fuel consumption reductions (by weight only) for the leading and following vehicles, respectively, during platooning. These results are in line with prior experience with the baseline system, given the 45-mph operational speed and the fact that the trailers were unloaded. Additional analysis is necessary for full quantification of fuel economy benefits.

The radio network performance is remarkably consistent across multiple tests. The team will validate the quantitative answers obtained using simulation, by physical testing at ACM. Future work in this project involves extension of the modeling and simulation to four-truck platoons.

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I.20 Solutions for Curbside-Charging Electric Vehicles for Planned Urban Growth (UNC Charlotte)

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Start Date: October 1, 2018 End Date: December 31, 2021
Project Funding: $1,885,514 DOE share: $942,757 Non-DOE share: $942,757

Project Introduction

The National Renewable Energy Laboratory estimates that, in the future, nearly 90% of electric vehicle charging will occur at home [1], but studies show that only about 50% of all vehicles have a dedicated, off-street parking space [2]. It is difficult, however, to add charging infrastructure curbside. The cost of installing such units can be as much as 10 times that of installing a charger at home [3], and the inclusion of many curbside pedestal charging stations will clutter the sidewalk. This project explores an alternative solution, which involves installing retrofit Level 2 EV charging units into existing streetlight infrastructure. Such installations would not require additional pedestals and may not require as much installation work to provide the additional electrical power that would be needed by a pedestal. The project team is led by the Energy Production Infrastructure Center (EPIC) at UNC Charlotte and includes the Centralina Council of Governments (CCOG), Duke Energy, and Eaton Corporation. The team is focused on developing and demonstrating several retrofit charging solutions around the City of Charlotte, North Carolina.

Objectives

This project aims to develop a retrofit charging solution that could be installed into existing streetlight infrastructure. The primary enabling technology is a cloud-connected electrical circuit breaker with built-in Level 2 charging capability. This device, known as the EV-EMCB (Electric Vehicle Energy Management Circuit Breaker) from Eaton Corporation, can be remotely actuated from commands given by a smart phone or web-based application. The team at UNC Charlotte is tasked with developing a prototype charging station, and performing the industrial design work needed to encapsulate the charger into an enclosure that can be easily and safely installed on a streetlight. Duke Energy and Eaton Corporation are providing critical in-kind support for both the installation and system design. The final product will allow a user with a smart phone to enable and disable EV charging. By the end of the performance period, the project team will install as many as five prototype charging stations throughout the City of Charlotte. Project partner Centralina Council of Governments is coordinating this public demonstration. At the conclusion of the project, the team expects to have detailed information on the process of installing charging infrastructure into streetlights, and will have a prototype unit that is ready for commercialization.

Approach

This project has been designed to proceed in eight basic tasks:

- Task 1: Prototype engineering – In this activity, the team at UNC Charlotte is working with project partners Eaton Corporation and Duke Energy to develop a prototype charging station. The primary emphasis is on the industrial design work needed to create an acceptable enclosure and product.

- Task 2: Community engagement / pilot-site determination – This task, which will occur in Budget Period 1, is focused on determining pilot sites for public demonstration. This task is led by Centralina Council of Governments.
- Task 3: Techno-economic analysis of market uptake and infrastructure needs – This task is focused on a larger market study to determine how impactful this solution could be, and, in particular, what impact it would have on existing electrical infrastructure.
- Task 4: Off-grid deployment and testing – Once the prototype charging station has been designed and built, the team at UNC Charlotte will test it in their laboratory. The emphasis will be on assessing the electrical functionality and the status of the communications framework required to remotely actuate the charger.
- Task 5: On-grid deployment and testing – Once testing is complete in the UNC Charlotte laboratory, the team will test the prototype charging stations in Duke Energy's Mt. Holly Laboratory. This facility is equipped with streetlights and other systems, allowing the team to test many of the issues associated with installation and use when connected to a real grid and real vehicles.
- Task 6: Field test deployment – Once the prototype has passed testing at Duke Energy's Mt. Holly Laboratory, the team will install as many as five charging stations throughout the City of Charlotte.
- Task 7: Field testing, monitoring, and evaluation – Once charging stations are installed, the team will allow the public to use the chargers for as long as one year at no cost. The team will document charging station usage and customer experience.
- Task 8: Commercialization planning – The team will work to ensure that the technology solutions developed as part of the project can be commercialized by project end. Much of this activity will be led by UNC Charlotte, in partnership with Eaton Corporation.

Results

The project team is currently in the first budget period of a three-year project. During the first year, the team successfully met its first go/no-go decision, which was the determination of public partners for a demonstration beginning at the end of 2020. In addition, the team successfully created specifications and requirements for its prototype charging station and developed an initial prototype. Figure I.20.1 shows this initial prototype station in action. During the remainder of 2019 and into early 2020, the team will be focused on designing a final enclosure that can be safely and easily installed on existing streetlights.

Figure I.20-1 Prototype charging station in action in a test facility on the UNC Charlotte campus.

During the first year, the team also obtained significant information about the ability to install Level 2 charging stations into existing streetlight infrastructure. In most cases, the electrical circuits providing power to the actual streetlights do not have enough spare capacity to support multiple Level 2 chargers. Additional electrical service is likely needed at most streetlights, but often there is room underground for the necessary cabling to be pulled without needed additional trenching or boring. Ultimately, the work needed for the additional electrical infrastructure is highly location dependent. Future work by the team will focus on codifying these important details.

Conclusions

This project is only in its first year of a three-year performance period, so it is early to be able to form full conclusions on project success. That said, the team has been able to successfully identify interested municipal partners and has made significant strides in the development of its prototype charging stations. The inclusion of a major electrical component manufacturer and a major utility will help ensure that the team has adequate resources to develop a commercially viable product that can be installed into existing utility infrastructure.

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I.21 Multi-Unit Dwelling and Curbside Plug-In Electric Vehicle Charging Innovation Pilots in Multiple Metropolitan Areas (The Center for Sustainable Energy)

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Start Date: October 1, 2019 End Date: March 31, 2022
Project Funding (FY18): $3,000,000 DOE share: $1,500,000 Non-DOE share: $1,500,000

Project Introduction

Electric vehicles (EVs) are poised to take a significant share of new car sales in the near future. IHS Markit forecasts that more than 130 EV models, from 45 brands, will offer electrified propulsion systems by 2026. Battery electric vehicles and plug-in hybrid vehicles are projected to account for 7.6% of the new car market by 2026, compared to only 1.2% of the nationwide market in 2018. With the proliferation of EVs comes a growing need for charging infrastructure to supply sufficient power for those vehicles. In general, EV charging occurs at three locations: home, work, and other (e.g., destinations). Home charging accounts for approximately 90% of current vehicle charging; access to home charging is critical to achieve widespread EV adoption.

While residential charging at single family homes has developed rapidly, barriers to providing multi-unit dwellings (MUDs) and curbside residential charging stations have limited deployments in apartments and condominiums. MUDs make up approximately 34% of the nations' housing inventory in major metropolitan areas [1]; however, less than 5% of home-based charging occurs at MUDs [2]. Some of the primary barriers that have limited widespread deployment of EV charging at MUDs and curbside residential locations include:

- High capital cost to install infrastructure and upgrade electrical systems
- Unique site design requirements (e.g., station location, parking constraints, access control)
- Complicated ownership, operation and management models
- Multiple stakeholder engagements/approvals required to make decisions.

This project seeks to transform the MUD charging market and support deployment of EV charging infrastructure. This will require creating a baseline understanding of current market conditions, identifying the material barriers that key stakeholders feel need to be addressed, and addressing those barriers. Key stakeholders include MUD owners/operators, tenants, industry associations/organizations, technology providers, Clean Cities coalitions, utilities, state and federal organizations, and developers. This project will demonstrate innovative technologies, create tools that help stakeholders overcome the identified barriers, and disseminate project findings across national, regional, state, and local channels.

Objectives

The objective of this project is to develop a *MUD and Curbside Residential Charging Toolkit* that includes all the necessary information on technical considerations and developing the business case for EV charging, as well as sample agreements and sample policies. This information can be used to evaluate and implement innovative, cost-effective, and flexibly-expandable charging solutions that will enhance the residential MUD and curbside EV charging systems market. Project results and the *Toolkit* will be broadly disseminated to ensure a meaningful and lasting market impact, including increased charging infrastructure deployment and EV adoption by MUD residents.

Approach

The project will run for three years. Each year is structured around activities that develop the required knowledge to create a comprehensive *MUD and Curbside Residential Charging Toolkit* that MUD operators can use to select the best solution for their property and overcome existing barriers to widespread deployment of EV charging infrastructure.

First year activities are focused on engaging stakeholders to determine the current technical and soft barriers that make deployment of EV charging infrastructure at MUD and curbside locations challenging. The project team will evaluate technical barriers through analyzing MUD EV charging infrastructure usage data from various MUD sites across the nation. This activity will illuminate current charging/demand patterns, identify improvement opportunities, and serve as the baseline dataset that will be compared to data collected from EV charging locations equipped with innovative technologies, during demonstration activities conducted in year two. The team will identify soft barriers by aggregating and issuing surveys to key stakeholder groups, and will use historical and project-developed survey data results to create a list of barriers that currently impact deployment. The project will identify tools and resources currently available in the market and evaluate their capacity to overcome the identified barriers. Where gaps exist, the project team will develop tools and resources (e.g., fact sheets, webinars, articles, and a website) that provide a clear approach for tenants to work with MUD owners/operators to deploy EV charging infrastructure. At the end of the first year, the project team will have completed the baseline evaluation and will share the insights with project stakeholders. The team will also use data results to design an innovative charging infrastructure technology demonstration program that will operate in year two.

In year two, the project team will demonstrate several EV charging innovations at real-world MUD and curbside residential charging sites; collect operational and business case data; analyze the data; quantify the innovations' impacts; and compare results with baseline data. The findings will be used to develop an informative and easy to understand *MUD and Curbside Residential Charging Toolkit* with a technology down-selection tool for site hosts to evaluate suitable options. The project team will share results from the demonstrations with stakeholders and continue to create tools and resources specifically focused on best practices for EV charging infrastructure installation, operation and maintenance.

The final year of the project will focus on refining the *MUD and Curbside Residential Charging Toolkit* and disseminating project learnings. The project team will finalize the *Toolkit* and broadly disseminate it to key stakeholder audiences nationally, to ensure the project has a meaningful and broad impact on the market. The project team will track dissemination activities throughout the project to quantify how many stakeholders have been reached, and issue a final survey to project stakeholders to evaluate the impact of tools and resources that were created during the project.

Results

During 2019, the project team assembled a project advisory committee (PAC) and engaged them through quarterly meetings, monthly calls, and monthly newsletters. The PAC is integral to project success because the members are actively engaged in promoting, siting, evaluating, and operating EV charging infrastructure. The project team designed and issued a survey to the PAC to evaluate barriers to EV charging infrastructure deployment. The PAC membership is shown in Table I.21.1.

Table I.21.1 Project Advisory Committee Members

Organization	Category	Primary Role
Center for Sustainable Energy	Project Awardee	Program Management & Planning
Energetics	Project Lead	Data Evaluation & Demonstration Planning
Forth	Project Lead	Outreach & Communications
Chicago Area Clean Cities	Clean Cities Coalition	Advisory & Outreach
Chicago Department of Transportation	Clean Cities Coalition	Advisory & Outreach
Clean Communities of Central New York	Clean Cities Coalition	Advisory & Outreach
Columbia-Willamette Clean Cities	Clean Cities Coalition	Advisory & Outreach
Greater Washington Region Clean Cities	Clean Cities Coalition	Advisory & Outreach
Los Angeles Clean Cities	Clean Cities Coalition	Advisory & Outreach
Maryland Clean Cities / Maryland Energy Administration	Clean Cities Coalition	Advisory & Outreach
Massachusetts Clean Cities	Clean Cities Coalition	Advisory & Outreach
South Shore Clean Cities	Clean Cities Coalition	Advisory & Outreach
Tulsa Clean Cities and Indian Nations Council of Governments (INCOG)	Clean Cities Coalition	Advisory & Outreach
Utah Clean Cities	Clean Cities Coalition	Advisory & Outreach
Virginia Clean Cities	Clean Cities Coalition	Advisory & Outreach
Western Washington Clean Cities	Clean Cities Coalition	Advisory & Outreach
Wisconsin Clean Cities	Clean Cities Coalition	Advisory & Outreach
City of Los Angeles	Government/Assocation	Data Provider
National Association of State Energy Officials (NASEO)	Government/Assocation	Advisory & Outreach
The Ross Group	MUD Stakeholder	Demonstration Site
St. John Properties/Bozzuto	MUD Stakeholder / Site Host	Data Provider & Demonstration Site
Cyber Switching Solutions, Inc.	Technology Provider	Technology Provider

Organization	Category	Primary Role
Electric Vehicle Institute	Technology Provider	Data Provider & Technology Provider
FreeWire Technologies	Technology Provider	Data Provider & Technology Provider
Liberty Plugins	Technology Provider	Technology Provider
OpConnect, Inc.	Technology Provider	Data Provider & Technology Provider
Powerflex	Technology Provider	Technology Provider & Demonstration Site
Baltimore Gas and Electric	Technology Provider	Advisory & Outreach
ComEd	Utility	Data Provider & Demonstration Site
Rocky Mountain Power/Pacific Power	Utility	Data Provider & Demonstration Site
Snohomish County Public Utility District (PUD)	Utility	Advisory & Outreach
Electrify America	Market Advisory	Advisory & Outreach
Idaho National Laboratory	Project Advisory	Data Advisory
New York State Energy Research and Development Authority (NYSERDA)	Government/Assocation	Advisory & Outreach
Plug In Connect	Market Advisory	Advisory & Outreach
Puget Sound Electric	Utility	Advisory & Outreach
Seattle Department of Transportation (DOT)	Government/Assocation	Advisory & Outreach
Seattle 2030 District	Market Advisory	Advisory & Outreach
Los Angeles Department of Water and Power	Utility	Data Provider

The project team collected station-level data from data providers and secured demonstration sites, a process that will continue into 2020. The project team also identified innovative technologies for demonstration that will occur during year two; Table I.21.2 identifies innovative technologies.

Table I.21.2 Innovative Technologies for Demonstration

Company	Innovative Solution	Application
Liberty PlugIns	Parking meter integration and smart controls	MUD & Curbside
CyberSwitching	Rotational Charging	MUD
EV Institute	Turnkey Management	MUD & Curbside
PowerFlex	Adaptive charging	MUD
OpConnect	Smart Management	MUD & Curbside
Freewire	Mobile energy storage	MUD

This project is still in the early stages of gathering data and establishing partnerships for demonstration projects. As such, the project team has not yet published any reports. The project's Principal Investigator presented on the project design at a number of conferences, including:

- EVs & the Grid Conference, Los Angeles, California, October 1, 2019
- Charge Expo Symposium, San Diego, California, October 2, 2019
- California Clean Cities Coalitions Regional Meeting, Long Beach, California, April 30, 2019.

Conclusions

The project team made significant progress developing a project plan and engaging key stakeholders to participate in the PAC, provide baseline data, and participate in the innovative technology demonstration. The project team issued a survey to the PAC on barriers and requested data from data partners. Neither dataset, however, has been completely collected or analyzed. As a result, no significant conclusions can be drawn about baseline conditions or the impact of innovative technologies set for demonstration.

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Acknowledgements

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I.22 EVSE Innovation: Streetlight Charging in City Rights of Way (Metropolitan Energy Center)

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Start Date: October 1, 2018 End Date: December 31, 2021
Project Funding: $2,534,610 DOE share: $1,201,709 Non-DOE share: $1,332,901

Project Introduction

Streetlight charging for electric vehicles (EVs), whether on streets in central business districts or on residential streets, provides easy charging access for apartment residents and homeowners alike. Most EV drivers charge their vehicles at home, in their garages or driveways. For residents of multi-family properties, there are no such options. Most rental property owners are reluctant to provide EV charging, also known as electric vehicle supply equipment (EVSE), at their own expense. Opportunities for cost recovery are limited, and tenant turnover is far higher than rates of change in areas of single-family housing. Beyond that, residents of multi-family housing tend to have lower household incomes than homeowners. A used EV is an affordable option for a lower-income household, particularly when used as a commuter car; Edmunds [1] cites average 2018 EV costs ranging from 42% to 73% less than a comparable new model. But without easy access to charging, even a low-cost used EV is a non-starter for a prospective buyer, despite the demonstrated low total cost of ownership (TCO) of an EV. An affordable curbside charging network has the potential to expand EV adoption into neighborhoods that have, to date, seen minimal interest and uptake of the technology.

Objectives

The objective of this project is to expand the availability of EV charging at low cost in urban settings. We plan to use existing electrical infrastructure – streetlights – to provide on-street EV charging, as well as charging for multi-family residences, in Kansas City, Missouri. By using grid-tied systems already in place, this approach can substantially cut installation costs and create a replicable approach for flexible, affordable charging systems that are feasible anywhere cities operate streetlights. This project will test charging and data technologies, track use of charging networks for on-street and residential applications at 30 to 50 new EVSE locations, and generate a process for siting EVSE while balancing concerns related to demand and equitable access.

Deployment equity matters, and one of the project's goals is to ensure availability of this EV charging network to residents, regardless of socio-economic or housing status. While Kansas City's Permitting Office receives continual inquiries about EVSE installation from business owners in relatively prosperous areas, installing traditional on-street EVSE in low-income and rental neighborhoods remains for the most part cost-prohibitive. Lower income individuals and families could benefit the most from the long-term savings an inexpensive EV provides, yet they are least likely to have access to convenient, affordable charging networks. Geographic diversity is one part of unlocking the equity puzzle, and another is deployment in multi-family housing locations. A 2017 California draft study estimated installation costs of Level 2 charging for multi-family properties at an average price of $5,400, over triple the average cost for installation at a single-family residence. [2] Between 2006 and 2014, the percentage of Americans who rent rather than own rose from 36.1% to 41.1%. [3] With more people becoming renters, and residential EVSE more unattainable for renters, streetlight charging presents a more equitable alternative.

Approach

Metropolitan Energy Center (MEC) is working with several community partners on this project. Missouri University of Science and Technology (MST) is building out a demand-driven model of potential siting locations. The National Renewable Energy Laboratory (NREL) is modeling potential locations based on equity concerns. MEC is working with all partners to gather additional siting criteria (i.e., costs, community interest, and impact on resiliency) and develop a site ranking matrix. Community listening sessions may reveal additional criteria. Simultaneously, LilyPad, Black and McDonald, the City of Kansas City, and Evergy are working together to design the schematics for upgrading the streetlights and integrating and mounting the EVSE units. See Figure I.22-1 for a sample cost estimate. The City of Kansas City is also leading an effort to evaluate City policies related to EVSE, and provide a list of best practices. Installation and monitoring are expected to begin in 2020.

Figure I.22-1 Sample cost estimate, Black and McDonald

Results

At this stage, we have a beta version of the demand-based siting model from MST and a draft of the equity-driven model from NREL. We also have pricing estimates and sample schematics for installation. A draft policy framework is under review. We anticipate conducting listening sessions in the spring and beginning EVSE installation in the summer of 2020.

MST modified its site selection model to use available data where many ideal data sets were not available. Mid America Regional Council (the local Metropolitan Planning Organization) and the Parking and Streetlights Departments of the City of Kansas City have been valuable sources of this data, much of which the project team had not known was available until face-to-face meetings with analysts and other staff. Another surprise for the team was the discovery that a large percentage of City-owned streetlights were not built to code; they had been purchased from the utility and grandfathered in, so they did not have the expected electrical capacity, and needed more upgrades than previously thought.

Lessons Learned:

- Community buy-in is critical to project success. Failure to involve the community can cause the project to be viewed as an attempt to gentrify a community, which will result in lower usage and potentially unreported vandalism.

- Upgrading existing electrical capacity can be quite expensive when it involves boring and trenching. Although above-ground lines are more susceptible to extreme weather disturbances, this may be preferable when trying to limit installation costs.
- While it was previously thought that switching to LED streetlights would free up the capacity required for a Level 2 charger, it only frees up 5 to 10 % of the needed capacity. This is very rarely enough to tip the scales, particularly with older streetlights that have little unused capacity remaining.

Conclusions

This project has encountered many unexpected challenges, but it remains on target thanks to the flexibility and persistence of the project partners.

References

1. https://www.edmunds.com/car-buying/the-pros-and-cons-of-buying-a-used-ev.html
2. http://southbaycities.org/sites/default/files/ARV-14-035%20ZEV%20MUD%20-%20Final-Draft%20Rpt%20Exec%20Summary.pdf
3. https://www.citylab.com/equity/2016/02/the-rise-of-renting-in-the-us/462948/

I.23 Multi-Modal Energy-Optimal Trip Scheduling in Real-Time (METS-R) for Transportation Hubs

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Start Date: October 1, 2018 End Date: December 31, 2020
Project Funding: $594,531 DOE share: $476,223 Non-DOE share: $118,308

Project Introduction

The project develops the Multi-modal Energy-optimal Trip Scheduling in Real-time (METS-R) platform as the next generation travel solution at urban transportation hubs, to substantially reduce transportation energy usage. Passenger trips at urban transportation hubs have several distinct characteristics that differ from urban commuting trips, and it requires specialized solution approaches to develop an energy-optimal travel platform for efficiently serving these passengers. First of all, trips to and from a transportation hub share the same trip origin or destination: the hub itself. This provides an opportunity to promote ridesharing at transportation hubs so that the total number of trips, and therefore energy consumption, may be significantly reduced. Second, multiple transportation modes are available at transportation hubs, and it is therefore important to optimally balance the usage of existing modes to achieve optimal energy use. Third, the arrival of passengers at transportation hubs is highly dependent on the timetables (of trains and flights) at the hubs, thereby leading to more predictable demand, which makes it more convenient to optimize trip scheduling in real-time. Finally, compared to regular commuting trips, some passengers at transportation hubs are less mobile due to the luggage they carry, having special needs, or having different preferences for their arrival and departure times.

Considering these issues, the METS-R platform combines data acquisition techniques with energy saving automated electric vehicles (AEV) to design a data-driven smart transportation mode, as a supplement to existing travel modes, to optimize energy flow at transportation hubs. The project team collects mobility data from different sources to obtain a comprehensive understanding of the current city-wide energy consumption condition, builds models and operation algorithms to support the decision making of the METS-R platform, and uses high performance computing (HPC) clusters to develop an advanced simulation-based platform to support and validate real-time energy optimal trip scheduling, and to achieve impactful travel time and energy savings.

Objectives

The METS-R system is evaluated by implementing the developed system at real-world transportation hubs in New York City (NYC), including Penn Station in Manhattan, and the LaGuardia (LGA) and John F. Kennedy (JFK) airports in Queens. These hubs are major passenger trip attractors/generators in the NYC metropolitan area, as well as major traffic bottlenecks with heavy traffic congestion and high energy consumption. With the implementation of the METS-R system, the overall objectives of the study are threefold:

- Design an efficient management approach for a multi-modal transportation system at major hubs in NYC, supplementing existing transportation solutions with a shared AEV fleet
- Develop a high-performance agent-based simulation platform to model usual and anomalous scenarios for the proposed system
- Understand the overall energy consumption at transportation hubs of present transportation systems and improve the energy flow and travel efficiency with the METS-R system during real-time operations.

Approach

In the first year, the project team focused on the data collection and preparation, the analysis of travel needs, and the development of planning and operation algorithms to support the deployment of AEVs at transportation hubs. Our approaches can be summarized as follows:

Data collection and preparation

The data collected covered the taxi and for-hire-vehicle (FHV) data in the past 5 years in our study area; the vehicle trajectory data of major FHV operators in the first 9 months of 2019; and various other data sources such as the weather condition, the flight arrival and timetable, and socioeconomic and demographic data. The team undertook data cleaning, map matching, and data annotation, and developed a data warehouse for efficient management of the collected data.

Travel needs analysis

The team used the collected data to understand how travel time varied among the transportation hubs for different modes of travel, at different times of day, and different days of the week. The project team analyzed the data to understand where the demand was distributed to and from the transportation hubs, at different times of day, and investigated the resulting impacts on energy consumption. The project team also looked into anomalies for travel time and demand around transportation hubs.

Planning and operation algorithms

Based on the insights obtained from analyzing the data, the team designed the service zones and the route generation algorithm for operating the AEV services at transportation hubs. The team also developed a charging station planning model to support the deployment of charging stations for city-wide usage of electric vehicles, to reduce energy consumption.

Results

The project team achieved five milestones during the first year of the project.

1. The project team completed the collection of the proposed historical and streaming data within the study area (NYC). The collected data include the historical taxi data; the trajectory data from Uber and Lyft; the transit usage data from NYC MTA; the flight schedules at JFK and LGA; the train schedules at Penn Station; the weather data; NYC GIS data; NYC mobility survey data; demographic data; socioeconomic data; historical energy and emissions data; and the specification data for AEVs. The team also documented and described the data as it was collected.

2. The project team developed a data warehouse for storing and processing all the collected data, using PostgreSQL as the database solution, and stored the database on the team's server. The data warehouse contains more than 60 gigabytes of FHV data and over 90 gigabytes of taxi data. The project team also built an interactive data visualization tool to present the traffic and energy flow to and from major transportation hubs, based on the data collected (see Figure I.23.1). The project team is currently adding the results of the energy analysis to the data warehouse.

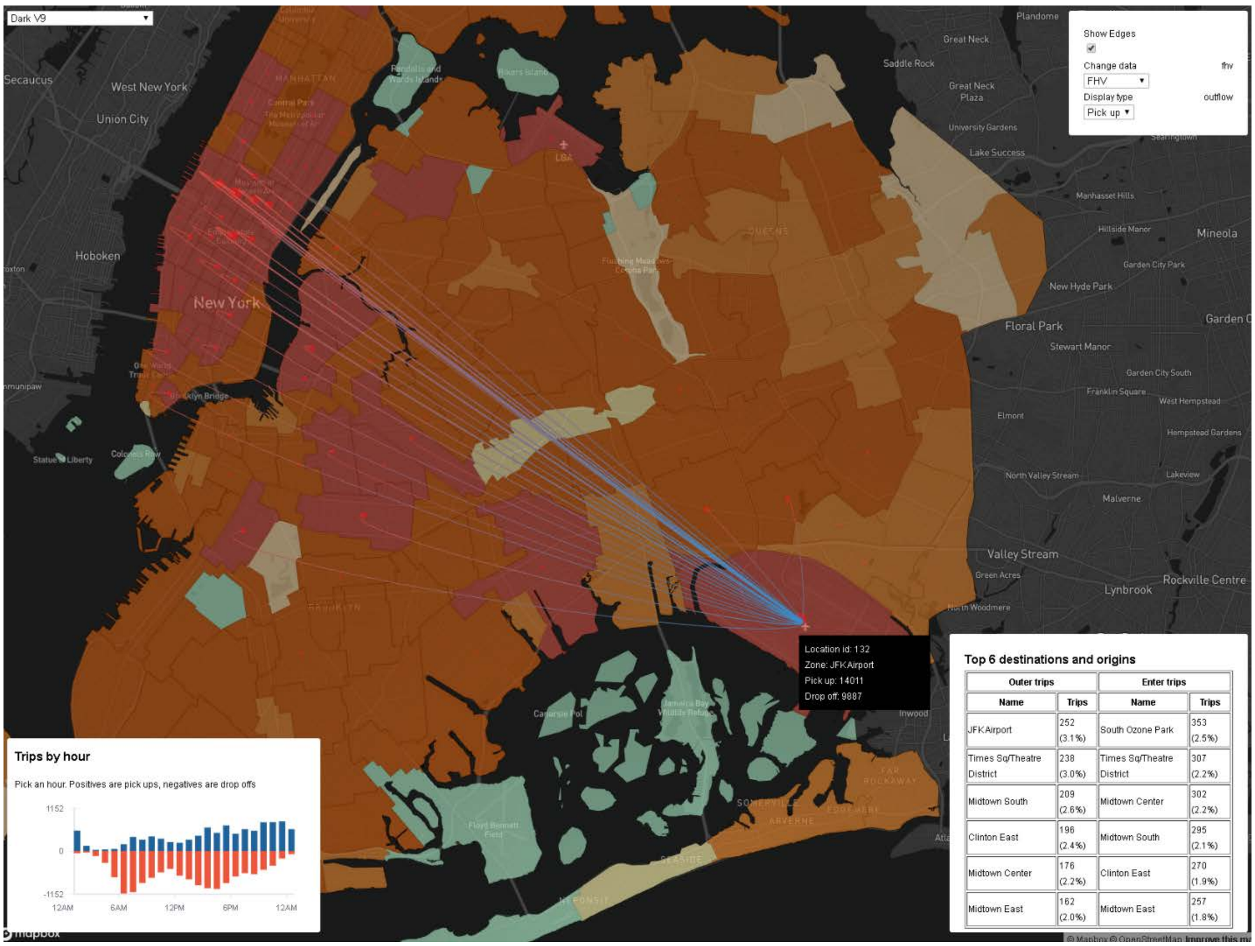

Figure I.23-1 Interactive visualization tool for visualizing the collected data. (Left: usage of taxis at LGA airport; Right: usage of FHVs at LGA airport)

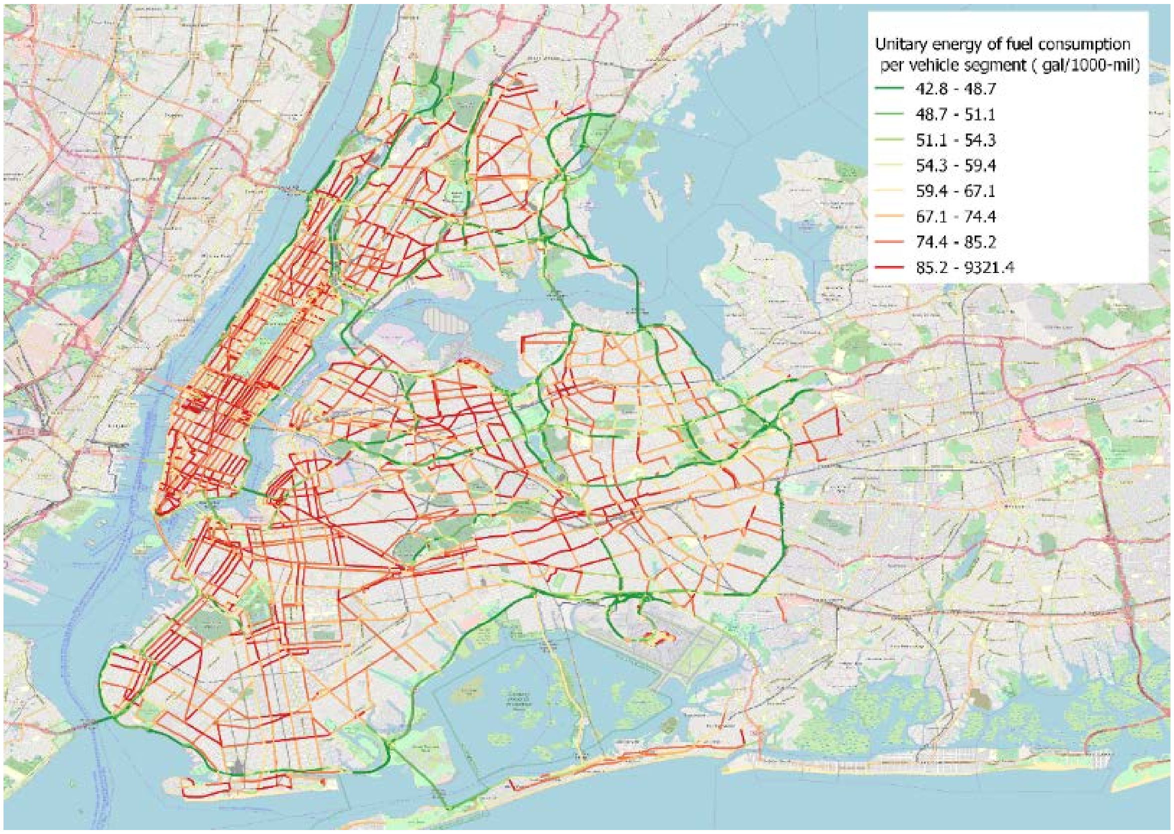

Figure I.23-2 Visualization of energy consumption (gallons per 1000 miles) based on the calculation from FHV trajectory data

3. The project team mapped the collected trajectory data to the road segments (13,000 links) and calculated the travel speed and corresponding energy consumption across the city (See Figure I.23.2). The team found the energy consumption within Manhattan to be significantly higher than other places in NYC, due to both low average speed and a high number of trips. The project team also conducted the analysis for comparing the change in city-wide energy consumption between 2017 and 2019, based on the Uber trajectory data. The team found that City-wide travel speed had decreased by 11.4% from 2017 to 2019. This led to 11.9% more gasoline consumptions, 19.4% more carbon monoxide and 22.1% more hydrocarbon emissions during weekdays.

4. The project team proposed a hybrid prediction model to extract the most information from a 60-minute aggregated dataset and predict total outgoing vehicles, The model is a non-linear regression that takes external influences into consideration, including incoming flights; weather information (temperature, precipitation, snow); and temporal indicator variables (e.g. time of the day and day of the week), followed by the ARIMA model, to best comprehend the prediction performances of the models. The team then performs the anomaly detection based on residues between actual ridership and the model baseline prediction, using a Gaussian Mixture Model (GMM) to perform clustering of similar temporal patterns, and detect anomalies with under 0.01% likelihood. One component classifies many of the major NYC holidays, cultural events and extreme weather conditions. Further ongoing research utilizes novel representation learning methods over temporal networks being developed by the NYU team, to include the entire urban mobility network in the prediction model, accounting for origin and destination distribution of the ridership, to inform the dispatching block of the future AEV system.

5. The project team proposed a three-stage optimal process for the generation of optimal travel routes and optimal AEV bus fleets, as shown in Figure I.23-3. The overall framework takes the trip demand and road traffic conditions as the inputs, and outputs the fleet size and set of selected operation routes and their corresponding operation frequency, under the budget constraints. We conducted field experiments for planning AEV at JFK airport. The results of the route generation suggested that using 9, 18 and 37 routes may cover approximately 43%, 67% and 87% of taxi and FHV passengers, respectively, while 61 routes can cover all potential passengers.

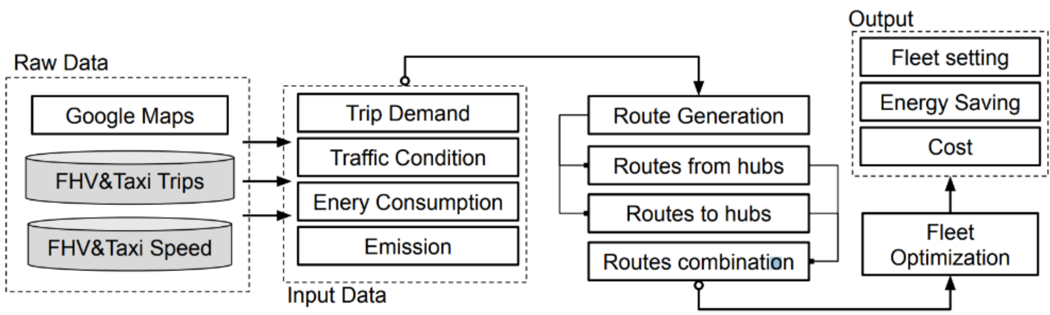

Figure I.23-3 AEV planning framework

Conclusions

During the first year of the METS-R project, the team successfully completed the collection of trip data, the processing of the data and the development of the data warehouse. The team conducted preliminary analysis of the data to understand the current energy consumption from FHV trips, and the trip anomalies at transportation hubs. The project team also identified the framework for planning the operation of AEVs, and validated the feasibility of using AEV buses to effectively reduce the energy consumption at the transportation hubs. These findings serve as important practical and theoretical bases for the second phase of the METS-R project.

Key Publications

1. Stanislav Sobolevsky et. al. 2019. Anomaly Detection in Temporal Networks. NetSci, May, 2019, Burlington, VT, USA.

2. Qian et al. 2019. Stationary Spatial Charging Demand Distribution for Commercial Electric Vehicles in Urban Area. IEEE ITSC 2019.

3. Lei et al. 2019. Optimal Proactive Vehicle Relocation for On-Demand Mobility Service with Deep Convolution-LSTM Network. IEEE ITSC 2019.

4. Qian et al. 2019. Demand-Adaptive Transit Design for Urban Transportation Hubs. Accepted for presentation at 2020 Transportation Research Board (TRB) annual meeting.

5. Qian et al. 2019. Charging Infrastructure Planning for Commercial Electric Vehicles Based on Stationary Spatial Demand distribution. Accepted for presentation at 2020 TRB annual meeting.

6. Qian et al. 2019. Understand the Impact of Transportation Network Companies on Urban Traffic Using Large-Scale Trajectory Data. Accepted for presentation at 2020 TRB annual meeting.

II National Laboratory Projects

II.1 Alternative Fuels Data Center (National Renewable Energy Laboratory)

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Start Date: October 1, 2018 End Date: September 30, 2019
Project Funding (FY19): $1,100,000 DOE share: $1,100,000 Non-DOE share: $0

Project Introduction

The U.S. Department of Energy (DOE) launched the Alternative Fuels Data Center (AFDC) in 1991 as a repository for alternative fuel vehicle (AFV) performance data. Since that time, it has evolved to become an indispensable resource for a diverse set of users including fleets, fuel providers, policymakers, Clean Cities coalitions, and others working to find ways to reach their energy and economic goals with alternative and renewable fuels, advanced vehicles, and other energy/fuel-saving measures. The AFDC has achieved this level of engagement because of the many successful public and industry partnerships built in the past 28 years that have contributed to the quality and quantity of information contained on the AFDC website.

AFDC data, information, and tools enable transportation stakeholders to reduce total operating costs, and improve emissions impacts, while improving transportation energy efficiency using alternative fuels and other advanced vehicle technologies. Alternative fuel use can provide substantial benefits to the country's economy, energy security, and environment. As a trusted third-party data provider, the AFDC is used in multiple ways to support both public and private industry.

Based on expertise from the National Renewable Energy Laboratory (NREL) and partnerships with Argonne National Laboratory and Oak Ridge National Laboratory, the AFDC provides extensive information on alternative fuels, including biodiesel, electricity, ethanol, hydrogen, natural gas, and propane. Users can learn about considerations when using alternative fuels, vehicle operation and availability, fuel properties, production, distribution, and prices, as well as station locations, emissions benefits, and more. The website features information not only on the vehicles and engines that use these fuels, but also on the unique fueling infrastructure necessary to dispense them. The AFDC also offers content on fuel-saving strategies like idle reduction, fuel economy improvements, and efficient driving practices. The site's diverse group of users can examine long-term trends, conduct cost estimates, estimate emissions benefits, and identify fuels and technologies that are appropriate for their operational needs and geographic locations, by using the site's many tools.

In sum, the AFDC's vast collection of information, tools, and robust data empowers fleets and individual drivers to identify the strategies and technologies that will best help them meet their environmental and energy goals in the most cost-efficient manner.

Objectives

The AFDC's primary objective is to be a leading, trusted site for information and data on alternative fuels and advanced vehicle technologies. The AFDC provides a wide range of accurate content that is updated and maintained on a continuous basis through in-depth reviews by subject matter experts, the identification of changing market conditions, and timely responses to those changes. This enables the AFDC to maintain its position of credibility within the public and private sectors, while continuing to grow its use among key stakeholders.

Approach

The AFDC has become an expert resource because of its approach to producing, updating, and sharing content that is supported by technical expertise in alternative fuels and advanced vehicles. While multiple National Laboratory experts are tapped to review new and existing content, the site ensures accuracy and objectivity by often relying on close industry partnerships to identify and fill any critical gaps. Behind its user-friendly interface, the AFDC also contains an extensive set of neutral, accurate, and vetted data. That data is rigorously maintained and presented in an accessible format to ensure target audiences get the information they seek in the most efficient manner possible. Multiple pathways (outlined below) safeguard the effective delivery of credible and objective information and data, which remain the foremost focus of the AFDC's content and tools.

Efficient Delivery

There are many ways to deliver data and information, and each has its own advantages. A diversified delivery strategy ensures that information is easily accessible in a variety of formats, for a variety of devices. The AFDC approach is to provide information and data in the following ways:

- **AFDC Website**: Data and information are accessed directly through the content and tools on the AFDC website. The data is also accessed via referral links from other organizations. Linking to the site as the trusted third-party, objective resource helps organizations demonstrate that their information or product is developed from vetted, factual information.
  - **Tools**: A host of calculators, interactive maps, and data searches make up the site's set of tools.
  - **Content**: The AFDC provides up-to-date content on commercially available alternative fuels, vehicles, and fuel-saving methods.
- **Application Programming Interface (API)**: Several of the AFDC's datasets are available via an API and are used both internally (to support analysis and tools) and externally by public and private enterprises. API data is delivered from computer to computer and updated automatically on a continuous basis. This kind of data delivery is primarily used by organizations wanting to build their own applications with the data.
- **Data Downloads**: AFDC data is also available for download. Data downloads are most often used by organizations wanting to build applications and upload the data into those applications, or by analysts doing research related to alternative fuels.

- **Mobile Apps**: The Alternative Fueling Station Locator is available as a native app for iPhone and Android. The AFDC website is also designed to function on various mobile devices, such as tablets and smartphones.
- **Widgets**: Several of the AFDC tools are available as widgets, which are snippets of code that let users embed AFDC content on their websites, blogs, or social networking sites. This allows users to include the content in their own websites without the expense of building their own tools. See Figure II.1.1, below, for an example of an AFDC widget.

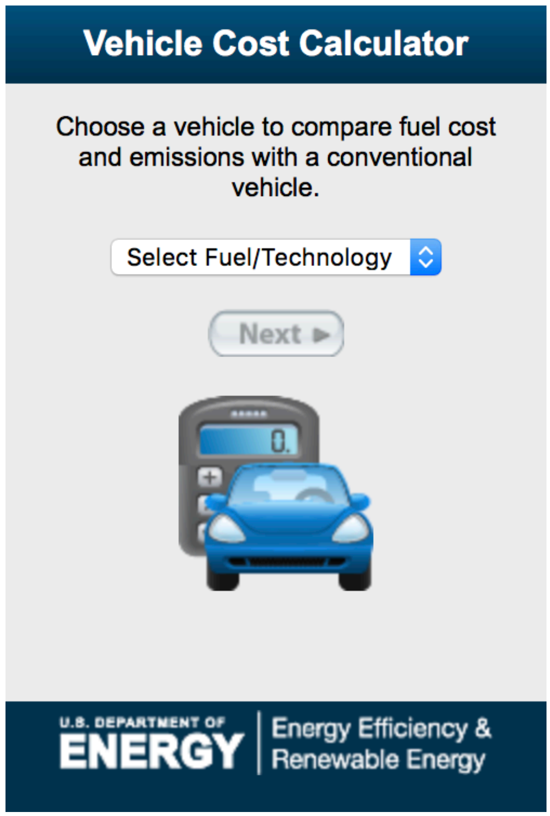

Figure II.1-1 Vehicle Cost Calculator widget

Depending on the type of organization accessing the AFDC, its business strategy, and use case, any combination of the data sourcing strategies above may be preferred. By providing multiple pathways for using and obtaining the information and data, the AFDC provides a valuable service to help organizations meet their policy or business goals. By measuring how the data endpoints are used, NREL can quantify their value to the market and the AFDC's partners.

Credible and Objective Data

To ensure the integrity of the information and data, the AFDC undergoes an in-depth annual content review. During this process, subject-matter experts from multiple national laboratories review the content using evidence-based research, their expertise in the industry, and information on identified changes in the market. NREL maintains a cadre of experts who ensure the AFDC is accurate and robust.

Results

The AFDC continues to grow as a relevant and trusted resource. In fiscal year (FY) 2019, the AFDC boasted an 18% increase over FY 2018 in page views, with more than 2.7 million visitor sessions and 1.9 million unique visitors. Those visitors accessed pages on the AFDC website more than 9.1 million times. Visits to the site included an average of 14% returning visitors and 85% new visitors.

The AFDC has long been a top-performing website within the Office of Energy Efficiency and Renewable Energy's (EERE) informational portfolio. In fact, 36% of all EERE website page views are from AFDC pages. Additionally, 10 of the top 30 most-viewed pages in the EERE portfolio are AFDC pages.

Referral Quality

The AFDC serves the fleet and transportation industry audience, and one way to measure its effectiveness is to look at the quality and quantity of referrals to the AFDC. (A referral is a website that directly links to AFDC content and tools.) One goal is to gain referrals from sites where the AFDC audience spends time, such as industry websites.

DOE and NREL have been consistently building partnerships with industry and attracting quality referrals for many years. For example, an evaluation of the top 40 referrals in FY 2019 shows that the fleet and industry audiences continue to be the main referral base. In addition, a significant number of visits to the AFDC are direct traffic from fleet and industry audiences (i.e., people in this group who bookmark the AFDC or go directly to known AFDC pages from their browsers, without using a search engine or a link from another website). Figure II.1.2 shows a breakdown of sources of AFDC visits, based on the top 40 referrals.

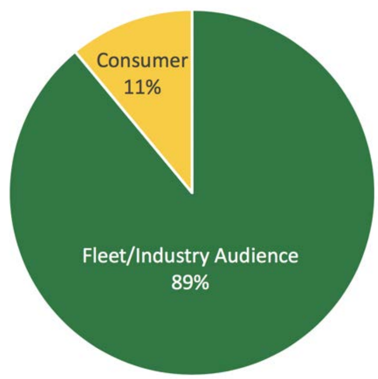

Figure II.1-2 Sources of AFDC visits based on the top 40 referrals

Some of the top referrers in FY 2019 included several vehicle Original Equipment Manufacturer (OEM) sites linking to the laws and incentives information, with Honda leading the referral count. In FY 2019, the Federal and State Laws and Incentives pages were viewed more than 1.5 million times, particularly via referrals from numerous vehicle manufacturers. During FY 2019, there were more than 5,800 websites linking to the AFDC, resulting in more than 500,000 sessions, which indicates the number of times users visited the site after clicking on a link from a referral website. Referrers include companies and organizations of every size and type, such as utilities, major corporations (including vehicle OEMs and equipment manufacturers), small startups, non-profits, cities and states, and search engines. See Table II.1.1.

Table II.1.1 Top 20 Referrers to the AFDC Website in FY 2019

Referrer	Sessions
automobiles.honda.com	80,352
switchingtosolarpv.com	57,803
energysage.com	18,449

Referrer	Sessions
smartusa.com	17,189
chevrolet.com	14,988
subaru.com	14,169
accessrvrental.com	13,161
fueleconomy.gov	12,754
search.usa.gov	12,446
cleanngreenfuel.com	11,733
expo.mlive.com	7,666
bmwusa.com	6,715
m.facebook.com	5,833
plugintothepresent.com	5,742
mlive.com	5,234
youtube.com	5,155
edmunds.com	4,568
oringcng.com	4,467
westcoastgreenhighway.com	4,365
audiusa.com	3,995

AFDC Content Interest

The interest in AFDC data shifts among the tools and fuels, depending on policy developments and market economics. By continuously providing the best, most current data and information on all types of fuels and technologies, the AFDC is able to remain relevant, despite changing interests based on trends.

The AFDC contains six main areas of content based on the alternative fuels defined by the Energy Policy Act of 1992 (EPAct). These content areas include biodiesel, electricity, ethanol, hydrogen, natural gas, and propane. In FY 2019, interest in fuels and vehicles information accounting for 31% of the total page views on the AFDC, compared to 32% in FY 2018. Historical data shows that the most frequently accessed pages by fuel type vary from year to year. In FY 2019, ethanol was the most popular topic in terms of page views for fuels and vehicles information compared to FY 2018, when electricity took that spot.

Figure II.1-3 depicts the breakdown of interest in content by fuel type in FY 2019. Of the total page views for fuels and vehicles information, 32% was for ethanol, while 31% was for electricity.

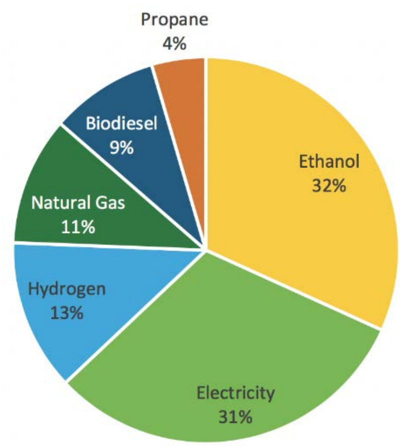

Figure II.1-3 Interest in fuels and vehicles information by subject based on page views, FY 2019

As shown in Figure II.1-4, 46% of the queries for fueling station locations involved ethanol. This is an increase over ethanol's 40% share in FY 2018.

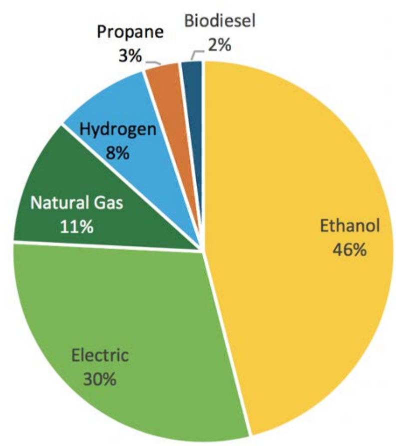

Figure II.1-4 Interest in stations information by subject based on page views in FY 2019

Tools

The tools on the AFDC range from those that are broad and appeal to multiple audience segments, to specialty tools designed for more focused audiences. The tools directory page [1] received more than 12,700 views in FY 2019; however, a user's discovery of the tools more commonly comes from links on other AFDC pages or referrals from other sites. Direct traffic—meaning visitors that bookmark the page or come to the site without clicking on a link within the AFDC or another site—also provided a significant number of page views for the tools.

Table II.1.2 shows primary tools on the AFDC website by popularity. Notably in FY 2019, EVI-Pro Lite saw a 115% increase in page views, and the Vehicle Cost Calculator saw a 93% increase compared to FY 2018. The State Information Search, the Alternative Fueling Station Locator, and the Case Studies Search each saw a significant increase in page views compared to FY 2018. On the other hand, the Laws and Incentives Search, the Publications Search, and the Fuel Properties Comparison each saw a modest decrease in page views.

Together, the tools accounted for 67% of the total page views on the AFDC in FY 2019, compared to 66% in FY 2018.

Table II.1.2 Page views for the Primary Tools on the AFDC Website

Tool	FY 2019 Page Views	FY 2018 Page Views	% Change
Alternative Fueling Station Locator	3,266,514	2,418,635	35%
Laws and Incentives Search	1,570,229	1,690,491	-7%
Maps and Data Search	501,717	503,483	0%
Vehicle Cost Calculator	487,338	252,510	93%
Vehicle Search	120,774	108,684	11%
State Information Search	51,745	31,566	64%
Case Studies Search	37,124	28,257	31%
Publications Search	32,641	34,959	-7%
Fuel Properties Comparison	15,619	16,257	-4%
EVI-Pro Lite	7,321	3,404	115%

Data, APIs, and Downloads

A significant growth area for the AFDC has been sharing data and tools with a wider audience. Table II.1.3 summarizes the data activity in FY 2019 by showing the total number of API requests (people searching or using the dataset on other websites or systems), the number of unique API users, and the number of data downloads, which are offered on the data downloads page [2] and provide a snapshot of various data offerings at any point in time.

Table II.1.3 API Requests, Users, and Downloads in FY 2019

Data	API Requests	Unique API Users	Downloads
Alternative Fueling Stations	20,282,059	8,611	2,895
Laws and Incentives	650,612	31	2,187
Vehicles	5,288*	14*	5,097

* This API was launched in May 2019 and does not include statistics for the entire fiscal year.

Stations data downloads and requests via the web service, also known as an API, have expanded use of AFDC data over time. The alternative fueling stations API (a live data feed of stations data) received more than 20.2 million requests in FY 2019, which was up from about 7.9 million requests in FY 2018. The Alternative Fueling Station Locator widget had more than 282,000 page views while embedded on other websites in FY 2019, accounting for 9% of the total stations traffic.

The laws and incentives API received more than 650,000 requests in FY 2019, which was up from about 560,000 requests in FY 2018. Many OEMs now link to the laws and incentives site. This is a growing opportunity for outside users to filter the laws and incentives data using the API, which increases the value of their own websites. Beyond data downloads, the most downloaded document on the AFDC in FY 2019 was the fuel properties comparison chart, with more than 91,000 downloads, followed by the Alternative Fuel Price Reports with more than 64,000 downloads.

Cloud Migration

In FY 2019, NREL completed migrating the AFDC from servers hosted at NREL to a cloud environment. This migration improved the security, availability, and performance of the website. In the new cloud environment, the servers and databases are easier to maintain with the latest software updates and security patches, which reduces cyber security risk and maintenance costs. The overall availability of the website is improved with a higher uptime than traditionally hosted systems, because the cloud environment provides redundancy, which means the site is hosted by multiple servers. If one server goes down, another parallel system is ready to take over and keep the site available for users. Moving the AFDC to the cloud also increased the performance of the website by adding the capability to handle traffic spikes dynamically. As traffic on the website increases, the cloud servers can allocate new resources to meet the demand and then downsize as traffic decreases.

Vehicle Search Tool

NREL enhanced the Vehicle Search Tool in FY 2019 by adding database fields, displaying new data, and populating existing fields, like E85 fuel economy, that were missing data. These improvements are part of an ongoing effort to keep the AFDC data and tools informative and useful. Users can access new fuel economy values for plug-in hybrid electric vehicles based on whether the vehicle operates in electric-only mode or gas and electric. In addition, the displayed information now provides more detail about individual vehicles, to be consistent with FuelEconomy.gov. This effort also included publishing a web service for the vehicles data. In the four months that the web service was publicly available at the end of the year, the vehicles API received more than 5,200 requests, which indicates a strong interest in the data.

Maps and Data

In FY 2019, NREL completed a comprehensive update of the Maps and Data content, which included reviews by subject matter experts, collection of new data, and updates to the descriptions, sources, and notes for each chart in the database. This effort resulted in updating 85 datasets and completing a quality-control edit to ensure consistency among the charts. NREL also identified 18 outdated or obsolete charts and removed those from the site. The Maps and Data tool is a valuable resource in the transportation industry because it communicates important trends related to alternative fuels and vehicles. The charts are interactive and annotated to provide practical context, and they are downloadable and shareable as widgets that can be embedded on other websites.

Electric Vehicle Content

During the annual content review of the electricity section, NREL identified a need for more in-depth content on developing electric vehicle charging infrastructure. NREL devised a better way to organize the content and communicate the differences between the types of charging equipment available. Through this process, NREL also created content for the charging infrastructure pages, to address the topics of procurement, operations, and maintenance. Together, these pages are intended to help transportation stakeholders, planners, and utilities evaluate their infrastructure development needs and prepare for electric vehicle charging in their area.

Conclusions

The AFDC provides robust and relevant information to advance the goals of DOE's Vehicle Technologies Office, as is evident by the fact that usage continues to grow every year, with an increasing number of referrals from public and private industry. This underscores the need for credible, objective, third-party data and information in the growing market for alternative fuels and advanced vehicles. Through thoughtful management and many partnerships, the AFDC helps ensure that the content and tools are relevant and reach the right audience, by providing information and data in a variety of formats, including web applications, APIs, data downloads, and embeddable widgets. This valuable resource continues to lead EERE websites as a content provider and forward-thinking driver of data and tools to help people find transportation solutions.

Key Publications

1. AFDC home page: afdc.energy.gov

2. Alternative Fueling Station Locator: afdc.energy.gov/stations
3. Laws and Incentives Search: afdc.energy.gov/laws
4. Maps and Data Search: afdc.energy.gov/data
5. Vehicle Cost Calculator: afdc.energy.gov/calc
6. Vehicle Search: afdc.energy.gov/vehicles/search
7. Publications Search: afdc.energy.gov/publications
8. State Information Search: afdc.energy.gov/states
9. Case Studies Search: afdc.energy.gov/case
10. Fuel Properties Comparison: afdc.energy.gov/fuels/properties
11. EVI-Pro Lite: afdc.energy.gov/evi-pro-lite
12. Data Downloads: afdc.energy.gov/data_download
13. Widgets: afdc.energy.gov/widgets
14. Developer APIs: developer.nrel.gov/docs/transportation/alt-fuel-stations-v1

References

1. afdc.energy.gov/tools
2. afdc.energy.gov/data_download

II.2 AFLEET Tool (Argonne National Laboratory)

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Start Date: October 1, 2018 End Date: September 30, 2019
Project Funding (FY19): $230,000 DOE share: $230,000 Non-DOE share: $0

Project Introduction

This project updates and expands the existing Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool first released in 2013. Researchers at Argonne National Laboratory (Argonne) developed the AFLEET Tool for the U.S. Department of Energy (DOE) Vehicle Technologies Office's (VTO's) Technology Integration Program to estimate petroleum use, emissions, and cost of ownership of light-duty vehicles (LDVs) and heavy-duty vehicles (HDVs), using simple spreadsheet inputs. AFLEET examines both the environmental and economic costs and benefits of conventional, alternative fuel, and advanced technology vehicles for 18 different fuel and vehicle pathways, 7 major vehicle types and 23 different vocations. The tool has both a Simple Payback calculator, to examine the payback of a new conventional vehicle versus an alternative fuel vehicle (AFV), and a Total Cost of Ownership (TCO) calculator that examines the costs during the entire life of the vehicle.

Argonne had previously updated AFLEET in 2018 and included changes that matched results to Argonne's Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) 2018 model. In addition, Argonne developed a user-friendly online version of AFLEET to supplement the spreadsheet version. Since AFLEET's inception the number of users has grown to 8,500 individuals for the spreadsheet and 2,300 for the online version. The primary audiences for this tool are Clean Cities coordinators, industry, fleet managers, academia, and policymakers at all levels of government. The tool can be accessed directly from Argonne's web site or from the Alternative Fuels Data Center website [1]. The tool has been used to examine real-world fleet data for several VTO case studies, authored by Argonne.

Objectives

In fiscal year (FY) 2019, the AFLEET Tool had several factors that needed updating. Similar to the 2018 revision, AFLEET required an annual update to match new modeling results from GREET [2] and MOVES [3]; new fuel price data from the Alternative Fuel Price Report (AFPR) [4], and the Energy Information Agency (EIA) [5]. New data on the maintenance costs of a wide range of light-duty and heavy-duty vehicles, which included more recent information on both conventional and alternative fuels, became available. In addition to the on-road vehicles in the tool, stakeholders indicated that they would like AFLEET to include off-road equipment emission analysis. Stakeholders also wanted to be able to estimate the emission benefits of public electric vehicle charging.

Approach

Argonne used the GREET 2019 model as the basis to update existing data in AFLEET, and to update default fuel economy and electricity consumption data for both LDVs and HDVs. Argonne updated state and national emission factors for gasoline and diesel vehicles using calendar year 2019 results from the EPA MOVES 2014a version. In addition, Argonne used EPA MOVES to generate national emission factors for non-road gasoline and diesel equipment. Electric non-road equipment emissions are estimated using data from GREET. In AFLEET 2019, only emissions data is available for non-road equipment, while in future versions, cost analysis will be explored. AFLEET use fuel price data from the Vehicle Technologies Office's AFPR for the Simple Payback and TCO calculators, and fuel price escalation factors from the EIA's Annual Energy Outlook for the TCO calculator. These values change each year, so Argonne updated AFLEET 2019 to account for the latest data. Argonne used data from Utilimarc to estimate the parts, labor, and contract costs of over 750,000 data points covering municipal and utility light-duty and heavy-duty vehicles. Argonne aggregated the data from 54 vehicle types in Utilimarc to 20 vehicle types, for ease of use in AFLEET.

Funding from the Volkswagen Clean Air Act Civil Settlement is available for the deployment of public charging infrastructure as part of nitrogen oxide emission mitigation efforts; however, there is limited information on the environmental impacts of public charging infrastructure. Therefore, Argonne analyzed three major issues to understand the environmental impact of public charging infrastructure: the relationship of plug-in electric vehicle (PEV) adoption and public charging, the relationship of PEV driving range and public charging, and the relationship of PEV market penetration and public charger utilization. The research shows that while there is a correlation between availability of public charging infrastructure and PEV adoption, no causal relationship could be identified. In addition, while research has shown that the availability of workplace charging increases PEV driving range, no relationship between availability of public charging infrastructure and increased driving range could be identified. Finally, by analyzing public charging data from various sources, Argonne developed estimates on the weekly utilization of chargers by type and PEV market penetration. From this research, Argonne developed a new calculator as part of AFLEET to help decision makers quantify the environmental impacts of charging stations based on their specific location and market conditions, as seen in Figure II.2-1 and.

Results

During FY 2019, the AFLEET Tool was downloaded more than 1100 times, and the accompanying AFLEET user manual about 3000 times. To date, 8000 individual users have downloaded the tool. The user-friendly AFLEET online tool released in FY 2019 had more than 2300 new users.

EV Charging Inputs

Level 2 Charging Infrastructure				
Predicted Weekly Utilization	Moderate			
COOK County PEVs	**6820**			
COOK County L2 Chargers	**221**			
Venue	**Number of Chargers**	**Weekly Utilization (sessions/week / station)**	**Average Session Power (kW)**	**Average Charge Time (minutes/ session)**
Parking	1	6.0	4.1	144
Auto Dealership	0	3.5	4.1	132
Shopping	3	3.0	4.1	108
Education	0	4.5	4.1	126
Hospitality	6	2.5	4.1	120
Parks and Recreation	0	8.0	4.1	102
Healthcare	0	6.0	4.1	138

Figure II.2-1 AFLEET public EV charging inputs

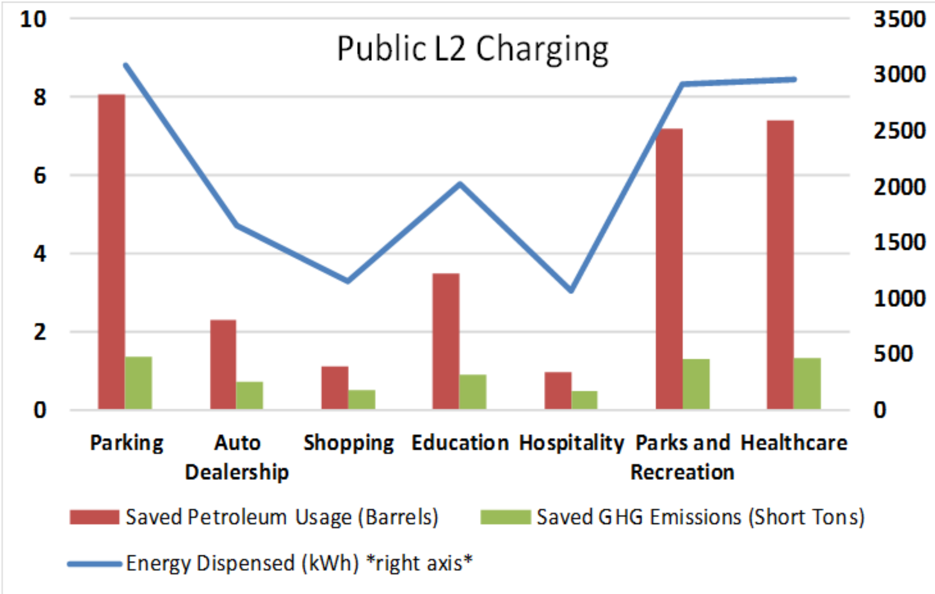

Figure II.2-2 AFLEET online result

Conclusions

In FY 2019, this project addressed the stakeholder requests to continue updating both the AFLEET spreadsheet and online versions with the latest emissions and cost data. This included incorporating data from the latest GREET research, EPA MOVES simulations, AFPR station price data, and maintenance costs from Utilimarc. In addition, Argonne developed a calculator to help stakeholders estimate the environmental impacts of public electric vehicle charging. This effort will support decision makers looking to analyze the costs and benefits of environmental mitigation projects.

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1. National Renewable Energy Laboratory, Alternative Fuels Data Center, https://afdc.energy.gov/
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3. Environmental Protection Agency, 2015. Motor Vehicle Emission Simulator (MOVES) - MOVES2014a version. http://www.epa.gov/otaq/models/moves.
4. Bourbon, E., 2019. Clean Cities Alternative Fuel Price Report, https://afdc.energy.gov/publications/.
5. Energy Information Administration, 2019. Annual Energy Outlook 2019, https://www.eia.gov/outlooks/AEO/.

II.3 EcoCAR Advanced Vehicle Technology Competition (Argonne National Laboratory)

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Start Date: October 1, 2018 End Date: September 30, 2022
Project Funding (FY19): $4,650,257 DOE share: $ 2,383,850 Non-DOE share: $2,266,407

Project Introduction

The U.S. Department of Energy, MathWorks, and General Motors have joined forces with more than 20 government and industry sponsors to establish the EcoCAR Mobility Challenge, a DOE Advanced Vehicle Technology Competition (AVTC). This workforce development program will seed the industry with hundreds of engineering, communications and business graduates who have hands-on experience designing, building and promoting advanced technology vehicles and connected and automated vehicle (CAV) technologies.

Managed by Argonne National Laboratory (Argonne), the EcoCAR Mobility Challenge (EcoCAR) is a four-year competition series that challenges 12 North American universities to re-engineer a Chevrolet Blazer, to:

- Integrate advanced propulsion systems to enable significant improvements in energy efficiency
- Deploy CAV technologies to meet energy efficiency goals and Mobility-as-a-Service (MaaS) market needs
- Balance energy efficiency needs with the consumer acceptability, safety and cost considerations unique to the MaaS market.

EcoCAR teams are following General Motors' Vehicle Development Process (VDP), which serves as a roadmap for designing, building and refining their advanced technology vehicles. This unique real-world engineering competition provides student engineers with hands-on research and development experience with leading-edge automotive components and technologies. The competition just launched its first year, culminating in a competition finale in May 2019 in Atlanta, GA, where teams presented the results of their Year 1 design activities to judges from the auto industry.

Objectives

- Successfully plan, manage and execute the Advanced Vehicle Technology Competition (AVTC) Program, including the current four-year EcoCAR series, and ensure the competition is executed with technical integrity and fairness for all university competitors
- Incorporate current industry codes and standards into the testing and evaluation of the competition vehicles
- Develop safety system practices and procedures for university competitors to ensure a safe competition

- Develop real-world multi-year training and education programs on advanced vehicle technologies for university competitors with subject matter experts from government and industry, to develop a highly skilled workforce
- Promote and build awareness about the program and prepare the marketplace to adopt advanced technology vehicles
- Facilitate youth outreach to increase Science, Technology, Engineering and Math (STEM) awareness, including among underrepresented minorities.

Universities participating in EcoCAR, and the abbreviations used in this report, include: Colorado State University (CSU), Embry-Riddle Aeronautical University (ERAU), Georgia Tech (GT), McMaster University (MAC), Mississippi State University (MSU), Ohio State University (OSU), University of Alabama (UA), University of Tennessee, Knoxville (UT), University of Washington (UW), University of Waterloo (UWAFT) [1], Virginia Tech (VT), and West Virginia University (WVU).

Approach

Fiscal Year (FY) 2019 roughly aligned with the first year of the four-year EcoCAR Mobility Challenge. This 4-year competition series launched in August of 2018 and will run through May of 2022. While the EcoCAR Mobility Challenge is the next series in a more than 30 year legacy of AVTCs, the technical goals have shifted significantly from prior AVTCs. The competition now focuses on Connected and Automated Vehicle (CAV) activities; approximately 40% of engineering activities will be focused on CAV systems. AVTC competitions have always had a strong element of consumer acceptability, but the new competition series is now orienting the market focus toward a Mobility-as-a-Service application rather than a traditional consumer. These changes, among various other shifts, represent the largest paradigm shift for the AVTC program in its over 30 year history.

Over the four years of the EcoCAR competition, each team will design, build, and test an advanced technology vehicle. Because the full development process covers multiple academic years, teams are given milestones for each year of the competition. This Vehicle Development Process (VDP), which is illustrated in Figure II.3-1, mimics General Motors' own VDP and provides developmental goals for the teams and their vehicles.

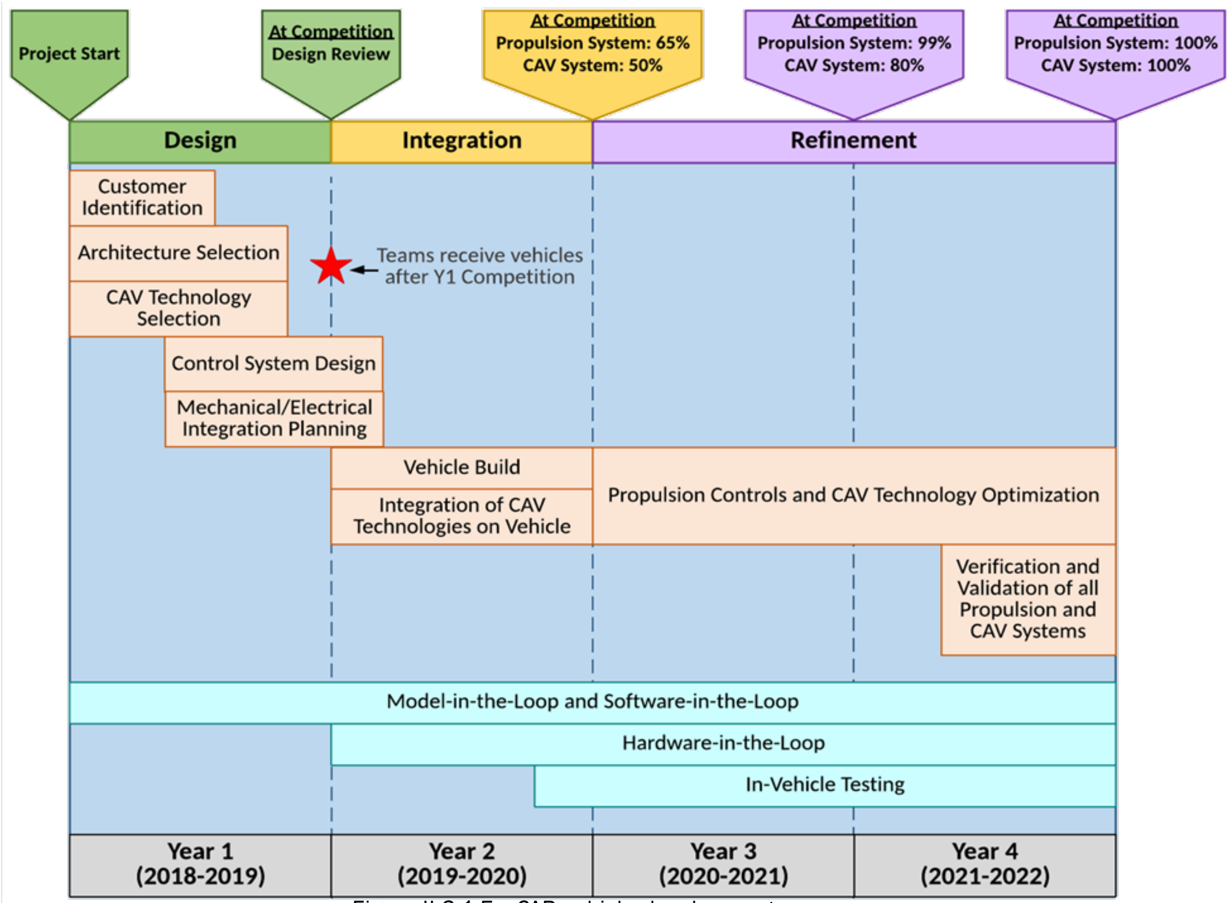

Figure II.3-1 EcoCAR vehicle development process

Table II.3.1 Technical Goals for Each Annual Competition

Year	Propulsion System Activities	CAV Activities
Year 1	• Customer Definition • Architecture and component selection • Low-level component packaging and integration design finalized • Donated vehicle delivery	• Customer definition • Definition of intended CAV technologies to be developed • Sensor selection and low-level packaging and integration design finalized • Simulation of longitudinal driving scenarios
Year 2	• Complete vehicle integration • Vehicle propulsion system can complete selected dynamic events	• Sensor integration (longitudinal sensors) • Longitudinal CAV system baseline functional • V2X system baseline functional
Year 3	• Reliable coordinated propulsion system operation • Calibration not yet refined to customer's satisfaction	• All CAV hardware integrated • Fully functional longitudinal CAV system • V2X system fully functional
Year 4	• Refined and reliable propulsion system • Refined calibration – close to consumer acceptable level (99%) • All consumer features in place	• All CAV systems fully functional and meet consumer expectations • Vehicle demonstrates target autonomy level in closed course environment

Because the competition has a strong element of CAV systems, the EcoCAR Mobility Challenge defined distinct goals for both CAV systems and propulsion systems for each year of the competition, as shown in Table II.3.1.

For Year 1 in particular, the teams focused on defining their target MaaS market for their vehicles, designing a propulsion system to meet the needs of that MaaS market, and also designing their CAV systems. The keystone of year 1 was the Architecture Selection Report, in which each team proposed a propulsion system architecture and components, as well as the CAV system architecture. The competition steering committee reviewed and approved these proposals, which will serve as the teams' foundations for the remainder of the competition.

The EcoCAR Mobility Challenge also includes a strong emphasis on Communications/Public Relations, diversity, and STEM Outreach. Teams focused heavily on promoting the benefits of EcoCAR to the community and preparing the marketplace to adopt advanced vehicle technologies. Teams were also engaged with recruiting and STEM outreach, including outreach to underrepresented minority groups. By including communications deliverables in EcoCAR, the competition provided learning in areas of public relations and social media, in addition to engineering principles.

Results

During FY 2019, all 12 teams successfully completed the following technical goals:

- Characterized a MaaS target market for their vehicles
- Selected vehicle propulsion system components and architecture
- Selected CAV sensors and CAV system architecture
- Received donated 2019 Chevy Blazers.

The program was also successful in achieving its core objective: training the next generation of automotive engineers, communicators, and business leaders. In Year 1, a total of 913 students participated in the competition. Table II.3.2 summarizes student participation by major.

Table II.3.2 EcoCAR Mobility Challenge Year 1 Student Participation by Major

Student Major	Total	% of Total	STEM?
Mechanical Engineering	402	44.0%	Y
Electrical/Computer Engineering	189	20.7%	Y
Computer Science	62	6.8%	Y
Mechatronics Engineering	58	6.4%	Y
Automotive Engineering	50	5.5%	Y
Chemical Engineering	30	3.3%	Y
Software Engineering	16	1.8%	Y
Aerospace Engineering	16	1.8%	Y
Industrial/Systems Engineering	17	1.9%	Y
Aeronautics & Astronautics	15	1.6%	Y
Civil Engineering	5	0.5%	Y
Nanotechnology Engineering	6	0.7%	Y
Communication/Public Relations	19	2.1%	N

Student Major	Total	% of Total	STEM?
Other	13	1.4%	N
Business/Economics	5	0.5%	N
Marketing/Advertising	5	0.5%	N
Human Factors	3	0.3%	N
Management	1	0.1%	N
Literature & Professional Writing	1	0.1%	N
Total	913	100%	

Based on data reported by EcoCAR universities, a total of 201 employers hired an EcoCAR student during the 2018-2019 academic year (Aug 2018 – Aug 2019), 159 employers hired at least one student for an internship or co-op position and 59 employers hired at least one student for a full-time position. EcoCAR students that accepted full-time jobs during this same time period out-earned their peers by $4000-$10,000 depending on major and degree, as shown in Figure II.3-2.

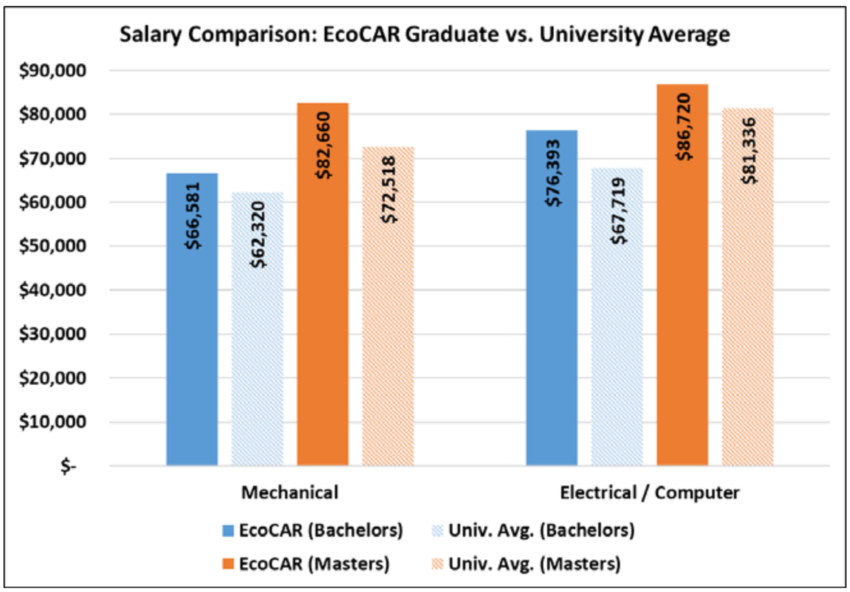

Figure II.3-2 Salary comparison of EcoCAR graduates and their peers

In Year 1 of the EcoCAR Mobility Challenge, the communications outreach focus was scaled back significantly due to lack of funding compared to previous years, as well as timing constraints for promotion of the program. This year did include an emphasis on diversity and STEM outreach where teams promoted the benefits of EcoCAR to students in grades 6 to 12, with a focus on recruiting students to consider STEM majors, including students from underrepresented minority groups.

In year 1 of EcoCAR Mobility Challenge, teams conducted 53 total youth outreach events, reaching more than 3,500 youth in grades 6 to 12. Table II.3.3 summarizes the overall youth impacts from the first year.

Table II.3.3 Youth Impacts of the Program in Year 1

Metric	#
No. of youth outreach events	53
No. of students at those events	3,500

EcoCAR brought awareness to the general public, stakeholders, sponsors and participants through social media and the Green Garage Blog, where students wrote and submitted nearly 50 blog stories about their efforts and involvement in the program. In addition, teams contributed to general awareness about EcoCAR through their social media channels including, but not limited to, Facebook, Instagram and Twitter. Public relations and media outreach efforts included issued press releases, earned placements and a paid social campaign highlighting the new competition. Total media impressions for Year 1 reached 120 million. See Table II.3.4.

Table II.3.4 EcoCAR Mobility Challenge Earned Media Outlets (sample) Year One

OUTLET
Forbes
Autoblog
Green Car Congress
Renewable Energy Magazine

Total number of organic social engagements (Facebook, Twitter & Instagram) for Year 1 reached 247,000 impressions with a total of 3,954 likes and 419 shares. The top Facebook post, that announced the kick off of the EcoCAR Mobility Challenge, generated 10,900 impressions, 210 likes, 34 shares, 14 reactions and 5 comments. Team members produced six videos highlighting various aspects of the competition and garnered 2,500 views on YouTube. See Table II.3.5.

Table II.3.5 EcoCAR Mobility Challenge Organic Social Media Results Year One

	Total Tweets/Posts	Total Likes	Total Shares/Retweets	Impressions/Reach
Twitter	65 tweets	382	122	145,700
Facebook	98 posts	2,670	297	92,000
Instagram	34 posts	902	21 comments	9,597

In conjunction with the launch of EcoCAR Mobility Challenge, the competition organizers executed a three-week paid social media campaign on Instagram, and specifically targeted students at participating universities to generate support and excitement for their university's EcoCAR team. Multiple posts on Instagram as part of the campaign included feed pictures, an overview video about the competition and "stories".

The campaign generated a total of 2.4 million impressions – which was 28% more than originally estimated. Users engaged with the content, driving 627 completed video views and 1,082 clicks to the site.

Conclusions

During Year 1, the EcoCAR Mobility Challenge forged a unique public-private partnership of more than 20 government and industry organizations that have joined forces to explore advanced propulsion systems and emerging technologies, such as connected and automated vehicle systems. Over the four-year series, this highly successful workforce development program is expected to provide more than 3,500 students hands-on experience with advanced technology vehicles and other innovative and emerging vehicle technologies. This will help transform the industry to meet the growing challenges in the transportation and energy sector. The program continues to have a major impact on today's youth, inspiring future generations, including underrepresented minorities, to follow STEM careers. Finally, the program is helping to educate and build awareness within the community about advanced technology vehicles.

Key Publications

The EcoCAR program funded student assistant positions on each EcoCAR team. This includes engineering graduate research assistants (from multiple disciplines), as well as a Project Manager and a Communications Manager. The publications produced in FY 2019, as a result of this funding, are summarized in Table II.3.6.

Table II.3.6 EcoCAR Team Publications (to date)

Team	Publication/Presentation Title	Lead Author Name	Conference / Journal
CSU	CSU EcoCAR 3 Final Technical Report	Gabriel DiDomenico	SAE International
CSU	Towards Improving Vehicle Fuel Economy with ADAS	Jordan Tunnell	SAE Journal of Connected and Automated Vehicles
ERAU	V.I.S.I.O.N. Versatile In-expensive Safety Information On Non-motorists	Andrew Ferree	SAE Connected Vehicle Challenge Results
MAC	A novel Multi-Mode A-ECMS approach for P1-P2-HEV architectures	Mike Haußmann	"IEEE Transportation Electrification
MAC	Real-Time Control of a Full Scale Li-ion Battery and Li-ion Capacitor Hybrid Energy Storage System for a Plug-in Hybrid Vehicle	Phillip J. Kollmeyer	IEEE Transactions on Industry Applications
MAC	Integration of On-line Control in Optimal Design of Multimode Power-split Hybrid Electric Vehicle Powertrains	Pier Giuseppe Anselma	IEEE Transactions on Vehicular Technology
MAC	Modeling and Simulation of an Autonomous-capable Electrified Vehicle: A Review	Richard Hamilton	2018 IEEE Electrical Power and Energy Conference (EPEC)
OSU	Systems and Safety Engineering in Hybrid-Electric and Semi-Autonomous Vehicles	Simon Trask	The Ohio State University
OSU	Computer Vision Techniques for Automotive Perception Systems	Evan Stoddart	The Ohio State University
OSU	Vehicle Architecture Selection for High Efficiency and Performance Applications	Jacqueline Karl-DeFrain	The Ohio State University
OSU	Camera-In-The-Loop Test Bench Development for Autonomous Vehicle Applications	Timothy Kirby	The Ohio State University
OSU	Systems Engineering of an Advanced Driver Assistance System	Evan Stoddart	SAE World Congress Experience
OSU	Effectiveness of Warning Signals in Semi-Autonomous Vehicles	Simon Trask	SAE World Congress Experience
OSU	Utilizing Dynamic Programming to Aid in the Hybrid Electric Vehicle (HEV) Component Selection Process to Minimize the Vehicle's Fuel Consumption	Kristina Kuwabara	The Ohio State University
OSU	The Ohio State University EcoCAR Program: Paving the Future for Sustainable Transportation	Kristina Kuwabara and Allison Mellor	Community Engagement Conference
OSU	Systems Integration and Validation of an Automated Transmission for the Ohio State EcoCAR 3 Vehicle	Phillip Dalke	The Ohio State University

Team	Publication/Presentation Title	Lead Author Name	Conference / Journal
UT	Machine Learning for Thermal Transport Analysis of Aluminum Alloys with Precipitate Morphology	Jiaqi Wang Nobakht	Advanced Theory and Simulations
UWAFT	Powertrain Selection and Integration of a Single Shaft Pre and Post-Transmission Series-Parallel Plug in Hybrid Electric Vehicle Camaro	Ramin Shaikhi	University of Waterloo
UWAFT	Predictive Powertrain Management through Driver Behaviour Recognition	Patrick DiGioacchino	University of Waterloo
UWAFT	Extensible Modeling of Compressed Air Energy Storage Systems	Siddarth Atul Kakodkar	University of Waterloo
WVU	Automotive Crisis: Volkswagen's Emissions Scandal & Response Strategies	Kelsey M. Plute	WVU ETD - ProQuest Dissertations and Theses
WVU	Vision-Based Road Defect Detection and Classification for Impact Effect Mitigation Using Adaptive Suspensions	Shane Haught	WVU ETD - ProQuest Dissertations and Theses
WVU	Generation and Sensitivity Analysis of Transmission Shift Schedule for Hybrid-Electric Vehicle	Nicholas Connelly	WVU ETD - ProQuest Dissertations and Theses
WVU	Hybrid Electric Vehicle Torque Split Algorithm for Reduction of Engine Torque Transients	Derek George	WVU ETD - ProQuest Dissertations and Theses

References

1. UWAFT is the abbreviation for the University of Waterloo Alternative Fuels Team.

II.4 EPAct Regulatory Programs (National Renewable Energy Laboratory)

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Start Date: October 1, 2018 End Date: September 30, 2019
Project Funding (FY19): $792,000 DOE share: $792,000 Non-DOE share: $0

Project Introduction

The National Renewable Energy Laboratory's (NREL's) Transportation Technology Integration group, within the Transportation & Hydrogen Systems Department, provides technical and analytical support to the Vehicle Technologies Office's (VTO's) Alternative Fuels Regulatory activity, which is mandated by federal legislation. Specifically, NREL supports DOE's implementation of Sections 507(o), 501, and 508 of the Energy Policy Act of 1992 (EPAct) through the provision and management of information products and other technical, program, policy, and regulatory analyses. EPAct Sections 507(o) and 501 mandate that covered state and alternative fuel provider fleets (respectively) acquire alternative fuel vehicles (AFVs) as specific percentages of their new light duty vehicles. EPAct Section 508 requires DOE to establish a vehicle credit trading program to provide compliance flexibility to covered fleets. In Fiscal Year 2019, NREL's work focused on two areas: State & Alternative Fuel Provider program support, and rulemaking and regulatory activities. In addition to project management and operational functions, NREL's role is to analyze, make recommendations and implement means to streamline this congressionally-mandated program. NREL also integrates work across several related alternative fuel programs to leverage resources and ensure that researchers have access to the latest developments and knowledge within related DOE research and development programs.

Objectives

The key overarching objective is to ensure full implementation of the statutorily-mandated program, and oversee compliance by covered entities. Within this objective there are two tasks, as follows:

Task 1: Implement legislative requirements for State and Alternative Fuel Provider (SAFP) fleets. The core activities in this task involve tracking and ensuring fleet compliance, analyzing and implementing any new legislative requirements and policies that may impact the program, and working directly with fleets, as needed, to ensure compliance. NREL developed and maintains an online reporting system and the vehicle acquisition and fleet compliance database to support this task.

Task 2: Support DOE's rulemaking activities. Tasks have included analysis and development of a revised national replacement fuel goal; development and promulgation of DOE's final private and local fleet rule determination; and development of rules to implement statutory requirements set forth in EPAct, as amended by EPAct 2005 and the Energy Independence and Security Act (EISA) of 2007. At times, support for rulemaking also requires evaluating proposed legislation that may impact SAFP fleets, and developing technical comments and suggested revisions, for communication to Congress through DOE's legislative affairs offices. This may include reviewing provisions that affect the availability and cost of vehicles, technology, and fuels; potential fuel savings; and programmatic requirements. NREL also addresses, as necessary, fuel petition review and analysis.

Approach

NREL's Transportation Technology Integration group works to increase the use of renewable energy technologies. The NREL team provides technical and analytical support to VTO's Alternative Fuels Regulatory activity, which implements elements of federal legislation related to the acquisition of alternative fuels and advanced fleet vehicles. This involves providing VTO with strategic planning, project management, and collection and management of program data, as well as technical, regulatory, and analytical support of the program.

NREL has developed an integrated system consisting of support personnel, online program information, online reporting tools for fleets, and a database of compliance data, which has served as a repository of vehicle and fleet data since the inception of the program. NREL's strategy provides timely and accurate information to fleets and streamlines the reporting process, which ensures maximum fleet compliance, while limiting administrative burden. NREL frequently reviews and updates online information and tools as well as performing routine maintenance and archiving of program data.

Results

Covered fleets report at the end of a calendar year for the preceding Model Year (MY), e.g., the reports submitted by December 31, 2018 covered MY 2018 vehicle acquisitions. In reports submitted at the end of 2018, the compliance rate for the State and Fuel Provider program for the more than 300 reporting entities, representing approximately 2,000 covered fleets, was 100%.

The program provides tremendous flexibility in terms of how fleets may achieve compliance, whether they select Standard Compliance or Alternative Compliance. Fleets complying via Standard Compliance may earn credits toward compliance if they acquire light-duty AFVs, purchase and use biodiesel, acquire hybrid vehicles, neighborhood electric vehicles, and medium and heavy-duty AFVs, and/or invest in alternative fuel infrastructure, non-road equipment, and emerging technologies related to electric drive vehicles. Nearly 300 fleets used Standard Compliance and exceeded their aggregate MY 2018 acquisition requirements by more 24%. Fleets complying via Alternative Compliance do so by reducing petroleum consumption in any number of ways, including through the use of alternative fuels, buying more efficient vehicles, implementing a telecommuting program, reducing trips made, or implementing other efficiency measures. The eight covered fleets that used Alternative Compliance exceeded their aggregate MY 2018 petroleum use reduction requirements by more than 18%.

Covered fleets may earn credits for acquiring more AFVs than are required for compliance; those credits can be banked for future use in complying with EPAct requirements. Covered fleets may also meet up to half of their acquisition requirements by using biodiesel fuel. This year, only a few fleets reported their total biodiesel usage, which typically exceeds the amount of biodiesel that could be counted toward credits. This resulted in a 29% decrease in the amount of biodiesel use reported, from just over 11.2 million gallons in MY 2017 to a little more than 7.9 million gallons in MY 2018. The gallons reported is trending downward overall since MY 2013. DOE also saw that fleets earned fewer total credits in MY 2018 for using biodiesel, a drop from 2,085 credits in MY 2017 to 1,108 credits in MY 2018.

Fleets reported a decrease in the number of reported creditable light-duty vehicles acquired (16,764) in MY 2018, which includes light duty AFVs, non-AFV hybrid-electric vehicles (HEVs), and neighborhood electric vehicles (NEVs), when compared to MY 2017 (17,535). MY 2018 marked the sixth year that fleets complying via Standard Compliance could earn credits for acquiring an expanded range of vehicles, including HEVs and NEVs, and for investing in alternative fuel non-road equipment, alternative fuel infrastructure, and emerging technologies. Covered fleets earned 756 credits for partial-credit vehicles and 231 credits for investments in alternative fuel infrastructure and non-road equipment in MY 2018 (28% and 7% increases, respectively, over MY 2017).

Conclusions

The data for MY 2018 demonstrated 100% compliance by all entities within the program, and the extent of over-compliance suggests an ongoing interest on the part of EPAct-covered state and alternative fuel provider fleets in supporting the AFV and advanced technology vehicle markets.

Key Publication

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II.5 Fuel Economy Information Project (ORNL)

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Start Date: October 1, 2018 End Date: September 30, 2019
Project Funding (FY19): $2,460,000 DOE share: $2,460,000 Non-DOE share: $0

Project Introduction

Oak Ridge National Laboratory (ORNL) manages the Fuel Economy Information (FEI) Program for the Department of Energy (DOE), in close collaboration with the Environmental Protection Agency (EPA). Under this program, ORNL produces and distributes the annual *Fuel Economy Guide* [1] and manages the FuelEconomy.gov website [2] to support the DOE's statutory responsibility to provide light-duty vehicle fuel economy information to the public (under the Energy Policy and Conservation Act of 1975 – 49 USC 32908). The FEI Program supports a continually updated electronic version of the *Guide* on the FuelEconomy.gov website, where consumers also have access to a wide array of additional information and tools. The website provides fuel economy information for over 42,000 vehicles from 1984 to present. The site also provides side-by-side comparison tools, fuel saving calculators, driving and vehicle maintenance tips, and information about advanced technologies, tax incentives, safety ratings, vehicle specifications, and more. When warranted, the FEI Program also conducts fuel economy research to support its efforts to provide timely, reliable driving tips to consumers. The project ensures that consumers have easy access to fuel economy information that is accurate, up-to-date, and useful.

Objectives

The FEI Program has several objectives:

- Help DOE fulfill its statutory responsibility to publish and distribute an annual *Fuel Economy Guide* providing information on fuel economy and estimated annual fuel costs of operating automobiles manufactured in each model year
- Provide consumers with reliable, unbiased fuel economy information. One of the goals of the FEI Program's FuelEconomy.gov website is to be the official government source of, and leading authority on, fuel economy.
- Help improve U.S. energy security by promoting fuel economy to consumers through education and outreach
- Help consumers make informed decisions when purchasing and operating vehicles by
  - Providing information about light-duty vehicle fuel economy and fuel costs

  - Educating consumers on the benefits of improved fuel economy
  - Providing tools that help consumers estimate fuel use and fuel costs
- Help DOE's Clean Cities coalitions promote alternative fuels, alternative fuel vehicles, and advanced vehicle and fuel technologies.

Approach

The FEI Program helps DOE fulfill its statutory responsibility to compile and distribute an annual *Fuel Economy Guide* by publishing the *Guide* for each new vehicle model year and maintaining an up-to-date electronic version on the FuelEconomy.gov website throughout the year. Using data collected from manufacturers by the Environmental Protection Agency (EPA), the Program publishes the *Guide* in the fall and updates it weekly throughout the year as new data become available. Through model year 2017, the FEI Program distributed the print version of the *Guide* to new-car dealerships, libraries, and credit unions. In addition, it provides an electronic version of the current *Guide* (and previous model year editions) on the FuelEconomy.gov website. Electronic versions of the *Guide* for the current and recent model years are updated with new vehicle models and/or gas prices weekly. For model year 2018 and 2019, the *Guide* was produced and distributed in the electronic version (except for a limited print run).

The *2019 Fuel Economy Guide* currently contains information for more than 1,250 light-duty vehicles, including conventional gasoline and diesel vehicles, plug-in electric vehicles, flex-fuel vehicles, and fuel cell vehicles. The *Guide* provides (1) EPA city, highway, and combined fuel economy estimates, (2) annual fuel cost estimates, (3) EPA greenhouse gas (GHG) ratings, and (4) interior volumes for each vehicle. The *Guide* highlights fuel economy leaders for each vehicle class and provides fuel-saving driving and maintenance tips to help consumers save money.

In addition to the annual *Fuel Economy Guide* publication, the FEI Program developed and launched the FuelEconomy.gov website in 1999. The website was developed to leverage the power of computers and the internet to reach more consumers and provide more functionality than possible within the limitations of a paper booklet. FuelEconomy.gov has become the FEI Program's most effective tool for reaching consumers and providing them with fuel economy information. In fact, it has become so popular that the Fuel Economy and Environment sticker displayed on new cars now has a QR Code that consumers can scan with a mobile device, taking them directly to the FuelEconomy.gov website.

Unlike the print versions of the *Guide*, which contain vehicles for a single model year, the website contains information for vehicles going back to model year 1984—more than 41,000 vehicles in all. In addition to fuel economy, GHG ratings, and annual fuel costs, the website provides driving range, cost to fill the tank, EPA Smog Rating, annual petroleum consumption, National Highway Traffic Safety Administration (NHTSA) crash test results from Safercar.gov [3], and fuel economy estimates from other drivers (via the website's *My MPG* feature). Vehicle and fuel cost data are updated weekly, making the website much more up-to-date and complete than would be possible with a printed booklet. Furthermore, FuelEconomy.gov allows consumers to personalize fuel economy estimates, annual fuel costs, and other estimates based on their driving environment and fuel prices. Users can also compare fuel economy and other estimates on up to four vehicles side-by-side.

FuelEconomy.gov provides users with several search tools to help them find specific vehicles or vehicles that meet their desired search criteria. Users can search by make and model, vehicle class, fuel type, engine and transmission, and other characteristics. They can also search for EPA-certified SmartWay vehicles, and vehicles with the best and worst fuel economy in each vehicle class.

FuelEconomy.gov provides users with fuel-saving tips and allows consumers to personalize these tips to see how much money they can expect to save by following them. The fuel economy tips are based on published research, much of which was supported through the FEI Program (these research efforts are described later in this report).

FuelEconomy.gov provides many other kinds of information useful to consumers:

- Federal tax credit information for advanced technology vehicles (e.g., all-electric vehicles and plug-in hybrids)
- Lists of best and worst fuel economy vehicles
- Answers to frequently asked questions about fuel economy
- Links to national and local fuel prices and answers to frequently asked questions about fuel prices
- Detailed descriptions of EPA Fuel Economy and Environment Labels
- Discussions about the benefits of improved fuel economy, such as saving money, increasing U.S. energy security, reducing GHG emissions, and improving sustainability
- Simple explanations of how fuel economy estimates are determined, how to select the right octane for your vehicle, and how advanced vehicle technologies save fuel.

Due to the significant increase in the popularity of smart phones and other mobile devices, the FuelEconony.gov website was recently re-designed in a mobile-friendly platform that displays content on any screen size from a smart phone to a desktop computer. This allows consumers to have fuel economy information at their fingertips at almost any location and at any point in the car-buying process.

FuelEconomy.gov's *My MPG* tool helps drivers calculate and track fuel economy for their vehicles. Drivers can also elect to share their real-world MPG estimates with other consumers who are shopping for vehicles. The *My MPG* tool employs methods to help ensure that the fuel economy estimates are as reliable as possible. This includes data checking to help drivers enter data correctly and a log-in process to help discourage users that may try to enter large amounts of erroneous data. *My MPG* was initially designed for use on a desktop computer; however, as mobile devices became more popular, the FEI Program developed a scaled-down version of the tool for these devices. The team recently redesigned the tool to provide full functionality on both desktop and mobile devices and plans are to launch this upgrade in FY 2020. Other enhanced features include an improved user interface, more graphs and tables for user analysis, and the ability to enter data for all-electric vehicles.

FuelEconomy.gov provides several tools and calculators to help consumers make informed decisions when buying or operating a vehicle:

- *Trip Calculator*. This calculator allows consumers to calculate the fuel costs for driving a vehicle on a specified trip. Users can enter their origin, destination, and any waypoints and select up to three vehicles they are considering taking on the trip. The tool will map out the best route, provide directions, and estimate the fuel use and fuel cost for each selected vehicle. This is one of the most popular tools on FuelEconomy.gov.
- *Fuel Savings Calculator*. The fuel savings calculator began as a simple tool to help users compare the fuel costs of two vehicles with different fuel economies. The FEI Program has enhanced the tool, keeping its ease of use but also allowing users to compare specific vehicles, as well as adding vehicle purchase and financing/lease costs into the equation. This is helpful when considering a vehicle that has a higher initial purchase cost but a lower fuel cost, which may save the consumer money in the long run. The FEI program also added charts to help illustrate the results.
- "*Can a Hybrid Save Me Money?"* When hybrid vehicles were first introduced, there were questions about whether their fuel savings would outweigh their higher initial cost. Many news articles were written comparing the costs of hybrids to their conventional counterparts over time, but most of these

articles had a significant flaw: they compared a hybrid model, which was typically equipped with many upgraded features, to the base model, which had very few amenities. Therefore, the results of these analyses were skewed against hybrids, without pointing out that the user was getting more features, and not just better fuel economy, with the hybrids. Therefore, the FEI Program added a tool to FuelEconomy.gov that compared each hybrid to a comparably equipped conventional vehicle from the same manufacturer. This allows consumers to weigh the benefits of improved fuel economy when comparing vehicles with similar features.

- *My Plug-in Hybrid Calculator.* The fuel economy of a plug-in hybrid is highly variable and depends greatly on how it is driven and how often it is charged. This tool allows consumers to estimate the gasoline and electricity costs of a plug-in hybrid based on their driving habits, charging schedule, and gasoline and electricity prices. The tool even provides users with the choice of a simple model or a more complex model for personalizing their driving and charging patterns.
- *Used Car Label Tool*. This tool generates printable fuel economy labels that sellers can affix to their vehicles or electronic images they can include in on-line ads. A vehicle's fuel economy changes very little over time if it is properly maintained. The used car label tool helps make official EPA fuel economy ratings part of the buying/selling process of used cars, just as it is for new ones.

FuelEconomy.gov makes much of its fuel economy information available to other websites, researchers, and other organizations via web services and data download. Edmunds, CHROMEDATA (used by more than 70% of U.S. vehicle manufacturers), the California Air Resources Board (CARB), Uber, and the Florida Department of Transportation are just a few of the organizations that rely on FuelEconomy.gov for fuel economy data. In addition, DOE has two website tools that use FuelEconomy.gov's data, as does EPA's Green Vehicle Guide. The FEI Program has also developed Find-a-Car and driving tips widgets that website developers can incorporate into their sites.

Providing reliable, defensible fuel economy tips to consumers is a primary objective of the FEI Program. Studies show that driving more efficiently can improve most drivers' fuel economy by about 10%; however, to get buy-in from consumers, these tips must be accurate and up to date. FuelEconomy.gov's fuel-saving tips are compiled based on available literature from U.S. government agencies, auto experts, and other credible sources. As vehicle technologies evolved over time, many of these tips became dated, and in several cases over the last few years the FEI Program has supported research projects aimed at quantifying factors that can increase or decrease fuel economy. FEI research has included literature reviews, analysis of available data sets, as well as vehicle experiments. Research has focused primarily on aspects of fuel economy that can be improved by driver behavior. Past research topics have included (1) the effect of a dirty air filter on fuel economy and performance, (2) the effect of driving speed on fuel economy, (3) fuel economy effects of roof racks, cargo carriers, trailers, and tire pressure (4) the effect of cold weather on fuel economy, (5) the effect of driving with the windows down vs. using the air conditioner, (6) the amount of fuel consumed by idling, (7) fuel economy tips for hot and cold weather, (8) fuel economy tips for hybrids and plug-in vehicles, and (9) the effect of driving style on fuel economy. Most of the fuel-saving tips on FuelEconomy.gov are now based on research performed by the FEI Program, and these tips are often cited by news outlets, car companies, consumer sites, and other entities. Publications developed as part of this program are listed at the end of this report.

Find and Compare Cars is the primary search tool on FuelEconomy.gov. It is used to look up fuel economy and other information for light-duty passenger vehicles. The FEI Program developed a Find-a-Car app for Apple and Android devices, for those consumers that prefer to use mobile apps rather than the Find and Compare Cars tool on the FuelEconomy.gov website. The Find-a-Car app has similar functionality to the website feature, but it can be downloaded to a personal device, can be accessed with the touch of a button, and allows users to save vehicle searches. The apps are available for free download from Google Play and the Apple App Store.

As part of its objective to help Clean Cities coalitions with their public outreach and education efforts, the FEI Program has worked in cooperation with Maryland Public Television (MPT) over the years to develop a number of MotorWeek and MotorNews segments covering topics related to alternative fuels, fuel economy, and advanced vehicle technology. MotorWeek is television's longest running automotive show and airs on 92% of PBS stations nationwide. It can also be seen on cable's Velocity and V-me Spanish-language network. After airing, these segments are posted on the Clean Cities TV YouTube channel, the Fuel Economy YouTube channel, and FuelEconomy.gov. In FY 2018, the FEI Program and MPT develop and aired a new MotorWeek segment on smart car shopping, featuring several websites supported by the federal government: FuelEconomy.gov, the Alternative Fuels Data Center [4], andSafercar.gov. Segments completed in FY 2019 included three related to electric vehicles (Electric Vehicles Hit the Open Road, EV Dollars and Sense, and Electric City, Utah), as well as three Clean Cities Success Stories (Natural Gas Trains Make the Grade in Florida, Natural Gas Makes a Splash in Florida, and Clean Cities: Fred Weber Inc.). [5]

Ensuring that consumer access to the FuelEconomy.gov website is dependable and uninterrupted is critically important. The FuelEconomy.gov servers are located at the ORNL main campus for improved security and backup, and they are maintained by the FEI Program with help from ORNL's computer network staff. Staff monitor systems around the clock to ensure that they are safe, functional, and compliant with all applicable cybersecurity regulations.

FuelEconomy.gov is a consumer-oriented website, and the FEI Program prides itself on being responsive to consumer comments, suggestions, and questions. Consumers and media contacting FuelEconomy.gov can expect a response within a couple of business days (usually sooner), and follow-up emails or even phone calls are not uncommon if they are needed to understand a problem or resolve an issue. In FY 2019, the team responded to approximately 800 emails.

Results

In model year 2019, the FEI Program continued to help DOE meet its statutory requirement to produce an annual *Fuel Economy Guide* for light-duty vehicles. Model year 2019 was the second year for a primarily electronic-only *Guide*, with a limited print run. In previous years close to 200,000 guides were printed and mailed to nearly 31,000 new car dealers, more than 27,000 public libraries, and 20,700 credit unions. Instead, the FEI Program now mails letters inviting these parties to register for routine email communications about the new *Guide* for 2019 and encouraging the use of the website to view the more up-to-date *Guide* or to use Find and Compare Cars. The electronic version of the 2019 *Guide*, which the FEI Program updates weekly, is available on-line at FuelEconomy.gov. In addition, a preliminary, data-only version of the 2020 *Guide* has been made available to the public on FuelEconomy.gov as of the second quarter of FY 2019. This preliminary version contains data for model year 2020 vehicles already released by manufacturers. The 2020 *Guide* will be finalized and distributed in the first quarter of FY 2020.

FuelEconomy.gov is one of the U.S. government's most visited websites—it ranked in the top 1% of federal websites (18th out of 2,100) in 2016. Since its launch in 1999, the website has hosted more than 470 million user sessions. Traffic on the website has increased significantly since 1999, peaking at more than 58 million visitors per year in 2013 when fuel prices increased significantly (See Figure II.5-1.) In FY 2019, FuelEconomy.gov hosted more than 25 million user sessions, more than 303 million page views, and more than 69,000 daily visits on average.

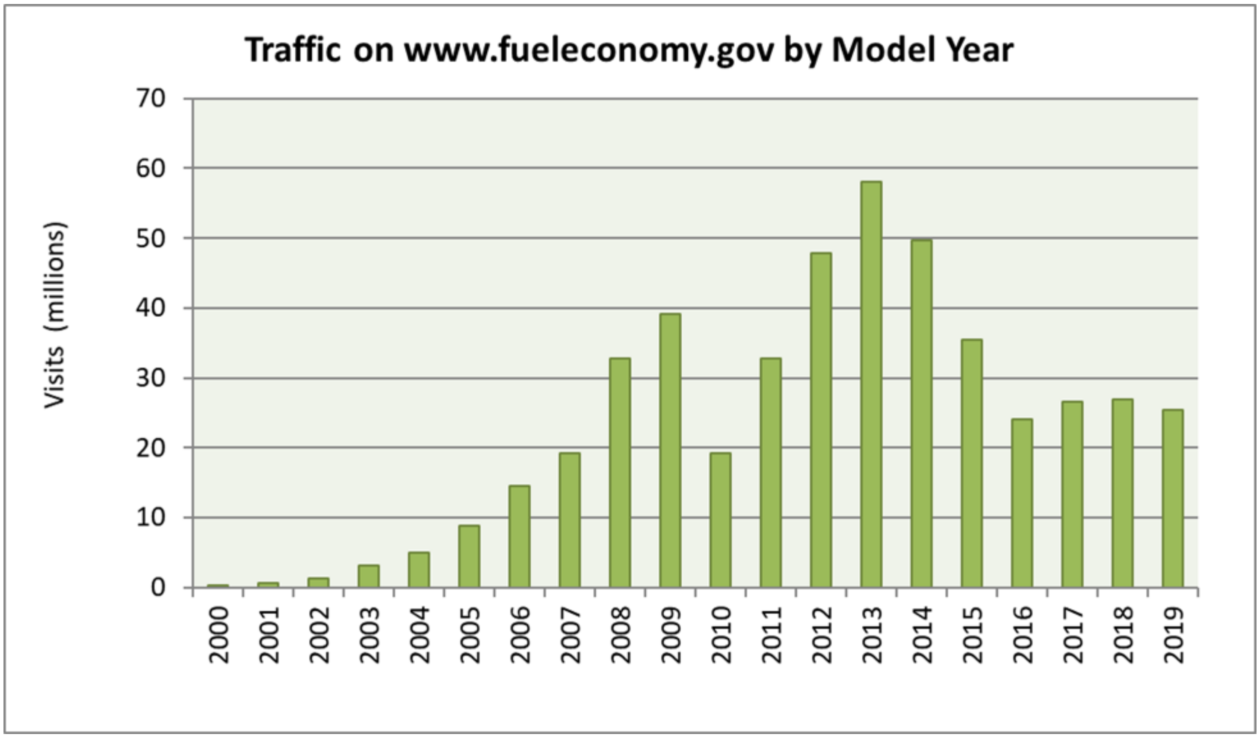

Figure II.5-1 Traffic on FuelEconomy.gov grew steadily after its initial launch in 1999, peaking in 2013 when fuel prices were high.

FuelEconomy.gov's My MPG tool continues to be popular with consumers. More than 34,500 drivers have shared fuel economy estimates for more than 49,500 vehicles. This fuel economy data has become a valuable resource for both the car-buying public and researchers looking to understand the relationship between on-road fuel economy and EPA estimates. In fact, My MPG data has been used to evaluate EPA test methods and identify potential problems with fuel economy estimates provided to EPA by manufacturers.

The Find-a-Car mobile app has been successful, though not as popular as the FuelEconomy.gov website. At the end of FY 2019, over 46,000 users had installed the app (over 24,000 on Apple devices and nearly 22,000 on Android devices). The app has a combined user rating of over 4.0 out of 5.0.

Research by the FEI Program into driving and maintenance factors that affect fuel economy provides useful, actionable information for drivers wishing to improve their vehicle fuel economy. The fuel-saving tips pages are a popular destination on FuelEconomy.gov, and the tips are frequently featured by the news media. In FY 2018, ORNL Communications staff developed a web highlight describing a recent ORNL publication on aggressive driving and fuel economy. The story received significant media attention and was picked up by at least 20 news sites. In addition, automotive researchers frequently use information on FuelEconomy.gov and cite the website, reports, and papers produced under the auspices of this program. To date, reports and papers from this program have been cited over 250 times in the technical literature.

This year, the team reviewed Owner's Manuals for six electric vehicles and six conventional vehicles and compared major recommended maintenance for each, to develop an estimate of the cost difference of ownership between conventional and electric vehicles. Selected EVs included the Tesla Model 3, Nissan Leaf, Chevrolet Bolt, Volkswagen (VW) e-Golf, BMW i3, and Fiat 500e. Comparable gasoline vehicles included the Lincoln MKZ AWD 3.0L turbo, Ford Focus hatchback, Nissan Kicks 1.6L, VW Golf 1.8L, Toyota Yaris iA 1.5L, and Fiat 500 1.4L. The team consulted dealerships and service centers to estimate cost of routine service over 150,000 miles of ownership, prepared a draft report and delivered it to DOE. The subject of this study was developed into a full-length MotorWeek story.

In addition to its popularity with consumers, FuelEconomy.gov is a trusted resource for television, print, and online media. Over the years, information on FuelEconomy.gov has been featured in articles by national news outlets like CBS News, Fox News, NBC News, USA Today, CNN, the Washington Post, and Time Magazine; financial news outlets like MarketWatch, Bloomberg.com, Forbes.com, and Fortune.com; automotive news such as Car and Driver, Automotive News, Cars.com, Motor Trend, and autoblog.com; local newspapers and television news; and college newspapers. It is also cited by Ford Motor Company Newsroom, Toyota USA, and Volkswagen of America. So, in addition to reaching consumers directly, FuelEconomy.gov also reaches them through print and online materials from other sources.

Conclusions

In FY 2019, the FEI Program continued to meet its objectives.

FuelEconomy.gov is an effective information resource for consumers and an effective outreach tool for promoting fuel economy and alternative fuels. Its popularity with consumers and reputation with media make it a powerful platform for educating the public about fuel economy.

FEI Program research on factors affecting vehicle fuel economy have played an important role in assuring that FuelEconomy.gov's fuel-saving tips are accurate and up-to-date. The fuel-saving tips produced from this research are part of the reason FuelEconomy.gov is trusted by consumers, auto industry researchers, and news media as the authoritative source of fuel economy information.

The large number of media outlets that feature information from FuelEconomy.gov indicates that the website has become a primary source, and perhaps the authoritative source, for fuel economy information in the United States. Website content has also been used in research publications, which further speaks to the website's reputation for providing reliable information. This allows FuelEconomy.gov's reach to far exceed just those consumers that visit the website.

The FEI Program plays an important role in educating the public about fuel economy and providing information to consumers. Through the *Fuel Economy Guide*, FuelEconomy.gov, and its education and outreach efforts, the FEI Program continues to help increase U.S. energy security by promoting the efficient use of energy resources.

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Acknowledgements

The ORNL and University of Tennessee team acknowledge the steadfast support of the Department of Energy and the Environmental Protection Agency. Thanks also to auto industry partners and consumers for their valuable feedback and questions. Many consumers share their personal fuel economy on the *MyMPG* tool, which is also appreciated.

II.6 Technical Assistance/Technical Response Service (National Renewable Energy Laboratory)

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Start Date: October 1, 2018 End Date: September 30, 2019
Project Funding (FY19): $1,100,000 DOE share: $1,100,000 Non-DOE share: $0

Project Introduction

The National Renewable Energy Laboratory (NREL) leads a group of in-house and contracted experts to provide technical assistance and information that helps improve transportation efficiency and advance the use of domestic fuels and technologies. The Technical Assistance project and Technical Response Service connect transportation stakeholders with objective information that can smooth integration, reduce risks, and ensure their alternative fuel and advanced technology projects are conducted efficiently and cost effectively. These efforts can also identify technology gaps and help inform ongoing research to improve fuels and advanced vehicle technologies, with industry and consumer needs in mind.

Fleets across the nation have made great progress integrating alternative fuels, advanced vehicles, and fuel-saving measures into their operations. These efforts have reduced transportation energy costs, improved resiliency, contributed to improved air quality and earned fleet managers recognition as sustainability leaders. Yet as fleet managers evaluate their options to use alternative fuels and advanced vehicles, they frequently need additional information or expert guidance to make informed decisions or overcome technical issues they encounter. Similarly, policymakers, analysts and other transportation decision makers need objective information from expert sources to inform research investment, incentive programs, and projects. To address these challenges, the U.S. Department of Energy's (DOE's) Vehicle Technologies Office (VTO) offers technical assistance that connects stakeholders with experts who can provide objective information, and answer questions about, and assist with, alternative fuels, fuel economy improvements, and other emerging transportation technologies. The type of technical assistance provided (or requested) runs the gamut, from fielding one-time questions that can be answered with a list of resources to in-person assistance from a subject matter expert on how a particular technology functions. Through these trusted, time-tested methods, DOE has helped fleets and other stakeholders deploy hundreds of thousands of alternative fuel vehicles (AFVs) and fueling stations that serve a growing market. The project is continually evolving to tackle the biggest integration barriers, contribute new expertise, and inform emerging technology research needs.

Objectives

The objective of the technical assistance project is twofold. First, it directly assists end-users by providing a conduit to make informed decisions and solve problems. Second, it provides critical feedback to support next generation research and transportation technologies. This is accomplished by employing a few key methods:

- Providing unbiased information, resources and assistance to a broad base of transportation stakeholders, by sharing and applying practical real-world experience, lessons learned, and best practices
- Securing in-house (across National Laboratories) and subcontracted experts that provide a range of expertise across fuels, vehicle types and technologies, and identifying additional technical experts as new technologies emerge in the marketplace
- Maintaining robust knowledge of the alternative fuels industry and monitoring inquiry topics, to identify knowledge and integration barriers that should be addressed
- Using results to inform future research and development efforts.

Approach

The Technical Assistance project makes varying levels of technical assistance available to transportation stakeholders, ranging from email exchanges that connect stakeholders to existing online tools and documents, to in-person consultations that address specific in-depth challenges. NREL assigns inquiries to appropriate experts, based upon the type of assistance requested and the required depth of response. Additionally, Technical Assistance can be either reactive, to respond to an urgent challenge in real-time, or proactive, to collect knowledge and develop resources that address a common issue.

A base level of Technical Assistance is offered through the VTO Technical Response Service (TRS). NREL subcontracts the TRS activity through a competitive process. The TRS is a phone- and email-based service staffed by seasoned experts who help stakeholders find answers to technical questions about alternative fuels and fueling infrastructure, fuel economy improvements, idle-reduction measures, advanced vehicles, and other related resources. TRS representatives are experienced with a broad range of resources including online tools and calculators, state and federal laws and incentives, peer-reviewed research, academic publications, program-accumulated case studies, and lessons learned. While much information is available on a variety of VTO and other websites, there is still significant demand for assistance that addresses individual questions or that rapidly connects people with critical information when safety incidents or other urgent needs arise. The TRS helps clients focus in on resources that address their situations. Upon receiving an inquiry, TRS experts provide a tailored response by curating a list of current, relevant resources and pinpointing the applicable material within those resources, on a case-by-case basis. Each inquiry is documented in a database, and through analytics, DOE can identify trends and information needs. The TRS is an important resource that answers inquiries, but it also enables VTO to identify information gaps, technology shortfalls in the field, and other technical topics that need to be addressed.

For inquiries that require specific expertise to successfully execute a project or address a problem, DOE provides technical assistance through Tiger Teams, a group of highly skilled experts from National Laboratories and industry. Industry experts are identified through a competitive process and subcontracted by NREL. These experts have deep knowledge, either in a specific area, or across the range of alternative fuels, including natural gas, hydrogen, propane, and biofuels, such as ethanol and biodiesel. They also have expertise in plug-in electric vehicles (PEVs), and emerging topics and technologies, such as electric vehicle supply equipment (EVSE) infrastructure assessment and planning, and using data to better execute energy efficient transportation projects. With many years of hands-on experience, these experts work with fleet operations staff, fuel providers and fueling equipment suppliers, vehicle conversion companies, and equipment and vehicle manufacturers, to assist with all phases of a project. From concept to implementation, operation, and maintenance, Tiger Teams can help industry and fleets tackle difficult technical and implementation challenges that might otherwise cause projects to stall. Building on extensive learning opportunities from previous consultation experiences, Tiger Teams are constantly evolving, to streamline projects and help stakeholders achieve better results, more quickly and cost-effectively. Designed to not compete with private industry, Tiger Team experts come alongside existing project teams in situations that challenge local resources, or in instances where local expertise does not exist. Acting as a neutral third-party, Tiger Teams provide technical expertise, help address problems, resolve differences, and get stalled projects moving again.

After a Tiger Team is utilized, the findings are shared with other stakeholders, either formally, through a publication, report or a website, or more informally, through webinars and presentations.

Results

A sampling of fiscal year (FY) 2019 TRS and Technical Assistance projects includes the following:

Technical Response Service Inquiries

A lodge in a National Park inquired about available incentives for electric shuttles. The TRS referred the client to the Alternative Fuels Data Center (AFDC) Laws and Incentives database [1] and various federal websites to identify funding opportunities. Additionally, the TRS recommended contacting the local Clean Cities coalition [2] for information on possible local or private incentives.

Cushman and Wakefield, a commercial real estate services company, asked if Station Locator [3] EVSE data could be sorted to understand station growth. The TRS provided a spreadsheet of historical station data and direction on how to review that data. The TRS also referred the questioner to AFDC Station Locator pages to download future data, and the Maps and Data pages for charts.

Google, Inc. asked for networked EVSE data covering countries outside of the U.S. and Canada. The TRS referred the client to a number of resources including: Open Charge Map, which has networked EVSE data by country, the European Alternative Fuels Observatory, and My Electric Avenue. Additionally, the client was sent a link to an International Council on Clean Transportation (ICCT) report that includes station counts in 14 different countries, and links to the data sources for the counts in the ICCT report.

The Hawaii State Energy Office asked which states have passed legislation that allows energy performance contracting to include vehicles. The TRS provided the client with several examples of legislation and informed the client that the Department of Energy tracks Energy Savings Performance Contracting legislation across the country, as well as state-specific resources and references. The legislation tracker can be found at https://www.energy.gov/eere/slsc/downloads/energy-savings-performance-contracting-legislation-data-and-other-resources

Massachusetts Clean Cities asked for guidance on pricing structures for state or municipal workplace charging. The TRS explained that many state workplace charging programs start by offering free charging for employees. The TRS referred to AFDC workplace charging resources and provided a list from the Station Locator of workplace chargers that offer free charging. Additionally, the TRS referred to workplace charging pricing guidance from DOE, CALSTART, and California PEV Collaborative. Similarly, a major hotel chain asked about typical fees for EVSE use. In the response, the TRS summarized how station owners charge for EVSE and referred to AFDC publications on setting payment structures for EVSE. Additionally, the TRS included example pricing structures from charging networks.

The Environmental Protection Agency inquired about states that mandate the sale and use of diesel fuel blends of 5% biodiesel (B5) or higher. The TRS provided a table of states with a B5 mandate. Additionally, the TRS included a separate table of states that currently have biodiesel blend requirements below B5 but that will increase the biodiesel blend level following a set schedule.

Louisiana Clean Fuels asked what the potential is for renewable natural gas (RNG) from wastewater treatment plants and landfills to supply electricity in the U.S. The TRS referred to DOE, NREL, the U.S. Department of Agriculture (USDA), and industry association publications on the potential of using RNG from different feedstocks to produce electricity or fuel vehicles with natural gas in the U.S.

A representative from Mercedes-Benz Research and Development North America, Inc. asked if the Station Locator had additional information on Level 2 EVSE installation dates or power output data, other than what is provided in the historical data spreadsheet. The TRS directed the client to a supplemental EVSE spreadsheet for the information requested and provided typical residential charging information.

A representative from private industry in Sri Lanka asked how much energy is consumed in the distillation of ethanol and petroleum. The TRS explained that, in general, the energy requirements are facility-specific. The TRS provided general energy consumption estimates from DOE, ANL, and USDA publications.

Coachella Valley Water District inquired about whether there is guidance on developing a request for proposal (RFP) for a fleet alternative fuels feasibility study. The TRS recommended the client contact the local Clean Cities coordinator. They also referred the client to RFPs for feasibility studies and examples of completed studies. The client expressed an interested in hydrogen vehicles and was referred to the AFDC hydrogen case studies and publications.

Philadelphia Gas Works asked how 18 inches of clearance is measured for sloped ceilings in natural gas vehicle maintenance facilities. The TRS recommended the client contact his local fire marshal or authority having jurisdiction to confirm the regulations in his area. Additionally, the TRS provided the document entitled, "Compressed Natural Gas Vehicle Maintenance Facility Modification Handbook" [4] and a link to NFPA 30, which details that clearance would be "in all directions from the dispenser enclosure."

A United Airlines representative asked for a contact in Hawaii to help with EVSE installations. The TRS referred the client to the Clean Cities coordinator in Hawaii and provided information about manufacturer websites which may also have recommended installers in his area.

Penske Truck Leasing inquired about the requirements for upgrading a maintenance facility for compressed natural gas (CNG). The TRS referred the client to DOE and NGVAmerica resources detailing the codes and standards that may apply. They also recommended the client contact the local authority having jurisdiction as well as the Clean Cities coordinator.

Technical Assistance Activities

Automotive Service Excellence (ASE) is the leader in providing accredited testing for technicians in the automotive, heavy truck, and bus industry. Technical assistance was consulted in rewriting the Compressed Natural Gas Engines portion of the F1 test, which is designed to evaluate the aptitude of technicians who work on natural gas vehicles. The test required an update to guarantee that technicians have the strong baseline of knowledge required to properly service modern natural gas engines. NREL first worked with ASE to develop a pool of potential test writers who are experts in the industry and possess experience in the multiple areas of the test. The test writers met and provided recommendations for questions that were less conversion-focused and more Original Equipment Manufacturer (OEM)-focused because OEM natural gas vehicles are rapidly outpacing converted vehicles in market penetration. The group also addressed existing test questions on which most participants were not scoring well, which potentially indicated the questions were not written well. The recommended changes have been implemented in the test.

A Clean Fuels Ohio stakeholder was experiencing problems with the company's CNG trucks. The company purchased used CNG trucks which were on track to require engine replacements sooner than a diesel engine would have been. The engines in at least eight of the trucks were failing in the range of 250,000 miles, while normally they should last for 500,000 miles. The stakeholder has worked with multiple repair shops and dealers to resolve the issue. Since this issue arose during the third quarter of FY 2019 it has not yet been resolved, but NREL will continue to work with the company to determine whether the issues are normal for engines in the duty cycle.

A municipality from the Northeast requested technical assistance regarding a challenge with biodiesel use. The fleet has used biodiesel for an extended period but had recently experienced what they thought were fuel quality issues. The fleet's fuel supplier had changed the source from which they procured biodiesel, and the fleet thought the change may be causing diesel particulate filter issues. NREL conducted several exploratory phone calls to gain a greater understanding of the issues. Together, NREL and the fleet determined the issues were not related to the biodiesel fuel and the change in supply was likely a coincidence. Instead the vehicle failures could be attributed to normal operation of modern diesel vehicles. Specifically, these vehicles were operated on short routes with considerable idle times. NREL worked with the fleet to improve their maintenance tracking system and to expect better reporting from their service repair facilities. Additionally, the company is seeking to add a fleet manager to its staff to better manage overall fleet operations.

The Natural Gas Vehicle Technology Forum, coordinated by the Technical Assistance project, took place in April 2019, at the Agility Fuel Solutions Training Center in Salisbury, North Carolina. There were nearly 70 attendees, including representatives from industry, government, utilities, and regulatory bodies. Discussions revealed that, although the industry has progressed significantly, this annual meeting was still critical to break down barriers and discuss technology needs. High interest topics included codes and standards, new technologies in off-highway vehicles, and concerns about Type IV fuel tanks. Considerable discussion occurred about pressure relief device activation and side-saddle installations for Type IV tanks.

Conclusions

The ready availability of industry experts, through the TRS and the Technical Assistance project, makes it possible for fleets to understand, select and integrate new transportation technologies. These experts can offer transportation stakeholders valuable insights into the various technology options, along with advice on making informed decisions, and anticipating, mitigating, or altogether avoiding common problems, thus increasing the chances of project success. Additionally, the interactions with end-users of real-world technologies provide valuable feedback that can provide a foundation for future DOE research.

References

1. Alternative Fuels Data Center Laws and Incentives Database, https://afdc.energy.gov/laws
2. Clean Cities Coalition Network, https://cleancities.energy.gov/
3. Alternative Fueling Station Locator, https://afdc.energy.gov/stations/#/find/nearest
4. https://afdc.energy.gov/files/u/publication/cng_maintenance_facility_mod.pdf

II.7 Technologist-in-Cities (National Renewable Energy Laboratory)

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Project Introduction

As cities around the country launch efforts to use data and mobility technology in more innovative and effective ways than ever before, smart cities are serving as living laboratories for increasing the energy efficiency and reducing the emissions of urban mobility systems, while increasing mobility services. The U.S. Department of Energy (DOE) Energy Efficient Mobility Systems (EEMS) program envisions an affordable, efficient, safe, and accessible transportation future in which mobility is decoupled from energy consumption. Technologies that may help achieve this vision include advanced vehicles and systems that are automated, connected, efficient, and/or shared (ACES). EEMS supports research and development that investigates these technologies and other opportunities to increase mobility energy productivity [1] in communities. As a part of an interagency Memorandum of Understanding (MOU) in support of the EEMS Program, DOE and the U.S. Department of Transportation (DOT) are working together to accelerate innovative smart transportation systems research. Through this coordination, DOE paired a Technologist in Cities (TIC) with Columbus, Ohio after the City of Columbus' Smart Columbus project won the DOT Smart City Challenge in 2016. The TIC works with the City and its partners throughout the life of the Smart Columbus project.

The Smart Columbus initiative is supported by two grants, totaling $50 million. A $40 million DOT grant supports multiple projects, including smart mobility hubs, automated electric shuttles, enhanced communications, such as Dedicated Short-Range Communications (DSRC), and truck platooning. Complementing the DOT grant is a $10 million grant from the Paul G. Allen Philanthropies (formerly Vulcan) to accelerate adoption of plug-in electric vehicles (PEVs), to enhance charging infrastructure to support PEV adoption, and to provide a cleaner and more efficient electric grid.

Now in its third year of the DOT grant, many of the projects, particularly with respect to PEV adoption, are highly mature, and many of the mobility based projects are nearing full implementation. With the end of the grant period looming in 2020, Smart Columbus is now planning for the transition from grant funded projects to sustained initiatives within the city.

Objectives

The TIC supports the City of Columbus in its Smart City endeavors, serving as a liaison on energy and mobility issues. The TIC advises the city's innovation and technology team on transportation energy efficiency and connects the city to experts throughout the DOE National Laboratory system. The TIC facilitates feedback between DOE's EEMS research team and the City, to inform modeling and data analysis conducted at the National Laboratories. This is done by gaining access to data streams from Smart Columbus demonstration projects, as well as transportation, infrastructure, and energy data from the City of Columbus and regional partners. As the projects have matured and have been deployed, the opportunities for data sharing have increased, both within the grant funded programs as well as in a number of ancillary initiatives that have emerged, encouraged by the Smart Columbus initiative, though not directly funded by the grants.

Approach

The TIC support of Smart Columbus includes a variety of activities, methods and approaches as outlined below:

- Maintain a physical presence at adequate frequency to sustain a working relationship and serve as a liaison
- Provide access to DOE and National Laboratory resources as appropriate to meet needs within the Smart Columbus portfolio of projects
- Advocate for energy metrics and performance measures through the Smart Columbus program.
- Encourage data sharing, innovative uses of data, and access to critical data streams associated with advanced mobility, such as connected vehicle/automated vehicle (CV/AV) and Automated Electric Shuttle (AES) demonstrations
- Support the Smart Columbus Operating System, the centralized, modern data repository and exchange for Smart Columbus initiatives, and promote access to vital regional data sets housed at the City and with the City's partners, as well as integration of data into the DOE EEMS LiveWire lab data sharing system
- Provide communications between the City and its partners to the DOE and the National Laboratories
- Promote opportunities for collaboration between Smart Columbus and the DOE, Energy Efficiency and Renewable Energy, Vehicle Technologies Office's (VTO's) EEMS programs, such as SMART research and Technology Integration (TI) projects.

As Columbus is nearing the end of the formal DOT grant period, many of the grant funded projects are transitioning to operational programs within Smart Columbus, including the Smart Columbus Operating System, plug-in electric vehicle (PEV) adoption programs, and various other mobility initiatives. Simultaneously, several initiatives have emerged in Columbus that synergize with the Smart Columbus themes, though not directly funded through the Smart Columbus grant. Such initiatives have emerged within the City, with enhanced parking and curb management initiatives; at the Central Ohio Transit Authority (COTA), with initiatives to efficiently solve employer labor access issues; at Ohio Department of Transportation (Ohio DOT), with the formation of DriveOhio to promote ACES activities within the state; and with Clean Fuels Ohio and its partners, through various grant initiatives to test innovative mobility solutions. Additionally, Smart Columbus has inspired private industry to embark on other initiatives in alignment with the City's goals, such as Columbus Yellow Cab's transition to an electrified fleet of vehicles. Not only have the Smart Columbus grant activities yielded significant results in 2019, the momentum generated by the grant has begun to sprout other significant EEMS initiatives within the community.

Results

In Fiscal Year (FY) 2019, the TIC program was able to carry out its objectives in a variety of ways. Select project accomplishments include:

- **Support for Smart Columbus Electrification Program (CEP) Performance Metrics Plan** (PfMP) – This effort has fully matured. The TIC initiated and supported the PfMP during the first year of the program. In the second year, the TIC transferred responsibility for maintaining and updating the PfMP to internal Smart Columbus staff. The PfMP in its third year is now fully supported internally by Smart Columbus. Staff report progress towards electrification goals, including the number of PEVs adopted, and the greenhouse gas (GHG) and energy reduction benefits resulting from various activities and projects in the CEP, such as education and incentives for PEV purchases. This initiative has helped to inspire and support the VTO TI research project, entitled the Transportation Energy Analytics Dashboard, as explained in the following highlight.

- **Transportation Energy Analytics Dashboard (TEAD)** – Envisioned through the TIC program and funded through a VTO TI grant led by the University of Maryland (UMD), the TEAD project is prototyping a mobility analytics platform that fully integrates energy and emissions, using Columbus, Ohio and Washington, DC as test cases. The team is integrating real-time and historic traffic volume and speed data with detailed roadway information and data on vehicle powertrain models, to estimate the gasoline gallon equivalents (GGEs) consumed on each segment of roadway. The prototype will ultimately be incorporated into the industry-leading Regional Integrated Traffic Information System (RITIS) mobility data analytics platform, hosted at the UMD Center for Advanced Transportation Technology Laboratory (CATT Lab), which services over half of all states. When fully deployed, TEAD will enable leading energy and GHG metrics to be incorporated into traffic operations, planning and research, ultimately providing a more comprehensive tool for transportation decision-making. The expertise of the Mid-Ohio Regional Planning Commission, as well as lessons learned through the Smart Columbus program, are helping to guide the initial prototype.
- **Leveraging Emerging Mobility Data Sources – Trip Trajectory Data** – In 2017, the Ohio DOT completed the procurement of cutting-edge transportation planning and analysis data sets from industry sources. Through TIC collaboration, the SMART research initiative gained access to the entire Ohio trip trajectory data set for research purposes. In terms of size and scope, each year of data approaches one terabyte (TB) in size and contains data reflecting approximately 2% of all trips made in the state of Ohio from 2016 through 2018. A National Renewable Energy Laboratory (NREL) visualization of one year of such data is shown in Figure II.7.1, to demonstrate its size and extent.

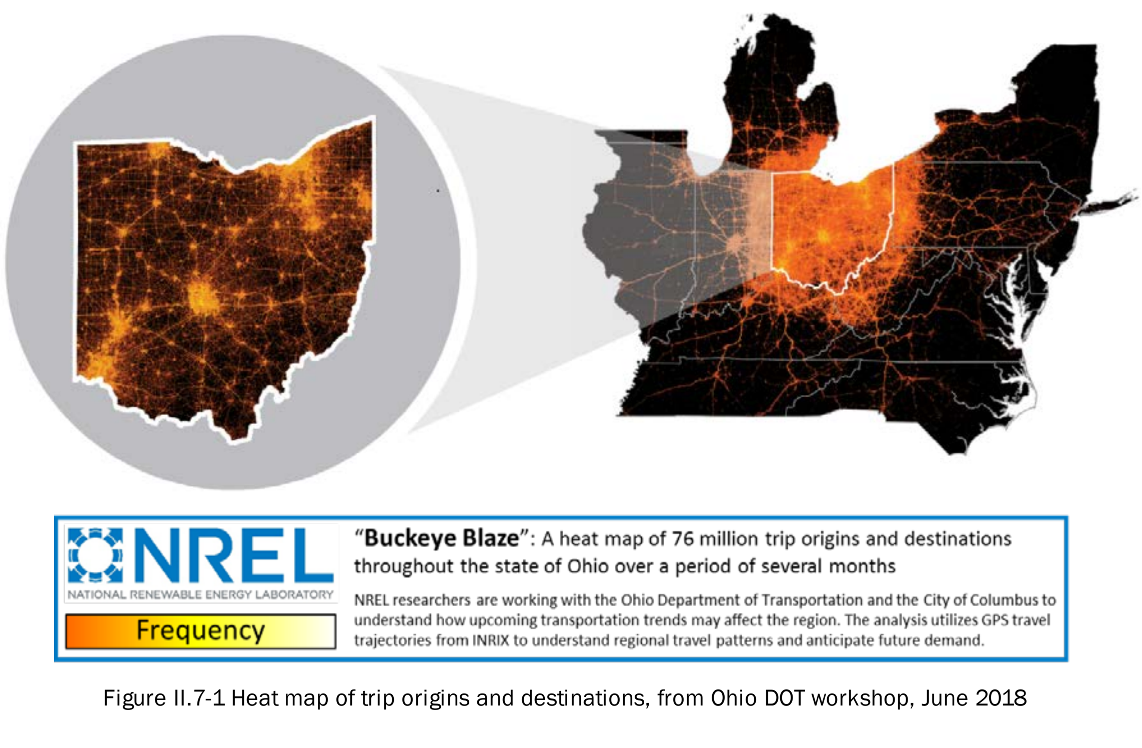


Figure II.7-1 Heat map of trip origins and destinations, from Ohio DOT workshop, June 2018

In 2019, NREL partnered with researchers from Wayne State University to leverage this probe vehicle trajectory data to assess performance and optimize traffic signal along ten critical corridors in Columbus. (See Figure II.7-2 .) This new method of utilizing big data sets of sampled vehicle

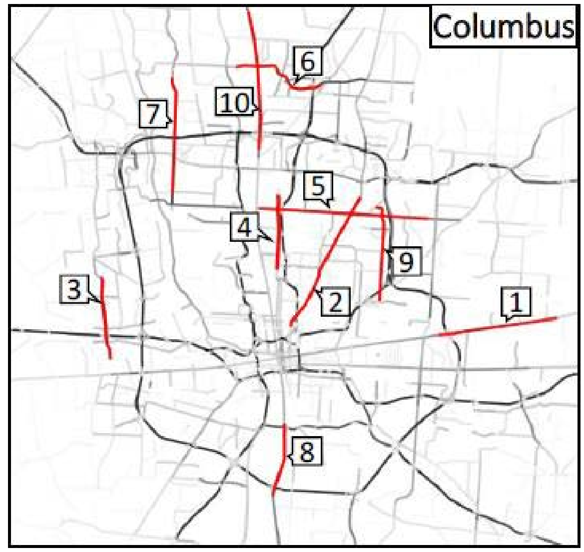
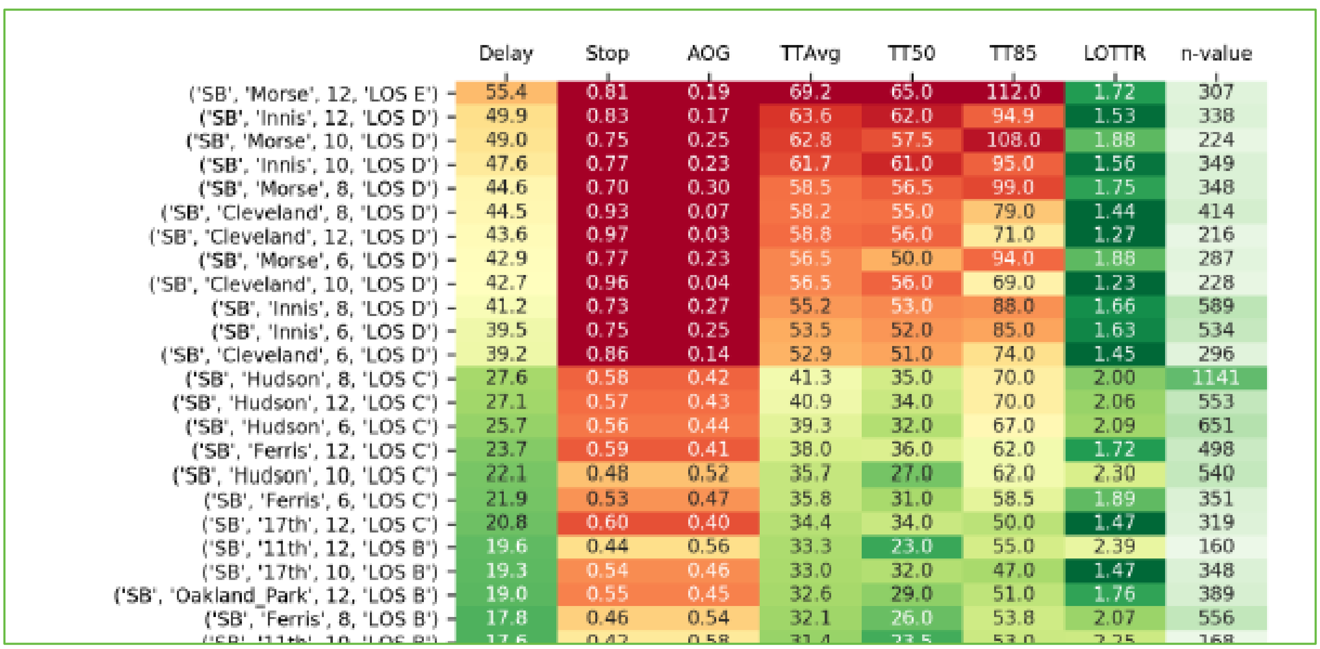


Figure II.7-2 Location of the 10 critical corridors

trajectories provides a level of signal performance detail not available otherwise without major investments in sensor and controller upgrades. It is also more proactive than historic approaches, which rely on complaints from residents or periodic manual data collection to assess and implement signal retiming. NREL and Wayne State researchers presented the results of the effort to Smart Columbus in the summer of 2019, giving a full performance assessment of each corridor, and each segment and signal within the corridor. (See Figure II.7-3.) The process was even able to isolate and diagnose abnormal intersection phenomenon, as shown in Figure II.7.4, in which a malfunctioning pedestrian call button was obstructing traffic progression. Subsequent work and focus of the collaboration will be on scaling the effort to a much larger region – statewide or even nationally. This research holds significant potential for improved mobility, safety and energy efficiency of traffic movement through improved signal operations, with significantly lower financial and personnel resource requirements. This methodology is documented in a 2020 Transportation Research Board submission [2], and is now being integrated into the Regional Mobility research initiative, in which a digital twin for the City of Chattanooga is being created to enhance the energy efficiency of the mobility system in the region.



	Delay	Stop	AOG	TTAvg	TT50	TT85	LOTTR	n-value
('SB', 'Morse', 12, 'LOS E')	55.4	0.81	0.19	69.2	65.0	112.0	1.72	307
('SB', 'Innis', 12, 'LOS D')	49.9	0.83	0.17	63.6	62.0	94.9	1.53	338
('SB', 'Morse', 10, 'LOS D')	49.0	0.75	0.25	62.8	57.5	108.0	1.88	224
('SB', 'Innis', 10, 'LOS D')	47.6	0.77	0.23	61.7	61.0	95.0	1.56	349
('SB', 'Morse', 8, 'LOS D')	44.6	0.70	0.30	58.5	56.5	99.0	1.75	348
('SB', 'Cleveland', 8, 'LOS D')	44.5	0.93	0.07	58.2	55.0	79.0	1.44	414
('SB', 'Cleveland', 12, 'LOS D')	43.6	0.97	0.03	58.8	56.0	71.0	1.27	216
('SB', 'Morse', 6, 'LOS D')	42.9	0.77	0.23	56.5	50.0	94.0	1.88	287
('SB', 'Cleveland', 10, 'LOS D')	42.7	0.96	0.04	56.5	56.0	69.0	1.23	228
('SB', 'Innis', 8, 'LOS D')	41.2	0.73	0.27	55.2	53.0	88.0	1.66	589
('SB', 'Innis', 6, 'LOS D')	39.5	0.75	0.25	53.5	52.0	85.0	1.63	534
('SB', 'Cleveland', 6, 'LOS D')	39.2	0.86	0.14	52.9	51.0	74.0	1.45	296
('SB', 'Hudson', 8, 'LOS C')	27.6	0.58	0.42	41.3	35.0	70.0	2.00	1141
('SB', 'Hudson', 12, 'LOS C')	27.1	0.57	0.43	40.9	34.0	70.0	2.06	553
('SB', 'Hudson', 6, 'LOS C')	25.7	0.56	0.44	39.3	32.0	67.0	2.09	651
('SB', 'Ferris', 12, 'LOS C')	23.7	0.59	0.41	38.0	36.0	62.0	1.72	498
('SB', 'Hudson', 10, 'LOS C')	22.1	0.48	0.52	35.7	27.0	62.0	2.30	540
('SB', 'Ferris', 6, 'LOS C')	21.9	0.53	0.47	35.8	31.0	58.5	1.89	351
('SB', '17th', 12, 'LOS C')	20.8	0.60	0.40	34.4	34.0	50.0	1.47	319
('SB', '11th', 12, 'LOS B')	19.6	0.44	0.56	33.3	23.0	55.0	2.39	160
('SB', '17th', 10, 'LOS B')	19.3	0.54	0.46	33.0	32.0	47.0	1.47	348
('SB', 'Oakland_Park', 12, 'LOS B')	19.0	0.55	0.45	32.6	29.0	51.0	1.76	389
('SB', 'Ferris', 8, 'LOS B')	17.8	0.46	0.54	32.1	26.0	53.8	2.07	556

Figure II.7-3 Sample of corridor signal assessment metrics

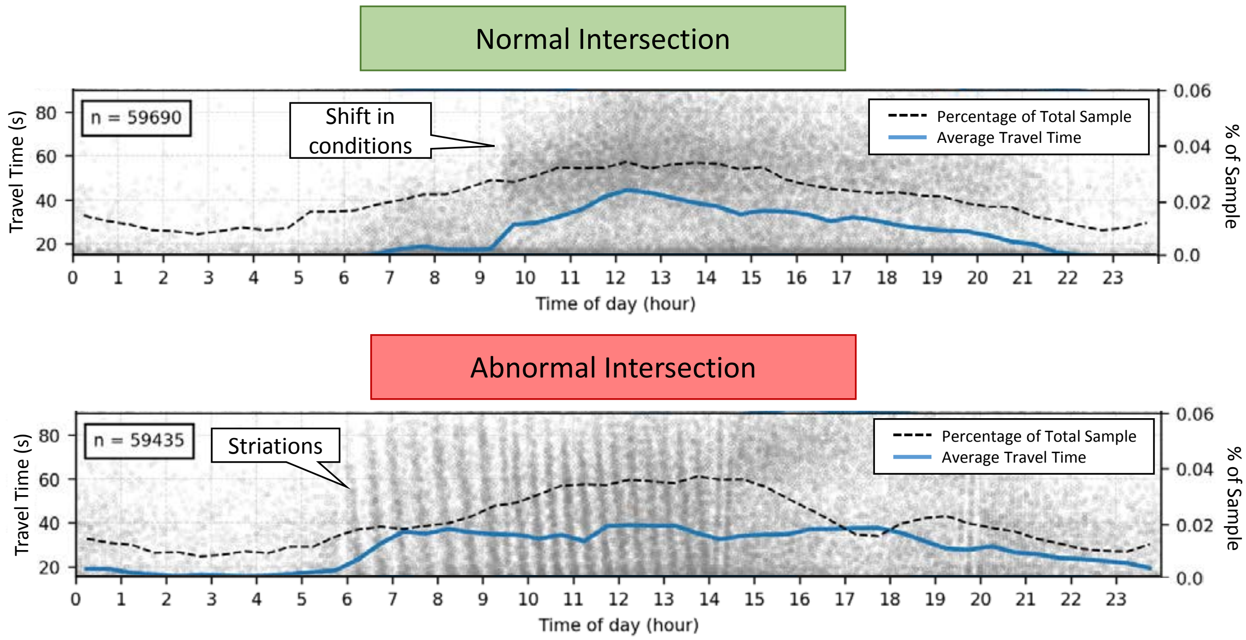


Figure II.7-4 Normal and Abnormal (caused by a malfunctioning pedestrian call button) Intersections in Columbus

- **PEV Infrastructure Support and Analysis -** Beginning in 2017, NREL provided analysis support to the Columbus Electrification Program (CEP), by using the Electric Vehicle Infrastructure Projection (EVI-Pro) tool to estimate the number, type and location of charging stations needed to support various levels of PEV adoption within the Columbus region. This study was completed in December 2017, and results continue to be used in the CEP. NREL continued to support the CEP program in 2019 as Smart Columbus incentivized Transportation Network Company (TNC) drivers to use PEVs in service, by providing telematics to log the trips, charging events, and driving characteristics of TNC drivers that participated in the program. Although only three TNC drivers elected to participate, the interaction with Smart Columbus led to a larger driver recruitment program hosted by NREL, as well as efforts to research and model large fleets of on-demand PEVs. Additionally, the TNC incentive funds were made available to other commercial fleets, allowing Columbus Yellow Cab to add ten Tesla Model 3 vehicles to its fleet. (See Figure II.7.5.) Data from this deployment in Columbus is being made available to SMART research as the fleet is utilized for passenger carrying service. These interactions and resulting data access have contributed to the development of the NREL Highly Integrated Vehicle Eco-system initiative, or HIVE, being prototyped in conjunction with Ford Motor Company. As an additional effort to normalize PEV adoption, Smart Columbus has facilitated PEV Ride and Drive events, having completed more than 11,000 individual test drives with local consumers as of Q4 2019.

- **Smart Columbus Operating System (SCOS) – support and interaction.** The SCOS, which became operational in 2019, is the data repository and data transactional engine through which all the Smart Columbus projects operate. As the centralized data initiative, SCOS is core to the DOT portfolio of projects. The SCOS is designed to support the electrification initiative and other emerging Smart Columbus initiatives, as well as those of its stakeholders. The TIC is facilitating coordination among the SCOS and Livewire teams to eventually allow SCOS data to be discoverable through the Livewire platform, enabling a broader range of researchers, including those within the National Laboratory system, to gain access to valuable data. The TIC also continues to serve as a resource for other DOE-funded projects that wish to leverage SCOS data.

Figure II.7-5 Columbus Yellow Cab EV fleet [Electrek August 2019]

- **Ohio Vehicle Registration Data -** The number of new PEVs purchased as a proportion of the entire consumer fleet in Columbus is a key performance metric; however, verifying this number remains an ongoing challenge in Columbus and in many other cities with PEV adoption goals. Commercial sources of registration data, such as IHS Markit subscriptions, have been able to provide estimates of PEV purchases for 2014 through the present, but are not seen as a long-term, reliable, consistent, and sustainable source of vehicle registration data. In 2017, Smart Columbus, in collaboration with the TIC, initiated discussions with the Ohio Bureau of Motor Vehicles (BMV) to obtain direct access to vehicle registration data. In 2018, Smart Columbus and the Ohio DOT began receiving data directly from the Ohio BMV. In 2019, Ohio state legislation required differentiated vehicle registration fees for PEVs, hybrid non-plug-in vehicles, and internal combustion engine (ICE) powered vehicles; this forced the BMV to begin tracking the vehicle propulsion type (PEV versus ICE) in the BMV database. Previously, this information was inferred from Vehicle Identification Numbers (VINs) stored with registration records, requiring substantial processing and updates with commercial data sources to decode the VIN identifier. The BMV, Ohio DOT, and Smart Columbus are collaborating on the process to develop native reporting of PEV adoption at the state level, both to meet the legislative requirement to assess fees based on vehicle drivetrain variants, and to enable Ohio cities to track their PEV adoption goals. In the interim, Smart Columbus still relies on periodic IHS industry summary reports for its performance metrics. Although initial data from the BMV has been processed to meet the July 2019 implementation date for the drivetrain based fees, validating the data against other sources has revealed issues that remain to be resolved. The TIC will continue to monitor this situation into 2020, and data from the initiative is targeted for inclusion in the TEAD project.

- **Employer Provided Mobility (EPM) Benefits** – NREL researchers have identified a commuting trend that is emerging across the nation. Employers, motivated by several economic and socio-demographic factors, are helping to shape the commuting behavior of employees. There is a growing need to provide commute options, especially to younger employees, who tend to be less interested in vehicle ownership than previous generations, and often delay acquiring driver's licenses by one or more years, compared to previous generations. Employers recruiting this demographic are being pressed to provide them with other commuting options, to be more competitive in attracting workers. Employers are also motivated by a desire to expand existing company facilities without having to add expensive structure-based parking. NREL researchers noted that in 2018, JP Morgan Chase began a program to provide commute options to its employees, to reduce single occupancy vehicle use and minimize parking demand at its headquarters in suburban Columbus. JP Morgan Chase's motivations aligned with nationally observed trends. Similar interests and efforts from other employers have spurred Columbus to better connect employers with the employee labor pools, to ensure continued economic growth in the region. Such efforts are coordinated through the Columbus Partnership, a non-profit organization of more than 70 CEOs from Columbus' leading businesses and institutions, whose primary goal is to improve the economic vitality of the Columbus Region. The Central Ohio Transit Authority (COTA) is also actively experimenting with mobility solutions to connect labor pools efficiently with many of the blue-collar employment centers in the Columbus region. In 2019, NREL hosted an EPM workshop in Denver, Colorado, that was attended by representatives from COTA, and is now planning a similar event in Columbus, in collaboration with the Columbus Partnership and COTA. NREL is also working with the Columbus Partnership on a framework to identify challenges that employers are experiencing in the region in gaining mobility access for potential employees, and to explore possible solutions. The goal is a document that lays out the motivation, options, and benefits for EPM from an employer's perspective, for use in the Columbus region.

- **New Mobility in Rural America** – As urbanization has intensified in recent years, much of the focus of new transportation technologies and practices has been on dense urban cores; however, much of the U.S. population continues to live in small towns and rural areas adjacent to major population centers. These areas are insufficiently served by public transit, and were the subject of a 2019 DOE TI Funding Opportunity Announcement (FOA), focused on the potential impacts of emerging mobility. Both the City of Columbus and NREL, aware of the need to better link rural and ex-urban communities to employment and services, such as healthcare, education, and commerce, are involved with three of five rural mobility projects that were awarded through this FOA. One of the projects was awarded to the organization Rural Action in Ohio, and supported by NREL and Clean Fuels Ohio. NREL, through the TIC program, plans to convene a rural mobility consortium involving the five awardees, to facilitate information exchange and collaboration. As new mobility technologies and practices allow for better inclusion of exurban and rural areas, there is a need to identify how best to serve these communities and communicate best practices, to inform other rural mobility efforts throughout the nation.

- **Columbus Yellow Cab (CYC)** – As highlighted in previous sections, Columbus Yellow Cab, an established local cab company, is emerging as an example of successful commercial use of PEV technology. Morgan Kauffman, the CEO and owner of CYC, has been highly involved with the Smart Columbus effort, and was recently awarded an open topic project through the FY 2019 VTO TI funding announcement. The project, titled "Decentralized Mobility Ecosystem: Market Solutions for 21st Century Electrified Mobility," is a collaboration with Clean Fuels Ohio and NREL, It is an entrepreneurial approach to applied science in a living lab setting, providing automated access to shared electric vehicles for short-term use by the Columbus community. The project envisions a system of shared electric vehicles of various sizes made available from automated check-out stations in central Columbus that will enable people to use these vehicles for passenger and goods movement, including gig economy services. CYC is at the forefront of testing new mobility options, moving toward an electrified cab fleet and aiming to offer a variety of ACES mobility services in Columbus. CYC is also a valued collaborator with the SMART Mobility consortium, freely sharing operational data to inform the development of analytical tools. In September, during the Midwest Green Transportation Expo, the Smart Columbus team recognized Mr. Kauffman for his civic leadership in promoting energy efficient and innovative transportation.

- **Parking and Curbside Management** – Robert Ferrin, the Parking Manager for the City of Columbus, has engaged with NREL TIC researchers regarding emerging trends and practices for curbside management. The proliferation of mobility as a service (MaaS) options, such as Uber and Lyft; micro-mobility vehicles, such as shared e-scooters and bicycles; increased deliveries due to e-commerce adoption; and standard curbside parking activity have resulted in crowded curbsides. Mr. Ferrin has identified an acute need for better management and coordination of curb activities, and has acknowledged a potential need to restructure payment for use of this space. Curbside management is a trend that is emerging in many cities, and is under investigation by NREL researchers as part of the EEMS Curbside Topology project. The City of Columbus was one of the first cities to adopt proactive polices based on observed data, to improve the efficient use of curb space, and has been a strong partner in the ongoing SMART research work.

Parking Data Assessment – Despite the important role parking plays in urban mobility, comprehensive citywide parking inventories have generally not been available in the past. This is beginning to change as innovative data collection and management approaches are maturing, and the industry has begun to recognize that parking data can be monetized. To support ongoing efforts, the TIC and NREL undertook an assessment of available parking data in Columbus. The assessment determined that several parking datasets are available through the Smart Columbus OS, but that these vary in terms of attributes collected and data storage formats. Further work in this area is exploring the feasibility and usefulness of data collected and managed by private entities. The ability to catalog and measure the quantity, availability and cost of parking in various districts within the city, and at various times of the day, has emerged as critical for accurately modeling real-world travel choices and resulting energy consumption. Areas of immediate application include improving the accuracy of the DOE's Mobility Energy Productivity (MEP) metric by incorporating parking cost and time, including accurate parking cost and times penalties in the SMART workflow modeling process, and assisting cities with developing appropriate policy regarding parking, Transportation Network Company (TNC) operations, and curbside management.

Conclusions

While city governance is complex and each city's experience with implementing smart city projects will be unique, relationships and data are unifying, collaborative elements of any project designed to enhance mobility, while minimizing energy use. Year three activities with the TIC program reinforced this, and witnessed the blossoming not only of grant-supported projects in Columbus, but also several other initiatives inspired by the original Smart Columbus award. The TIC effort in Columbus embedded an experienced transportation researcher as an adviser to the city and as a liaison between Smart Columbus and the DOE. This resulted in substantial contributions to the Smart Columbus Electrification Program, including performance metrics, data, collaboration with the SCOS, and various joint research opportunities. The TIC program has helped Columbus gain technical insights related to transportation energy use, integrated energy and mobility planning, and access to emerging data and National Laboratory expertise, while DOE gained a greater understanding of city decision dynamics and insight into the challenges that other cities will face as they pursue similar projects.

Year one of the TIC program concentrated primarily on relationship building. Year two witnessed the start of substantial research and data collaboration that benefited both Smart Columbus and the DOE EEMS program. In year three of the program, the collaboration has resulted in data sharing, and significant collaboration not only on the original Smart Columbus projects, but also several efforts that have sprouted as a result of the momentum and motivation derived from the original Smart Columbus grant initiative.

References

1. The EEMS Program uses the term mobility energy productivity (MEP) to describe the value derived from the transportation system per unit of energy consumed. Increases in mobility energy productivity result from improvements in the quality or output of the transportation system, and/or reductions in the energy used for transportation.

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