U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Technology Integration

2020 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.

We would also like to express our appreciation to Allegheny Science and Technology (AST) for their technical support in preparing, editing, compiling, and publishing the 2020 Technology Integration Annual Progress Report.

Acronyms

AC	Air conditioning
ACES	Automated, connected, efficient and shared
ACFC	Alabama Clean Fuels Coalition
ACM	American Center for Mobility
ADA	Americans with Disabilities Act
ADAS	Advanced Driver Assistance Systems
AEO	Annual Energy Outlook
AEV	Automated electric vehicle
AFDC	Alternative Fuels Data Center
AFLEET Tool	Alternative Fuel Life-Cycle Environmental and Economic Transportation Tool
AFPR	Alternative Fuel Price Report
AFV	alternative fuel vehicle
AHJ	authority having jurisdiction
ANL	Argonne National Laboratory
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
BSSD	Blue Springs School District
CACC	Cooperative Adaptive Cruise Control
CAN	Controller Area Network
CARB	California Air Resources Board
CARTA	Chattanooga Area Regional Transportation Authority
CARTS	Capital Area Rural Transportation System
CATT Lab	Center for Advanced Transportation Technology Laboratory

CAV	Connected and Automated Vehicle
CCoD	City and County of Denver
CMU	Carnegie Mellon University
CNG	compressed natural gas
CO2	carbon dioxide
CRuSE	Clean Rural Shared Electric Mobility Project
CSU	Colorado State University
CTE	Center for Transportation and the Environment
CVLZ	Commercial Vehicle Loading Zone
DAS	Data acquisition system
DC	direct current
DCFC	direct current fast charger
DNL	Dynamic Network Loading
DOE	Department of Energy
DOT	Department of Transportation
DP	Dynamic programming
DSA	data sharing agreement
EEL	energy efficient logistics
EEMS	energy efficient mobility systems
EERE	Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
ELM	Electric Last Mile
EMS	energy management strategy
EPA	Environmental Protection Agency
EPAct	Energy Policy Act of 1992
EPIC	Energy Production and Infrastructure Center
ERAU	Embry Riddle Aeronautical University
ETCF	East Tennessee Clean Fuels

EV	electric vehicle
EVI-Pro	Electric Vehicle Infrastructure Projection
eVMT	electric vehicle miles traveled
EVSE	electric vehicle supply equipment
EV WATTS	Electric Vehicle Widescale Analysis for Tomorrow's Transportation Solutions
EVZion	East Zion National Park Electric Vehicle Shuttle System Plan
FAST Act	Fixing America's Surface Transportation Act
FDACS OER	Florida Department of Agriculture and Consumer Services Office of Energy
FE	fuel economy
FEI	Fuel Economy Information
FFRDC	Federally Funded Research and Development Center
FHWA	Federal Highway Administration
FSEC	Florida Solar Energy Center
FtC	Fort Collins, Colorado
FTG	freight trip generation
FY	fiscal year
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
GVSD	Grain Valley School District
H2	hydrogen
HDV	heavy duty vehicle
HEV	hybrid-electric vehicle

HPC	high performance computing
ICE	internal combustion engine
ICI	intelligent connected infrastructure
ICV	intelligent connected vehicle
IEEE	Institute of Electrical and Electronics Engineers
INL	Idaho National Laboratory
ITEM	Integrated Transport-Energy Model
JFK	John F. Kennedy International Airport
KCI	Kansas City International Airport
KCMO	Kansas City, Missouri
KPI	key performance indicator
KU	Kansas University
kWh	kilowatt-hour
L2	level 2
LDV	light duty vehicle
LiDAR	Light Detection and Ranging
LGA	LaGuardia Airport
LNG	liquefied natural gas
LSCFA	Lone Star Clean Fuels Alliance
LSEV	low speed electric vehicle
M&HD	medium and heavy duty
M2M	Michigan to Montana
MaaS	Mobility as a Service
MAC	McMaster University
MAC-POST	Mobility Data Analytics Center – Prediction, Optimization and Simulation Toolkit
MD	medium duty
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
MST	Missouri University of Science and Technology
MSU	Mississippi State University
MUD	multi-unit dwelling
MWCOG	Metropolitan Washington Council of Governments
MY	model year
NASEO	National Association of State Energy Officials
NCAT	National Center for Asphalt Technologies
NFPA	National Fire Protection Association
NGV	natural gas vehicle
NGV UPTIME	NGV Updated Performance Tracking Integrating Maintenance Expenses
NHTSA	National Highway Traffic Safety Administration
NOx	oxides of nitrogen
NREL	National Renewable Energy Laboratory
NTEA	National Truck Equipment Association
NYC	New York City
NYSERDA	New York State Energy Research and Development Authority
OCPI	Open Charge Point Interface
OD	origin-destination
OEM	original equipment manufacturer
OHD	off-hour deliveries
ORNL	Oak Ridge National Laboratory
OSU	Ohio State University

PAC	Project Advisory Committee
pdf	portable document format
PeMS	Performance Measurement System
PEV	plug-in electric vehicle
PfMP	Performance Metrics Plan
PHEV	plug-in hybrid electric vehicle
PM	particulate matter
PNNL	Pacific Northwest National Laboratory
POEMS	Predictive Optimal Energy Management Strategies
PY	project year
RAMP	Rural County Mobility Platform
RPC	Regional Planning Commission
RFP	request for proposals
RITIS	Regional Integrated Transportation Information System
ROADMAP	Rural Open Access Development Mobility Action Plan
RPI	Rensselaer Polytechnic Institute
SAE	Society of Automotive Engineers
SAFP	State and Alternative Fuel Providers
SDOT	Seattle Department of Transportation
SEAFDP	Southeast Alternative Fuel Deployment Program
SQL	Structured Query Language
TCO	total cost of ownership
TEAD	Transportation Energy Analytics Dashboard
TI	Technology Integration
TIC	Technologist in Cities
TMC ID	Traffic Message Channel identifier
TMS	traffic management strategy
TNC	transportation network company

TRB	Transportation Research Board
TRS	Technical Response Service
TSP	transportation service provider
UA	University of Alabama
UAV	unmanned aerial vehicle
UCC	Utah Clean Cities
UCF	University of Central Florida
UMD	University of Maryland
UNC	University of North Carolina, Charlotte
UPS	United Parcel Service
USU	Utah State University
UT	University of Tennessee, Knoxville
UT-Austin	University of Texas at Austin
UU	University of Utah
UW	University of Washington
UWAFT	University of Waterloo Alternative Fuels Team
V2I	vehicle to infrastructure
V2V	vehicle to vehicle
VDP	Vehicle Development Process
VIN	vehicle identification number
VT	Virginia Tech
VTC	Volunteer Transportation Center
VTO	Vehicle Technologies Office
VW	Volkswagen
WestSmart EV	Western Smart Plug-in Electric Vehicle Community Partnership
WU	Waynesboro University
WVU	West Virginia University
ZNP	Zion National Park

Executive Summary

The 2020 Technology Integration Annual Progress Report covers 46 multi-year projects funded by the Vehicle Technologies Office. The report includes information on competitively awarded projects, ranging from rural shared mobility demonstration projects to medium- and heavy-duty electric vehicle deployment to statewide alternative fuel resiliency planning. It also includes projects conducted by several of the Vehicle Technologies Office's (VTO) 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 about 30% of total U.S. energy needs[3] and the average U.S. household spends over 15% of its total family expenditures on transportation, making it the most expensive spending category after housing.[4]

The Vehicle Technologies Office (VTO) funds a broad portfolio of research, development, demonstration, and deployment (RDD&D) projects to develop affordable, efficient, and clean transportation options to tackle the climate crisis and accelerate the development and widespread use of a variety of innovative transportation technologies. The research pathways focus on electrification, fuel diversification, vehicle efficiency, energy storage, lightweight materials, and new mobility technologies to improve the overall energy efficiency and affordability 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 accelerate sustainable transportation technologies 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 RDD&D barriers, and accelerate progress. VTO focuses on research that supports DOE's goals of building a 100% clean energy economy, addressing climate change, and achieving net-zero emissions no later than 2050 to the benefit of all Americans.

Annual Progress Report

As shown in the organization chart (below), VTO is organized by technology area: Batteries & Electrification R&D, Materials Technology R&D, Advanced Engine & Fuel R&D, Energy Efficient Mobility Systems, and Technology Integration. 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) 2020. In this APR, each project active during FY 2020 describes work conducted in support of VTO's mission. Individual project descriptions in this APR detail funding, objectives, approach, results, and conclusions during FY 2020.

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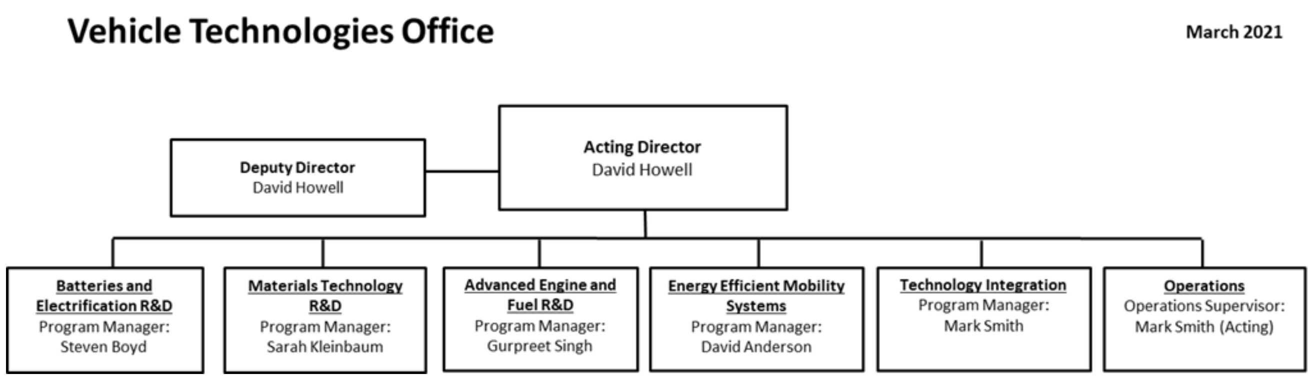
[1] Bureau of Transportation Statistics, Department of Transportation, Transportation Statistics Annual Report 2018, Table 4-1. https://www.bts.gov/tsar.

[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 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 more than 75 active coalitions covering nearly every state 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 U.S. Fuels Across America's Highways - Michigan to Montana (Gas Technology Institute)

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Start Date: January 19, 2017 End Date: September 30, 2021
Project Funding: $ 10,045,195 DOE share: $ 4,999,983 Non-DOE share: $ 5,045,212

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, electric vehicle (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 is 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 (GLACC), South Shore Clean Cities, Chicago Area Clean Cities, Wisconsin Clean Cities, Twin Cities Clean Cities, North Dakota Clean Cities, ZEF Energy (ZEF), Ozinga Ready Mix (Ozinga), Veriha Trucking, and Contract Transportation Services.

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, 4 publicly accessible CNG fueling stations, 1 propane station, and 40 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

EV Charging and Alternative Fueling Stations Infrastructure

Using results from a Needs Analysis completed earlier in the project, the M2M team continued efforts to close identified gaps in the locations of alternative fueling and electric vehicle charging stations infrastructure. To identify gaps in the EV charging and alternative fueling infrastructure along the corridor, the Needs Analysis reviewed various studies and established maximum acceptable separation distances between charging or fueling stations to provide sustainable infrastructure and reduce drivers' range anxiety.

Because their analysis overlaps with many of the goals of the M2M project, the M2M team is following the Federal Highway Administration (FHWA) suggested distances. FHWA recommends maximum acceptable separation distances for a corridor to be considered "corridor-ready" as follows: 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 created a map of the existing infrastructure along the corridor that identifies gaps in the locations of fueling and EV charging stations (Figure I.1-1). 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. When evaluating opportunities for deploying additional infrastructure along I-94, the M2M team attempts to direct project resources in such a way that identified gaps are addressed.

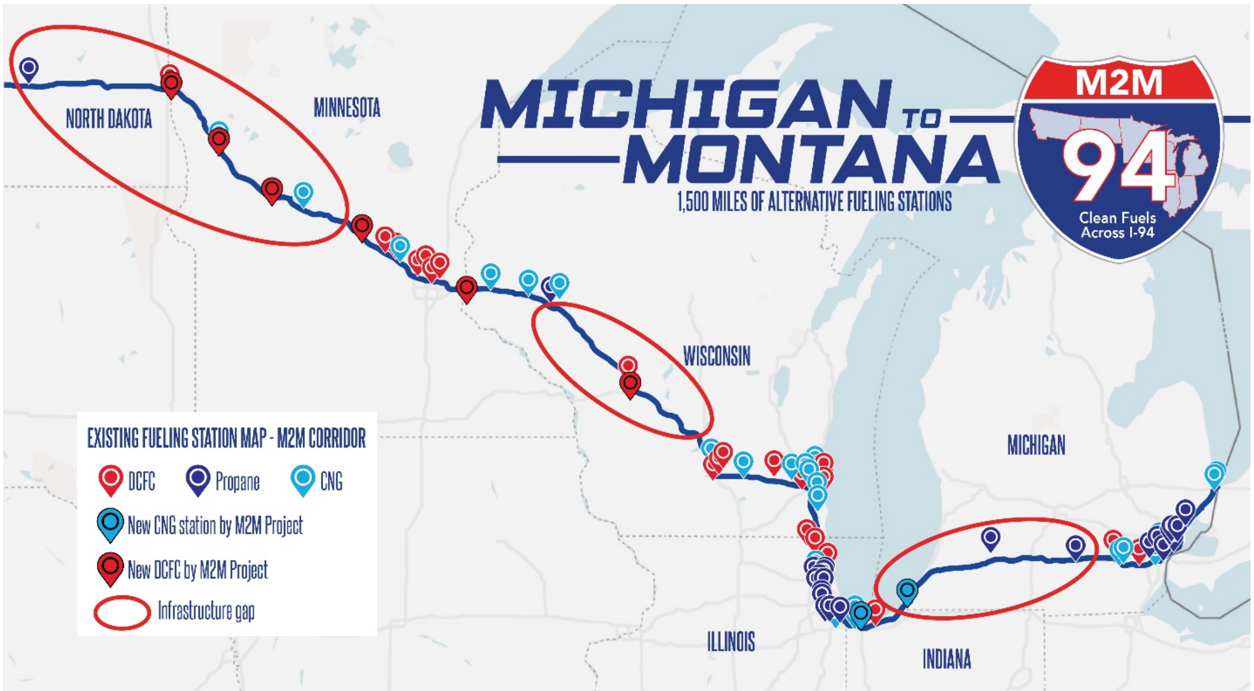

Figure I.1-1. Infrastructure Gap Analysis and Station Locations (Note: Red ovals denote major gaps in fueling infrastructure on I-94)

In filling the gaps identified in the map above, the M2M team 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. This is because 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 relative to highway driving. Accordingly, it may be inappropriate to use these same distances for both urban and highway driving along the I-94 Corridor. Therefore, the team is concentrating on identifying opportunities to increase infrastructure that supports “anchor fleets” and thereby reduces barriers to adoption and increased utilization of AFVs on and near the corridor.

The M2M team also believes that infrastructure redundancy could be a critical attribute of a robust and sustainable alternative fuels corridor. Without redundancy, a shutdown at a fueling station could result in substantial lost revenues. Large fleets that require reliable vehicle availability and have high utilization rates will not switch to alternative fuels if they cannot rely on the fueling station network. In view of these considerations, it was decided that fueling station deployment would be targeted at “filling gaps” and increasing the probability of adoption by, and retention of, end-users.

EV Fast Charging Station Deployment

During the reporting period, the M2M team continued to make substantial progress in addressing previously identified gaps in EV charging, CNG and propane fueling stations. Our EV charging station partner, ZEF, installed and commissioned four additional DCFC stations along the I-94 Corridor at Hudson, Wisconsin; and Alexandria, St. Cloud, and Fergus Falls, Minnesota. See Figure I.1-2 for photographs of these new charging stations.

Figure I.1-2. EV Fast Charging stations installed and commissioned in FY 2020 (Source-ZEF Energy)

With two charging stations completed during FY2019 (at Tomah, Wisconsin, and Moorhead, Minnesota), this brings the total to six completed since project initiation. ZEF also has four new sites at different stages of development at the following locations: Dickinson and Fargo, North Dakota; and Billings and St Joseph, Minnesota. During the reporting period, our Clean Cities Coordinator partners also confirmed that several new DCFC stations were installed and commissioned by others in locations that will support the I-94 Corridor.

CNG Fueling Station Deployment

During FY2020, Ozinga initiated and completed permitting, site preparation, equipment installation and commissioning of two new public CNG fueling stations. The first new station (Figure I.1-3) is located in Gary, Indiana and was commissioned in the fourth quarter of 2019. A second new station was recently completed in the third quarter of 2020 and is located in New Buffalo, Michigan (Figure I.1-4). These two new stations will help address an alternative fuels infrastructure gap along I-94 that includes Northwest Indiana and Southern Michigan. During FY2020, one of our existing partners, Hot Shot Properties (HSP), was planning to build a CNG station located in Bismarck, North Dakota. Unfortunately, HSP encountered problems during negotiations with other partners and has withdrawn their request for M2M support. The project team is engaging additional stakeholders to limit overall project schedule slippage as the team works to secure a new partner.

Figure I.1-3. Ozinga station in Gary, Indiana

Figure I.1-4. Ozinga station in New Buffalo, Michigan

Propane Station Deployment

In FY2020, Landmark Services Cooperative approached the team with renewed interest in participating in the M2M project. Specifically, Landmark proposed to follow through on its earlier commitment to build and commission a new public propane fueling station in Cottage Grove, Wisconsin. GTI and Landmark are close to completing contract negotiations with a target completion date of early 2021.

CNG Truck Deployment

New M2M team member, Veriha Trucking, ordered an additional ten CNG trucks to increase the anchor fleet that is critical to growing and sustaining an Alternative Fuels Corridor along I-94. This increases Veriha's CNG fleet that travels through most of the I-94 Corridor states from 39 to 49 trucks.

Sustainable Corridor Planning

The M2M team members continued work that will serve as a model platform for creating a sustainable Alternative Fuel Corridor that can subsequently be used to guide other communities with future corridor development. Once adequate access to EV charging or alternative fuel stations is available along an interstate highway corridor, the next priority is to ensure that travelers/users are made aware of the availability of this infrastructure. One means is through the use of signage. The Fixing America's Surface Transportation (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. In response to nominations submitted by M2M team members, FHWA has designated several sections of I-94, resulting in signage along I-94 in Michigan, Indiana, Illinois, and Wisconsin. An example of new signage installed on I-94 during FY2020 is shown in Figure I.1-5.

Figure I.1-5. Signage on I-94 between the Wisconsin-Illinois border and Madison, Wisconsin

Outreach and Coordination

MotorWeek – The M2M project team worked with MotorWeek to support their efforts in producing a video segment dedicated to our project (Michigan 2 Montana: National Alternative Fuel Corridor, MotorWeek Auto World, https://www.youtube.com/watch?v=ysIio-Dz93A&feature=youtu.be). This was a wonderful accomplishment for the team, providing vast market reach, and satisfying several of the outreach/marketing objectives.

M2M Flyers – Each of the M2M Clean Cities Coordinators created state-specific flyers. The first page of the flyers includes general information about the I-94 Corridor and the M2M project. The second page of the flyers provides a state-specific map and summary of alternative fuels infrastructure supporting the I-94 Corridor. M2M flyers are available for all states included in the I-94 Corridor and are distributed at team member events.

M2M Corridor Website – The team has been working to develop a website for the project that is almost ready to go live. Information on this site will include links to resources that can assist in searches regarding project partners, progress, events, and available resources.

Events- The major Corridor-wide event planned for the project in FY2020 was an M2M Roadshow that had to be indefinitely postponed due to COVID-19. Instead, each Clean Cities Coordinator organized and executed state-level events that supported M2M project outreach objectives such as webinars, virtual ride and drives, and virtual gatherings.

Socio-Economic Benefits Analysis – GLACC contracted with Michigan State University to complete the analysis entitled: "The Economic Impact of Conversion of Internal Combustion Engines to Electric Vehicles and Alternative Fuel Vehicles along the I-94 Corridor."

Social Media – Several Clean Cities coalitions collaborated on social media messaging and communications related to the M2M project. These communications are being posted on Facebook and Twitter.

Conclusions

The M2M Corridor Project remains on track to accomplish all of its goals and objectives within the planned budget. Unfortunately, COVID-19 has impacted the project schedule in FY2020 for deployments and outreach events; however, every effort is being made to limit overall project schedule slippage. While most of the planned live outreach efforts by the team members from the Clean Cities coalitions had to be converted to "virtual" and video segments, the results are impressive and are paving the way to establishing a sustainable alternative fuel corridor along I-94.

Acknowledgements

The M2M Corridor Project Team would like to acknowledge the guidance and involvement of its DOE Project Manager, Mr. David Kirschner, during this challenging period affected by COVID-19.

I.2 WestSmart EV: Western Smart Plug-in Electric Vehicle Community Partnership (PacifiCorp)

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Start Date: January 19, 2017 End Date: October 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 (UCC), 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.2-1.

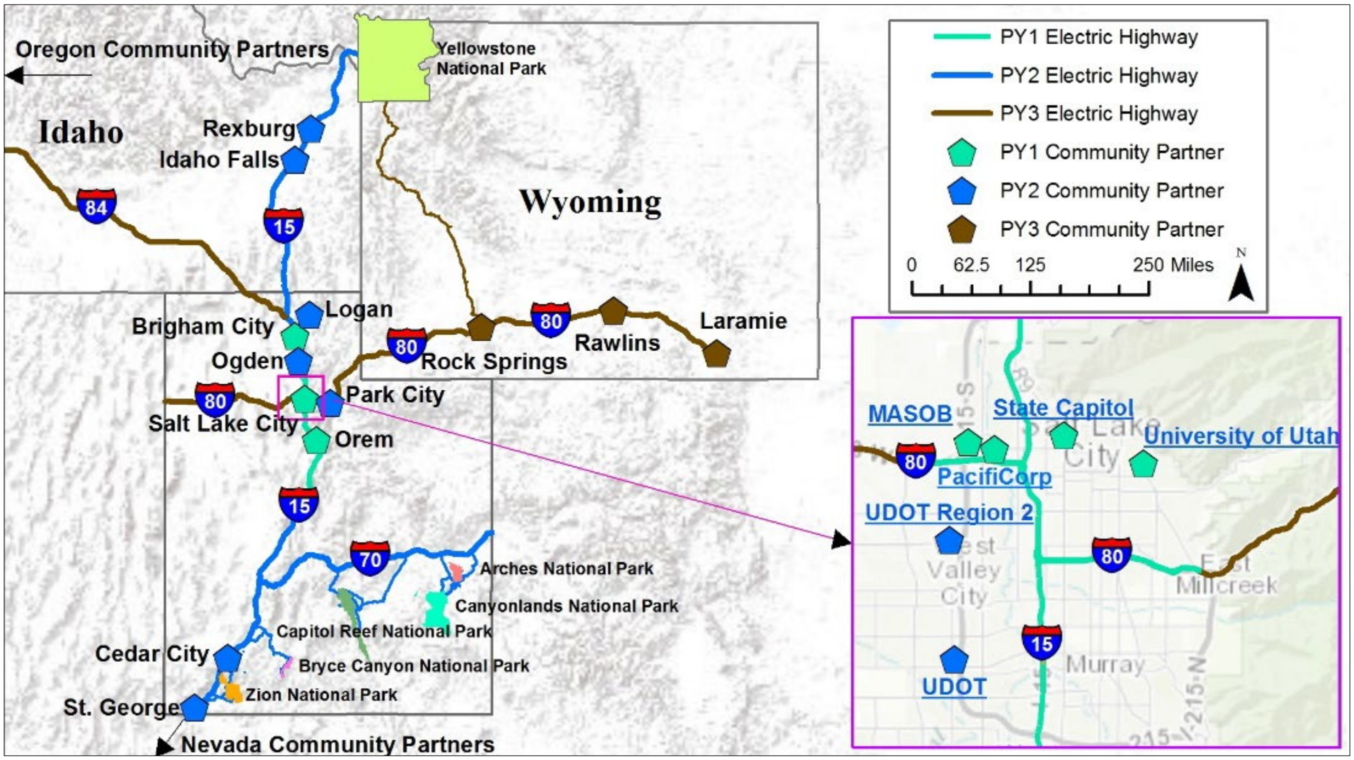

Figure I.2-1. WestSmart EV three-year project implementation plan

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.2-2. 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.

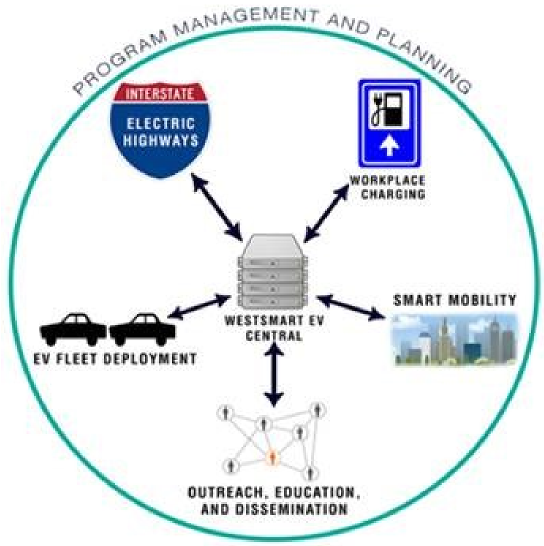

Figure I.2-2. WestSmart EV major task diagram

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) 2020:

- On January 24, 2020, DOE approved a no cost extension extending the project to October 18, 2020.
- Successfully published two research papers characterizing charging flexibility and risk analysis of EV charging coupled with solar operation on the distribution grid
- Successfully collected data from transportation network company (TNC) drivers
- Successfully held workshops, webinars, and podcasts highlighting the results from the project

Task 1 - Electric Highways Results:

- Installed 20 DC Fast Chargers (DCFC) in FY 2020:
  - Two at Garden City, Utah
  - Four at Timpanogos Harley Davidson, Lindon Utah
  - Two at Garf car dealership in Salt Lake City, Utah
  - Two at Castle Dale, Utah
  - Six at Utah Department of Transportation facilities
  - Two at Utah Soccer Stadium, in Sandy, Utah
  - Two at Solei Apartment, in Herriman, Utah

Task 2 - Workplace Charging Results:

- Installed 724 workplace L2 chargers in FY 2020.

Task 3 – EV Fleet Deployment Results:

- This Task is complete

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:

- Continued coordinating data collection consensus with ChargePoint, EVgo, BTCPower, and Greenlots.
- Smart Mobility – Analyzed driving and energy data from participating TNC drivers.
- Updated 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 outreach and education workshops in the region.

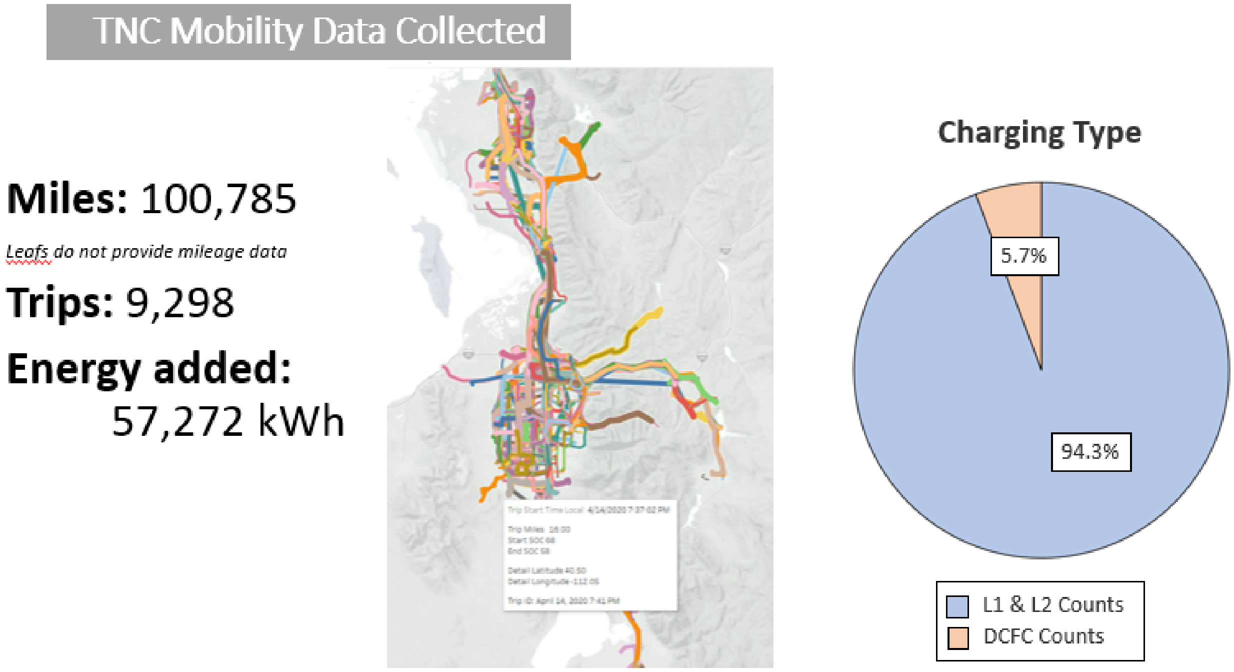

Figure I.2-3. WestSmart EV highway corridor

Conclusions

The project team continued to implement the key activities associated with all primary objectives of the WestSmart EV project's third budget year. The Company requested and received a no cost extension for the third budget year, extending the project to October 18, 2020. The team successfully installed 20 DC Fast Chargers (DCFCs) across the project territory and collected data from the chargers. Due to COVID 19, some of the planned DCFC installations were cancelled because of supply chain issues, however the cancellations did not impact the task requirements. 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 TNC activities, including an App that can be downloaded that tracks the charging characteristics and telematics of the vehicle. The team analyzed the telematics and energy data from drivers (Figure I.2-3) illustrating the need for public DCFCs. 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

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.

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.*

Palomino, A and Masood P. (2018). "Probabilistic Impact Analysis of Residential Electric Vehicle Charging on Distribution Transformers." *2018 North American Power Symposium*

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.*

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.*

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.*

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.*

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.*

Palomino, A., and Parvania M. (2019) “Advanced charging infrastructure for enabling electrified transportation.” *The Electricity Journal Vol 32, 21-26*

Palomino, A, and Parvania, M (2020) “Bayesian Hierarchical Model for Characterizing Electric Vehicle Charging Flexibility,” in *Proc. 2020 IEEE PES General Meeting,* Montreal, Canada.

Palomino, A, and Parvania, M, (2020) “Data-Driven Risk Analysis of Joint Electric Vehicle and Solar Operation in Distribution Networks,” *IEEE Open Access Journal of Power and Energy*, vol. 7, no. 1, pp. 141-150.

I.3 Electric Last Mile (Pecan Street, Inc.)

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Start Date: October 1, 2017 End Date: September 30, 2021
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

National Highway Traffic Safety Administration (NHTSA) notified Pecan Street in June 2019 that the autonomous vehicle (AV) demonstration application was not approved, so the team looked at alternate route options and different strategies to design a route that met the limitations of the autonomous vehicle and the requirements of NHTSA. Since the AV could not operate on roads with a speed limit higher than 30MPH the team focused its efforts on locating route options that could run on private campuses or roads, for ease of permitting. Pecan Street met with Capital Metro to learn about opportunities for an autonomous vehicle demonstration to assist with their research efforts and to discuss potential route options. Additionally, Pecan Street reached out to local business contacts with large campuses where the AV shuttle would be able to make a connection with a Capital Metro bus line and improve the commute for employees on the respective campuses. The team identified and reviewed a couple of route options on the University of Texas at Austin campus. The team then began coordinating with the University of Texas at Austin Parking and Transportation Services to evaluate the best route. The table below includes all the issues and limitations encountered during the route planning process.

Table I.3-1 Issues Impacting Pecan Street AV Demonstration

Issue	Impact on Pecan Street AV Demonstration
AV can't operate on roads signed faster than 30 MPH	Pecan Street focused most of its efforts in residential areas where the speed limit is 30 MPH or less. However, most areas still contained a main road through the community that the AV would need to cross at least once to be close to a Capital Metro bus stop to help with the last mile solution.
AV operates at 3MPH when not in autonomous mode	This is an issue when it comes time to get the vehicle to and from the storage facility to the autonomous route. Pecan Street looked at alternate routes within the same community but found that the most viable options for routes would still take over 30 minutes to get the vehicle to and from the route from the storage facility.
AV cannot cross-roads with moderate traffic without 4-way stop designated	Most of the routes that were designed contained at least one intersection that the AV would be required to drive through or cross. Pecan Street spoke with the city about installing temporary signage at these intersections, but they could not guarantee installation of the signage within the designated project period.
AV cannot operate unattended on public roads	The AV must have an operator onboard while underway.
AV cannot operate on congested (with parked vehicles) roadways where the vehicle must operate in the middle of the roadway	This issue was one of the larger risks that NHTSA could foresee with the route that was submitted for approval in June. The route included a residential street where cars park on both sides of the road and required the AV to drive down the middle of the roadway.
AV has a maximum operation speed on our route of under 15 MPH	A maximum speed of 12.3 MPH while on route has significantly limited the number of streets available that the vehicle can operate on. Many residential streets have a speed limit of 30 MPH and the community would not approve of a vehicle driving on a high traffic street at low speeds causing traffic to back up.
AV has difficulties operating alongside large amounts of undeveloped property	Pecan Street has been forced to rule out certain streets and areas that contain undeveloped land such as parks or other green spaces from the route planning, as the AV needs fixed development for LIDAR operation.
AV has difficulties operating alongside	Pecan Street has also been limited to areas where construction is not underway or will be beginning during the demonstration phase because the

Issue	Impact on Pecan Street AV Demonstration
properties under active development	vehicle could have trouble operating in those areas under development, due to the change in physical landscape and the change in the base LIDAR map.
AV has height restrictions which require clearance over 9 feet	The AV height restrictions have not been a concern while the vehicle is operating on the proposed routes, but the height clearance has significantly limited the project team to choosing routes that are very close to a storage facility with a 9-foot clearance.
AV has charging constraints – requires secure, covered location	This issue directly correlates with challenges of finding a 9-foot clearance. If the AV did not require a secure, covered parking location, the vehicle could be stored and charged in more locations, allowing for a greater number of route options.
AV requires signage at vehicle stopping locations	The vehicle requires signage at each location where the vehicle plans to stop and pick up riders. This has limited Pecan Street to areas where the project team is able to get express permission from the City or property owners to include a sign on the designated property.
AV needs permission from NHTSA to operate	AV cannot operate on roadways without approval from NHTSA.

Results

Pecan Street continued its discussions with the University of Texas to find the best route option. The main constraint with the route locations on the UT campus were finding secure, covered storage for the vehicle in close proximity to the route. All conversations with the campus' Parking and Transportation Services were put on hold in early March as schools and businesses began closing their doors and working from home as a result of COVID-19. Due to the undefined impact and timeline of the pandemic and return of students and faculty to the University of Texas campus, the project team amended the project plans to complete an Autonomous Vehicle Technology Guide, drawing from the lessons learned and experiences with AV technology procurement. The guide will include an assessment of AV technologies across different vendors, an overview of the value proposition for these types of technology demonstrations, and best practices for permitting, community engagement and route selection.

Conclusions

So far, the program has identified many opportunities for last mile solutions that improve quality of life while potentially reducing overall vehicle emissions. The electric shuttle demonstration program has resulted in changes for overall Capital Metro transportation route design and programs. However, Pecan Street has identified many obstacles to developing an AV demonstration that have revealed some best practices for AV route development and demonstration use cases. Pecan Street will document lessons learned from the team's experiences that can be transferred to others considering a similar program.

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.4 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, 2021
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, 2 and 4 roughly correspond to the year 2018, 2019 and 2020, respectively, while Thrust 2 is expected to be completed across the duration of the project.

Results

During the past year, the team worked on the development of simulation tools to model supply chains, and computational systems and algorithms to characterize baseline conditions in terms of supply chain practices and energy use in the Albany - New York City Corridor. Lastly, the team started working on assessing the effectiveness of possible initiatives that would increase the EEL in the corridor.

Behavioral Micro-Simulation for Study of Energy Efficient Logistics (BMS-EEL)

A major component of the project is the development of the enhanced Behavioral Micro-Simulation (BMS). The original BMS was developed by Rensselaer Polytechnic Institute 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) [1]; Holguín-Veras and Aros-Vera, 2014) [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. It considers a complete representation of the supply chain, including freight flows (i) from gateways to large establishments, (ii) from large to large establishments, (iii) from large to small establishments, and (iv) from small to small establishments.

During the past year, the team included an option to compute generalized costs, which allows for the assessment of pricing policies and their impacts on freight traffic. In combination with travel times and distances, estimates of value of time are used to calculate generalized costs. The generalized cost is taken into consideration in the selection of the receivers of a tour, meaning that a receiver will have a greater chance of being served by a shipper that has lower generalized cost. The user has the ability to change the parameters of the generalized cost in the selection of the receivers served by a tour. The addition of the values of time as an input and the computation of the generalized cost broadens the spectrum of EEL initiatives that can be assessed by the BMS in comparison to using only travel times as impedance to construct tours. The team has worked on a case study for the Capital District, modeling more than 10,000 tours, and assigning over 44 thousand deliveries. Figure I.4-1 shows examples of four delivery tours modeled by the BMS-EEL.

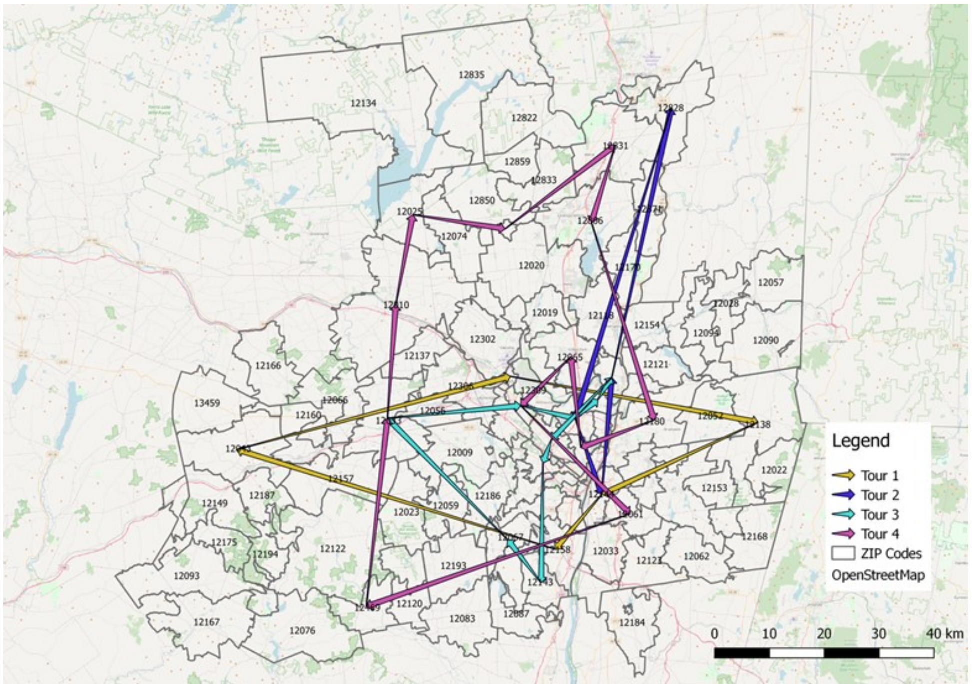

Figure I.4-1. Examples of tours simulated by the BMS-EEL

The team developed the case study to assess the impact of land use initiatives on vehicle miles traveled. It compared the development of logistical facilities in two different locations within the study area: Amsterdam, New York and Colonie, New York. Amsterdam is located in the west of the region, the outskirts of the area, where land cost is cheaper. In contrast, Colonie is in a central location, close to Albany, the urban core of the region. Land use decisions impact the efficiency of both upstream and downstream supply chains. Therefore, the objective of the case study is to quantify the impacts of locating logistical facilities in both locations on vehicle miles traveled, as a way to test land use policies that could be applied to the area. The team considered three scenarios: (1) locate a new Distribution Center (DC) in Amsterdam, (2) locate a new DC in Colonie, and (3) relocate an existing DC from Amsterdam to Colonie. Scenarios 1 and 2 consider an increment in demand induced by the addition of a DC; scenario 3 considers only the relocation of a current DC, with no influence on the demand of the base scenario. The demand is expressed in terms of number of freight trips attracted and produced by the DC. The team adopted average values correspondent to existing DCs; it is assumed that the DC in question produces 260 trips and attracts 160 trips. Table I.4-1 presents the increments and reductions of freight trips for Amsterdam and Colonie, relative to the base scenario.

Table I.4-1. Changes in Demand for the Three Modeled Scenarios

	Number of Freight Trips Produced		Number of Freight Trips Attracted	
Scenarios	**Amsterdam**	**Colonie**	**Amsterdam**	**Colonie**
1) Additional DC in Amsterdam	Base + 260	Base	Base + 160	Base
2) Additional DC in Colonie	Base	Base + 260	Base	Base + 160
3) Relocation of DC from Amsterdam to Colonie	Base - 260	Base + 260	Base - 160	Base + 160

The results (Figure I.4-2) show that locating the facility in Colonie, near the urban core, leads to fewer vehicle miles traveled by freight vehicles in the area, which would consequently lead to a more energy efficient freight system. A new DC in Amsterdam would generate an increment of 4.08% more miles on trips from large establishments to other large establishments, a larger increment than the 2.89% that would have been caused by locating the DC in Colonie. The relocation of an existing DC would cause the mileage of trips from gateways to large establishments to increase by 0.47%, however, due to the proximity of the DC to other establishments. In that scenario, mileage of trips from large to other large establishments would decrease by 1.02%, and from large to small establishments would decrease by 0.32%, generating fewer VMT in the system. These predicted freight traffic changes would be observed once the DC finishes construction and enters into operation (scenarios 1 and 2) or finishes the relocating process (scenario 3).

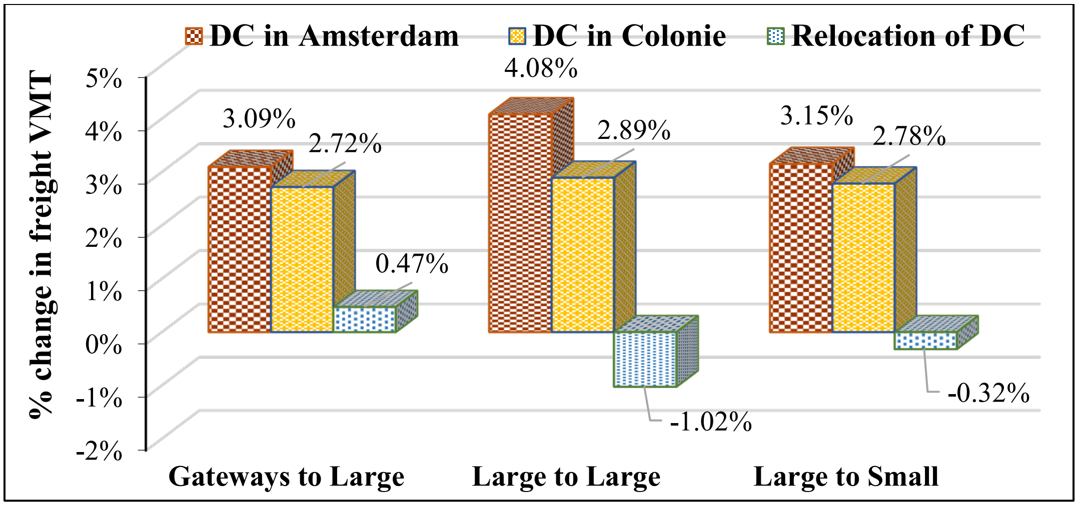

Figure I.4-2. Expected changes in VMT

Port Simulation

Ports are critical supply chain nodes that attract a high volume of freight vehicles which can generate congestion, and consequently affect the fuel consumption of all the vehicles in the surrounding areas. The team decided to investigate the influence of how the extension of port operating hours will affect the energy use and emissions at the system level. Though implemented by several seaports across the US, the effects of extended port operating hours on energy efficiency of the freight system remains unaddressed. Ports serve as major gateways for freight moving from vessels to the land side, where freight typically travels by truck. As a result, ports with a large volume of freight are generally regarded as the primary origins and destinations of freight vehicles. During a port's operating hours, a large number of trucks enter the port terminals, docks, and yards from local highways to load and unload cargo. As the freight demand increases, the dense freight vehicular traffic during the daytime peak hours can create severe congestion on highways, causing significant delays, and increasing energy consumption and emissions. Extending a port's operating hours can spread the freight vehicle distribution over a larger number of hours and suppress the truck demand during peak hours, to mitigate traffic congestion on the road network. This simulation aims to investigate how the extension of port operating hours will affect energy use and emissions at the system level.

The team did the simulation for the Port of Oakland, California, due to the availability of data. Even though this port is not located in the Albany-NYC corridor, the simulation can provide general insights on the effect of changing port operating hours on emissions and fuel consumption. The results can serve as an example of the effectiveness of these policies, which can then be applied to other ports in the US. During the last year, the team has been adjusting a microsimulation model of the I-880 corridor in Oakland, California. The effort involves three major components: (i) the development of time-dependent origin-destination (OD) demand tables in the simulation model to capture traffic variation over the day, (ii) a simulation of daily traffic flows after the port deploys different work schedules, and (iii) the analysis of the effect of different work schedule plans, including extended operating hours and staggered hours, on energy consumption.

In the first component, the team constructed the time-dependent OD demand tables in the simulation model based on the actual traffic data. To support the simulation and follow-up analyses, traffic demands must be recalibrated over four periods: morning peak period (6 a.m.–9 a.m.), midday (9 a.m.–3 p.m.), evening peak period (3 p.m.–6 p.m.), and nighttime (6 p.m.–6 a.m.), based on the definitions in McCormack and Hallenbeck (2006) [1]. One of the challenges the team encountered was that the OD demand table in the I-880 microsimulation model includes only two hours of the morning peak period (7 a.m.-9 a.m.). To address this challenge, the team sought to infer the OD demands of the other three time periods based on the available OD demand table and the traffic volume data collected from the loop detectors along I-880. The traffic flows on the I-880 corridor have been estimated against the real-world traffic volumes of I-880 from the Caltrans Performance Measurement System (PeMS) website (http://pems.dot.ca.gov/). The team selected five locations along the I-880, and obtained the traffic volume data from the five detectors with IDs: 401333, 400678, 400574, 400611, and 408756, respectively. We randomly picked 30 weekdays' volume data over one year (2019) and computed the average hourly volume data for the four periods, as shown in Figure I.4-3.

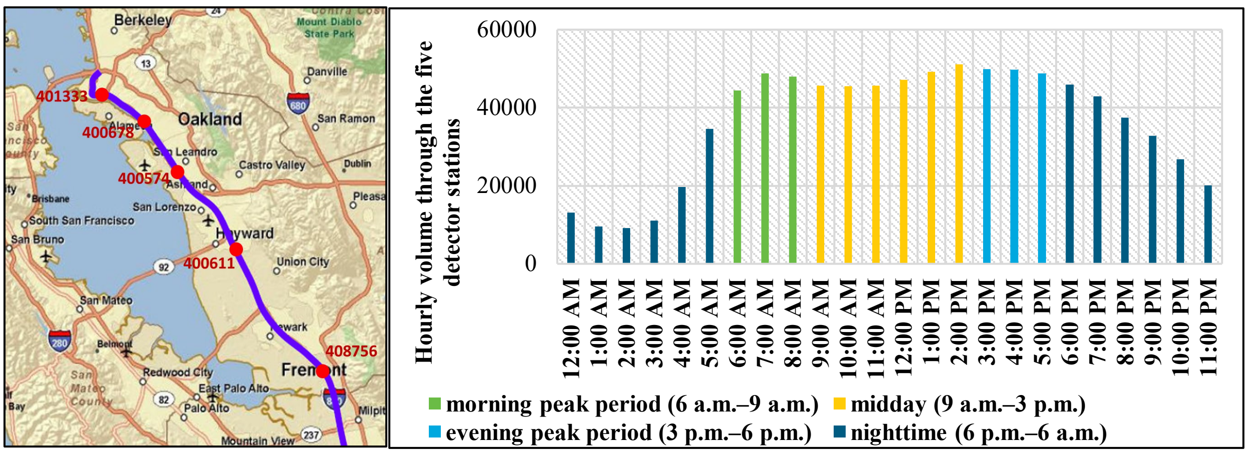

Figure I.4-3. Detector locations and average hourly volume

The team analyzed the simulation results of two scenarios with different port work hours. One scenario simulates the staggered work hours, representing a reservation-based port operation to suppress the truck demand during peak hours. The other scenario simulates an extension of the port hours by encouraging trucks to access the port during the off-hours, by staying open three hours longer or opening three hours earlier. Both simulation scenarios considered the traffic pattern changes in four periods of the day: morning peak (6 a.m.–9 a.m.), midday (9 a.m.–2 p.m.), evening peak (2 p.m.–6 p.m.), and nighttime (6 p.m.–6 a.m.) By comparing the simulation results of different scenarios, the team found that truck demand redistribution over a larger number of hours can reduce energy consumption (Figure I.4-4). To support more detailed analyses of how changes in port operating hours affect system energy consumption, the team improved the I-880 simulation model to develop more complicated port work hours scenarios.

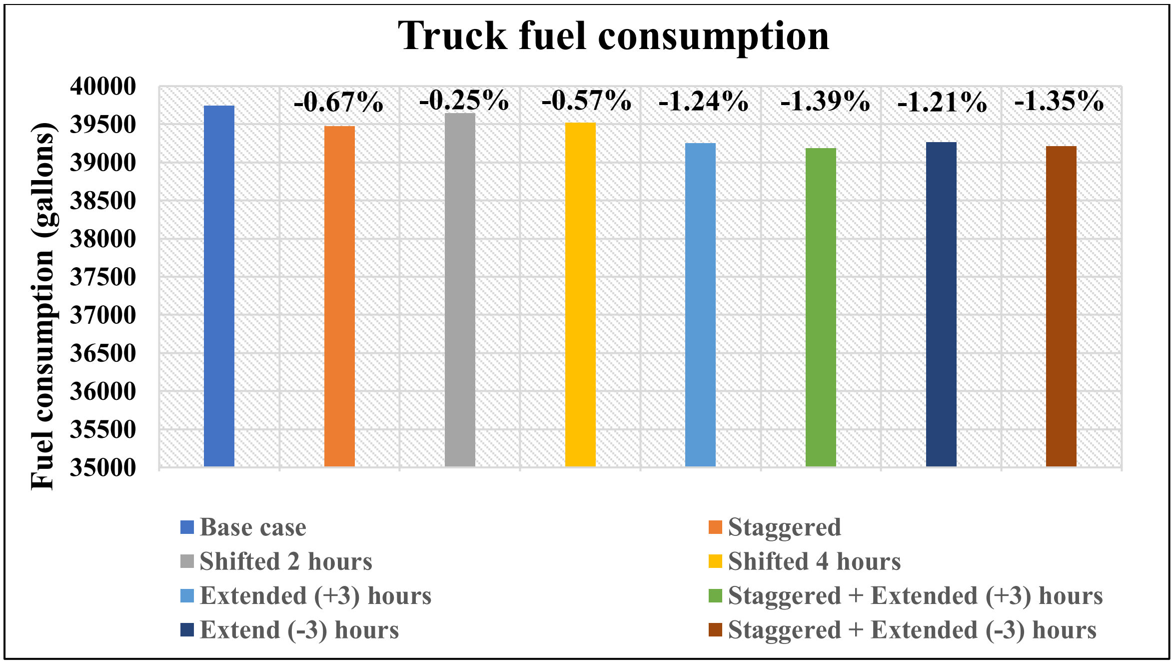

Figure I.4-4. Truck fuel consumption savings under different scenarios

Comparing these simulation scenarios shows that the combinations of extending work hours and staggered work hours achieve the highest energy savings by over 1.3%, indicating the potential benefit of integrating both types of changes into port operations. The main reason is that the spread truck demand reduces the traffic in the congested periods and helps reduce energy consumption. Both extended (+3) hours (extend working hours by 3 hours in the evening) and extended (-3) hours (extend working hours by 3 hours in the morning) reduce energy consumption by over 1.2%. This is because the longer operating hours help suppress the truck demands in a longer period and further reduce traffic congestion in the peak periods. When the work hours are shifted 4 hours earlier, there are energy savings because truck flows will be redistributed to the early morning period (4 a.m.–6 a.m.), which is an off-peak period. In all seven simulation scenarios, the scenario of shifted 2 hours has the least fuel consumption savings. The main reason is that the port operating hours still contain the morning peak, midday, and evening peak hours, which result in a minor impact on energy savings.

Baseline Conditions

This section presents the results of the estimation of baseline conditions of the Albany-NYC corridor. The main objective of this task is to develop a quantitative analysis of the current patterns of energy use, emissions, and delivery costs due to freight activity in the area.

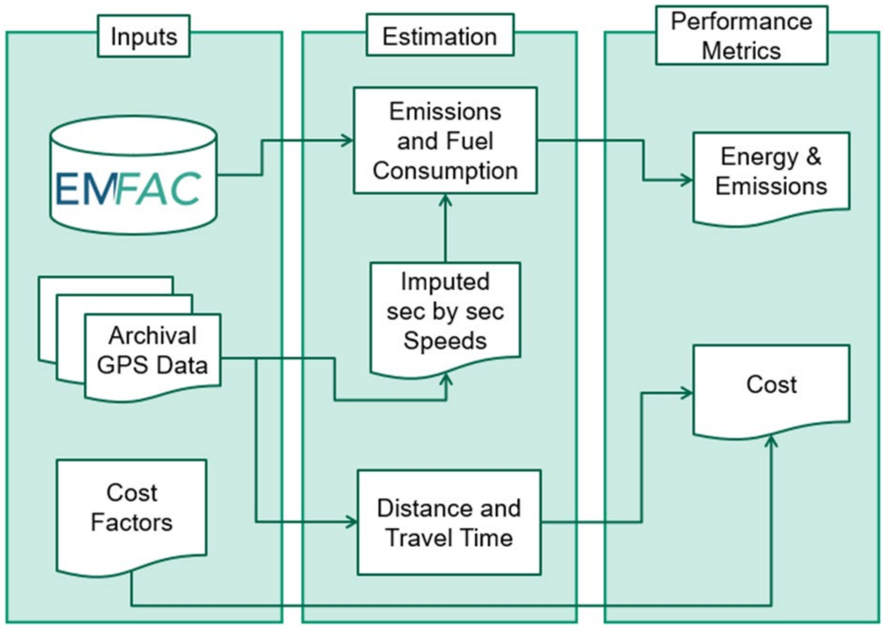

Figure I.4-5. Overview of baseline conditions characterization process

During the last year the team used archival Global Positioning System (GPS) data acquired from the American Transportation Research Institute (ATRI) to characterize baseline conditions of emissions and fuel consumption in the Albany-New York City corridor, including the metropolitan areas of NYC and Albany. The process is illustrated in Figure I.4-5. The main inputs are EMFAC emission factors (California Environmental Protection Agency 2016) [4], archival GPS data and freight transportation cost factors. These inputs are processed to estimate performance metrics that include fuel consumption, transportation costs and pollutants emitted, including reactive organic gases, total organic gases, carbon monoxide, carbon dioxide, oxides of nitrogen, and particulate matter. The results in Table I.1.2 show that fuel consumption is larger in the NYC metropolitan area (21.98 gallons/100 miles), the corridor comes in second (21 gallons/100 miles), and finally the Albany metropolitan area has the lowest fuel consumption (20.79 gallons/100 miles). Table I.4-2 also shows the emissions for the three geographical areas, which follow a compatible pattern with the fuel consumption results. Overall, the results obtained were expected due to the larger incidence of traffic congestion in NYC.

Table I.4-2. Fuel Consumption and Emissions Rates

Geographical Areas	Albany	Corridor	NYC
Vehicles	234	7,086	1,408
Data Points	805,133	25,663,927	5,315,390
Fuel Consumption (gallons/100 miles)	20.79	21.00	21.98
Emissions (g/mile) Pollutant: CO	0.29	0.43	0.50
Emissions (g/mile) Pollutant: CO2	2072.75	2296.49	2408.50
Emissions (g/mile) Pollutant: NOx	2.36	3.33	3.74
Emissions (g/mile) Pollutant: PM10	0.02	0.02	0.02
Emissions (g/mile) Pollutant: PM2.5	0.02	0.02	0.01
Emissions (g/mile) Pollutant: ROG	0.03	0.03	0.04
Emissions (g/mile) Pollutant:TOG	0.03	0.04	0.04

Behavioral Modeling: Internet Surveys

Collection of data from surveys of commercial establishments to gain insights on their acceptance of energy-efficient initiatives is a major component of behavioral modeling. The original plan was to implement surveys in the first semester of 2020. However, the COVID-19 pandemic created an unprecedented scenario of uncertainty, in which behavioral data collection was inadvisable. Companies were focused on adapting their supply chains to overcome the economic turmoil, and, understandably, to ensure the well-being of their collaborators. Any data collected during these difficult times would not represent business' behavior under "normal" conditions, and would affect the interpretation of the results for longer-term policy planning. Therefore, the team decided to postpone the implementation of surveys of commercial establishments until the pandemic situation is more controlled. As part of the new plan, the team requested and was granted a one year no-cost extension by DOE to allow the task of behavioral modeling to be done at an adequate moment.

Meanwhile, the team elaborated two questionnaires for the surveys, one for receivers and another one for shippers. The questionnaires ask their willingness to adopt energy-efficient initiatives (e.g., off-hour deliveries, freight consolidation), as well as aspects of their current operations. The team plans to launch the surveys in the Fall of 2021. In addition, the team conducted in-depth interviews with nine large traffic generators (LTG) such as port and rail line operators, to gain insight into the freight activity of businesses.

Conclusions

Even with the obstacles imposed by the COVID-19 crisis, the team has made substantial progress on the project and is on track to achieve the objectives. The team focused on the activities of tasks 1.3 "Develop draft tools and algorithms" of thrust 2; task 2.1 "Characterization of baseline conditions" and task 2.2 "Assess initiatives' effectiveness", both of thrust 3.

Regarding task 1.3 "develop draft tools and algorithms", the team produced a draft module of the BMS-EEL that models freight tours among commercial establishments. The team also conducted traffic simulations to analyze the effect of port working hours on traffic and fuel consumption; regarding task 2.1 the team got the necessary data and assessed baseline energy consumption and emissions for the Albany-NYC corridor. Lastly, as part of task 2.1 the team developed two questionnaires to assess the willingness to accept energy-efficient initiatives for receivers and shippers.

References

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[3] McCormack, E. and Hallenbeck, M.E., 2006. ITS devices used to collect truck data for performance benchmarks. Transportation research record, 1957(1), pp.43-50.

[4] California Environmental Protection Agency. (2016). "EMFAC Web Database." Retrieved July 11, 2016, from http://www.arb.ca.gov/emfac/.

I.5 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, Alabama Clean Fuels Coalition (ACFC), Palmetto State Clean Fuels Coalition, Southern Company, UPS, Waste Management, DeKalb County, City of Atlanta, and McAbee Trucking.

Alternative fuel vehicles can provide operational benefits, including lower fuel costs, lower or no emissions, and positive public image; however, the up-front capital costs are still often higher than gasoline and diesel vehicles, especially for all-electric vehicles and medium- and heavy-duty (M&HD) vehicles. Infrastructure is costly, and often times 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 range capabilities and 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 strategically identify best practices, policies, and procedures resulting from four major activities:

- Purchase of Alternative Fuel Vehicle (AFV) Fleets and Infrastructure
- Development of Alternative Fuel Corridors
- Development of Strategic AFV Fleet Partnerships
- Analysis of CNG Stations for Future Hydrogen Infrastructure Deployment.

Approach

The SEAFDP will purchase a mix of commercially available AFVs, including compressed natural gas (CNG), plug-in hybrid electric vehicles (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 provide data to 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
- 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 U.S and
- Develop a hydrogen infrastructure integration study based on lessons learned from the CNG station deployments and literature review.

Results

Deployment of AFV Fleets and Infrastructure

During fiscal year (FY) 2020, CTE conducted the following key activities towards the completion of this objective:

- Continued key performance indicator (KPI) reporting which estimated fuel economy, fueling requirements, and operating costs for each partner. This information helps project partners conceptualize the impacts of each vehicle and infrastructure deployment. Figure I.5-1 below represents the overall fuel and tailpipe emissions reductions to date.

Figure I.5-1. Overall fuel and tailpipe emissions reductions to date

- Conducted site visits to confirm delivery and deployment of 203 alternative fuel vehicles, as outlined in Table I.5-1
- Submitted quarterly reports to DOE
- Continued to coordinate vehicle and fueling infrastructure equipment purchase orders, vehicle deliveries, infrastructure installation, and data collection and reporting activities, as outlined below.

Table I.5-1. Fleet Partner Vehicles Delivered To-Date

SEAFDP Partner	Expected # of Vehicles	Vehicles Delivered to Date	Percentage of Vehicle Share Delivered	Percentage of Total Vehicle Share	Completion Date
City of Atlanta	58	6	10%	21%	4Q20
DeKalb County	32	32	100%	12%	N/A
McAbee Trucking	4	0	0%	1%	4Q20
UPS	150	150	100%	57%	3Q19
Waste Management – Hardeeville	25	15	60%	9%	1Q21
SEAFDP Project Total	269	203	75%	100%	1Q21

City of Atlanta

To date, the City of Atlanta has taken delivery of two (2) CNG refuse trucks, three (3) Nissan LEAFs, and one (1) Chevrolet Bolt. CTE held bi-weekly calls with the City of Atlanta throughout the period to develop a plan to complete the deployment of its alternative fuel fleet. However, competing priorities within the city departments, along with unforeseen events stemming from the global pandemic and civic unrest, made further procurement of vehicles and infrastructure unlikely in the near term. The project team also discussed the potential for development of a strategic full fleet transition plan for deployment of electric vehicles and infrastructure at the City of Atlanta as an alternative use of the funding. However, the City indicated that retrieving the relevant fleet data would be a major obstacle for the transition plan and did not move forward. The original agreement between CTE and the City of Atlanta was allowed to expire on September 30, 2020. The remaining funds originally intended for the City of Atlanta will be utilized in a replacement Request for Proposals (RFP) which is slated for development next quarter.

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.

McAbee Trucking

Freightliner completed production on McAbee’s four (4) Class 8 CNG trucks in September 2019. Once the trucks are paid for and enter service, the project team will begin to collect operating data to include in quarterly KPI reports. The data will be collected using telematics devices provided by Verizon.

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. It should be noted 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.

Waste Management – Hardeeville, South Carolina

In FY 2020, Waste Management took delivery of eight (8) CNG refuse trucks. To date, Waste Management has deployed a total of fifteen (15) refuse trucks in addition to the CNG refueling station. CTE and Waste

Management continued collecting operational data to support a 12-month KPI study. Waste Management expects delivery of the remaining ten (10) vehicles in FY 2021.

Clean Energy and Waste Management – Birmingham, Alabama

In FY 2020, Waste Management successfully deployed and commissioned a CNG refueling station in Birmingham, Alabama. CTE and Waste Management began collecting operational data to support a 12-month KPI study of fuel consumption.

Contract negotiations with Clean Energy Fuels continued throughout FY 2020. However, they could not identify a sufficient CNG vehicle market (consumers) to provide enough demand to justify investing in the station that was originally proposed. CTE and ACFC worked with them to increase efforts to reach out to potential fleets, and provide awareness and incentives to encourage CNG vehicle purchases. Clean Energy Fuels ultimately removed itself from the project in May 2020. CTE began preliminary discussions with the DOE program manager regarding partner replacement. CTE will be issuing a replacement RFP with the remaining funds, upon DOE approval.

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 the following:

- 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
- Helping facilitate local and regional partnerships between AFV market players throughout the supply chain to alleviate barriers for AFV adoption and
- Providing consultation for organizations as they enter the market.

The final scope of work is complete, subcontracts for the three Clean Cities coalitions are executed, and geographic information system (GIS) mapping activity is also complete. During the second quarter of 2020, CTE worked with the Clean Cities coalitions to release a survey to their coalition networks in the Southeastern region, which include utilities, vehicle providers, fueling station operators, consultants, nonprofit organizations and others. During the third quarter of 2020, CTE continued work on a case study draft that includes the results from vehicle network surveys. The project team intends to finalize and publish the case study during the fourth quarter of 2020.

Figure I.5-2 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.

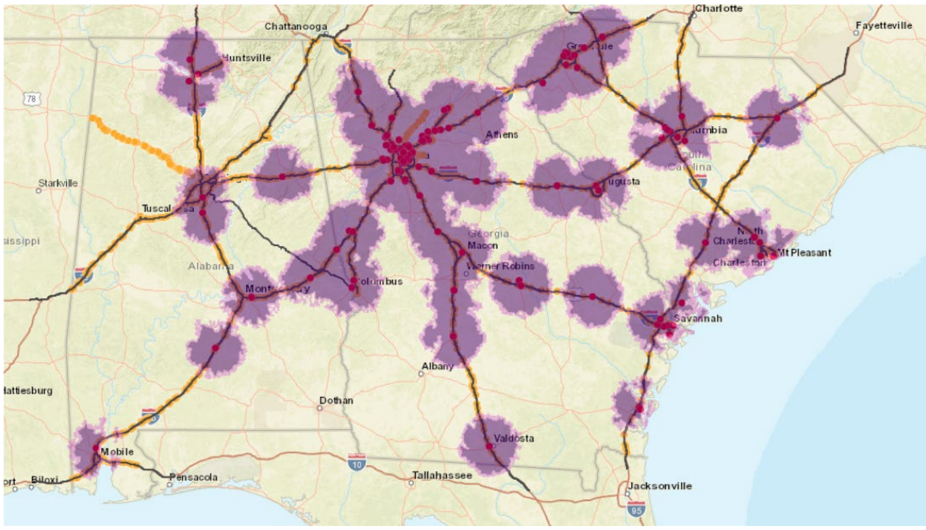

Figure I.5-2. EVSE drive-time area function

Conclusions

The three-year project began on October 1, 2017, and after a six-month no-cost extension, is currently 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. 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. Additionally, it was a challenge for project partners to send clear and consistent data in a timely manner.
- 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.
- Federal funding through the SEAFDP project was key to the deployment of two (2) CNG fueling stations and 203 CNG, hybrid-electric, and electric vehicles across Alabama, Georgia, and South Carolina. These vehicles and stations have reduced diesel consumption in the region by 260,125 gallons, which translates into a reduction of 2,919 tons of carbon dioxide emissions.

I.6 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, 2021
Project Funding: $4,204,158 DOE share: $1,967,229 Non-DOE share: $2,236,929

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 (Atlas) to consider, test, and evaluate different electric shared mobility interventions. Project teams in each city focus on one type of market intervention and analyze the impact on EV adoption and electric vehicle miles traveled (eVMT) by shared mobility services. The project's EV Shared Mobility Playbook highlights intervention results, providing guidance for other cities to electrify shared fleets across the country.

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 develops, tests, and aims to prove market-viable techniques to support EV adoption in shared mobility fleets. This is achieved through:

- Deploying new charging infrastructure (also known as electric vehicle supply equipment, or EVSE) and supportive pilot programming in several major 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 adoptions
- Developing an EV Shared Mobility Playbook, which summarizes the project's findings. It provides a comparative analysis of each city's program and identifies factors that affect the success of shared mobility electrification programs.

Approach

Each regional partner applies unique interventions to meet project objectives, in collaboration with local partners including Clean Cities coalitions and shared mobility providers, as described below and shown in Table I.6-1. Interventions are evaluated and compared throughout the course of the project and in the EV Shared Mobility Playbook.

Table I.6-1. Interventions by Regional Lead, Including Region, Actions, and Key Partners

Regional Lead	Region	Actions	Key Partners
Seattle Department of Transportation (SDOT)	Seattle, WA	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	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	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	Deploy EVs via collaboration with ride hail companies and local electric utility; conduct an outreach and marketing campaign developed with communications agencies in the area; create a Fair Financing Pilot to address lack of purchasing options for individuals with low income or poor credit; and conduct direct engagement with drivers to advance shared mobility in marginalized communities.	Uber, Portland General Electric, Brink Communications

Results

The shared mobility environment is rapidly evolving and has changed significantly since the launch of this project in October 2017. Fiscal Year (FY) 2020 brought further unexpected changes due to the COVID-19 outbreak which the World Health Organization declared a pandemic in March 2020. The pandemic and resulting actions to minimize its spread significantly altered the transportation landscape in urban areas, particularly the shared mobility market. For example, ride hail ridership in the Seattle area and EV charging station usage at Seattle City Light charging stations both declined at the onset of the COVID-19 pandemic. While partners were able to absorb COVID-19 impacts in FY2020 through project adjustments that did not impact overall deliverables, these impacts may pose significant challenges to future work.

In FY2020, 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 have been 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 listserv, webinars, and public presentations. New content added to the Shared Mobility Playbook in FY2020 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 to identify information gaps.

Documents published in FY2020:

- Assessment of EVs in TNC Fleets – This initial EV Fleet Assessment examines the number of EVs in transportation network company (TNC) fleets within each of the EV Shared Mobility project participating cities, and highlights the change and make-up of their fleets from January 2019 through June 2020. Preliminary results from the initial assessment are highlighted further under Task 3 – Operations to Facilitate EV Deployment.

- Project Living Case Studies – Atlas developed living case studies for each regional intervention that are updated throughout the course of the project. Each cast study outlines project partners, successes and challenges, and status of the project in that region. In FY2020 Atlas published the first iterations of its case studies for New York City, Seattle, and Denver, and the second iteration of its case study for Forth.

- Seattle Department of Transportation's EVSE Roadmap (Version 2) – The Seattle Department of Transportation (SDOT), in close collaboration with other City and external partners, developed this Electric Vehicle Supply Equipment (EVSE) Roadmap for Shared Mobility ("EVSE Roadmap") to support the transition to electrically-powered shared mobility services such as car share and ride hail services. Version 2 of SDOT's EVSE Roadmap is updated to reflect responses to project changes and lessons learned since the document was first released in November 2018. Those changes include refocusing partnerships and expanding beyond shared mobility hubs to look for potential EVSE locations in the Seattle area.

Tools developed in FY2020:

- The EV Shared Mobility Analysis Tool (FINAL) 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 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. In FY2020, consultancy Fehr & Peers performed minor updates for SDOT on the tool and its supporting documentation, to improve usability.

- Data dashboards - Atlas Public Policy integrated EVSE usage data from Seattle, Portland, and Denver into interactive data dashboards published in July 2020. The dashboards have the ability to be continually updated as new data become available. See Figure I.6-1 for a depiction of the data dashboard showing available EV charging station data in the Seattle region.

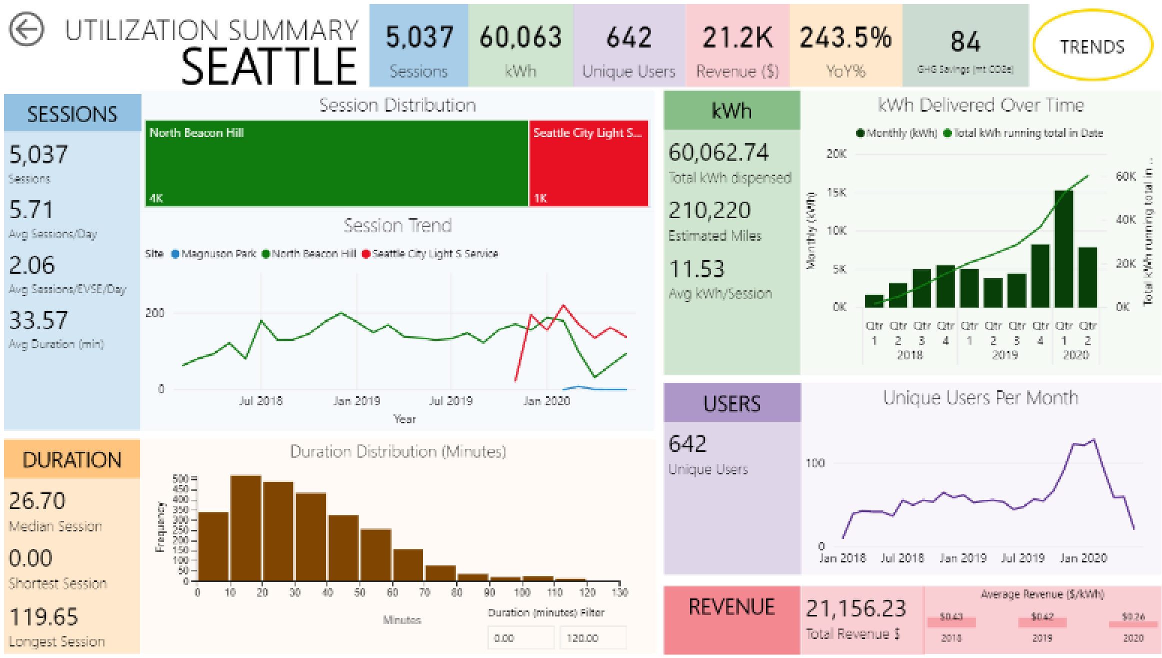

Figure I.6-1. Data dashboard for available Seattle area EVSE data from February 2018 - June 2020

Task 2 - EV Charging Station Deployment

The Cities of Denver, New York, and Seattle are deploying EVSE as a part of this project. In FY 2020, EVSE implementation is 59% complete, detailed further in Table I.6-2. Portland General Electric also contributes data from their Electric Avenue stations to the project's data dashboards, although these stations were not installed as a part of this project.

Table I.6-2. Implementation of Planned EV infrastructure as of September 30, 2020

Regional Lead	Planned # of Charging Stations	Sites Selected (Host Agreement Secured)	Siting Designs Developed	Permits Obtained	Construction in Progress	Charging Stations Ready for Public Use
Seattle Department of Transportation (SDOT)	7	7	6	6	6	4
City of New York (NYC)	10	4	4	4	4	0
City and County of Denver (Denver)	20	14	13	13	13	11
Total	37	25	23	23	23	15
% Implemented	59%					

All stations are Direct Current Fast Charging Stations, and pricing structures, ownership models, and locations vary across regions. For example, Seattle's EVSE are owned and managed by the municipal utility, Seattle City Light, and located on City property, including the public right-of-way and City-owned parking lots that are open to the public. In Denver, stations are owned and managed by EVgo (See Figure I.6-2). More data are needed to draw meaningful comparisons in usage across stations and regions. In the Seattle area, project funding is also available to support an EVSE Wayfinding Signage pilot. The first wayfinding signage was installed to support the EVSE in Seattle's Beacon Hill neighborhood (See Figure I.6-3).

Figure I.6-2. (Left) EVgo stations in a Denver, CO Whole Foods parking lot (Photo Credit: Michael Salisbury).

Figure I.6-3. (Right) Wayfinding signage for EVSE in Seattle's Beacon Hill neighborhood (Photo Credit: Shannon Walker).

Task 3 – Operations to Facilitate EV Deployment

Partners in all regions continued engaging with EV shared mobility providers, developing and/or conducting outreach and marketing activities, and supporting the EV Fleet Assessment, as feasible, in FY2020. Many planned Task 3 activities were postponed or adjusted due to COVID-19 social distancing restrictions. Some activities shifted to being online, over the phone, or through email listservs. Despite these unexpected changes, the project team made significant progress on Task 3 activities in FY2020, including:

- Forth hired Brand Definition to help design an exciting and accessible online campaign, which is occurring amidst COVID-19's restrictions on public events. Forth completed an Outreach Summary for this work, explaining how "Phase 3" outreach with Brand Definition builds upon previous outreach and marketing conducted as a part of this project, and Atlas posted it on the EV Shared Mobility website in June 2020. Forth developed a variety of materials for this campaign that will eventually include six podcast episodes including driver testimonials, short videos, and an infographic.

- Preliminary analysis of available data from the EV Fleet Assessment provided useful insights on fleet size and composition. For example, across each city, local TNC fleets are adopting an increasing number of EVs, despite some shorter periods of decline, and in both New York City and the greater Seattle area, Tesla was the most common EV model for registered for-hire drivers. See Figure I.6-4.

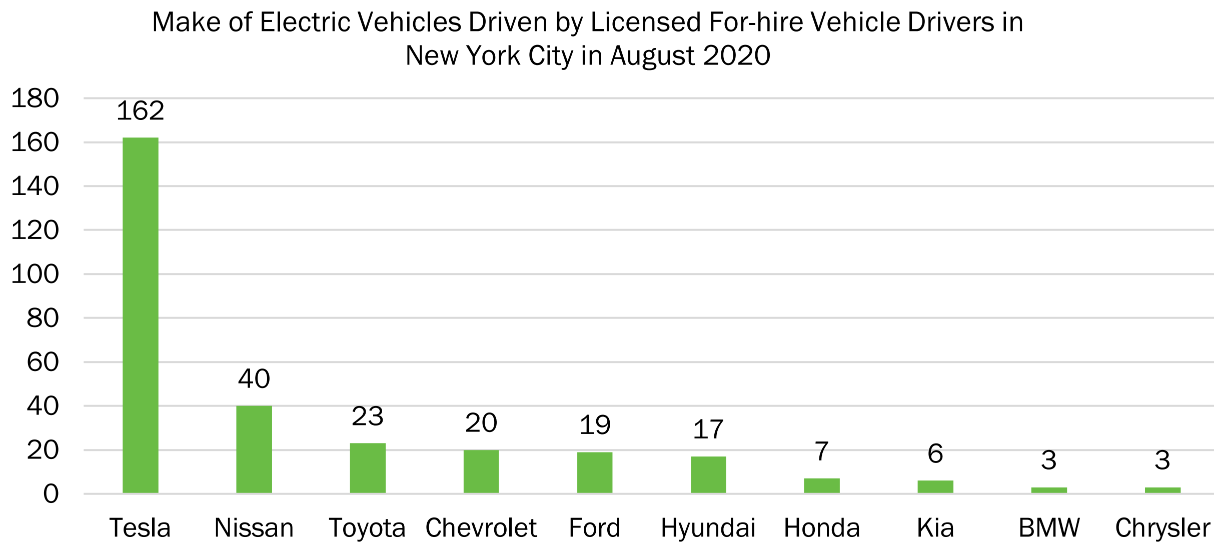

Figure I.6-4. Make of electric vehicles driven by licensed for-hire vehicle drivers in New York City in August 2020, from Atlas Public Policy analysis of data from the New York Taxi and Limousine Commission.

Conclusions

During FY2020, partners moved forward portions of the EV Shared Mobility Playbook (Task 1), EVSE Deployment (Task 2), and Operations to Facilitate EV Deployment (Task 3). Significant progress was made on planned interventions, as well as collecting and communicating the results of those interventions via the EV Shared Mobility Playbook.

Key Publications

Atlas Public Policy. 2020. "Assessment of EVs in TNC Fleets." http://evsharedmobility.org/resource/assessment-of-evs-in-tnc-fleets/.

Atlas Public Policy. 2020. "Denver Project Living Case Study 1.0." http://evsharedmobility.org/resource/denver-project-living-case-study/.

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

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I.7 Accelerating Alternative Fuel Adoption in Mid-America (Metropolitan Energy Center)

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Start Date: October 1, 2017 End Date: September 30, 2022
Project Funding: $7,630,417 DOE share: $3,803,793 Non-DOE share: $3,826,624

Project Introduction

The goal of this project is to expand the use of alternative fuels and fueling infrastructure in Kansas and Missouri. In addition to supporting new and expanded fleet adoptions of alternative fuels, the project team plans to increase access to alternative fuels along major travel corridors. There are significant gaps in alternative fueling infrastructure along the I-70, I-29, and US-400 corridors in Kansas. I-70 and I-29 are major shipping corridors, and US-400 is in the middle of the Beef Belt. Insufficient fueling infrastructure is inhibiting alternative fuel adoption throughout the Midwest. The project team continues to promote projects and education that support biodiesel, CNG, and electric vehicles (EVs).

Objectives

The project's objectives are to establish alternative fuel options with EV charging, biodiesel and compressed natural gas (CNG) corridors throughout the state of Kansas; expand access to gaseous fuels and EV 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 City of Kansas City, Missouri; Garden City, Kansas; El Dorado, Kansas; the Grain Valley School District in Missouri; Kansas City International Airport; University of Kansas; 24/7 Travel Stores, and DS Bus Lines (pending). DOE funding covers 45% of the allowable costs of purchasing alternative fuel vehicles and purchasing and installing refueling infrastructure; the remaining 55% is paid for by the grant subrecipients.

MEC's relationship management approach involves project coordinators working directly with assigned subrecipients as single points of contact and fostering a consultative relationship that allows us to connect subrecipients with resources and prospective vendors, thus generating public-private partnerships.

Using MEC's 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

COVID-19 – related shelter-in-place orders resulted in huge reductions in tax revenue for municipal agencies and reduced travel volume, which substantially impacted cash-on-hand for potential for-profit subrecipients that were considering public-access fueling projects on the corridors. While the pandemic impeded the speed with which many of the project partners were able to proceed, the project team was able to make a positive impact as we navigated through it. While the project team could have done more without the restrictions of COVID-19, we were able to adapt in many areas to meet the needs of our sub-recipients.

An additional challenge was the retirement of key personnel from two original partners, the Blue Springs School District (discussed below), and Stirk CNG. The new management at Stirk CNG was no longer interested in speculative CNG station installations, leading to the cancellation of their contract. Market forces also impacted the subproject managed by 25/7 Travel Stores. See more information below.

Grain Valley School District (GVSD): MEC submitted a draft Propane School Bus Fleet Case Study on the Grain Valley School District to DOE in September of 2020. The case study is interview style with Shawn Brady, Director of Transportation at GVSD. It highlights the district's real-world experiences integrating 21 propane buses into the fleet, and discusses how they worked with Clean Cities throughout the entire process.

Kansas City International (KCI) Airport: MEC staff is finalizing a deployment guide focused on the electrification of airport fleets. The goal of the guide is to help airports plan, deploy, and manage EVs in their fleets and future proof their infrastructure to ensure there is electrical capacity on site for future EV deployments. In addition to interviewing KCI Airport staff, reviewing case studies, and attending informational webinars, MEC interviewed project stakeholders, as well as alternative fuel stakeholders across the country, including fleet managers, utilities, representatives from EV bus manufacturers, Clean Cities Coordinators, telematics experts, and EV consultancies. The final draft will be submitted to DOE for review by the end of the year. The airport installed direct current fast charger (DCFC) stations in the fourth quarter of 2017, updated some CNG shuttles in the first quarter of 2019 and replaced other CNG vehicles with EVs in the third quarter of 2020.

The City of Kansas City, Missouri worked to install EVSE charging stations at its Neighborhood and Housing Services Department, off Blue Parkway. The charging stations are positioned and will be convenient to charge the department's electric fleet. Construction of the EVSE is still underway, but is nearly complete. See Figure I.7-1. Meanwhile, the City continues to replace aging diesel work trucks with CNG trucks, where budgeted.

Figure I.7-1. The City of Kansas City installed EVSE at its Neighborhood and Housing Services Department (Photo Credit: City of Kansas City)

24-7 Travel Stores operates 10 retail and truck stop fueling locations on I-70 and I-35 spurs in Kansas. Due to market forces suppressing interest in new CNG installations, and development partners having never signed an installation agreement, 24/7 Travel Stores elected to pursue DCFC and biodiesel in five or more stores, instead of installing two CNG stations as originally planned. MEC and DOE worked with them to finalize a new plan, culminating in the first biodiesel installation at one of their two Salina, Kansas locations. See Figure I.7-2. A small terminal on site feeds that station and provides truckloads of blended biodiesel fuel to five other 24-7 Travel Store locations in Salina, Abilene, Maple Hill, WaKeeney and Russell, Kansas. Originally planning to install CNG in western Kansas, the retailer is now planning to provide or install biodiesel and/or DCFC stations at nearly all of its sites.

Figure I.7-2. The 24-7 Travel Store in Salina, Kansas installed underground tanks for bio-diesel storage (Photo Credit: Tami Alexander)

Blue Springs School District (BSSD) had originally planned to add time-fill CNG stations to its school bus lot; however, the Superintendent and Assistant Superintendent for Operations of BSSD both retired, and new leadership was more focused on cost cutting, including within the pupil transportation department. Changing priorities for the district and an indefinite hold on new bus purchases meant that the district had to withdraw from the program. This withdrawal was formalized in the first quarter of 2020, with a letter of termination of the agreement between the MEC and the school district. MEC has now reassigned the funding originally slated for BSSD's fueling expansion to other projects described herein.

Kansas University (KU) Biodiesel Program is unique in that the university does not receive any funding from the project, but benefits from technical assistance and relationship facilitation. With the impact of the COVID-19 pandemic shutting down the KU campus, biodiesel production ground to a halt in March of 2020. MEC had reached an agreement to use biodiesel produced by the Chemical Engineering Department's biodiesel program to fuel Parks & Recreation equipment run by the City of Lawrence and gather data from that deployment. However, with production slowly coming back online in Q3, the revised plan is to use the fuel in KU fleet vehicles for now, since Parks & Recreation’s active season has ended until spring 2021. A Kansas Biodiesel conference is coming up in January 2021, a venue where the project team may make new decisions about timing and biodiesel blending volume.

New Project Selections: The City of Olathe and DS Bus Lines, which provides contract bus services to Olathe Public Schools and other area school districts, applied for funding through the project’s summer 2020 Request for Proposals. The City of Olathe, Kansas has been selected to join the project as a new subrecipient (pending DOE concurrence). Also pending DOE approval, the plan for DS Bus Lines is to buy used late-model

CNG buses and deploy them in Olathe, using the City's existing natural gas fueling facility. The City plans to purchase six solar-powered mobile charging stations (Figure I.7-3). These will be stationed in existing parking lots on City property. Two will be deployed at each of the three determined City locations. These charging stations will require no construction and will be open for public use at no charge. The City will also be purchasing five EV Chevy Bolts EVs for use in its fleet.

Figure I.7-3. City of Olathe, KS is preparing to install 6 EV mobile charging stations in coming months (Photo Credit: Beam)

Conclusions

Market conditions affecting fuel pricing and the global pandemic played havoc with the original project plan, contributing to major changes to, or cancellation of, half of the original projects. Efforts to revise the project's focus toward achievable and beneficial outcomes have taken a considerable amount of time over the last 18 months. The project's travel corridor focus has necessarily shifted from CNG at all target locations to biodiesel and DCFC, almost to the exclusion of CNG. MEC is seeing much more engagement with opportunities in 2020, since making the shift. We are also increasing electrification of municipal fleets, and are in the early stages of assisting the City of Olathe with mobile, solar electric charging stations. This innovation will surely bring local and regional attention to flexible electrification strategies. Being able to adapt to changing needs, we have seen more progress towards alternative fuels adoption. Even with the challenges of COVID-19, the project has gained some momentum that should carry into 2021 and the final 20 months of the project.

Lessons Learned:

- Fleet managers and drivers may be hesitant to try new technology, just as consumers are. Personal experience using a new technology can open their eyes to its benefits. This was demonstrated in the City of Kansas City, where drivers indicated they would never have considered purchasing an EV for themselves, prior to driving one on the job.

- Changes in administration and executive leadership can and do change project plans. The original partners at BSSD and Stirk CNG were strong supporters of clean fuels; with them no longer in these positions, the project lost its local advocates.

- COVID-19 certainly made an impact, and even though the number of cases started to significantly decrease, the negative effects are clearly long term. The pandemic caused supply chain and vehicle delivery delays. The disrupted schedules and impacted budgets will take on a new shape. It might be a few years to fully understand the impacts and paths forward for economic recovery, including for AFV investments. One observable impact is that climate change activists are having a much bigger impact on municipal planning and policy than previously, and there is a much greater interest in electrification, even when investment costs are higher.

I.8 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 (University of Washington)

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Start Date: October 1, 2018 End Date: December 31, 2021
Project Funding: $1,809,484 DOE share: $1,169,284 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, part of the Supply Chain Transportation and Logistics Center at the University of Washington, the Pacific Northwest National Laboratory, 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 developed integrated technologies and finalized the pilot test parameters. This involved finalizing the plan for placing sensory devices and common parcel locker systems on public and private property; issuing the request for proposals; selecting vendors; and gaining approvals necessary to execute the plan. The team also developed techniques to preprocess the data streams from the sensor devices, and began 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 executed the implementation plan, as follows:

- Oversaw installation of the in-road sensors, and collected and processed data
- Managed installation, marketing and operations of three common locker systems in the pilot test area
- Tested the prototype smart phone parking app with initial data stream, and
- Developed a truck parking behavior simulation model.

In Year 3, the project team will evaluate the impact of these tools and technologies on urban freight operations in the test area. The team 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

Key accomplishments of the project over the past fiscal year (January 1, 2020 through September 30, 2020) are summarized below, in terms of each project objective.

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

Achievement #1 – All sensors in place

The Seattle Department of Transportation and the Bellevue Transportation Department released Requests for Proposals for the procurement and deployment of parking occupancy sensors in the two case study areas. Seattle and Bellevue selected Fybr and Cleverciti Systems, respectively, as designated vendors. Parking occupancy sensors and respective gateways for data communications have been deployed and installed in the 10-block study area in Belltown, Seattle (see pictures in Figure I.8-1), and a one-block area in downtown Bellevue.

Figure I.8-1. Left: A gateway installed in Belltown, Seattle, that collects sensors' data and sends it to the cloud; Center: passenger load zone with sensors installed; Right: close-up photo of a sensor.

Achievement #2 – Parking application displaying real-time data

The Pacific Northwest National Laboratory developed and published an online application to display real time and predicted parking occupancy information for the test areas in Seattle and Bellevue. The first version of the application is currently available online at https://uwtechint.pnnl.gov/ and a beta version is currently being tested. Sensors in Bellevue and Seattle are streaming occupancy data.

Achievement #3 – Parking simulation model coded

A parking simulation model was developed to generate synthetic parking occupancy data. The data has been used to test an initial version of the online parking application and to derive a first parking occupancy prediction model.

Key Finding #1 – Commercial vehicles spend 28% of their time seeking parking.

The research team developed a methodology to estimate and analyze parking seeking behavior for commercial vehicles using Global Positioning System (GPS) data from commercial vehicle fleets. The team further collected GPS data from 3 commercial companies and implemented the developed method to estimate the time commercial vehicles spent looking for available parking in the study area. The results represent the first empirical estimate of parking seeking behavior in the scientific literature. [1]

Key Finding #2 – Drivers prefer early-block commercial vehicle load zones (CVLZs).

During Year 1, the research team performed ride-alongs with commercial vehicle drivers to learn about the delivery process and their parking behaviors. During each ride-along, observers collected quantitative data and performed interviews with drivers. In Year 2, the team analyzed the obtained data. These observations resulted in recommendations for how to modify commercial vehicle load zones to improve their utilization.

Key Finding #3 – Commercial drivers reorder deliveries and consolidate deliveries, when parking is scarce.

During Year 1 ride-alongs, the team also identified four different behaviors drivers adopt in response to the lack of available parking: cruising for parking, re-routing, unauthorized parking and walking.

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

Achievement #4 – All lockers installed and functioning

The project team successfully installed three common-carrier parcel lockers in the study area in Belltown, Seattle, in the following locations (see pictures in Figure I.8-2):

- Locker 1 - Royal Crest building: 2100 3rd Ave, Seattle, WA, 98121
- Locker 2 - Market Place Tower building: 2033 1st Ave, Seattle, WA, 98121
- Locker 3 - REEF public parking lot: 314 Bell St., Seattle, WA, 98121

Locker 1 is located indoors and is accessible only by tenants of the residential Royal Crest building. Locker 2 is located in a publicly available parking area under Market Place Tower, a building with a mix of commercial and residential floors. Locker 3 is located in an off-street REEF surface parking lot and can be accessed by anyone upon registration. All three lockers are currently operating. Two of the lockers are actively receiving deliveries from six major carriers (UPS, FedEx, USPS, Amazon, OnTrac and DHL)

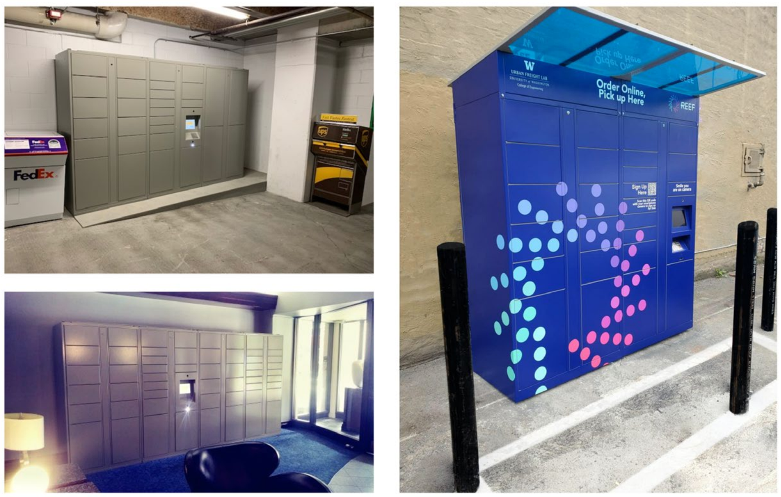

Figure I.8-2. Top left: locker installed inside the Market Place building; Bottom left: locker installed inside the Royal Crest building; Right: locker installed on the REEF public parking lot.

Achievement #5 – 43 customers enrolled after marketing campaign

The project team launched an integrated marketing campaign in August 2020 to align with the installation of Locker 3 located in the REEF parking lot. The campaign included a joint press release with the University of Washington and Parcel Pending; a targeted social media campaign; multiple rounds of direct mailers sent to over 5,000 Belltown residents and businesses; posting of flyers in public areas in nearby buildings; sidewalk sandwich board signage at the parking lot; and coverage in local media.

Achievement #6 – Locker use data streaming

The research team is monitoring, through field data collection and data received by the locker company, locker usage, both from the perspective of consumers and the delivery drivers' behaviors. The team designed a statistical framework to evaluate the impact of the introduction of common-carrier parcel lockers on several performance metrics, including commercial vehicles' dwell time, total time spent delivering in a building, and parking occupancy, among others. During Year 2, the project team is collecting baseline data for both buildings where the team installed a parcel locker, as well as control buildings without parcel lockers. Preliminary findings showed that the average dwell times before the introduction of common parcel lockers were 25.7 min (Locker 1), 35.4 minutes (Locker 2), and 27.9 minutes (Locker 3).

Objective 3 - Increase network and commercial firms' efficiency by increasing curb occupancy rates to roughly 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.

Achievement #7 - Baseline established

The project team collected the “Before” data on commercial vehicle activities in the surrounding curb spaces near the parcel locker locations. The team used the data to create a baseline for commercial vehicle parking behavior before installation of common-carrier parcel lockers and deployment of a parking information system for the study area.

Key Finding #1 – CVLZ occupancy rates have been reduced by COVID-19.

The average commercial vehicle occupancy was the highest for commercial vehicle load zones in the residential building (Royal Crest) at just over 40%.

Key Finding #2 – Drivers use CVLZ and pedestrian load zones fluidly for goods deliveries.

At the commercial building (Market Place Tower), average occupancy rates for commercial vehicle load zones and pedestrian load zones were nearly equal (about 30% and 25% respectively).

Key Finding #3 – Drivers choose load zones over paid parking areas.

Average occupancy for paid parking and no parking was below 5% for all locations.

Conclusions

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

1) It will provide new and deep knowledge of urban goods 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. 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 achievements to date are:

1. Parking occupancy sensor networks deployed in the two study areas in Seattle and Bellevue are currently streaming data, and will be tested and validated before the end of Year 2.
2. A parking occupancy information app has been developed, tested, released, and is receiving data from sensors.
3. The project team developed a parking occupancy prediction model on synthetic data that simulated parking behaviors that is currently being calibrated, as more data is collected by the sensor networks.
4. The team deployed three common parcel lockers in the study area in Seattle. The lockers are currently functional. One locker is operating at capacity with 157 users, while marketing campaigns are underway to increase the use of the other two.
5. The project team collected data at three locations with, and three locations without, parcel lockers to evaluate the impacts of lockers on delivery efficiency.

Key Publications

[1] Dalla Chiara, G. and Goodchild, A. “Do commercial vehicles cruise for parking? Empirical evidence from Seattle,” *Transport Policy* 97, (2020): 26-36.

[2] Dalla Chiara, G., Krutein, F.K., Ranjbari, A., Goodchild, A. (under review) “Commercial Vehicle Driver Behaviors and Decision Making: Lessons Learned from Urban Ridealongs”, *Transportation Research Record*

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- King County Metro Transit
- Puget Sound Clean Air Agency
- Seattle Department of Transportation
- Sound Transit
- UPS
- USPS

I.9 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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Start Date: October 1, 2018 End Date: December 31, 2021
Project Funding: $1,878,290 DOE share: $1,502,632 Non-DOE share: $375,658

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 64% of transportation energy use and 60% of transportation GHG emissions. [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 and sizes, carrying a range of payloads through various campaigns and altitudes. (See Figure I.9-1.) The team recorded testing environment conditions of wind speed, temperature, and other factors, and on-board sensors recorded voltage and current, Global Positioning System (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.9-1. 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.9-2.) The team also estimated the theoretical propulsion energy use of electric, rubber-tired 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.9-2. Automated ground delivery robot used for testing (Photo: CMU Team)

In Fiscal Year 2020, the team also used traffic data for the Pittsburgh, Pennsylvania region to develop a regional model of a goods delivery network, 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. The team collected high resolution data across a range of variables for each test, and with a subset of the data developed a generalizable model to estimate the energy use for a package delivery drone. The energy model was validated against the remaining measured energy data, as shown in Figure I.9-3. The team analyzed three distinct regimes of flight operations: ascent, cruising, and descent. 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.

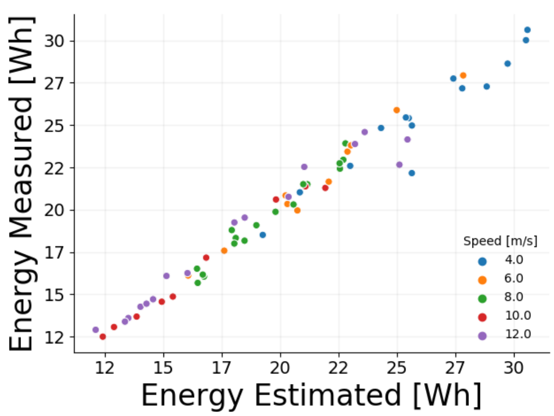

Figure I.9-3. Energy model developed was validated against measured data

The team also developed generalizable results of the energy use of a roundtrip package delivery drone to help understand efficient routing of drones to maximize energy productivity of delivery. Figure I.9-4 shows a model of cumulative energy consumption of a package delivery drone as a function of distance.

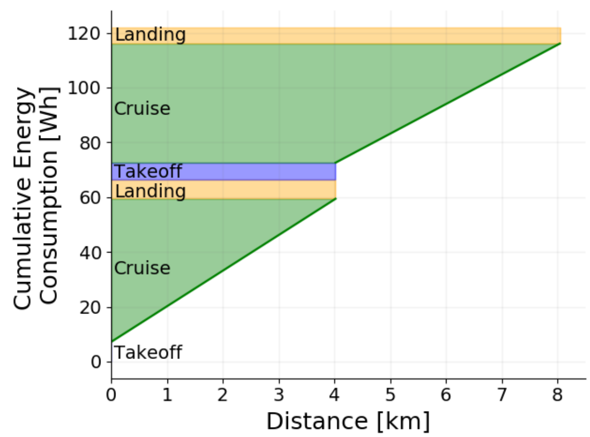

Figure I.9-4. Model of cumulative energy consumption of a package delivery drone as a function of distance.

Drone energy use is also affected by wind speeds, and high-quality estimates of wind fields can potentially improve the safety, energy use, and performance of package delivery drones operating in dense urban areas. Computational Fluid Dynamics simulations can help provide a wind field estimate, but their accuracy depends on the knowledge of the distribution of the inlet boundary conditions. The team developed a real-time methodology using a Particle Filter that utilizes wind measurements from an unmanned aerial vehicle (UAV) to solve the inverse problem of predicting the inlet conditions as the UAV traverses the flow field, as shown in Figure I.9-5. These results have implications for route planning and energy productivity of delivery.

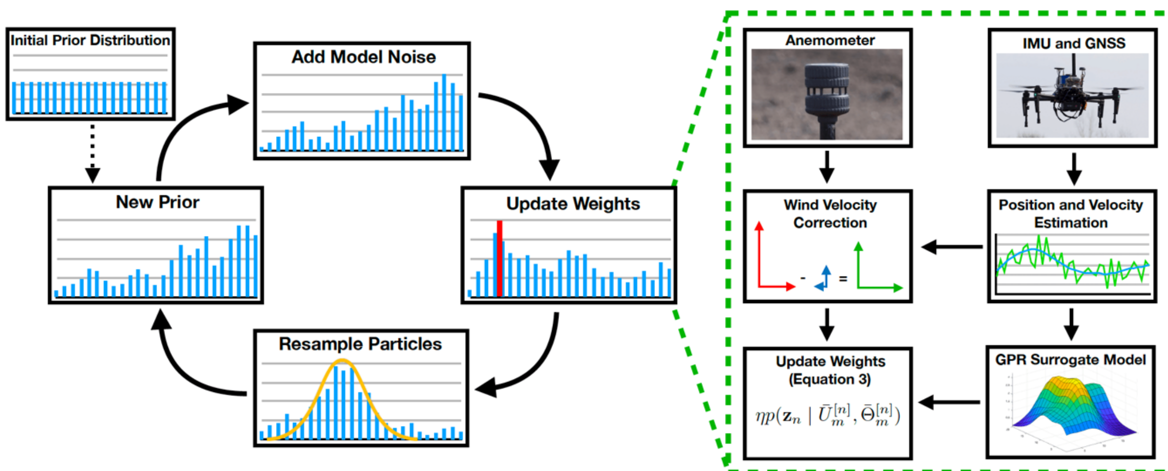

Figure I.9-5. Methodology using on-board drone wind energy measurements to estimate urban wind fields for path planning

The team published a dataset of drone energy use and submitted a data descriptor article, which is under review at *Nature Scientific Data.* The PI also discussed the approach and initial results at the SAE Government Industry Conference in January 2020 in Washington, D.C. in a presentation titled "Energy and Emissions Impacts of Automated Vehicles Under Uncertainty". Additional planned field tests in FY2020 have been limited due to COVID-19 restrictions. One of the research tasks proposed additional tests, but the team was able to conduct more than expected tests before COVID-19 and has sufficient data. The team will continue to evaluate the potential for additional field tests after COVID-19 restrictions subside. The team filed a patent in Q3 2019: "System, Method, and Computer Program Product for Transporting an Unmanned Vehicle", which relates generally to vehicle parking spaces and unmanned vehicles and systems, methods, and computer program products for transporting an unmanned vehicle and managing a plurality of vehicle parking spaces. In 2020, this patent is pending review/examination in the U.S. Patent Office's 3600 Technology Unit.

Conclusions

In FY 2020, the team made substantial progress on the project, and the results from this year align with achieving the project objectives. Publicly available real-world data on drone energy use is extremely limited, and the team published a novel vehicle energy use dataset. The team is continuing vehicle simulation of the pathways to improve the energy productivity of delivery on both the vehicles and the regional network with several variants and scenarios, which will provide insights to entrepreneurs, researchers, designers, and decision-makers. The team also delivered several conference presentations this year. In addition, two publications resulted from the project in the second year; one publication is under review, and the team is finalizing several more research publications for submittal to peer-reviewed journals.

Key Publications

Patrikar, J., Dugar, V., Arcot, V., Scherer, S. (2020). Real-time Motion Planning of Curvature Continuous Trajectories for Urban UAV Operations in Wind, International Conference on Unmanned Aircraft Systems (ICUAS). 10.1109/ICUAS48674.2020.9213837.

Patrikar, J. Moon, B., Scherer, S. (2020). Wind and the City: Utilizing UAV-Based In-Situ Measurements for Estimating Urban Wind Fields. International Conference on Intelligent Robots and Systems (IROS), October 25-29, 2020, Las Vegas, NV, USA.

Rodrigues, T. A., Patrikar, J., Choudhry, A., Feldgoise, J., Arcot, V., Gahlaut, A., Lau, S., Moon, B., Wagner, B., Matthews, H. S., Scherer, S., & Samaras, C. (2020). In-flight positional and energy use dataset of package delivery quadcopter UAVs. Under Review at *Nature Scientific Data*.

Rodrigues, T. A., Patrikar, J., Choudhry, A., Feldgoise, J., Arcot, V., Gahlaut, A., Lau, S., Moon, B., Wagner, B., Matthews, H. S., Scherer, S., & Samaras, C. (2020). Data Collected with Package Delivery Quadcopter Drone. https://doi.org/10.1184/R1/12683453.v2

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Acknowledgements

The team is grateful to DOE National Energy Technology Laboratory Project Manager Darren Stevenson for valuable feedback and advice that improved the project.

I.10 Integrating Microtransit with Public Transit for Coordinated Multi-Modal Movement of People (Ford Motor Company)

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Start Date: October 1, 2018 End Date: October 31, 2022
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 and financially viable. In this project, we focus 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. Two comprehensive field experiments that shuttle riders to and from major transit stations near Seattle, in collaboration with King County Metro, and in Northern Minneapolis, in collaboration with Metro Transit

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

Approach

Our project addresses one of the fundamental challenges for both transit agencies and customers with microtransit: the lack of connectivity between microtransit and mainline transit services. Transit agencies around the country are launching microtransit pilot programs with the intention of helping riders to better connect with their mainline bus and rail services [1-3]. However, agencies cannot be sure these new services are complementing existing transit systems and not competing with them. To address this issue, we are developing a routing and dispatch algorithm that will optimize the system for maximizing ridership under specific operational and behavioral constraints (e.g., not serving passengers with transit alternatives and limiting passenger detours). Not only will such an algorithm help ensure better connectivity between microtransit and mainline transit services, it will also improve user experience for riders and potential riders. To develop such an algorithm that is robust and broadly applicable, we have organized into three major workstreams.

In our first workstream, we have dedicated several tasks to algorithm development, broadly segmented into simulation and survey tasks. Through the simulation, we are developing demand models specific to our pilot program launch locations in both the Seattle and Minneapolis areas. These models will test the algorithm against a range of fleet operations alternatives to help our transit agency partners plan for the pilots, while also ensuring algorithm functionality. We are also conducting a survey to understand user preferences and to calibrate the simulation modeling. For our next workstream, we will demonstrate the algorithm in two real-word pilot programs, using dynamic microtransit software from TransLoc Inc., a Ford-owned subsidiary: a representative Midwest city (Minneapolis, in conjunction with Metro Transit) and a representative coastal city (Seattle, in conjunction with King County Metro). Our approach includes a final workstream to conduct a cost-benefit analysis of the microtransit pilots. We will begin that workstream in the upcoming year and will conclude it in the final year.

Results

The first workstream of algorithm development, including simulation modeling and survey deployment, drove key results for this year's Annual Progress Report.

Simulation Modeling

In collaboration with King County Metro, Cornell University and Ford simulated a first-mile/last-mile service for the Kent Valley, connecting the nearby industrial and residential communities to the rail and bus Kent Station. We report simulation results for eight service design scenarios across two service areas (shown in Figure I.10-1) and seven potential demand levels. For most scenarios, we required that all passengers served wait a maximum of 30 minutes, and we capped the total delay, i.e., the extra time taken to pick up additional passengers compared to an immediate taxi ride, at 30 minutes.

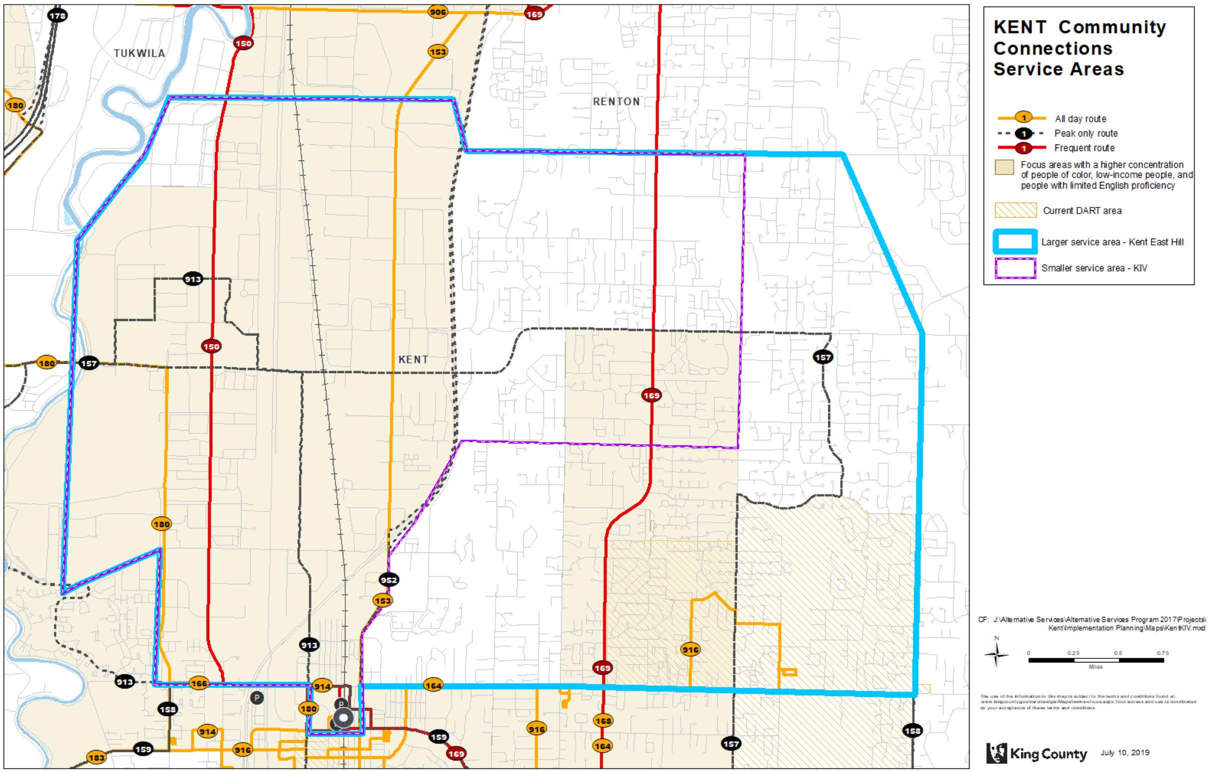

Figure I.10-1. Service area alternatives (in blue and purple outline, with the purple and blue lines converging in the west) for King County Metro service area

Overall, the scenarios with more vehicles demonstrated better performance, as expected. The scenario with the most vehicles produced the highest daily ridership, and the highest number of boardings per hour. These vehicles also reached the highest occupancy. While the larger fleets provided more trips to more people overall, the smaller fleets made better use of their more limited resources, with each vehicle having a higher daily ridership. Figure I.10-2 demonstrates these patterns by illustrating the percent served in each scenario for the small service area. The uppermost red line shows that in the small service area, the largest fleet can serve all customers even in the highest demand scenario simulated. Service quality tapers as the fleet loses vehicles, with two vehicles providing a poor level of service in medium to high levels of demand. These trends are even more pronounced in the large service area.

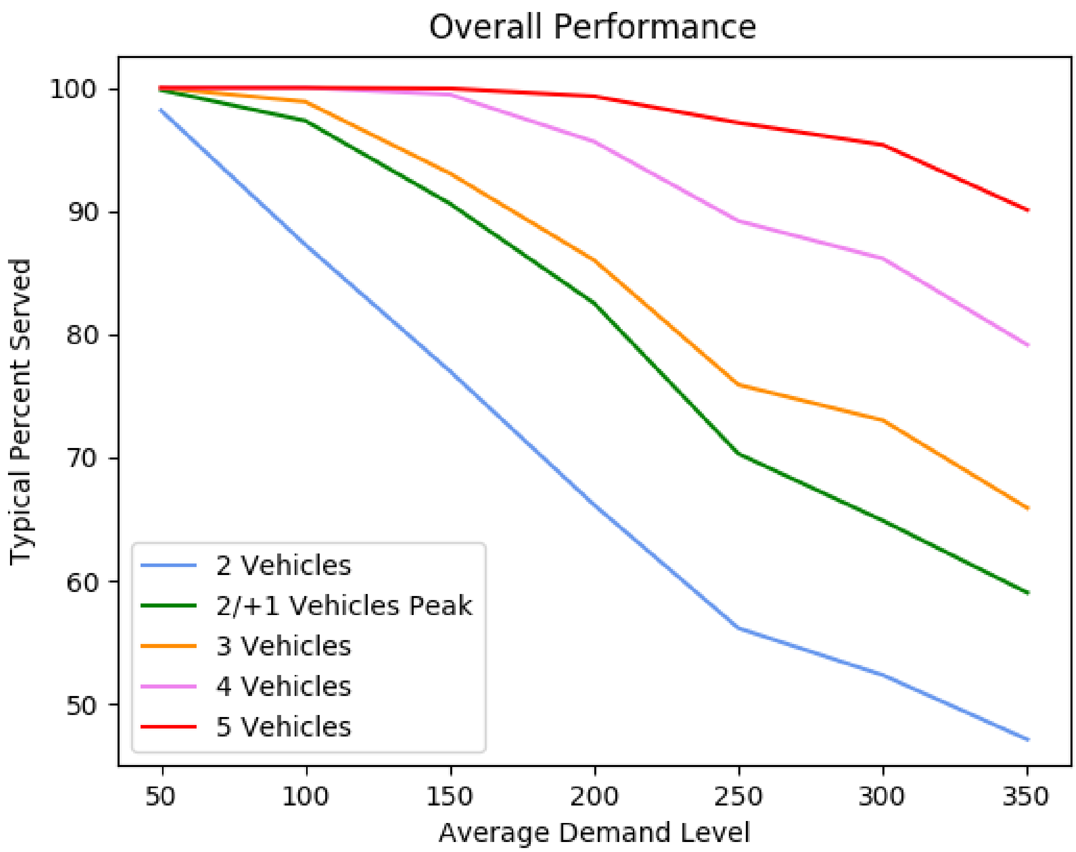

Figure I.10-2. Demand served by demand level, fleet size

In addition to testing the algorithm and ensuring technical connectivity between transit modes, these simulations are useful for the pilot planning teams at King County Metro, Ford, and TransLoc. The results help set expectations regarding pilot performance while also providing planners with the tools to make more data-backed decisions, which is particularly important given the relative novelty of this service.

The team is producing similar simulations for Metro Transit in Minneapolis.

Survey Deployment

To understand interest in microtransit while also determining the importance of various service quality parameters, we surveyed 2,399 residents in four representative metropolitan areas across the United States. We distributed the stated preference survey to participants via the online survey platform Qualtrics. All respondents were 18 years of age or older, regular commuters, and lived within 5 miles of a mass transit station. The sample also included gender quotas that enforced parity. The survey asked respondents to report various commute characteristics, such as commute mode and home and work locations. Then, we gauged participant interest in microtransit, followed by a series of hypothetical microtransit service scenarios. Before concluding the survey with a series of demographic and socioeconomic questions, we added several questions seeking to understand how the COVID-19 pandemic has shaped respondent propensity to use shared mobility services, among other impacts. Table I.10-1 shows some key descriptive statistics regarding demographics, socioeconomic characteristics, commute profile, and interest in microtransit.

Table I.10-1. Key High-level Results

	Miami	Minneapolis	Seattle	Washington DC
Respondents	600	600	599	600
Median age	35	37	36	36
Household income above $150,000 per year	16%	14%	20%	26%
Employed full-time	67%	63%	65%	71%
Daily car commuters	74%	75%	61%	54%
Daily transit commuters	5%	9%	15%	24%
Daily carpool commuters	3%	3%	4%	3%
Microtransit interest (extremely or very interested)	50%	20%	37%	27%
Percent of times microtransit selected in the scenarios	45%	23%	37%	32%

The survey investigated a number of service quality parameters. Most critically, the survey included a discrete choice experiment to determine value of time under various conditions. We found that the average values of time for respondents were $16.10 an hour for in-vehicle time and $38.70 an hour for access time (walking and waiting time). Generally, results follow a 1:2:3 trend for values of in-vehicle, waiting, and walking time with the in-vehicle value of time being close to the wage rate in these cities. Additionally, Figure I.10-3 shows the importance respondents ascribed to various service quality parameters.

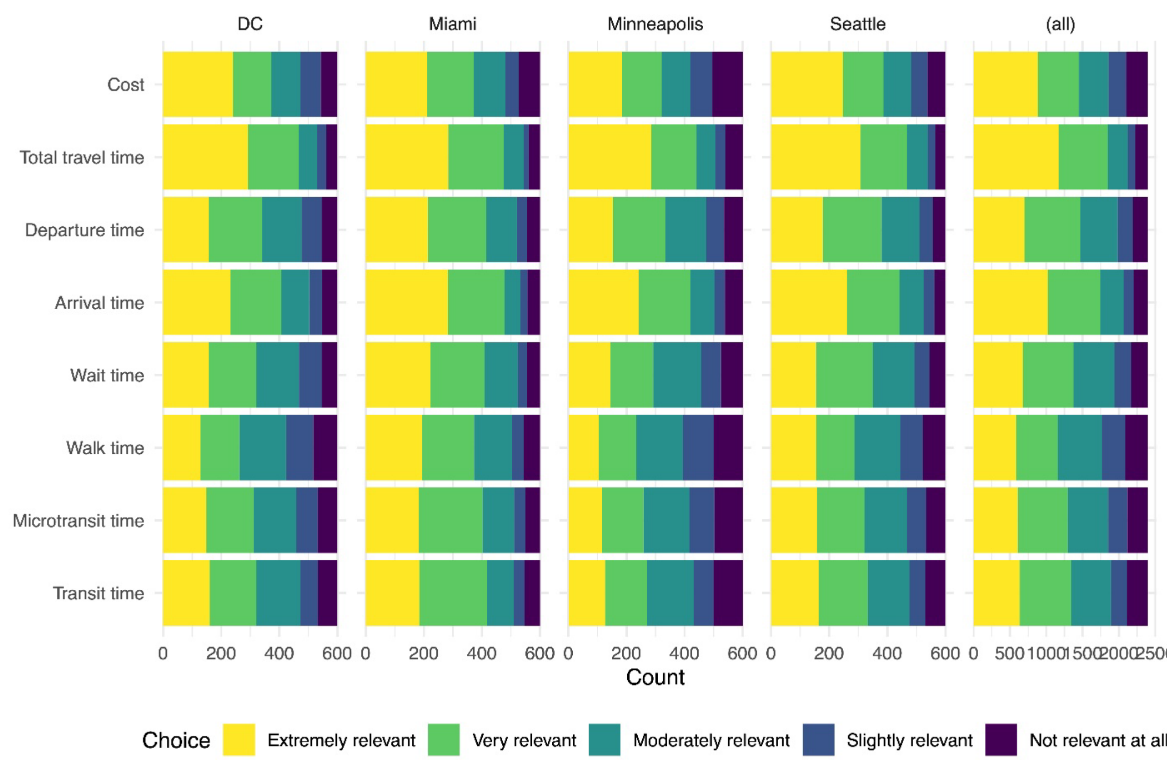

Figure I.10-3. Stated importance of attributes

These findings will contribute to the overall project in numerous ways. First, the value of time figures will be integrated into the simulations to guide algorithm development. Second, the cities are applying many of these findings to service planning of the pilot programs. Third, many of the findings will help guide the evaluation efforts of the cities as well as the cost-benefit analysis workstream of the overall project.

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I.11 Transportation Energy Analytics Dashboard (TEAD) (Center for Advanced Transportation Technology Laboratory and National Renewable Energy Laboratory)

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Start Date: October 1, 2018 End Date: December 31, 2020
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 research and development 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.

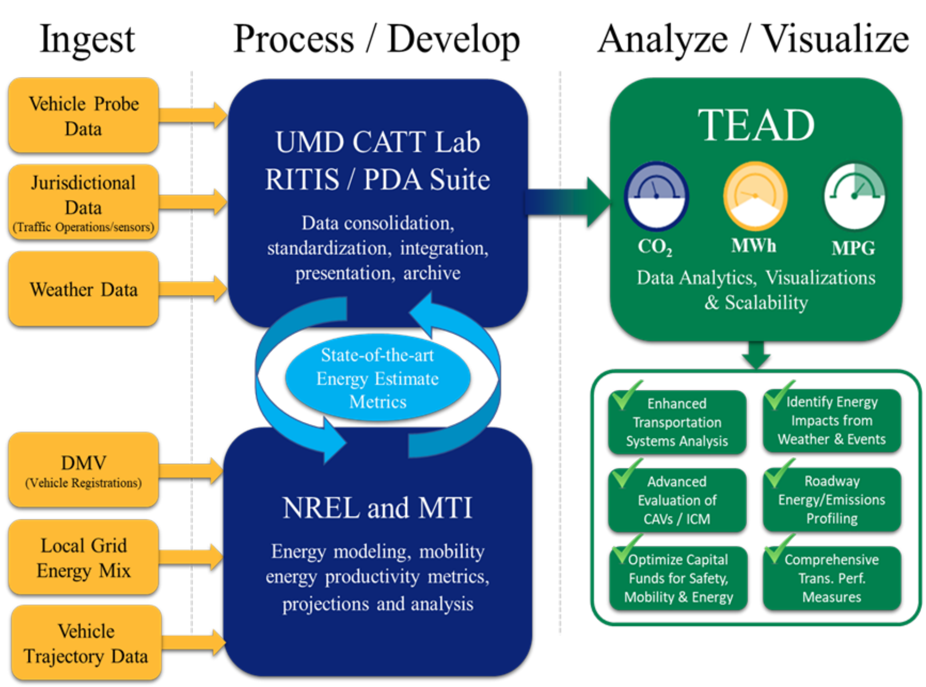

Figure I.11-1. Transportation Energy Analytics Dashboard (TEAD) dataflow framework

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.11-1 shows a conceptual information flow diagram of the TEAD framework.

TEAD is driven by two sustainability models. The first model is the Route Energy Prediction Model (RouteE) developed by NREL that provides estimates on vehicular energy use for real-time and historical applications. The framework of the RouteE model is presented in Figure I.11-2.

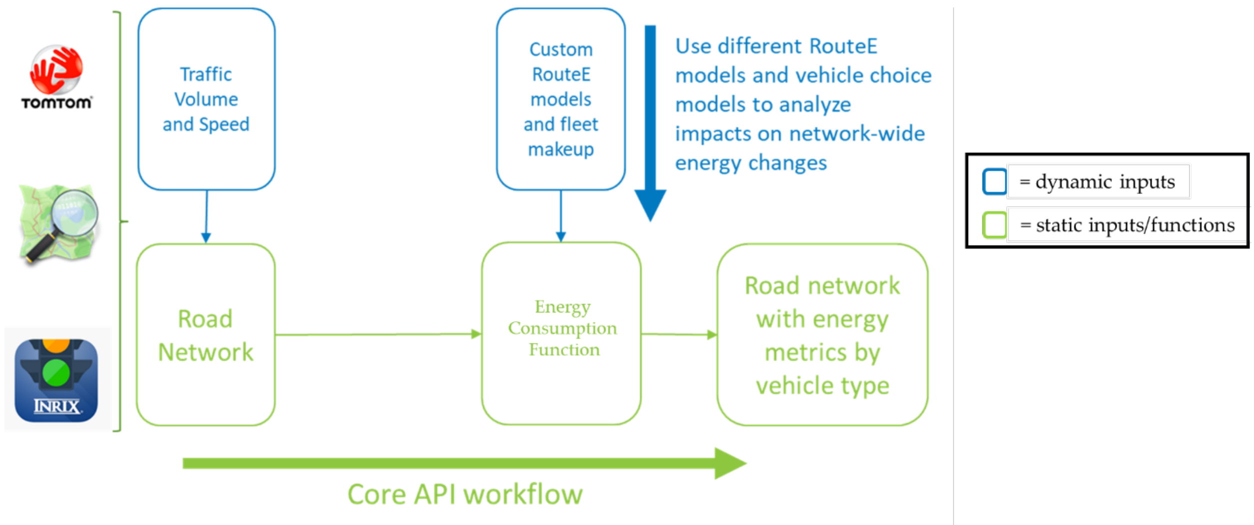

Figure I.11-2. RouteE model framework

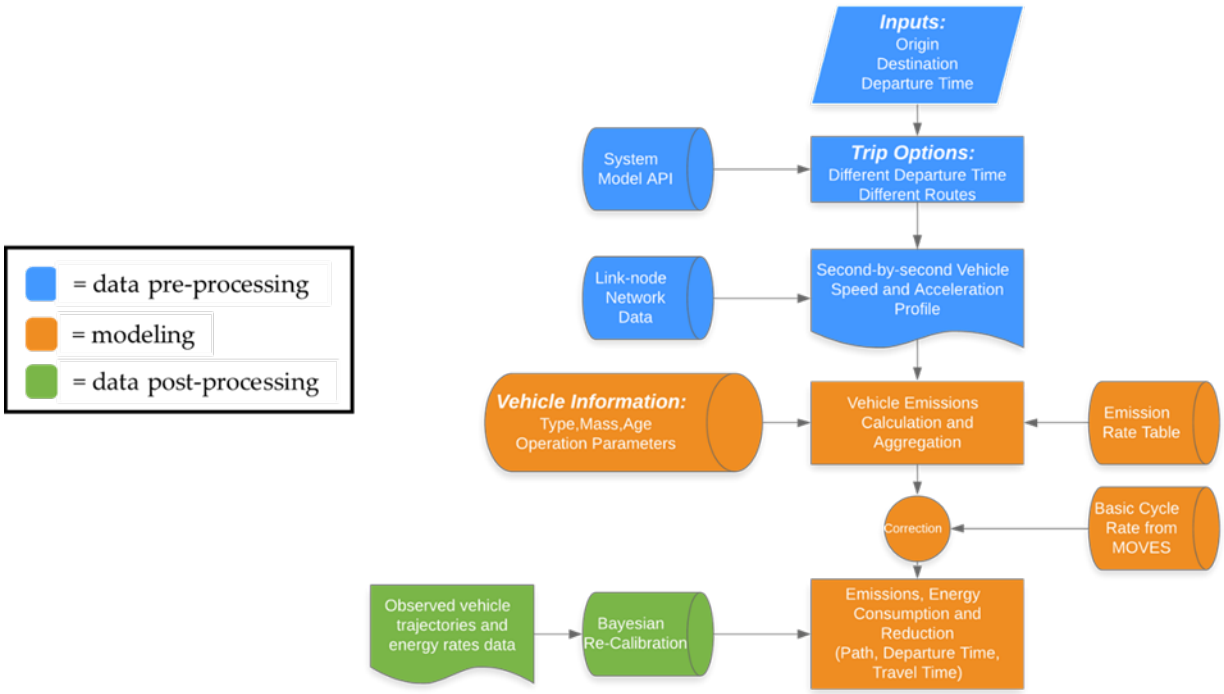

Figure I.11-3. MTI Bayesian model framework

The second model is a Bayesian Model developed by the Maryland Transportation Institute (MTI) that was derived from the EPA's MOVES model. The MTI Bayesian model is capable of estimating energy use, carbon dioxide (CO2), nitrogen oxides (NOX), particulate matter (PM), volatile organic compounds (VOC), and PM2.5-NOX precursor emissions for predictive, real-time, and historical applications. The framework of the MTI Bayesian model is presented in Figure I.11-3.

Results

A critical task in this project was a benefits analysis to show the merits of the proposed TEAD methodologies in relation to legacy sustainability estimation methods (i.e., EPA MOVES). To do so, the benefits analysis assessed modeling accuracy, computational efficiency, and automation of output metrics and visualizations.

For the modeling accuracy analysis, the project team used fuel consumption data from field-deployed vehicles equipped with OBD data records to assess the modeling accuracy at the individual vehicle level. Figure I.11-4 shows the results of the validation for both the RouteE (left, error rate of ~9%) and MTI Bayesian (right, error rate of ~10%) models.

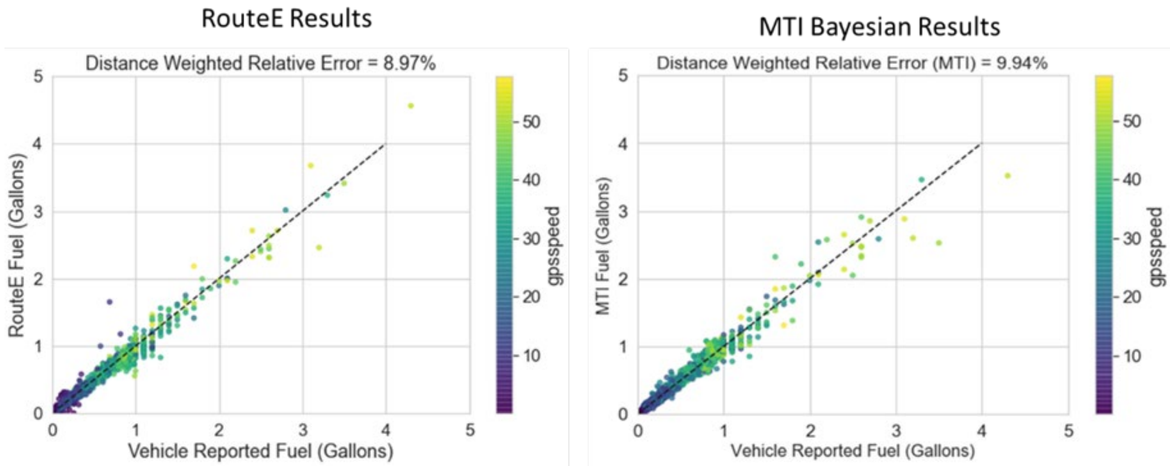

Figure I.11-4. Model calibration results

For the computational efficiency analysis, the project team compared the time compute network-level energy use and emissions estimates under the TEAD methodology to the legacy MOVES model. Here, a typical full day of traffic in Montgomery County, Maryland was modeled to compare the computation times between the three models. The results of this analysis are summarized in Table I.11-1 and show the significant improvements provided by both of the TEAD models.

Table I.11-1. Computational Efficiency Results

	MOVES Model	RouteE Model	MOVES-Based Bayesian Model
Average Computing Time (seconds)	101145	30.62	34.66
Longest Computing Time (seconds)	100757	31.78	34.95
Shortest Computing Time (seconds)	102667	30.06	34.02

The last component of the benefits analysis was the qualitative assessment of the automation of output metrics and visualizations. While the MOVES model provides a rich and robust series of output files, additional steps are typically needed to convert these files into metrics and visualizations to support data-driven decision support. Recognizing the opportunity to advance the automation of this process, TEAD was designed to generate such metrics and visualizations with a few clicks of a mouse. The process to create metrics and visualizations is summarized in Figure I.11-5.

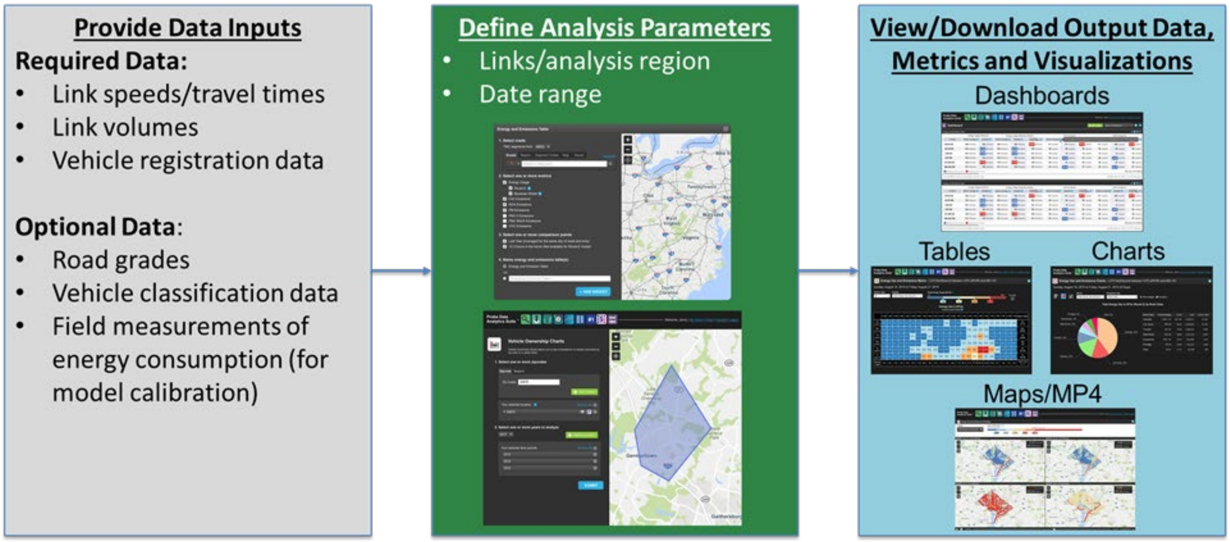

Figure I.11-5. TEAD process to generate metrics and visualizations

Conclusions

The results of the benefits analysis show that the TEAD methods meet the project objectives of providing a real-time, predictive, and historical analysis tool that automates the process of roadway sustainability analysis, without compromising estimation accuracy. As the project draws to a conclusion in December 2020, the online TEAD tool will be made available to our partner agencies, MORPC and MWCOG, via Regional Integrated Transportation Information System (RITIS). Once launched, real-world use cases will be documented to demonstrate the applications of the TEAD tools in supporting data-driven sustainability decision support.

I.12 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 $179 billion in 2017—according to the 2019 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 registrations), 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, was 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 require 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 [1]. 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 [2]. 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

This research results in a data-driven modeling framework for simulating all vehicular trips in large-scale networks. In particular, we use this model to establish a simulation platform for two regional networks: Southwestern Pennsylvania region and Philadelphia region, modeling 1.2 million and 2.5 million car/truck trips during peak hours, respectively. In those simulation processes, each individual car or truck trip is modeled in high granularity, from its respective origin location, along a specific roadway route, all the way to its destination location, second by second. The main hurdles we address in this modeling process are:

1. Using multi-source high-granular data to infer vehicular trips to replicate the actual transportation system performance and travel behavior. Those data sets include traffic counts, speed, weather, incidents, vehicle registration, parking, emissions and vehicle trajectories;

2. Mitigating computational complexity in a large-scale network through developing a machine-learning based algorithm to improve computational efficiency and developing parallel computing techniques for multi-core CPUs or Graphics Processing Units (GPUs). As a result, the large-scale network simulations are able to approach all those observations and can be completed in 5-10 minutes on a regular personal computer. We will continue to improve the accuracy and efficiency by deploying this model in DOE HPC framework in the next budget period.

We also improved the accuracy of the model outputs. The main task was to estimate high-granular emissions and energy consumption by individual cars and trucks through implementing MOVES Lite model [3]. MOVES (and MOVES Lite) model categorizes vehicles into different operating modes by the vehicle specific power (VSP), and assigns an emission factor to each class of vehicles in each operating mode. We ran the full dynamic network simulation with the updated emission models on the Pittsburgh and Philadelphia regional networks. Figure I.12.1 shows the roadway network of the Pittsburgh region as one of our experiments.

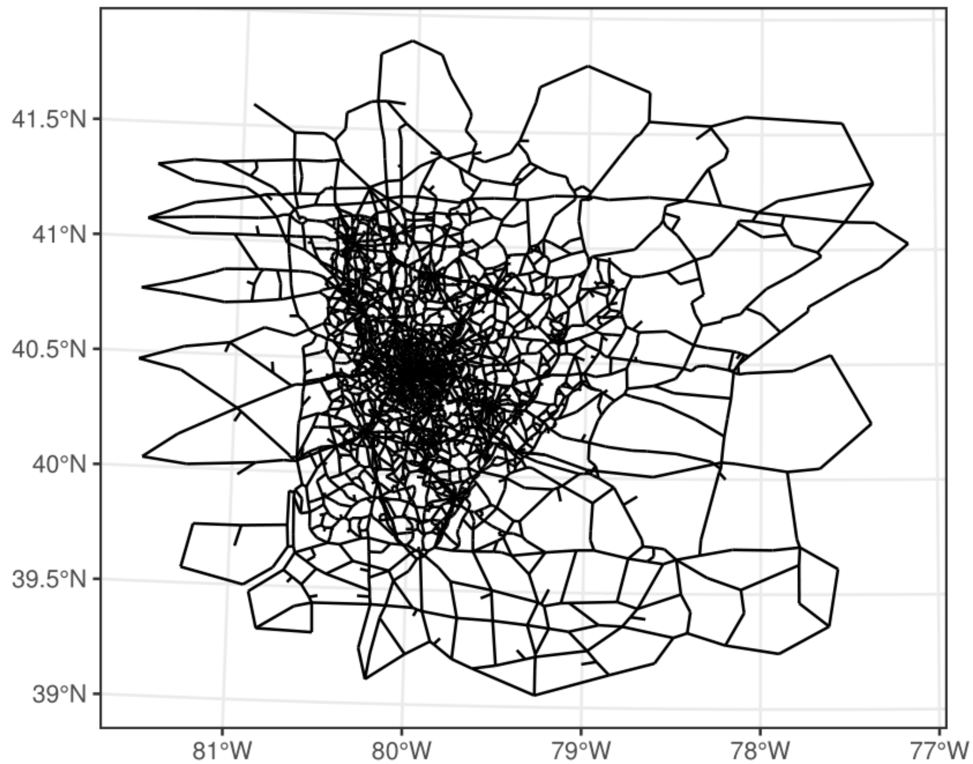
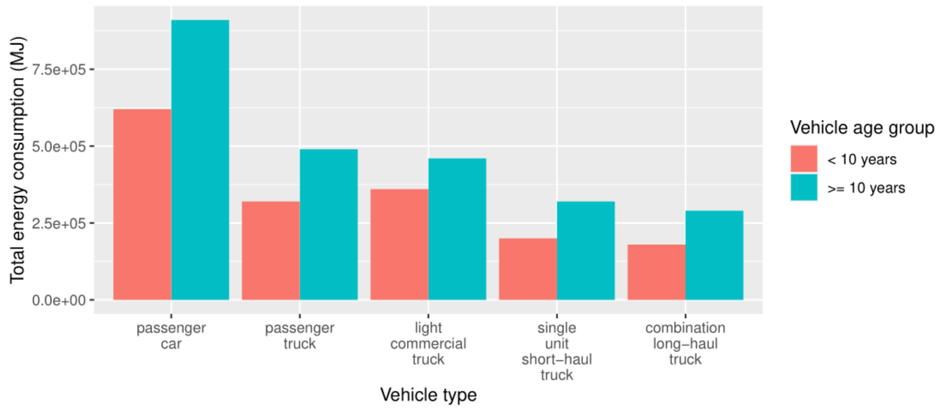
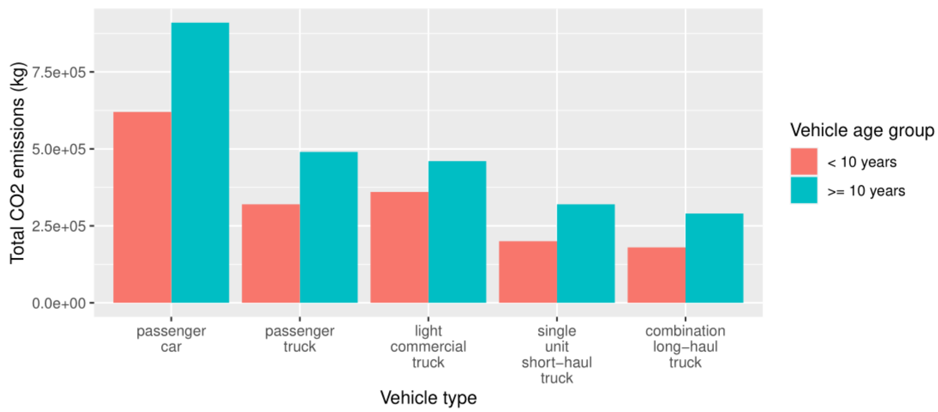


Figure I.12-1. Southwestern Pennsylvania regional transportation network

We categorized vehicles into ten groups: passenger car, passenger truck, light commercial truck, single unit short-haul truck, combination long-haul truck, electric car, and electric truck, as well as by two age groups: 0 to 10 years and more than 10 years old. As a result of the data-driven simulation work, we obtain high-resolution vehicle trajectories, in terms of several seconds and a few hundred feet, for every traveling vehicle among all those vehicle classes. Those outputs allow us to precisely calculate performance metrics, energy consumption and emissions, at any scale, from street blocks, neighborhoods, to the region, and from seconds, minutes, to hours. The performance metrics include, but are not limited to, vehicle miles traveled, average vehicle delay, fuel use, carbon dioxide emissions, emissions of various pollutants, accessibility, etc. For instance, we calculated the energy consumption and carbon dioxide emissions of different vehicle classes in the Pittsburgh region, shown in Figure I.12-2. The general modeling framework and computational platform will allow us to identify the sources of energy inefficiency in the regional network, as well as to evaluate the societal impact of various management strategies/policies related to demand or supply. This will be further studied in Budget Period 3.



(a) Total energy consumption (MJ).



(b) Total CO_2 emissions (kg)

Figure I.12-2. Total energy consumption and CO2 emission for each vehicle class in Pittsburgh region

One of the goals of the project is to develop a replicable framework for conducting similar analyses in other regions. To better accommodate the needs of replicability and generalization of the software program, we did a major refactoring on the code base, especially on the network simulation part. One big improvement is that now we clearly separate data analytics and processing from transportation models. For example, we decoupled the representation of a transportation network independently from the network simulation models. In our current implementation, a network is merely a representation of the real-world infrastructure and travel demand, which can be formed by any geographic information system data. Link-level traffic models, node-level traffic models, and other travel behavioral models are attached to network components dynamically via a dispatch table during the run-time. This work allows input of transportation networks and system-level data in any general format, independent of choices of transportation models, leading to flexibility and the ability to replicate this dynamic network's framework in any other regions.

Currently we are preparing the initial pre-alpha release of the software platform and once it is released the development will be fully transferred to the repository https://github.com/pengjiz/macposts.

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 electrification, 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, Wei Ma, and Zhen (Sean) Qian. Cluster Analysis of Probabilistic Origin-destination Demand Using Day-to-day Traffic Data. Transportation Research Board Annual Meeting, No. 19-05181. 2019.

Wei Ma, Xidong Pi, and Sean Qian. "Estimating multi-class dynamic origin-destination demand through a forward-backward algorithm on computational graphs." Transportation Research Part C: Emerging Technologies 119 (2020): 102747.

Pengji Zhang, Sean Qian. Estimating Multi-Class Dynamic Origin-Destination Demand with Multi-Source Data: Experiments on Regional Networks. Working paper. 2020

Chris Hoehne, Josh Sperling, Stan Young, Venu Garikapati, Sean Qian. Parking as a lens to the urban soul: exploring associations of parking, mobility, and energy. Proceedings of the 27th World Congress on Intelligent Transport Systems, 2020

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[3] Zhou, Xuesong, et al. "Integrating a simplified emission estimation model and mesoscopic dynamic traffic simulator to efficiently evaluate emission impacts of traffic management strategies." Transportation Research Part D: Transport and Environment 37 (2015): 123-136.

I.13 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: June 30, 2021
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, the project team developed a framework for capturing high-resolution multi-modal data from the transit fleet in Chattanooga. In the second project year, we have developed 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

Transportation accounts for 28% of the total energy use in the United States [1] and as such, it is responsible for immense environmental impacts, including urban air pollution and greenhouse gas emissions, and may pose a severe threat to energy security. As we encourage mode shift from personal vehicles to public transit, it is important to consider that public transit systems still require substantial amounts of energy; further, public bus transit services in the U.S. are responsible for at least 19.7 million metric tons of carbon dioxide ($CO2$) emission annually [2]. As such, it is absolutely crucial that we study the bottlenecks to energy efficiency in public transit and develop new algorithms that can help the public transit agencies, especially those that are still operating mixed fleets, which may consist of electric vehicles (EVs), hybrid-electric vehicles (HEVs), and internal combustion engine vehicles (ICEVs), to optimize their operations by deciding 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 of vehicles can have a significant effect on energy use and, hence, environmental impact. The key aspect of the project is the development of energy consumption predictors based on high-resolution telemetry gathered from the CARTA fleet and using these models within a real-time operation and network guidance system.

The project 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. This process required the following activities:

- Acquire high-resolution (updated every second) spatio-temporal telemetry data from CARTA vehicles and exogenous data sources, such as traffic and weather;
- Develop an efficient framework to store and process the operational data and external data, including street and elevation maps;
- Create multi-scale energy predictors using the real-world data;
- Develop guidance and network optimization algorithms that use the energy predictors and real-world data to optimize operations;
- Codify the results into visualization dashboards and simulators that can be used by other agencies for knowledge transfer.

Note that this project improves the state of the art because as described by the team's recent paper [3], most attention in the literature is focused on personal vehicles. In contrast, this project is focused on energy estimation of mixed transit vehicles that include diesel, electric, and hybrid-electric buses. 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 relationships between inputs and energy outputs, with certain assumptions or statistical techniques. 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, but as indicated by our results, we have found that neural networks are better suited for learning these models.

Acquiring High Resolution Data Telemetry from Transit 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 Americans with Disabilities Act (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 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 Global Positioning System (GPS) positioning for each record. In total, the team has already obtained approximately 32.3 million data points for electric buses and 29.8 million data points for diesel buses.

In addition, the team collects static geographic information system (GIS) elevation data from the Tennessee Geographic Information Council [4]. From this source, we download high-resolution digital elevation models (DEMs), derived from light detection and ranging (LiDAR) elevation imaging with a vertical accuracy of approximately 10 cm. We join the DEMs for Chattanooga into a single DEM file, which we then use to determine the elevation of any location within the geographical region of our project. The team also collects weather data from multiple weather stations in Chattanooga at 5-minute intervals using the DarkSky application programming interface (API). This data includes real-time temperature, humidity, air pressure, wind speed, wind direction, and precipitation. In addition, the team collects traffic data at 1-minute intervals using the HERE API, which provides speed recordings for segments of major roads, and data in the form of time-stamped speed recordings from selected roads. Every road segment is identified by a unique Traffic Message Channel identifier (TMC ID). Each TMC ID is also associated with a list of latitude and longitude coordinates, which describe the geometry of the road segment. A summary of datasets available is shown below in Table I.13-1.

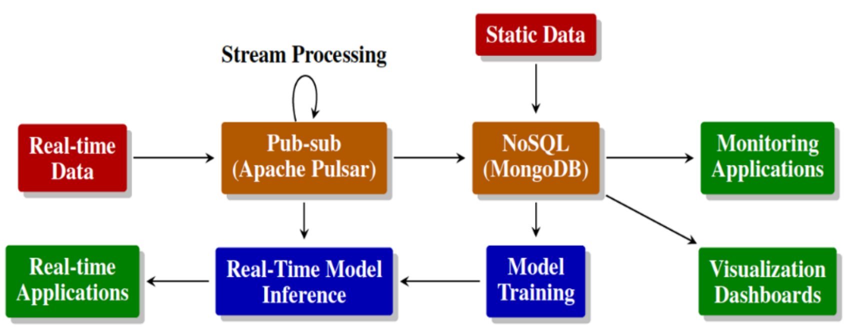
Table I.13-1. Available Datasets

Data	Source	Frequency	Scope	Features	Schema/Format
Diesel vehicles	ViriCiti and Clever Devices	1 Hz	50 vehicles	GPS, fuel-level, fuel rate, odometer, trip ID, driver ID	ViriCiti SDK and Clever API
Electric vehicles	ViriCiti and Clever Devices	1 Hz	3 vehicles	GPS, charging status, battery current, voltage, state of charge, odometer	ViriCiti SDK and Clever API
Hybrid-electric vehicles	ViriCiti and Clever Devices	1 Hz	7 vehicles	GPS, fuel-level, fuel rate, odometer, trip ID, driver ID	ViriCiti SDK and Clever API
Traffic	HERE and INRIX	1 Hz	Chattanooga region	TMC ID, free-flow speed, current speed, jam factor, confidence	Traffic Message Channel (TMC)

Data	Source	Frequency	Scope	Features	Schema/Format
Road network	OpenStreetMap	Static	Chattanooga region	Road network map, network graph	OpenStreetMap (OSM)
Weather	DarkSky	0.1 Hz	Chattanooga region	Temperature, wind speed, precipitation, humidity, visibility	DarkSky API
Elevation	Tennessee GIC	Static	Chattanooga region	Location, elevation	GIS - Digital Elevation Models
Fixed-line transit schedules	CARTA	Static	Chattanooga region	Scheduled trips and trip times, routes, stops	General Transit Feed Specification (GTFS)
Video Feeds	CARTA	30 frames/ second	All fixed line vehicles	Video frames	Image
Ridership	CARTA	1 Hz	All fixed line vehicles	Passenger boarding count per stop	Transit authority specific

An Efficient Framework to Store and Process Operational Data

Given the volume and the rate of the data being collected, the project team had to design a new data architecture for the project. The purpose of this architecture is to store the data streams in a way that provides easy access for offline model training and updates, as well as real-time access for system monitoring prediction. This architecture consists of a publish-subscribe cluster implemented with Apache Pulsar, which stores topic-labeled sensor streams, and a MongoDB database backend. An overview of the data architecture is provided in Figure I.13-1.



Data architecture overview - real time data is streamed to an Apache Pulsar cluster consisting of 5 broker/bookie nodes and 5 zookeeper nodes running on-site in VMWare. A MongoDB cluster running in Google Cloud reads from the Pulsar cluster, continuously updating its data view and adding spatial indexing for monitoring and dashboard applications.

Figure I.13-1. Data architecture structure

This architecture solves two challenges. The first challenge is the persistent storage of the high-velocity, high volume data streams. The second challenge is that the data is highly unstructured and irregular and different data streams have to be synchronized and joined efficiently. With this architecture, the team streams each data source to a topic-based publish-subscribe (pub-sub) layer that persistently stores each data stream in an append-only ledger. Once added, the topic can be used to read data in near real-time or to playback previous data streams to synchronize new downstream applications. All replication is handled at the ledger level, which allows downstream storage and applications to adapt and expand without concern for data resiliency. For this system the team used Apache Pulsar [5] due to its native support for authentication and access for real-time usage.

We include two methods for long term, structured access to the data streams. First, Pulsar includes support for Presto Structured Query Language (SQL) which is a distributed SQL query engine for big data. Presto SQL integrates with the Pulsar data stores to provide an SQL interface on top of the Pulsar topics. This is useful for analytics teams comfortable with SQL, however as it is designed for large scale batch queries and does not support geospatial indexing it is not optimal for user-centric applications such as visualization dashboards. Therefore, we implemented a downstream MongoDB cluster running in Google Cloud. MongoDB was chosen for its native support of geospatial, r-tree indexing which optimizes our system for aggregate geospatial queries for monitoring and visualization applications discussed later in the report.

As our framework has expanded, we are running numerous streaming join functions within Pulsar. An example is provided in Figure I.13-2, which outputs a data stream that is used for our energy prediction models and energy dashboard. The input is the telemetry data from ViriCiti, route, trip and driver data from Clever Devices, weather from DarkSky, traffic from HERE, and the video feeds. Additionally, our predictive models rely on road level information from OSM. As this data is static the latest OSM network is stored in a MongoDB collection which the function queries each evening to keep up to date. These data sources are merged at 1-second time windows, which is the resolution required by the predictive models.

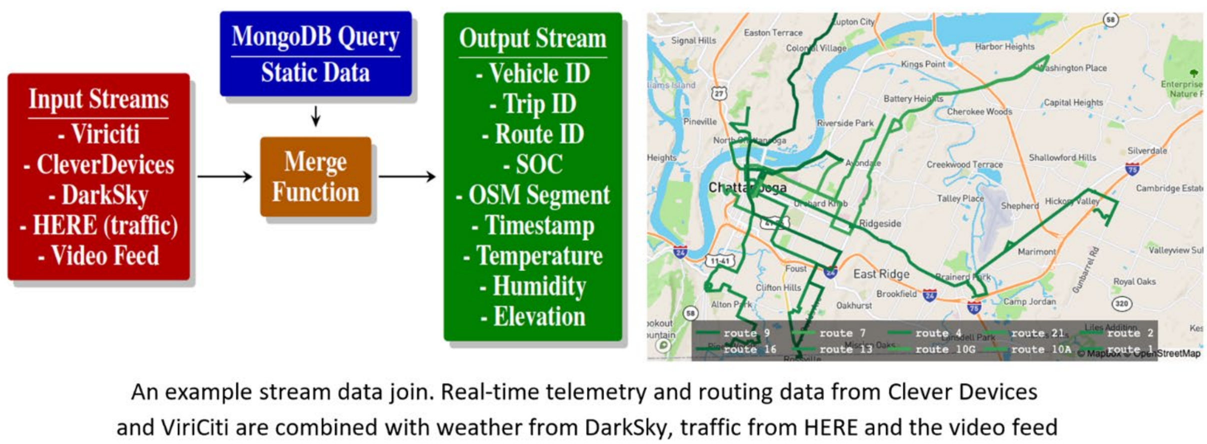


Figure I.13-2. Data join visualization sample

Data Analysis Dashboards

To help in analysis of the big data collected and being collected as part of the project we have developed data dashboards through which the users can query based on time, fleet and route. The data is presented to the user over the map of Chattanooga as shown in Figure I.13-2, and as a series of statistical visualizations, one of which is energy per fleet as shown in Figure I.13-3. This dashboard is used by the data management team and CARTA to monitor the performance of the CARTA fleets over time and is available to the public [6]. Additionally, we developed a ridership dashboard to visualize occupancy of the vehicles throughout the bus transit network. The presentation of the occupancy dashboard is similar to the energy dashboard and is available to the public [7].

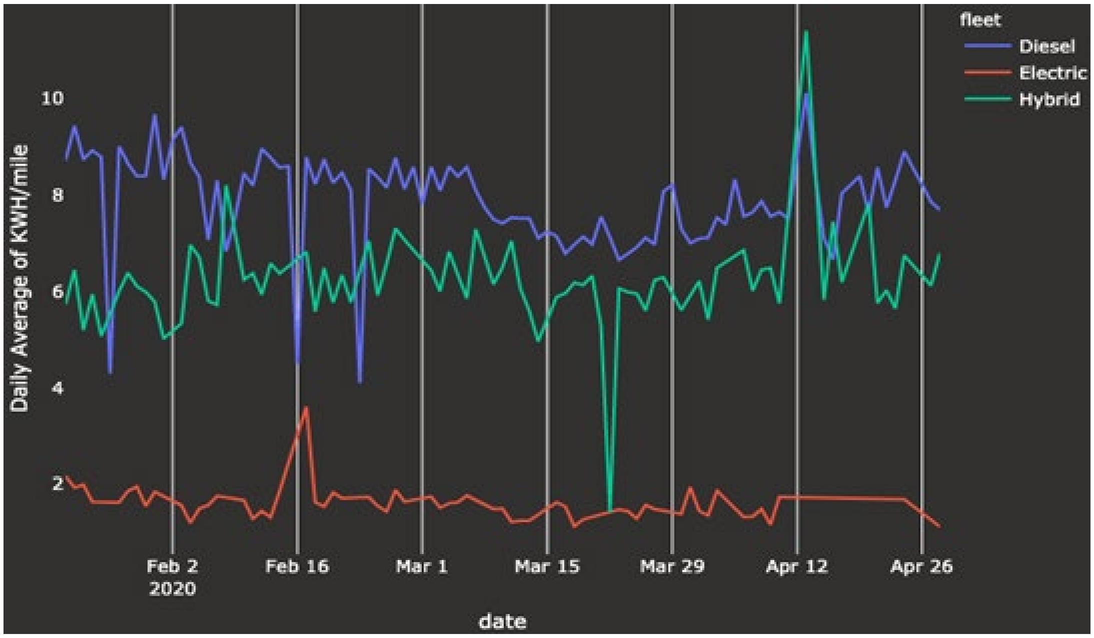


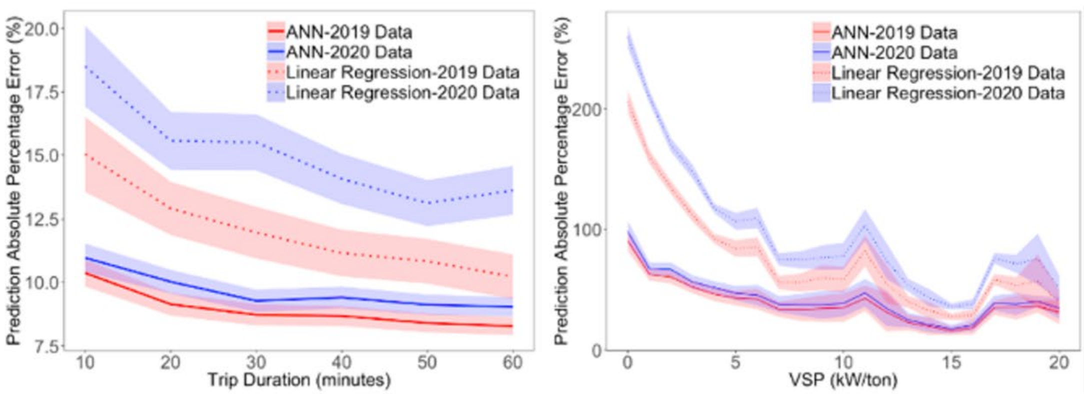
Figure I.13-3. Energy data visualization

Machine Learning Models for Energy Usage Estimation

One of the first machine learning models the project team built was a macro-scale energy predictor [8] that can provide planning foresight by estimating energy consumption at the level of route segments. To develop this model, we used the following features for EVs: 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-electric vehicles, instead of battery data, the team collected fuel level (%) and the fuel used, in gallons. We had to remove all data points that were recorded when the vehicle was in the garage or was charging (for EVs). Next, the team calculated 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. For diesel and hybrid-electric vehicles, the team performed similar steps with fuel used.

We discovered that different neural network structures work best for electric and for diesel vehicles. This is perhaps due to the way different features affect the powertrain of the vehicles. For electric vehicles, the best model has one input, two hidden, and one output layer. The input layer has one neuron for each predictor variable. The two hidden layers have 100 neurons and 80 neurons, respectively. For diesel, the best model required five hidden layers compared to the electrical vehicle model. The five hidden layers have 400, 200, 100, 50, and 25 neurons, respectively. We use sigmoid activation in all hidden layers and linear activation in the output layer. With these models, we saw that the relative prediction error is generally lower for longer trips; this is expected as the individual errors of large numbers of samples cancel each other out with an unbiased prediction model. In addition, we compared the neural network models with other machine learning models including decision trees and linear regression and found that the mean error was least with the neural network models.

In addition to the macro energy models, which are applicable for route specific analysis, we have also developed micro models [9] that have been finely tuned for individual vehicles. These models are essential for estimating 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. See Figure I.13-4.



(Left) Electric Vehicles: Mean and 95% confidence interval of absolute percentage errors of microscopic energy prediction for electric vehicles with trip duration for different models. (Right) Mean and 95% confidence interval of absolute percentage errors of microscopic energy prediction at with respect to the vehicle specific power.

Figure I.13-4. Microscopic energy prediction models

Energy Optimal Trip to Vehicle Assignment

Based on the energy prediction models, the team set up an optimization problem that focuses on minimizing fuel and electricity use by assigning vehicles to transit trips and scheduling them for charging, while serving the existing fixed-route transit schedule in Chattanooga. The problem formulation is general and applies to any transit agency that has to provide fixed-route transit service using a mixed fleet. To solve the problem, the team introduced an integer program, a greedy algorithm, and a simulated annealing algorithm.

Results

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. Based on the energy prediction models, the team set up an optimization problem that focuses on minimizing fuel and electricity use by assigning vehicles to transit trips and scheduling them for charging, while serving the existing fixed-route transit schedule in Chattanooga. The problem formulation is general and applies to any transit agency that provides fixed-route transit service using a mixed fleet. To solve the problem, the team introduced an integer program, a greedy algorithm, and a simulated annealing algorithm.

The team applied these algorithms on CARTA's transit routes using the macro-level energy predictors to evaluate the objective of total energy costs of the operations during the day for the fixed-route fleet. The results showed that the proposed algorithms are scalable and can reduce energy usage and, hence, environmental impact and operational costs. For CARTA, the proposed algorithms could save $48,910 in energy costs and 175 metric tons of CO_2 emissions annually across the whole fleet. The team is actively working on improving the optimization algorithms and developing comprehensive graph neural networks to improve the prediction results and are working on a real-time test of the optimization algorithms.

Conclusions

Through our work, the project team has developed and demonstrated a methodology that can be followed by other transit agencies to improve their efficiency. This includes:

- The design and demonstration of a big data infrastructure to store and analyze multimodal time series data collected from the fleet
- The design of algorithms to join and structure the separate data streams to provide analytical answers about efficiency bottlenecks of the transit agencies

- The demonstration of visualization interfaces that can be used to query and present the big data collected from the fleet in a tractable manner
- The design and demonstration of effectiveness of machine learning models to be able to predict the energy consumption of a heterogenous transit fleet at both micro and macro levels
- The design and analytical validation of the optimization models that can help the transit agencies improve the assignment of specific vehicle types to transit trips for the day to ensure energy optimization.

Project dashboards are available and will continue to be updated at the project website, www.smarttransit.ai.

Key Publications

Poster presentation at the 2019 Tennessee Sustainable Transportation Forum.

A. Ayman, M. Wilbur, A. Sivagnanam, P. Pugliese, A. Dubey, and A. Laszka, Data-Driven Prediction of Route-Level Energy Use for Mixed-Vehicle Transit Fleets, in *2020 IEEE International Conference on Smart Computing (SMARTCOMP 2020)*, Bologna, Italy, 2020.

A. Ayman, A. Sivagnanam, M. Wilbur, P. Pugliese, A. Dubey, and A. Laszka, Data-Driven Prediction and Optimization of Energy Use for Transit Fleets of Electric and ICE Vehicles, *ACM Transactions of Internet Technology*, 2020.

R. Sun, Y. Chen, A. Dubey, P. Pugliese, 2020. Hybrid Electric Buses Fuel Consumption Prediction Based on Real-world Driving Data. Transportation Research Board 100th Annual Meeting, Jan, 2021.

Y. Zhang, Y. Chen, R. Sun, A. Dubey, P. Pugliese, 2020. A Data Partitioning-based Artificial Neural Network Model to Estimate Real-driving Energy Consumption of Electric Buses. Transportation Research Board 100th Annual Meeting, Jan. 2021.

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I.14 Mobility and energy improvements realized through prediction-based vehicle powertrain control and traffic management. (Colorado State University)

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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 US.

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

Year one of the project saw success in developing a comprehensive Intelligent Connected Vehicle (ICV) urban driving dataset, vehicle level fuel economy modeling, system level traffic modeling for the City of Fort Collins CO, and a comprehensive system level Mobility, Efficiency, and Productivity metric (MEP). In year two, research activity shifted towards the application of these tools in the generation and sharing of impactful conclusions.

TMS

The project team developed a novel and generally applicable TMS method that combines the benefits of currently existing Intelligent Connected Infrastructure (ICI) methods, such as actuated traffic signals and dynamic phase selection, and enhances these with dynamic program selection, which allows for traffic lights to run different optimized programs, depending on conditions such as high or low traffic density and accident conditions, when the situation is appropriate. See Figure I.14-1.

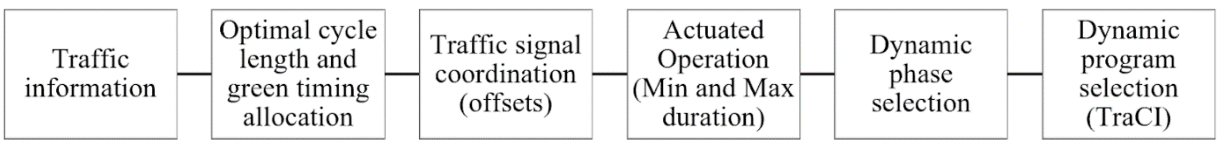

Figure I.14-1. Dynamic Optimal TMS high level logic flow

Application of a dynamic optimal TMS (DOTMS) in normal daily traffic conditions resulted in significant improvements in both average speed and delay time.

EMS

In an effort to understand how ICV and ITS technology can benefit the efficiency of individual vehicles in the near- and medium-term future, the project team conducted research into the development of Predictive Optimal Energy Management Strategies (POEMS) for hybrid vehicles. These strategies use ICV data streams such as Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), Advanced Driver Assistance System (ADAS) data, and normal vehicle controller area network (CAN) data to predict vehicle velocities in the 10-30 second time window, and then used Dynamic Programming (DP) derived solutions to compute an optimal power split for the time window. The team conducted research into the velocity prediction element of POEMS in 2019 and 2020 based on a comprehensive and publicly accessible dataset collected in the summer of 2019.

The team performed velocity prediction using various machine learning and artificial intelligence (AI) methods with the best being a deep, recurrent Artificial Neural Network (ANN) that was composed of three layers of Long Shor- Term Memory (LSTM) neurons.

The results of this research showed that high fidelity velocity predictions were possible for urban driving in the 10-20 second window and that the prediction accuracy was enhanced by the addition of Signal Phase and Timing (SPaT) data. The results also showed that the ANN, when trained on multiple drivers' data, predicted the velocity of each driver equally well and nearly as well as training on each driver individually.

The second part of POEMS is the energy management strategy. The EMS research focused on quantifying the relative value of whole-drive-cycle DP optimization; Model Predictive Control (MPC), a DP solution that only takes into account future velocities for a fixed time horizon; and a constant velocity prediction that assumes that the vehicle will remain at a constant velocity for the remainder of the time horizon. Both MPC and DP can be implemented in the real-time control of vehicles.

Results showed that MPC has the potential to result in a FE improvement of 50-60% of what can be attained by whole-drive-cycle DP, while the improvement from constant velocity predictions could approach 90% of that attainable with MPC. In all cases, urban driving benefitted more from POEMS than highway driving. See Figure I.14-2.

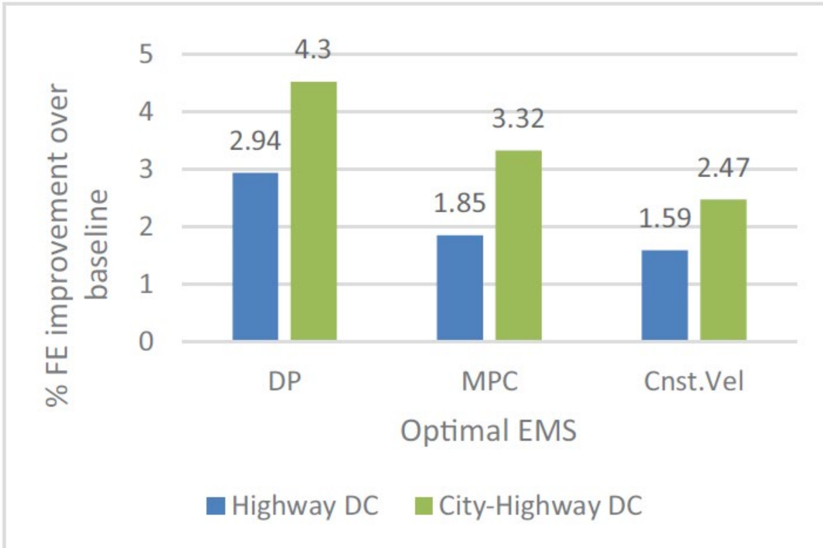

Figure I.14-2. Potential fuel economy gains from POEMS

Vehicle Class-specific Models of Fuel Consumption and Emissions

The project team performed research into predicting light duty vehicle emissions based on commonly available CAN data produced over a drive cycle by a vehicle. The team collected a dataset containing common CAN parameters and Portable Emissions Measurement System (PEMS) data in 2019 and this data was the basis for a study that attempted to predict diesel emissions with deep ANNs. Results from this study found that while high fidelity predictions for some pollutants such as carbon dioxide and hydrocarbons could be predicted accurately, others such as carbon monoxide could not.

The data for most of the emissions categories was mostly zero valued with occasional spikes, making error-based ANN training ineffective. In fact, a “null” prediction (predicting 0 at all time steps) proved to be nearly as good as, if not better than, even the best ANN predictions. See Figure I.14-3.

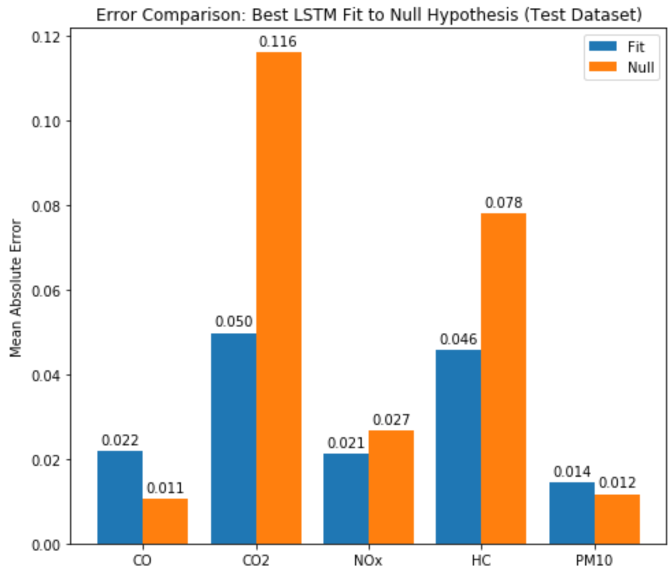

Figure I.14-3. Comparison of best ANN and "null" prediction errors

Novel Metrics

To quantify system level efficiency for transportation systems, the novel metric, MEP, was developed and applied to Fort Collins for further experimentation with the integration of TMS and EMS.

At the heart of the MEP metric are measures that build on existing accessibility theory and methodologies, assessing the number of jobs, goods, and services opportunities which are available within prescribed travel times from a location. This approach is fundamentally a geospatial analysis, providing both a visual map for comparative analysis and a numeric score to baseline performance metrics. Data to support travel-time calculations and land use (i.e., available goods, services, and employment opportunities) can be obtained from third-party travel data sources or outputs from regional travel demand models, along with land-use data from cities, metropolitan planning organizations, or commercial entities. The project team calculated the baseline MEP metric for the Fort Collins, Colorado urbanized area using average speed data and land use data obtained from third-party data providers, coupled with population and employment data from the US census.

Further specific calculations for Fort Collins are currently underway and will be completed in the next couple of weeks. MEP calculations for Fort Collins will include access by walk, bike, and car modes, and will quantify access to restaurants, hospitals, jobs, recreational activities, schools and retail establishments. Higher MEP scores represent a greater access to opportunities with lower cost, less energy, and more mode choices.

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 has used ICV and ITS data to develop implementable solutions to transportation system issues and the metrics to measure the resulting improvement. Future work should be done in the area of understanding potential synergies between TMS and EMS algorithms, which could allow for even greater system level efficiency gains.

Key Publications

Motallebiaraghi, F., Rabinowitz, A., Jathar S., Fong, A., Bradley, T., Asher, Z., "High-Fidelity Modeling of Light-Duty Vehicle Emission and Fuel Consumption Using Deep Neural Networks" SAE Technical Paper (in review)

Patil, A.A., Motallebiaraghi, F., Meyer, R., and Asher, Z.D., "Comparison of Optimal Energy Management Strategies Using Dynamic Programming, Model Predictive Control, and Constant Velocity Prediction," SAE Technical Paper 2020-01-5071, 2020, doi:10.4271/2020-01-5071.

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

I.15 Advancing Platooning with Advanced Driver-Assistance Systems Control Integration and Assessment (Cummins, Inc.)

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Project Funding: $5,000,000 DOE share: $2,500,000 Non-DOE share: $2,500,000

Project Introduction

Application of Cooperative Adaptive Cruise Control (CACC) to heavy duty trucks, known as truck platooning, has shown fuel economy improvements over test track ideal driving conditions. However, there is limited test data available to assess the performance of CACC under real-world driving conditions. In this project, truck platooning with CACC is tested under real-world driving conditions and the issues with this technology are identified through test data analysis. Potential solutions are proposed and demonstrated.

Objectives

This project will assess the benefits of platooning for reducing fuel consumption under real-world driving scenarios for two- and three-truck 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

***Objective 2*:** Assess technology integration with platooning control, including Advanced Driver Assistance Systems (ADAS) fuel economy control features in cruise and throttle operation, and tire connectivity technology to monitor tire 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 three budget periods:

Budget Period 1 - Integration of CACC for baseline

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

Test Plan: Test Route Terrain / Road Grade Characterization

The project team selected a test route in Indiana to conduct on road fuel economy tests and assess the impact of road grade variation on CACC platooning performance. As shown in Figure I.15-1, the route begins and ends in Columbus, Indiana at Cummins Machine Integration Center (CMIC), with a turnaround point in Evansville, Indiana. The round-trip length is 329 miles and consists of sections from I-65, I-265 and I-64, all within the state of Indiana.

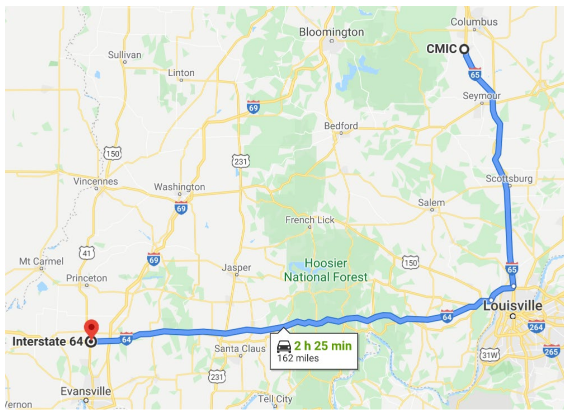


Figure I.15-1. Selected route for fuel economy tests

Comparisons of this route with the nationally representative road grade profiles on absolute road grade and half hill distance are shown in Figure I.15-2. Half hill distance is defined as the length of a continuous stretch of roadway where grade does not change sign, so it is either a climb or a descent. As can be seen in Figure 2, the current testing route possesses a larger fraction of low road grade profiles (road grade < 1.2%) and a smaller fraction of high road grade profiles (road grade > 1.2%) compared to the nationally representative road grade profiles. The average absolute error on road grade is around 4%. The half hill distance distribution also reflects a similar trend, where almost 80% of half hill distance is less than 1.2 miles. The average absolute error on half hill distance is a little bit higher at 6%. The comparison reflects that the candidate route is a bit low in rolling and steeper hills fraction, as would be expected in the state of Indiana. Both error levels were considered acceptable in the original work where nationally representative sample grade profiles for EPA greenhouse gas certification of medium- and heavy-duty vehicles are identified.

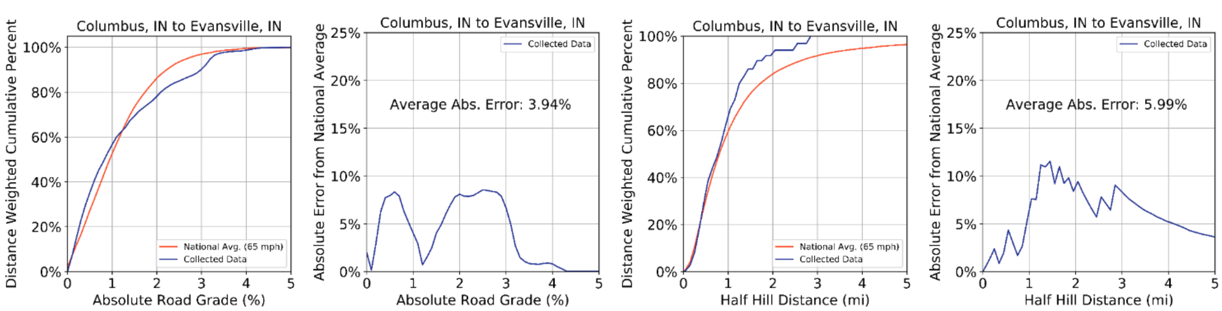


Figure I.15-2. Comparison of the Indiana selected test route and the nationally representative profiles

Test Plan: Traffic Test Characterization

Moderate traffic can have a significant impact on truck operation, causing vehicle speed to fluctuate while attempting to maintain highway driving speeds applicable for truck platooning. To understand the effects of traffic on platooning and fuel savings, the National Renewable Energy Laboratory (NREL) has completed an analysis of existing Class 8 highway long-haul truck data contained within the Fleet DNA database. The goal was to identify a statistically representative on-highway transient driving profile for truck platooning evaluations. While traffic density cannot be measured from existing Fleet DNA data, specific filters are applied to the on-road data to ensure the related operation is primarily affected by the interstate highway traffic around the vehicles and not by the impact of high road grade variations. The project team conducted an analysis of driving behavior to derive duty cycle metrics of each trip. In this study, two features are of substantial interest: average speed and kinetic intensity. The average speed is a direct indicator of the vehicle operation environment. Typically, if average speed is high, it is likely the data reflects interstate highway driving. Kinetic intensity is the ratio of characteristic acceleration to aerodynamic velocity, which provides a ratio of energy used to accelerate versus energy used to overcome drag. Characteristic acceleration is a mass- and distance-specific measure of energy put forth to accelerate or raise a vehicle. As a result, higher kinetic intensity of the trip indicates that the vehicle operation possesses more frequent acceleration and deacceleration processes. Figure I.15-3 shows the characterized duty cycle for traffic selected in this project.

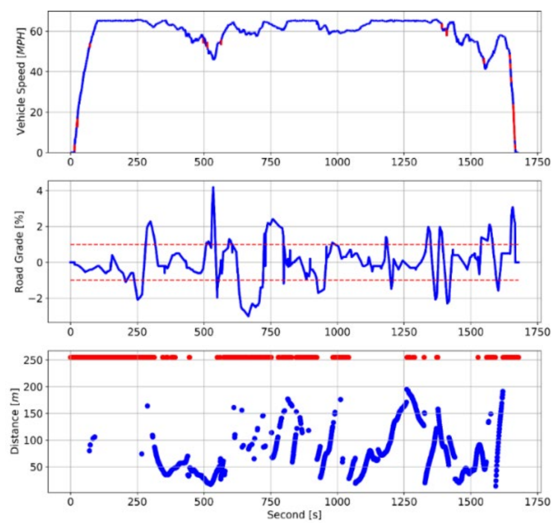


Figure I.15-3. Highway speed profile selected as the representative speed profile for a line haul truck operation in traffic

Test Procedures

Per the characterized test factors above, the team conducted four different test phases, as listed below.

1. Steady state (SS) CACC 0.6s: CACC test at 0.6 Sec headway time gap with lead truck in cruise operation at 65 mph (baseline: cruise operation at 65 mph without CACC)

2. Traffic CACC 0.6s: CACC test with imposed traffic speed profile on lead truck at 0.6 Sec headway time gap (baseline: commercial ACC at 2.3 Sec headway time gap)

3. On road CACC 0.6s: CACC test at 0.6 Sec headway time gap on Indiana route (see Figure 1) with lead truck in cruise without Cummins Advanced Dynamic Efficient Powertrain Technology (ADEPT) features/Cummins ADAS fuel economy features (baseline: cruise at 64 mph or at speed limit if below 65mph)

4. On road CACC 0.6s with ADEPT: CACC test at 0.6 Sec headway time gap on Indiana route with lead truck in cruise with ADEPT features enabled (baseline: cruise at 64 mph or at speed limit if below 65 mph).

Test Vehicles

Three trucks were used for all test phases. As shown in Table I.15-1, all three trucks are the same except Lead and Trail trucks that have Michelin tires with telemetry. Figure I.15-4 shows the side view of one of the test trucks. The Control truck was kept the same throughout all the tests. Test data was normalized against the control truck to minimize the impact from environmental effects.

Table I.15-1. Vehicle Specifications

	Control Truck	Lead & Trail Trucks
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	

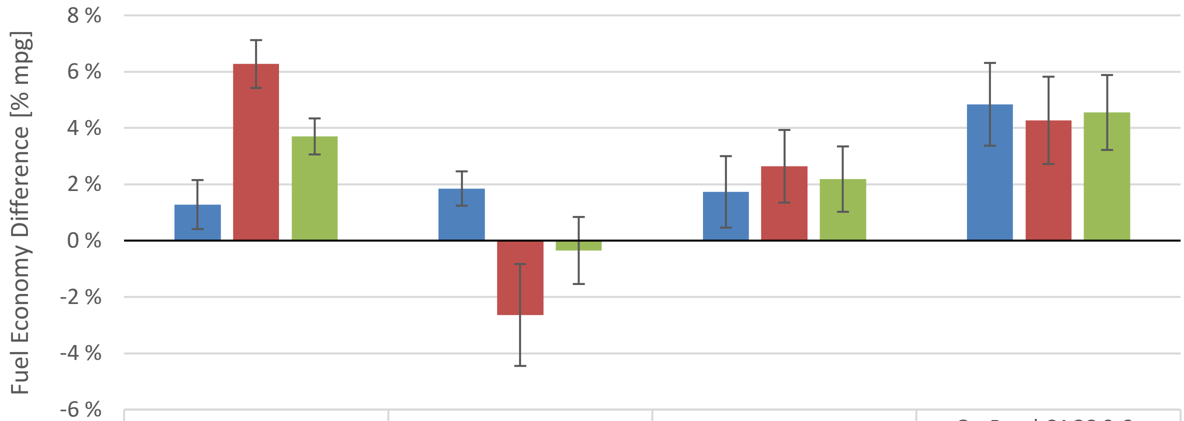
Figure I.15-4. Side view of test vehicle

Fuel Economy Test Protocol

The project team followed a modified SAE J1321 procedure when conducting all fuel economy tests on the test track and interstate highways.

Fuel Economy Test Results

The comparison of the fuel economy test results is summarized in Figure I.15-5.



	SS CACC 0.6s	Traffic CACC 0.6s	On Road CACC 0.6s	On Road CACC 0.6s ADEPT
Lead	1.28%	1.85%	1.73%	4.84%
Trail	6.27%	-2.64%	2.64%	4.27%
Platoon	3.70%	-0.35%	2.18%	4.55%

Figure I.15-5. Fuel Economy results

- The first set of data bars indicates the fuel economy benefits of the CACC platooning at 65 mph steady state cruise with headway time gap at 0.6 Sec (first test phase on test track). The results indicate considerable improvements over the baseline test, consistent with prior studies under ideal test track driving conditions.

- The second set of data bars shows the effect of traffic on fuel economy with the CACC operation at 0.6 Sec compared to commercial ACC at 2.3 Sec headway time gap (second test phase on test track). In this test phase, the characterized traffic duty cycle is imposed on the lead truck through speed automation. The results indicate a significant reduction of fuel economy on the trail truck while lead truck fuel economy is not impacted considerably. Overall, the average fuel economy of the platoon is not improved under the imposed traffic operation.

- The third set of data bars shows the on-road fuel economy tests on the Indiana route (third test phase on road). The CACC system improves fuel economy of the platoon by about 2.18%. This shows a reduction in fuel savings of almost 40%, when compared to the results of the ideal driving conditions on the test track (first test phase). In this phase, the baseline is regular cruise operation without platooning.

- The fourth set of data bars shows the on-road fuel economy test on the Indiana route when Cummins ADAS fuel economy features called ADEPT on lead truck are enabled (fourth test phase on road). When the system is complimented with ADAS features, the platoon fuel economy is improved significantly. These benefits come from both the Eco driving impact of the enabled ADAS features and CACC aerodynamic platooning improvements.

Conclusions

The project team tested truck platooning with CACC under real-world driving conditions, and the results are analyzed in this phase of the project. First, real-world driving conditions were characterized with the NREL Fleet DNA database to define the test factors. The key test factors impacting long-haul truck fuel economy were identified to be terrain and highway traffic, with and without ADAS features integrated. The team conducted track and on highway testing, guided by SAE J1321 procedures, to assess truck platooning operation under the characterized real-world driving conditions. On-highway testing was done on a route in

Indiana representing operation of long-haul class 8 trucks in the U.S. The road includes low-, medium-, and high-grade segments. The highway test results of a 2-truck platooning configuration indicate a considerable reduction in fuel savings, compared to the test track data collected under ideal driving conditions. The test data indicates platooning could lead to an increase in fuel consumption during traffic or high-grade hilly sections of the route, causing a reduction of the overall fuel savings on the road when compared to test track testing results. Integration of ADAS features on the lead truck during on road tests, however, led to significant improvement of fuel saving for both trucks in CACC operation.

Key Publications

T. Ard, F. Ashtiani, A. Vahidi and H. Borhan, "Optimizing Gap Tracking Subject to Dynamic Losses via Connected and Anticipative MPC in Truck Platooning," 2020 American Control Conference (ACC), Denver, CO, USA, 2020, pp. 2300-2305

H. Borhan, M. Lammert, K. Kelly, C. Zhang, N. Brady, C. Yu, J. Liu, “Advancing Platooning with ADAS Control Integration and Assessment-Test Results”, SAE 2021-04-06

I.16 Fuel-Efficient Platooning in Mixed Traffic Highway Environments (American Center for Mobility)

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Start Date: October 1, 2018 End Date: September 30, 2021
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 2 of this extended 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

Year 2 focus was on improving results from the year 1 testing. The focus areas for improvement were to

1. Improve the string stability characteristics of the platooning algorithm
2. Improve the accuracy of the fuel consumption measurements and testing metrics
3. Better classify the effects of cut-ins and merges on platoon fuel economy
4. Improve analysis of radio network in adverse conditions due to interference and low transmit power.

String stability is a measure of how a platoon of vehicles reacts to an error introduced into the system. For a string stable system, if a headway error-inducing disturbance (creating an error in following distance) is introduced to the first following vehicle in a platoon, the error will decay for each subsequent following vehicle. Conversely, if the system is not string stable, the errors introduced into the platoon will grow for every following vehicle, until there is a collision or the platoon ends.

String stability is typically evaluated through the sensitivity of the system. The sensitivity is a function determined by the dynamics of the system. This function then provides a basic measure of string stability. These analyses assume a linear-time-invariant system. The original analysis did not include any models for things such as engine lag, lag due to gear changes or communication delays. Figure I.16-1 displays the sensitivity of the year 1 Auburn platooning system. If a disturbance with a spectral frequency falls where the magnitude is above zero, then the error will grow for each subsequent vehicle. Most disturbances are of a low spectral frequency, which means the original controller design was susceptible to propagating errors down the line.

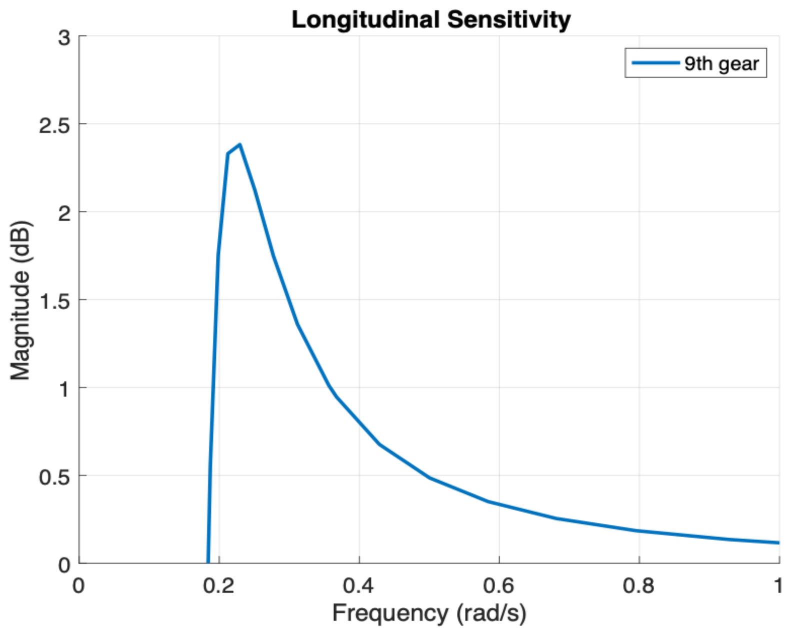

Figure I.16-1. Disturbance response for the year 1 Auburn control, indicating the string instability of the system

A major focus of year two was developing an expandable control architecture that eliminates the string stability issue. The solution began with a fundamental design change; rather than designing a controller around the dynamics of a single vehicle, the controller would be designed around a model that also includes the leading trucks. Equation 1 summarizes this fundamental design change, with x_0 being the lead vehicle and x_1 being the first follower.

$$\begin{pmatrix} \dot{x}_0 \\ \dot{x}_1 \end{pmatrix} = \begin{bmatrix} A_r & 0 \\ A_1 & A_0 \end{bmatrix} \begin{bmatrix} x_0 \\ x_1 \end{bmatrix} + \begin{bmatrix} B_r \\ 0 \end{bmatrix} u \qquad [1]$$

After establishing the new design methodology, the project team also determined a new criterion for string stability. The new stability criterion enforced that the complimentary sensitivity remain below zero for all frequency inputs. With this new modeling architecture and stability criterion, any velocity perturbation of the lead vehicle will not lead to following vehicle velocity perturbations that exceed that of the lead vehicle. The new controller design criteria then became selection of a control gain K such that

$$||\Gamma_i||_{H_\infty} \leq 1 \qquad [2]$$

Where Γ_i is the complementary sensitivity of the i_{th} vehicle. The resulting controller was implemented and validated during year 2 prior to the fuel efficiency testing campaign.

In year 1, hardware issues surrounding the fuel measurement equipment reduced the fidelity of fuel consumption measurement. Thus, year 1 results were limited to the CAN fuel rate signals, which has been justified in prior platooning studies [1–5]. For year 2, fuel flow meters were commissioned on all four trucks.

Additionally, the team redesigned the test matrix to incorporate a baseline for every truck on each test day. This greatly increased cross-checking capability for the results. The fuel switching hardware was replaced on A1 to allow use of the fuel flow meters, as the previous switching hardware was incompatible with the flow meter setup.

Year 1 string stability issues hindered the scheduled cut-in and merge testing. The redesigned controller of year 2 solved the string stability issues, and the team conducted both merge and cut-in tests in a 100' platoon successfully. The key difference between the merge and cut-in test is that the merge test pre-emptively opens a gap when a merging vehicle is detected while the cut-in test only opens a gap in response to a vehicle cutting into the platoon. The merge/cut-in vehicle acted between the second and third platooning trucks, splitting the four-truck platoon into two smaller two truck platoons.

Year 2 testing for the radio network focused on introduction of challenging scenarios which would lead to failures. In year 1, the radio network was not pushed to the limits in terms of available channel capacity or range.

Results

To date, three of the four fuel testing campaigns have been completed: year 1 testing at the National Center for Asphalt Technologies (NCAT) and ACM, and year 2 testing at NCAT. Year 1 testing highlighted the areas for improvement in control architecture. The project team tested and implemented a redesigned controller for year 2 testing, and introduced additional challenges in separate runs for the radio system.

The fuel economy analysis of the year 2 NCAT results is still underway, and further analysis of the year 1 data for NCAT and ACM has been completed. The dynamics induced by platooning can adversely impact the fuel economy of the platoon. Figure I.16-2 shows the impact of lead vehicle dynamics on the CAN fuel rates of a four-truck platoon at 100 feet normalized by their mean values:

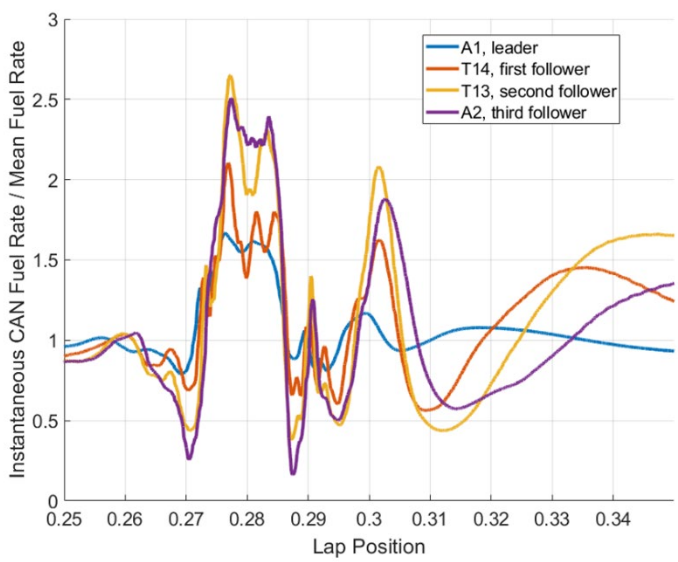

Figure I.16-2. Normalized fuel rates in a four-truck 100' platoon, year I at NCAT

The dynamics of the lead vehicle require the following vehicles to expend additional effort to maintain the platoon. Despite this, in year 1 at NCAT the platoons still experienced significant overall fuel savings. Figure I.16-3 shows the overall fuel benefit per truck on a percent basis during four-truck platooning at NCAT in year 1. The percent benefit ranged from 6-10% for the following vehicles and from 0-4% for the leaders. Several datapoints had low confidence due to high scatter and are denoted as hollow points; specifically, A1 at 100', and T14 at 35' and 50'. The low-confidence datapoint of 0% benefit at 100' for leaders was included in the percent benefit range, as the two-truck results at that distance also show little to no benefit. Prior studies have shown that lead trucks see little benefit at distances greater than 75' [6].

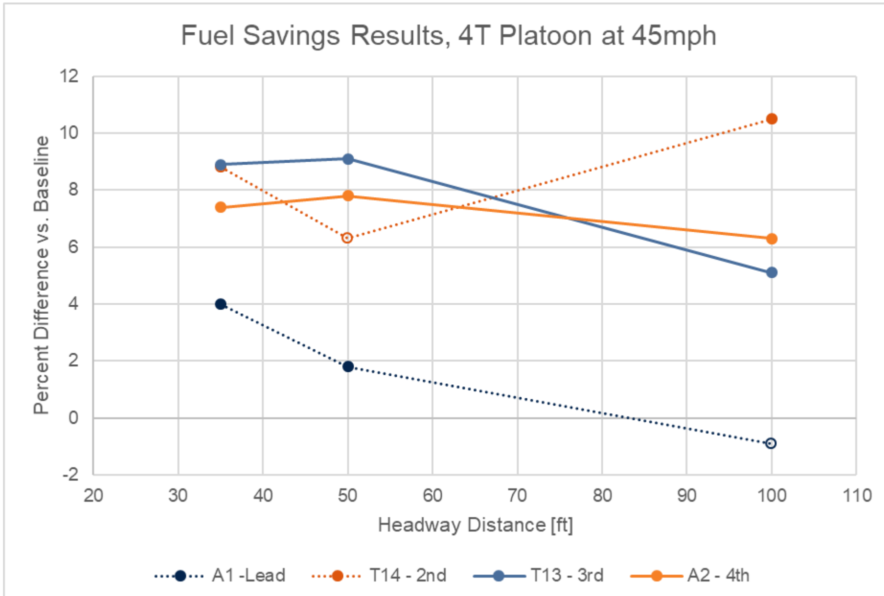

Figure I.16-3. Fuel Savings during four-truck platooning at NCAT, Year I

At ACM in year 1, the increased variations in vertical curvature (grade) of the roadway caused an increase in fuel consumption relative to the year 1 NCAT results.

Figure I.16-4 shows the fuel use per lap versus the headway standard deviation for the fourth truck in a four-truck platoon. Not only does the headway variation and fuel consumption at ACM greatly exceed that of NCAT, but the relationship between headway variance and fuel consumption follows a somewhat linear trend. Although the aerodynamic benefit of platooning was still occurring during the ACM tests, the variations in headway reduced or even overpowered this aerodynamic benefit.

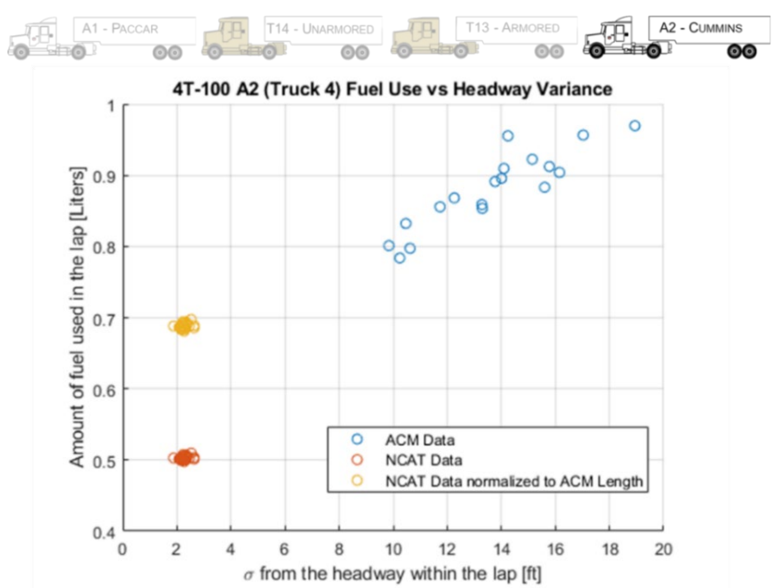

Figure I.16-4. Fuel use per lap versus the standard deviation of the headway

For year 2, the team tested the string stability performance of the redesigned controller at NCAT. The test performed was a step change between 35 and 45 miles per hour. Figure I.16-5 illustrates that the magnitude of the velocity for every following vehicle does not exceed, or only marginally exceeds, the velocity of the vehicle in front of it. The “chatter” seen on the V4 velocity graph between 1100 and 1150 seconds was caused by a sensor driver interface issue, and is not reflective of the actual dynamics of the vehicle at that time.

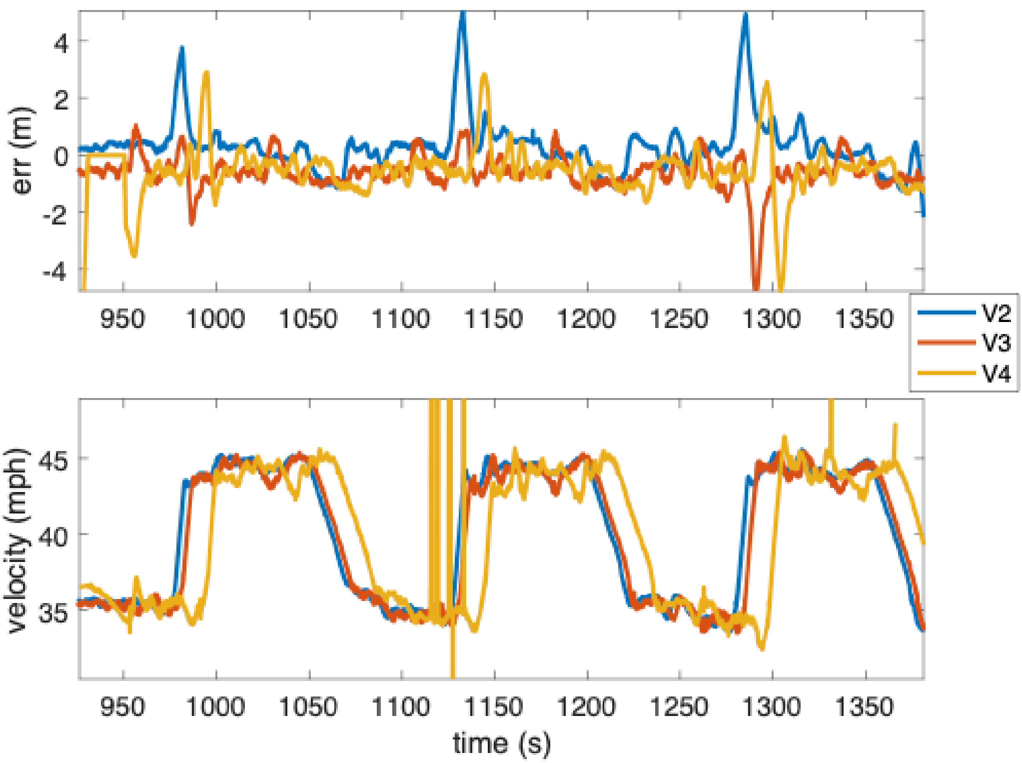

Figure I.16-5. Velocity step changes using the revised control architecture

The team then used this control architecture for the remainder of the year 2 testing at NCAT. At the time of this writing, the fuel economy results of the year 2 NCAT testing have not been sufficiently analyzed to compare them to the year 1 fuel results. In future months, the system will be taken back to ACM, where the new string stability characteristics will be fully tested using the constantly varying grade of the test facility roadway.

Similarly, the team will further test the radio network at the more dynamic track at ACM for the final phase of this project. Year 2 testing analysis thus far has been focused on a compare- and contrast-style of different gap distances. For the example shown in Figure I.16-6, T13 has been selected as a representative truck as the 3rd position in the convoy. These NCAT tests utilized a short following distance of 50’ and full transmit power of 23db to showcase the baseline performance of the radio network, primarily with Received Signal Strength Indicator (RSSI) at various positions of the track, in conjunction with the control performance data and a baseline based on a radar measurement. The chart below shows simultaneous overlays of RSSI, track elevation, control error, and radar error. This combined view allows for interpreting deviations from the nominal gap distance from the control algorithm to speculate as to whether the deviations were caused by an uncompensated change in grade or a gap in radio communications, while using radar measurements as a ground truth. Radio communications combine Global Positioning System (GPS) data, wheel speed information, and other measurements to be shared with the other trucks. The team will conduct future experiments on accumulated drift from individual measurements, which did not happen in this scenario due to the trucks being controlled such that drift does not accumulate, i.e., an erroneous value would be over-written by a strong control signal based on a radar measurement if GPS was denied.

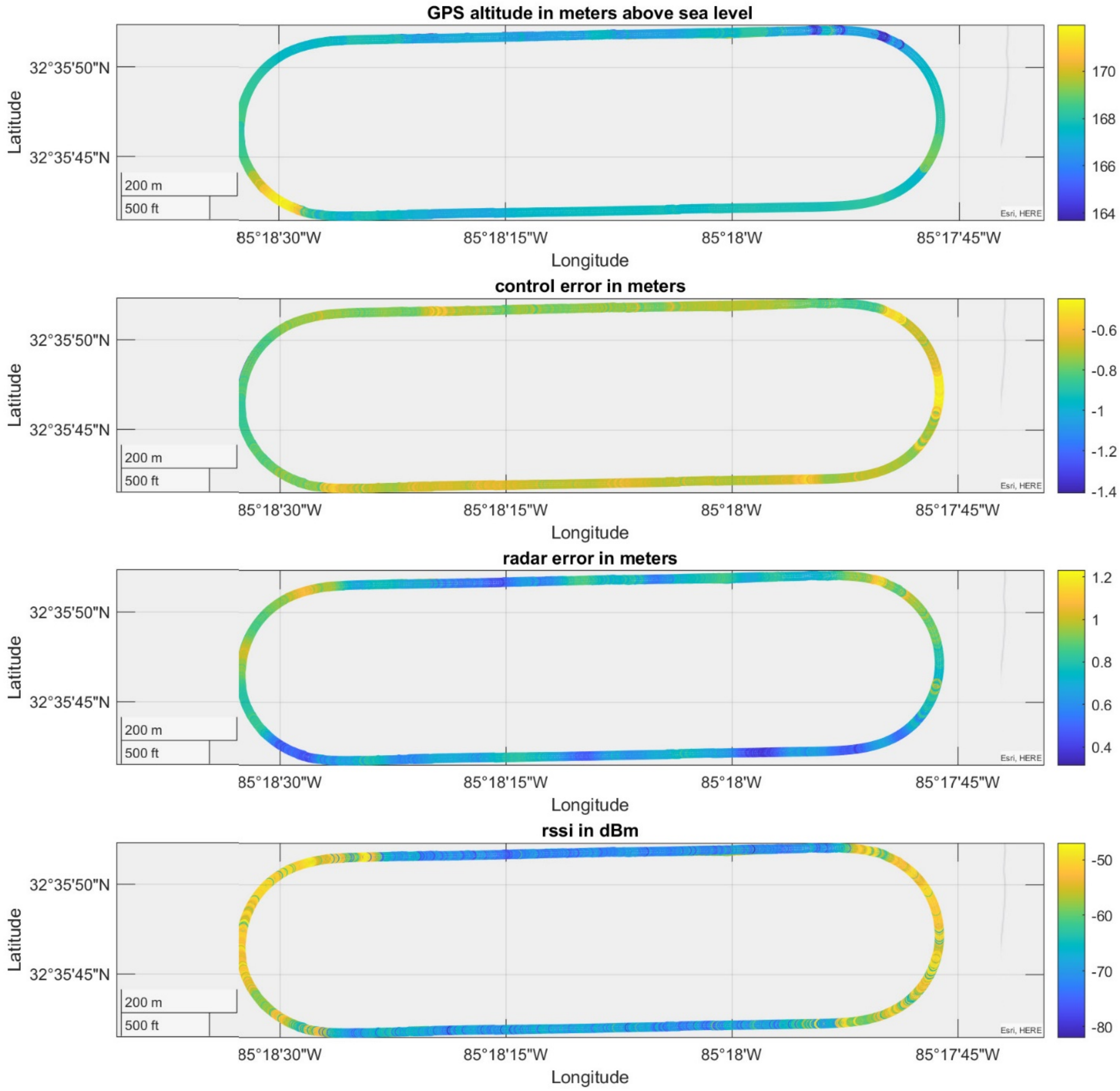

Figure I.16-6. Radio measurements with concurrent control statistics

Conclusions

The project team successfully tested four-truck platoons operating at NCAT and ACM in year 1. At NCAT, results indicate 0-4% and 6-10% fuel consumption reductions 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. At ACM, the platoon string stability and fuel economy were hampered due to the year 1 control design and the track elevation changes. The team redesigned the control system for the platoon to address the issues with string stability and year 2 NCAT testing was completed using the new controller demonstrating improved string stability.

Fuel measurement methodologies were improved for year 2 testing. This was accomplished by both changes in hardware and through an improved design of experiments to facilitate cross-checking.

The redesigned controller enabled merge and cut-in testing during year 2 NCAT testing.

The radio network performance is remarkably consistent across multiple tests. During year 2 ACM testing slated to occur next, more detailed analysis of fuel consumption during GPS or radio denied scenarios will occur.

Key Publications

Cheek, Eric, Hesham Alghodhaifi, Cristian Adam, Russell Andres, and Sridhar Lakshmanan. "Dedicated Short Range Communications used as Fail-Safe in Autonomous Navigation. "SPIE, 2020. doi:10.1117/12.2558925.

WCX SAE World Congress Experience 2020 (accepted):

- Adam, Critian, Sridhar Lakshmanan, Paul Richardson, University of Michigan-Dearborn; Evan Stegner, Jacob Ward, Mark Hoffman, David M. Bevly, Auburn University. 2020. “Correlation between sensor performance, autonomy performance and fuel-efficiency in semi-truck platoons” to be presented in session AE100, "ADAS and Autonomous Vehicle System"
- Stegner, Evan, Jacob Ward, Jan Siefert, David Bevly, and Mark Hoffman, Auburn University. 2020. “Experimental Fuel Consumption Results from a Heterogeneous Four-Truck Platoon” to be presented in session AE100, "ADAS and Autonomous Vehicle System"
- Siefert, Jan, Evan Stegner, Philip Snitzer, Jacob Ward, David M. Bevly, Mark Hoffman, Auburn University; Andrew Kotz, National Renewable Energy Laboratory. 2020. “Using Demanded Power and RDE Aggressiveness Metrics to Analyze the Impact of CACC on Fuel Savings for Heavy Duty Platooning” to be presented in session AE100, "ADAS and Autonomous Vehicle System"
- Snitzer, Philip, Evan Stegner, Jan Siefert, David Bevly, and Mark Hoffman, Auburn University. 2020. “Effects of Platooning Control Aggressiveness on Heavy-Duty Truck Fuel Economy” to be presented in session AE100, "ADAS and Autonomous Vehicle System"
- Adam, Christian, Russell Andres, Brandon Smyth, Timothy Kleinow, Katharina Grenn, Sridhar Lakshmanan, Paul Richardson, University of Michigan-Dearborn. 2020. “Performance of DSRC V2V communication networks in an autonomous semi-truck platoon application” to be presented in session AE303, "Foundations of Automobile Electronics: Electromagnetics and Antennas"
- Ward, Jacob, Evan Stegner, David Bevly, and Mark Hoffman. 2020. “String Stability and Disturbance Mitigation for Non-Homogeneous Class-8 Vehicle Platoons” to be presented in session SS900, “Vehicle Dynamics, Stability and Control”

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[5] McAuliffe, B., Raeesi, A., Lammert, M., Smith, P., Hoffman, M., and Bevly, D., "Impact of Mixed Traffic on the Energy Savings of a Truck Platoon," 2020-01–0679, 2020, doi:10.4271/2020-01-0679.

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I.17 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, 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 with 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 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

During the most recent budget period, the project team made significant technical progress. Figure I.17-1 shows one of the two prototypes currently deployed on the campus of UNC Charlotte. These stations include an initial version of the Energy Management Circuit Breaker from Eaton. The project team developed a mobile web application to allow users to initiate and conclude charging sessions. This platform has been developed using a cloud infrastructure that can be scaled to include thousands of charging stations. The stations will open to the public in January 2021, and usage information will be recorded throughout the year.

Figure I.17-1. Prototype charging station deployed on the campus of UNC Charlotte

During the second budget period the team has also started to investigate the cost-effectiveness of deploying EV charging stations into existing streetlighting infrastructure. The biggest driver of potential savings exists in cases in which no additional boring or trenching is needed for electrical wiring. In situations in which power is provided to a streetlamp from underground, the conduit may have room for additional wiring. In these cases, no additional underground work is needed, and installation costs can be reduced by nearly 75% compared to standalone pedestal stations. The solution is also attractive on poles that support overhead distribution lines. In these cases, connections can be made to the overhead cables without any need for additional underground work. This can lead to similar cost reductions relative to standalone pedestal stations. In the coming year, the project team will be working with utility partner Duke Energy to determine how extensive such situations are in the distribution network in several cities in North Carolina.

The proposed solution also offers significant potential to reduce hardware costs. Figure I.17-2 shows a design that has been under development in Budget Period 2. This unit can charge two vehicles and can be deployed either on streetlights or in parking garages. The unit includes only a circuit breaker with built-in EV charging capability. The team is currently working to manufacture this design, which would cost less than half of similar off-the-shelf solutions on the market. Significant cost reductions derive from the fact that the unit relies only on a smart-phone interface and does not require any additional human interface.

Figure I.17-2. Charging unit currently under development for deployment in both street lights and parking garages.

Conclusions

This project in the second year of its three-year performance period and has deployed two prototype charging stations. The team has determined that the proposed solution can reduce hardware costs relative to charging infrastructure currently available on the market. The team has also determined that installation costs can be reduced significantly in cases in which no underground work is required to provide power to the charging station. During the final year of the project, the team will be working closely with several municipal partners to determine the potential impact on soft costs associated with permitting.

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I.18 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: April 8, 2019 End Date: June 30, 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 very 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 these 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, and 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 dwelling (MUD) and curbside residential charging stations have limited deployments in apartments and condominiums. MUDs make up approximately 34% of the nation's 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/residents, 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 properties 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 created during the project.

Results

During 2020, the project team focused on MUD charging baseline characterization, charging infrastructure innovations demonstration planning, Toolkit development, and on-going partner and stakeholder engagement. With over 25 project partners, the project team worked closely with the project advisory committee (PAC) and engaged them through quarterly meetings and newsletters. The 79-member PAC, including Clean Cities coalitions, government agencies, electric utilities, innovative technology providers, MUD owners/managers, Idaho National Laboratory, and the National Association of State Energy Offices (NASEO), is integral to project success because the members are actively engaged in promoting, siting, evaluating, and operating EV charging infrastructure. The project team engaged the Clean Cities coalition partners on MUD stakeholder outreach, through monthly coordination meetings. Coalitions performed outreach in their respective regions, and provided over 60 completed interview forms documenting MUD stakeholder feedback on barriers to EV charging infrastructure deployment. Both the PAC and the Clean Cities partners have provided additional project outreach on identifying potential data providers and charging demonstration site hosts, as well as providing valuable feedback on Toolkit development. Cross-project communication with Kansas City and North Carolina Curbside Charging project teams has been facilitated through quarterly conference calls.

To maximize effective project communication, the project name was changed to Vehicle Charging Innovations for Multi-Unit Dwellings (VCI-MUD) to most accurately capture the intent of the project. The project team created a project website (www.VCI-MUD.org) as a resource for PAC members, Clean Cities coalitions, and stakeholders, along with a project logo and branding (Figure I.18-1).

Figure I.18-1. VCI-MUD Project Logo

The project team developed a MUD charging baseline characterization by identifying and contracting with data provider partners, and collecting and analyzing baseline installations to determine current state of practice, operating characteristics, business use, and areas for improvement. The project team documented the results of the baseline characterization in the project report, *Baseline Multi-Unit Dwelling Charging Infrastructure Data Analysis*. To prepare for the charging infrastructure innovations demonstrations, the project team developed a planning document, *Innovative Charging Infrastructure Technology Pilot Demonstration Plan,* which details how the demonstrations will be performed, and delivered both reports to DOE in June 2020. The project team has secured demonstration host sites in multiple metropolitan areas in California, Oregon, Utah, Wisconsin, Maryland, and Georgia, and has identified innovative technologies for demonstration. Table I.18-1 identifies the innovative technology providers who are participating in the technology demonstrations.

Table I.18-1. Innovative Technologies for Demonstration

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

Company	Innovative Solution	Application
EVmatch	Scheduling/reservations	MUD
Xeal	Scheduling/reservations	MUD

The project team prepared a data parameters set detailing the data points that will be collected at each of the demonstration sites, including operational costs and business case data.

The project team further developed the MUD and Curbside Residential Charging Toolkit, that will serve as the vehicle to convey project results, best practices, market transformation recommendations, and innovative tools to MUD stakeholders nationally. When complete and housed online on the project website, it will provide actionable information on MUD EVSE implementation, with appropriate tools so users can find relevant resources to go through the 'Journey of MUD EVSE'. With input from the PAC, the project team developed five (5) Innovative Charging Technology Fact Sheets and has defined five (5) Toolkit tools, including: 1) MUD EVSE Journey Roadmap, 2) MUD Resident and Building Owner 'Empowerment Toolkit', 3) MUD EVSE Technology Selection/Recommendation Tool, 4) MUD Self-evaluation Survey on Building EVSE Readiness, and 5) Outreach Presentation Tool. The project team established a partnership with the Virginia Clean Cities coalition, Generation 180, and Green Energy Consumers Alliance to co-develop a portion of tool #2 in the toolkit, that is focused on empowering MUD residents with education and self-advocacy tools.

Members of the project team had the opportunity to present on or discuss the VCI-MUD project at multiple venues and forums in 2020, including:

- Energy Independence Summit 2020, Washington D.C., February 10-12, 2020
- Radio interview with South Shore Clean Cities coordinator Carl Lisek on Northern Indiana's NPR station, February 26, 2020
- Tech Integration Data Collection Projects Webinar, May 7, 2020
- Smart Electric Power Association (SEPA) Working Group meeting, June 18, 2020
- Real Estate Adoption of EV Charging 'The State of EV Charging', July 28, 2020
- Association of Energy Service Professionals (AESP) Webinar, August 4, 2020
- Smart Charging and Real-World Applications webinar series, September 22, 2020.

The project team also submitted a presentation for the Green Transportation Summit & Expo (GTSE) in Tacoma, WA, originally scheduled for April 2020, but subsequently canceled due to COVID-19.

Other project impacts from COVID-19 have included limited in-person outreach/engagement, delayed start to some demonstration installations, and reduced cost-share from several project partners due to the cancellation of in-person events (e.g., conferences).

Conclusions

The project has assembled a large and diverse data set that deepens our understanding of MUD and curbside residential charging. The qualitative data has confirmed many of the barriers of deploying charging at MUDs, while also reinforcing that MUDs are not a monolithic sector, but have substantial differences in physical layout, ownership and decision-making structures. Both the quantitative and qualitative data have helped to inform the project's innovative charging technology demonstrations and toolkit development work. Leveraging the expertise and networks of the large project partner team has proven an effective strategy toward the goal of addressing and overcoming barriers to EV charging at MUDs.

Key Publications

Fuels Fix article, Clean Cities Coalitions partner on vehicle charging innovations for multi-unit dwellings (January 2020) http://www.fuelsfix.com/2020/01/clean-cities-coalitions-2/

Roadmap 2020/EVS33 technical paper (April 2020)

Baseline Multi-Unit Dwelling Charging Infrastructure Data Analysis (June 2020)

Innovative Charging Infrastructure Technology Pilot Demonstration Plan (June 2020)

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Energetics - Ziga Ivanic, Russell Owens, Chris Liu, Margaret Smith (formerly with Energetics),
Forth - Eric Huang, Whit Jamison, Jeff Allen
Center for Sustainable Energy - John Livermore, Lori Demaine

I.19 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 (the City). 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 the 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, Missouri, and Evergy are working together to design the schematics for upgrading the streetlights and integrating and mounting the EVSE units. See Figure I.19-1 for a sample cost estimate. The City is also leading an effort to evaluate its policies related to EVSE, and provide a list of best practices. Installation and monitoring are expected to begin in 2021.

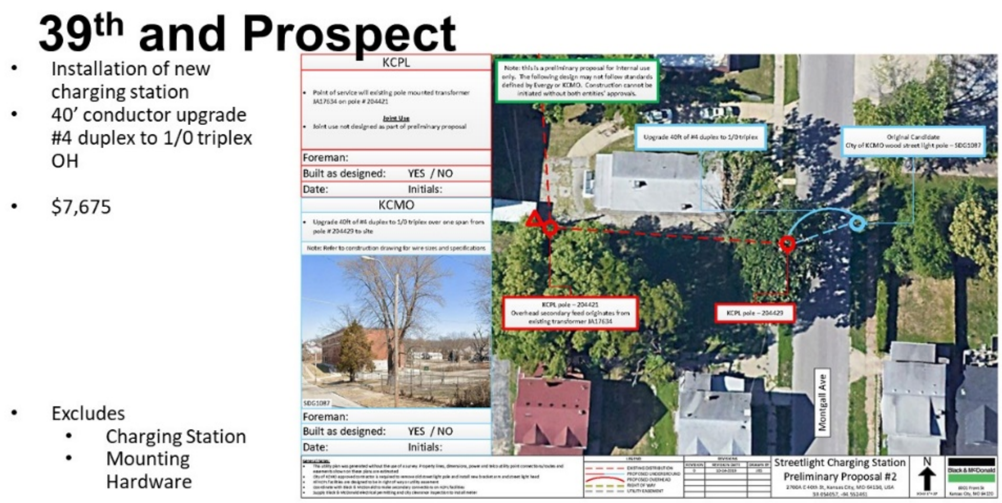

Figure I.19-1. Sample cost estimate, Black and McDonald

Results

At this stage, MEC has received the final version of the demand-based siting model from MST and the equity-driven model from NREL. MEC has pricing estimates and sample schematics for installation. The project team has drafted a policy framework, which is under review; drafted site selection criteria and site visit checklists; and created a community outreach plan and messaging documents. Each of these topics is discussed in detail below.

MST and NREL have completed the siting models. The data and approach used will be detailed in a final report. The MST model uses current usage statistics from existing charging stations and point-of-interest (POI) data to recommend specific candidate streetlight locations. The NREL model uses demographic data, including income, housing type, and EV adoption rates, to recommend broad areas of the City that are underserved by the existing charging network, and determine who may be likely to purchase an EV when the necessary infrastructure becomes accessible.

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 City's Parking and

Streetlights Departments 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.

The data is visualized in an interactive map for use by the site selection committee. The plan is to incorporate selected sites into MST's model as existing charging stations and generate a new set of recommendations. See Figure I.19-2 for an image of the interactive map showing both models.

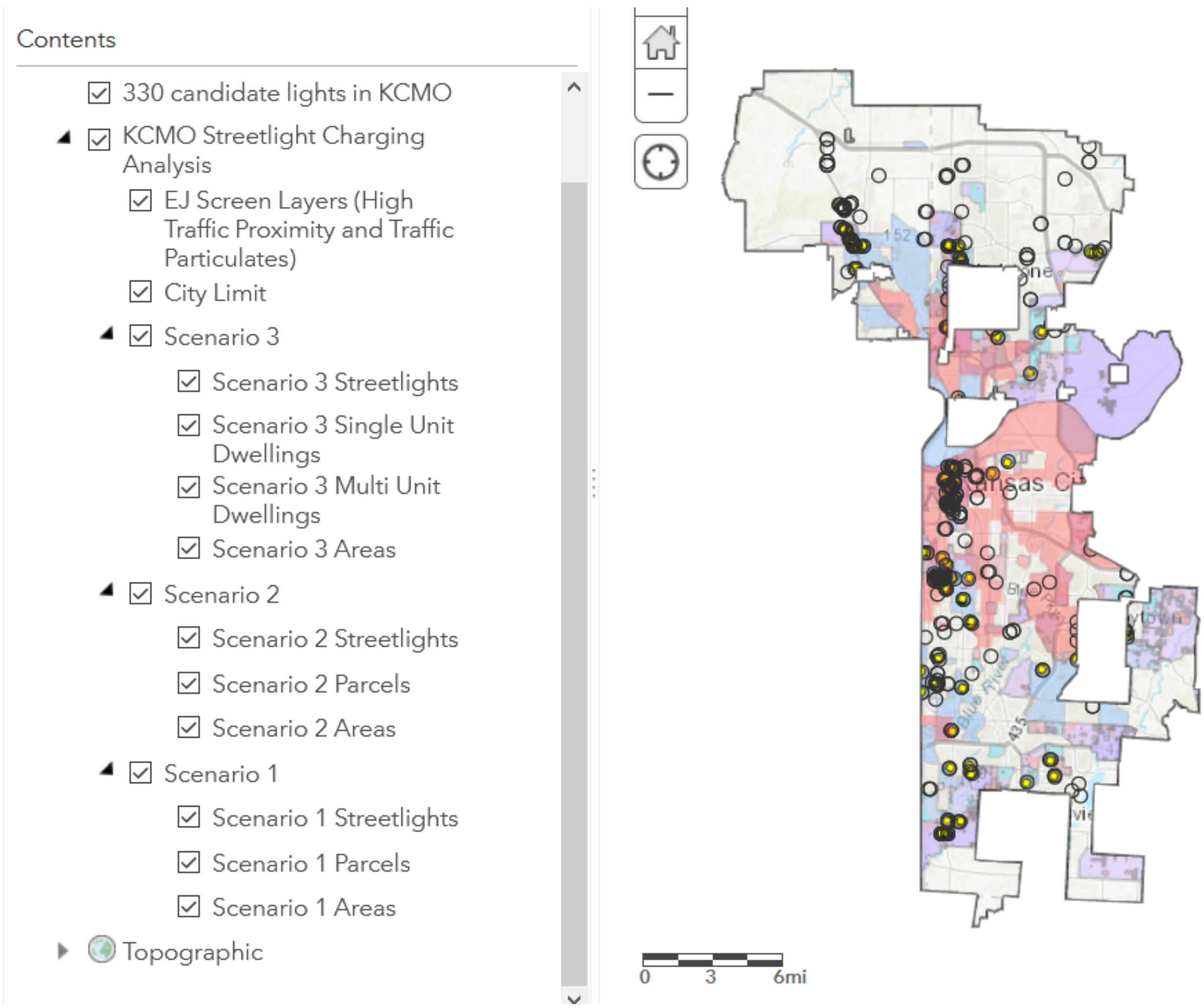

Figure I.19-2. KCMO streetlight charging analysis, NREL

MEC prepared a draft of the site selection criteria that will be used in the go/no go decisions. A site selection committee, comprised of project team members, has been formed to determine which criteria will be included in the final decision-making process and how each factor will be weighted. The committee will also consider input from other project team members. The first site selection committee meeting has been held. Committee members determined that the first step in the process should be review by the City's Streetlights and Parking Divisions. The City compared the proposed sites with detailed streetlight asset data, as well as street parking and zoning data, to recommend sites for elimination. This process eliminated about two-thirds of the proposed sites. MEC eliminated additional sites due to the likelihood of being flagged during the National Environmental Policy Act (NEPA) review process, causing delays. The next step in the process is site visits, which have been delayed due to the COVID-19 pandemic, but are planned for the end of the year. Project subrecipients have compiled checklists in preparation for the site visits. Items on the site visit checklists include but are not limited to environmental factors, parking restrictions, power source, and safety hazards. Prior to site visits, the project team plans to conduct limited community outreach, by notifying neighborhood groups of our plans and training site visitors on interacting with residents. Once site visits are complete, the site selection committee will reconvene to discuss which sites should be selected. The plan is to prioritize areas that overlap between the MST and NREL models, and sites with high cost-benefit ratios.

While evaluating site feasibility, one 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 would need more upgrades than previously thought.

NREL and MEC created a communications plan, which includes community listening sessions to gather data on end-user needs, as well as interests and concerns of area stakeholders who may not necessarily become end users. The communications plan will continue to be fine-tuned with input from project partners, as well as area stakeholders. NREL executed a contract with EV Noire, a communications strategy consultant organization. MEC, NREL, and EV Noire have drafted messaging for community outreach. The plan is to engage local organizations to assist with building out a stakeholder matrix of participants. Due to the ongoing COVID-19 pandemic, plans for community outreach are being revised to ensure they are in line with local plans to protect public health. MEC, NREL, and EV Noire are evaluating ways to engage community members virtually. We anticipate conducting listening sessions in the spring, results of which will be included in final site selection.

Black and McDonald provided pricing estimates and sample schematics for installation. Black and McDonald also designed an engineering plan and EVSE schematics. Lilypad EV determined the specifications for ChargePoint CT4000 level 2 commercial charging stations. Dual cord stations will be utilized where possible. The schematics plan for mounting hardware may need to be altered, dependent on site-specific needs, which will be determined by final site selection. See Figure I.19-3 for a sample mounting plate.

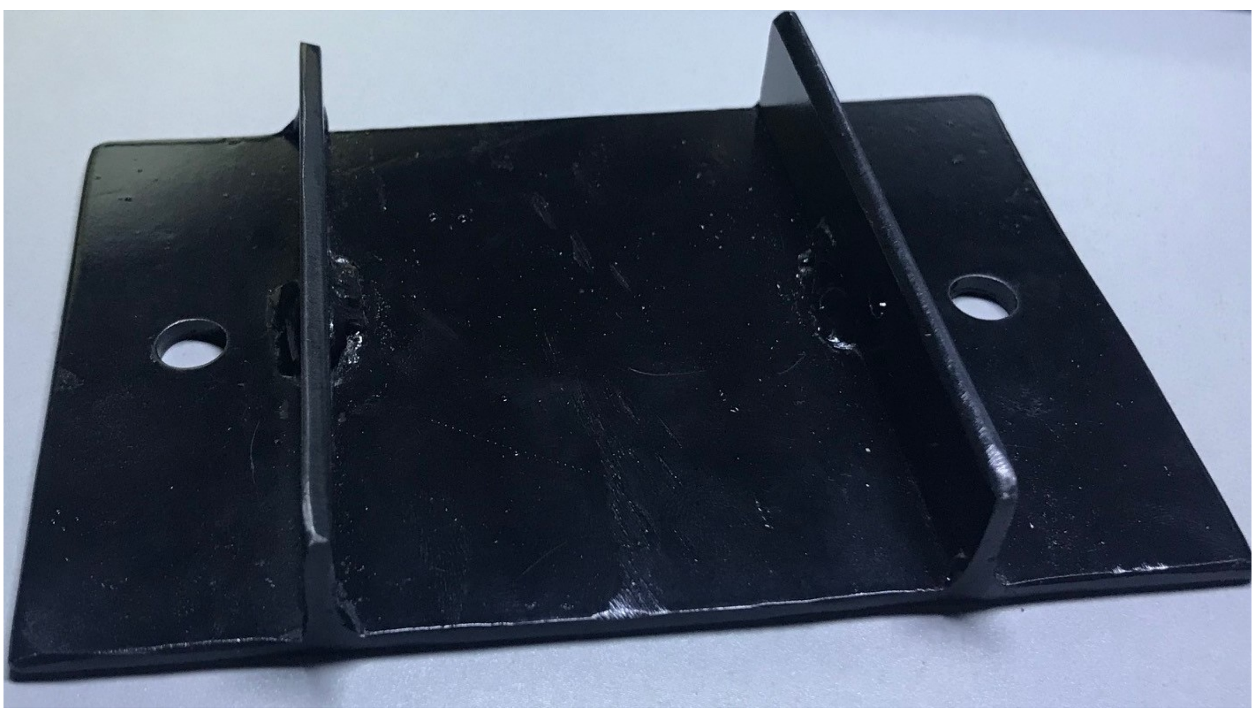

Figure I.19-3. Sample mounting plate, Black and McDonald

The project team met as part of the City's EV task force to finalize a draft policy framework, and presented it to the Director's Subcommittee, which rejected the draft because they wanted more directive policy statements, as opposed to a generic framework. MEC received permission from the subcommittee to share the draft with the rest of the project partners and began to solicit input from them on the document. The City's EV policy taskforce will consider this input as they finalize their specific recommendations. This task has been delayed due to reduced staff capacity at the City caused by turnover and the COVID-19 pandemic.

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 light-emitting diode (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.
- Some streetlight poles are unsuitable for EVSE. The engineering team will do a load analysis on each candidate pole to make sure it can support the weight of the station, both wooden and metal poles. This will be a criterion for site selection.
- Some streetlight locations and areas of the city are unsuitable for curbside parking. A review by the city is critical to ensure that selected streetlights are optimal for curbside parking. Many streetlights were eliminated after the city's parking evaluation.

Conclusions

This project has encountered many unexpected challenges, but it remains on target thanks to the flexibility and persistence of the project partners. Although we are seeing delays due to the COVID-19 pandemic and other factors, project staff are monitoring opportunities to lessen these delays and are preparing mitigating actions as necessary.

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.20 Multi-Modal Energy-Optimal Trip Scheduling in Real-Time (METS-R) for Transportation Hubs (Purdue University)

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Start Date: October 1, 2018 End Date: December 31, 2021
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 consumption. 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

To develop the METS-R platform, the project team implemented the framework illustrated in Figure I.20-1. In the first year of the project, the team achieved five milestones in data preparation and analytic modules. In the second year of the project, the project team has focused on designing and extending the planning and operation algorithms, in addition to developing the high-performance simulation platform. More details of our approaches are summarized as follows:

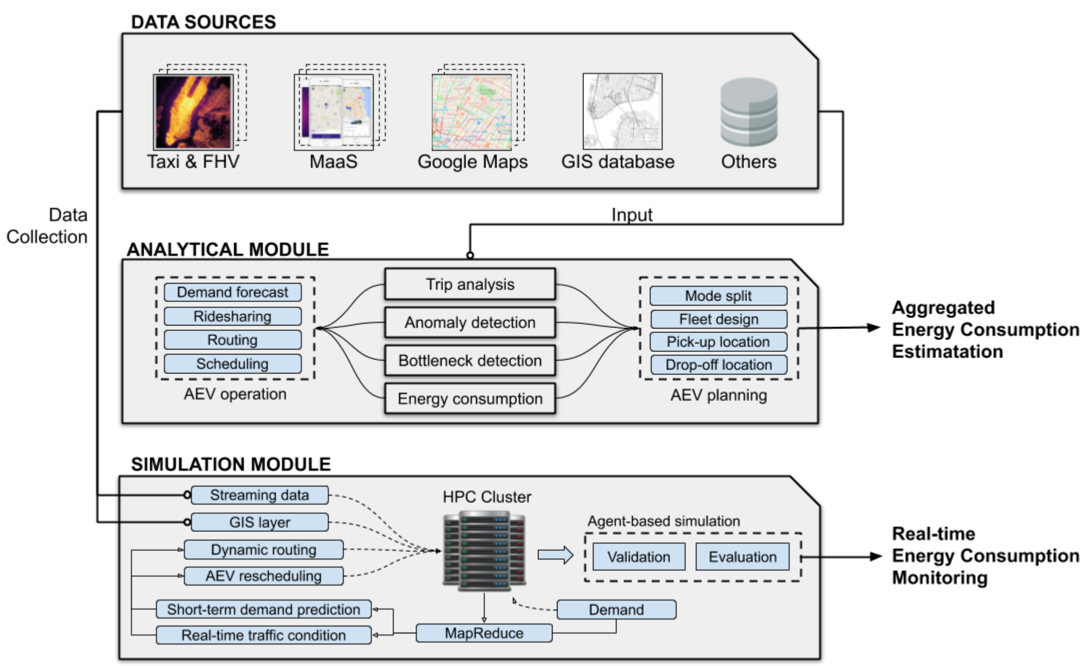

Figure I.20-1. Framework of the METS-R platform

Planning and operation algorithms

The project team developed an online routing and ridesharing algorithm for AEV services at transportation hubs. The proposed algorithm leverages the prediction results of passenger arrivals with the main objective of vehicle occupancy improvement. Moreover, the team revisited the route generation algorithm for AEV services and the charging station planning models by utilizing robust optimization techniques and capturing various scenarios.

Agent-based simulation

The project team developed a simulator based on the previous work [1]. The team divided the urban space into multiple service zones where each zone is considered as an agent for passenger generation and vehicle charging. The team developed two types of AEV agents to model the two AEV services: AEV taxi and AEV bus. For the AEV taxi, the team implemented the functions of pickup/drop-off passengers, eco-routing, fleet rebalancing, and recharging. For the AEV bus, the team implemented the functions of demand-adaptive route choices, passenger boarding, and recharging. The project team also documented the details of the simulation development.

High-performance computing (HPC)

The HPC module is implemented as the "brain" of multiple simulation instances to improve the computation performance. While the basic vehicle movement and passenger operations are handled within each simulation instance in parallel, the HPC module performs the expensive operation algorithms such as demand-adaptive transit scheduling and online routing algorithms. By pre-calculating the results of the AEV operation algorithms in the HPC module, the total runtime is improved. In addition, the HPC module allows multiple instances with the same setting to share the results of the operation algorithms, which further reduce the computational cost.

Results

The project team achieved four milestones during the second year of the project.

1. The team developed a high-performance agent-based simulation for evaluating the performances of AEV services. The inputs of the simulation platform are: 1) infrastructure data including the shapefiles of AEV service zones, road networks, and charging stations, 2) the candidate routes for AEV bus service, 3) the travel demand for each origin-destination pair, 4) the flight arrival data, and 5) the background speed data at each time period. The outputs of the simulation are the vehicle trajectories and the metrics of energy consumptions and service incomes. More details of the simulation process can be found in the online document at https://tjleizeng.github.io/doe-mets-r/. Using the data collected in the first year, the team created a case study for the transportation hubs (Penn station, LGA and JFK airports) in NYC. Moreover, the team also developed a visualization tool for monitoring the vehicle trajectories and the energy consumptions. See Figure I.20-2. A demo for this tool is available at https://engineering.purdue.edu/HSEES/METSRVis/.

2. The project team implemented the HPC module and validated its scalability. The team tested the HPC module by using the different numbers of parallel simulation instances, and examined whether the data communication was established properly. Each simulation instance was run for 30,000 ticks (2.5 hours), and the number of messages received and sent by the HPC module was recorded. The results showed that the HPC module can manage communication between many simulation instances (up to 16 parallel instances), and its performance was not impacted by the simulation load.

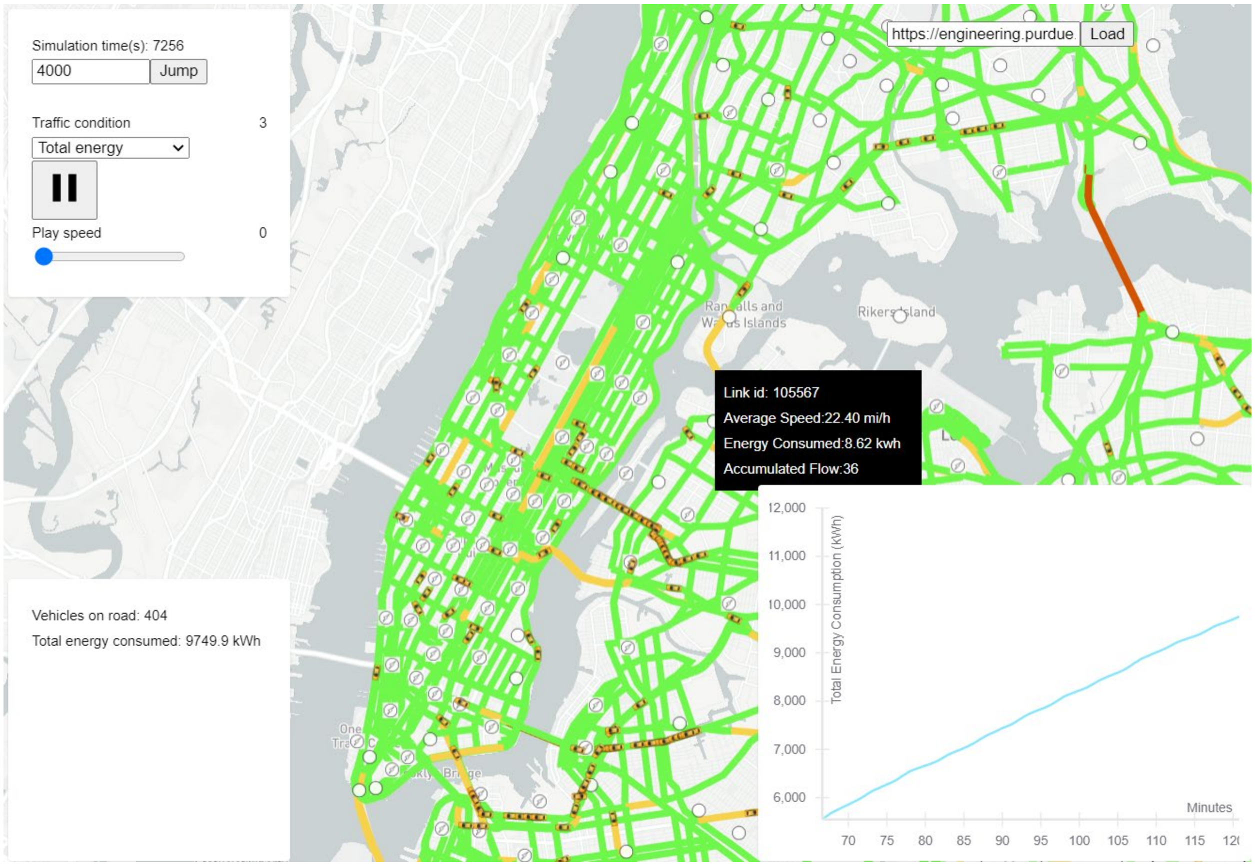

Figure I.20-2. Visualization of the simulation result (Middle: Energy map; Upper Left: Control panel of the visualization tool; Bottom left: Summary of the simulation results; Bottom right: Chart for cumulative energy consumption)

3. The team proposed a hub-based ridesharing algorithm to improve the vehicle occupancy at transportation hubs. The algorithm takes the predictions of the travel demands and vehicle supplies as inputs, and delivers the matching between vehicles and passengers by solving a two-stage stochastic optimization problem. The algorithm was validated by simulating the ridesharing services at JFK airport in NYC for the three time periods (7:30-7:40, 12:30-12:40, 21:00-21:10). The results suggested that our algorithm can save 25%, 36%, and 20% of vehicle mileage in these time periods, respectively, when compared with the algorithm that does not use predictive information.

4. The team developed an online learning algorithm for the eco-routing of AEV. The algorithm utilizes the observed AEV energy consumptions to balance the exploration of less-visited links and the exploitation of the conceived energy-efficient routes. We conducted the experiments by simulating AEV services in Penn Station, LGA and JFK Airports. The result showed that using eco-routing can reduce the energy consumption by 20% for the entire fleet.

Conclusions

In the second year of the project, the team accomplished the development of the high-performance agent-based simulation platform, and validated the scalability of the HPC module. Moreover, the team developed hub-based ridesharing and online eco-routing algorithms to reduce the traffic congestion and energy consumption for serving the passenger trips at the transportation hubs. The project team is currently conducting more experiments to extract useful insights for policy makers.

Key Publications

Chen, X., Xue, J., Qian, X., Suarez, J., & Ukkusuri, S.V. (2020). Online Energy-optimal Routing for Electric Vehicles with Combinatorial Multi-arm Semi-Bandit. In 2020 IEEE Intelligent Transportation Systems Conference (ITSC). IEEE.

Lei, Z., Qian, X., & Ukkusuri, S. V. (2020). Efficient proactive vehicle relocation for on-demand mobility service with recurrent neural networks. Transportation Research Part C: Emerging Technologies, 117, 102678.

Qian, X., Lei, T., Xue, J., Lei, Z., & Ukkusuri, S. V. (2020). Impact of transportation network companies on urban congestion: Evidence from large-scale trajectory data. Sustainable Cities and Society, 55, 102053.

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

Qian, X., Xue, J., Sobolevsky, S., Yang, C., & Ukkusuri, S. V. (2019). Stationary Spatial Charging Demand Distribution for Commercial Electric Vehicles in Urban Area. In 2019 IEEE Intelligent Transportation Systems Conference (ITSC) (pp. 220-225). IEEE.

Lei, Z., Qian, X., & Ukkusuri, S. V. (2019). Optimal Proactive Vehicle Relocation for On-Demand Mobility Service with Deep Convolution-LSTM Network. In 2019 IEEE Intelligent Transportation Systems Conference (ITSC) (pp. 3373-3378). IEEE.

Qian, X., Xue, J., & Ukkusuri, S. V. (2019). Demand-Adaptive Transit Design for Urban Transportation Hubs. Accepted for presentation at 2020 Transportation Research Board (TRB) annual meeting.

Qian, X., Xue, J., Sobolevsky, S., Yang, C., & Ukkusuri, S. V. (2019). Charging Infrastructure Planning for Commercial Electric Vehicles Based on Stationary Spatial Demand distribution. Accepted for presentation at 2020 TRB annual meeting.

Qian, X., Lei, T., Xue, J., Lei, Z., & Ukkusuri, S. V. (2019). Understand the Impact of Transportation Network Companies on Urban Traffic Using Large-Scale Trajectory Data. Accepted for presentation at 2020 TRB annual meeting.

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[1] Gehlot, H., Zhan, X., Qian, X., Thompson, C., Kulkarni, M., & Ukkusuri, S. V. (2019). A-RESCUE 2.0: A High-Fidelity, Parallel, Agent-Based Evacuation Simulator. Journal of Computing in Civil Engineering, 33(2), 04018059.

I.21 NGV U.P.T.I.M.E. Analysis: Updated Performance Tracking Integrating Maintenance Expenses (Clean Fuels Ohio)

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Start Date: October 10, 2019 End Date: December 31, 2022
Project Funding: $950,000 DOE share: $450,000 Non-DOE share: $500,000

Project Introduction

The NGV UPTIME Analysis project will implement a proven, multi-data set analysis approach to clearly determine the maintenance cost differences between multiple generations of natural gas vehicle (NGV) technology (current state-of-the-art and previous) and current advanced clean diesel engines (post-2010 and post-2017). The study will strive to capture the impacts of different technology solutions and best practices used by project partner fleets capable of impacting/reducing maintenance costs. The results will showcase the analysis findings by end-use application, engine/fuel system manufacturer, and vehicle chassis manufacturer, among others, to determine specific research, development, and outreach needs by application.

Objectives

The objectives of the project are to quantify the difference in maintenance costs between diesel and compressed natural gas (CNG) freight and goods movement vehicles; identify and quantify technology and process improvements between older and newer generation NGVs; and assess individual NGV fleets to identify opportunities to enhance operations using current and past NGV and diesel fleet data.

Approach

The project will include data from at least 1041 total vehicles, accumulated across at least 383 vehicle months. Vehicles included in the data set will have accumulated a minimum of 200 miles and two calendar months of data, from medium- and heavy-duty NGV fleets such as local, regional, and national freight and goods movement providers. The project will include raw data collection from current and historical vehicle use; data cleaning; analysis; compilation; summary; dissemination; visualization creation; reporting; National Laboratories review; data set structuring and integration; and transfer to the U.S. Department of Energy (DOE) in support of project objectives.

Results

Clean Fuels Ohio completed several tasks which have led to the successful completion of a series of milestones in the first year of the project. Milestones from year one include:

1. Develop a Data Collection and Analysis Plan: Complete a data collection plan and gain approval from DOE

2. Fleet Partners: Complete a list of key regional fleet partners

3. Data Gathering Project Advisory Committee (PAC) Meeting: Conduct PAC meeting to obtain feedback on data gathering efforts.

The Go/No Go for the first year of the project was to obtain fleet partnership agreements from regional partners capable of securing 1041 total project vehicles.

Clean Fuels Ohio developed a Data Collection and Analysis Plan, and DOE subsequently approved the plan. Clean Fuels Ohio partnered with and executed a sub-contract agreement with Energetics to perform the data storage, cleaning, repair, anonymization, analysis, visualization, and key reporting functions. Clean Fuels Ohio also partnered with the National Renewable Energy Laboratory (NREL) to assist with informing the set up and best practices for the data collection and analysis process. As described below, the project team assembled a diverse set of industry experts to serve on the PAC and convened a PAC meeting to gain input on data gathering and analysis best practices.

Additionally, Energetics drafted a comprehensive “NGV UPTIME Data Collection and Analysis Plan” and submitted it to Clean Fuels Ohio for review. This comprehensive plan covers the following key topics in detail: project schedule, data diversity, data partner recruiting, data partner data sharing agreements, data parameters and other collected information, data collection process, data storage methodology and security, and data analysis. Clean Fuels Ohio is working to finalize this draft with Energetics and NREL and submit it to DOE for final approval.

Clean Fuels Ohio partnered with and executed a sub-contract agreement with five Clean Cities Coalitions, including Virginia Clean Cities, Wisconsin Clean Cities, Dallas-Fort Worth Clean Cities, Central Oklahoma Clean Cities, and Tulsa Clean Cities. The Clean Cities coalitions identified key NGV fleet stakeholders in their regions and submitted information to the NGV UPTIME team in detailed spreadsheets. In addition, Clean Fuels Ohio is working with various partners, including fleets that are part of the DOE National Clean Fleet Partner program, NREL, and the National Truck Equipment Association, to identify and contact major corporate fleets such as Swift, UPS, Ryder, and others who have significant deployments of NGVs in freight and goods movement operations nationally. The goal of the project is to significantly exceed the stated Go/No Go fleet data goals outlined. See Table I.21-1.

Table I.21-1. NGV UPTIME: Fleet Partner Engagement

Fleet Name	Data Agreement Status	# of Vehicles
Paper Transport	Signed	900
Time Transport	Signed	63
Contract Transport	Signed	118
EVO Transportation	In Progress	1100
JRayl	In Progress	130
FST Logistics	In Progress	75
Smith Dairy	In Progress	40
Superior Beverage	In Progress	36
Braums/WBH Transport	In Progress	75
Chappel	In Progress	75
Schwarz	In Progress	20
Seaboard Energy	In Progress	30
Waste Connections	In Progress	5
Total	2,667 Vehicles	

Clean Fuels Ohio recruited a diverse PAC to participate in and advise on the NGV UPTIME project. See Table I.21-2. The PAC will hold quarterly meetings to advise on a range of project topics. In addition, PAC members volunteered for routine follow ups and additional information sharing in a one-on-one setting with key project team members. The project team discussed NGV fleet data partner recruitment, data gathering, and analysis best practices with PAC members as a critical first step. Clean Fuels Ohio convened the PAC for a virtual meeting focused on data gathering and analysis best practices on June 24th. During this meeting, participants gave feedback on their past work with NGV fleet data and best practices for gathering this information.

Table I.21-2. NGV UPTIME PAC Members

Organization	Point of Contact	Relevance
NTEA	Doyle Sumrall	National association whose members comprise numerous freight and goods movement fleets and NGV end users
GeoTab	Amir Sayegh	Leading telematics company with dataloggers on numerous freight and goods movement fleets
AssetWorks	Marc Knight	Leading maintenance database and fleet management company with dataloggers on numerous freight and goods movement fleets
Yborra & Associates	Stephe Yborra	Former Director of NGV America and current consultant to the natural gas vehicle industry
Energetics	Russ Owens	Energetics Project Manager for NGV UPTIME
Cummins	Patrick Campbell	Original Equipment Manufacturer (OEM) engine manufacturer whose products represent the largest market share of CNG engines for medium and heavy duty NGVs
ICOM	Albert Venezio	Conversion kit manufacturer specializing in propane autogas and natural gas vehicle technologies
Agility Fuel Solutions	Joe Reisz	Compressed natural gas fuel tank manufactuer and supplier
Clean Energy Fuels	Sandra Ballard	Natural gas station company that operates a large network of natural gas stations nationally
Trillium	Marc Rowe	Natural gas station company that operates a large network of natural gas stations nationally
NREL	Leslie Eudy	Key technical partner providing data analysis, outreach and dissemination support for NGV UPTIME
Columbus State Community College	Steve Levin	Gaseous fuel technician instructor
NREL	John Gonzales	NREL Tiger Team expert on natural gas vehicles

Conclusions

Clean Fuels Ohio and the project team are largely proceeding as planned with project set up and deliverables for budget year one. The team did not expect to find any significant conclusions currently, and there is nothing considerable to report.

The global COVID-19 pandemic remains the biggest development impacting the project to date. Clean Fuels Ohio staff are working remotely for the foreseeable future to comply with CDC and State of Ohio guidelines pertaining to COVID-19. We plan to continue work on our DOE funded projects, as do all contracted project partners.

The main impacts of the COVID-19 pandemic are on the NGV UPTIME fleet partners who will be providing project data. Our project team has been in contact with numerous fleet partners and has found that these impacts break down into two broad categories:

1. Business & Cash-flow Slowdowns – This stems from “non-essential” businesses being either largely shut down or having limited customer demand due to social distancing and the variety of COVID-19 mitigation efforts that have included “stay at home” orders.
2. Limited Staff – Over Capacity – This stems from any “essential” supply chain business working with skeleton crews but facing increasing orders and demands to keep supply chains moving.

As a result of the uncertainty regarding how long these challenges will persist, we anticipate some slow-down in securing data agreements with fleet partners. While initial fleet responses have been positive, and fleet partners continue to express that they remain committed to sharing data with the NGV UPTIME project, most fleets have had to defer “new” and non-essential projects to later dates to keep essential services moving and establish new safety processes and protocols.

I.22 Smart CNG Station Deployment (Gas Technology Institute)

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Start Date: October 1, 2019 End Date: December 31, 2022
Project Funding: $1,161,031 DOE share: $404,246 Non-DOE share: $756,785

Project Introduction

State-of-the-art compressed natural gas (CNG) stations fill vehicles directly from a CNG compressor or using a combination of the compressor and high-pressure storage tanks. The gas is delivered to the vehicle using a dispenser that processes payment, controls the filling sequence, and determines when the vehicle is full. Unfortunately, current dispensers consistently underfill vehicles due to issues arising from the gaseous nature of the fuel. During the filling process the pressure of the fuel in the tank increases from a low to a high level. As this happens the temperature of the gas rises due to a phenomenon known as the heat of compression. Immediately following fueling, the temperature in the vehicle cylinders is often greater than 120°F. Because gas expands as its temperature rises, its pressure increases due to this warming effect and the pressure gauge indicates a 'full' cylinder even though the vessel is under-filled compared to the target fill density. Natural gas vehicle (NGV) fuel systems are typically oversized in response to underfilling. By increasing confidence in the fuel status of the vehicle, the vehicle fuel storage capacity can be reduced, which can lower fuel system cost by as much as 20%. To overcome the barriers preventing full fills, this project is addressing the development, demonstration, and deployment of a complete smart CNG full-fill solution.

The Gas Technology Institute (GTI) possesses decades of CNG filling experience, including numerous projects related to vehicle and station component design and full-fill testing, as well as operation of a public CNG fueling station. Relevant projects include the development and licensing of GTI's AccuFill CNG dispenser algorithm for non-communications-based fills, the recent development of an advanced smart dispenser algorithm for the California Energy Commission using wireless communications, and many gas industry funded projects. These projects focused on topics such as modeling of in-cylinder gas dynamics, development of in-cylinder gas injection nozzles, analysis of national variations in natural gas composition, and development of a protocol for wirelessly connecting CNG vehicles and dispensers. These projects have resulted in a unique understanding of the barriers that prevent full fills and how to overcome those barriers.

Objectives

The overall goal of the smart CNG station deployment project is to develop an advanced vehicle and station solution for maximizing a CNG fill with or without pre-cooling of the natural gas. CNG stations without pre-cooling will be able to immediately see safer, fuller fills onboard their vehicles, using the communications hardware and advanced control algorithm. Stations with existing or retrofitted pre-cooling systems will be able to guarantee consistent full fills year-round, regardless of the ambient conditions. The project will show a definitive improvement in fill quality, safety, and consistency using a variety of vehicles in diverse climates with large variations in gas quality, enabling an increase in the usable CNG storage capacity of up to 25%.

Approach

The project includes the development, demonstration, and field deployment of sensors, software, and communication systems on multiple smart vehicles and dispensers which will be programmed with an advanced control algorithm to maximize full fills. In addition, several of the demonstration locations will include CNG pre-cooling to help overcome the heat of compression during a fill that causes CNG tanks to reach their pressure limit before they are full. The combination of these technologies will solve the issues of dispensing uncertainty and elevated pressures from heat of compression that result in NGVs being under-filled.

To ensure the project results in a commercially viable solution for the CNG industry, GTI's team includes Clean Energy and Kraus Global. Clean Energy is the largest natural gas transportation fuel provider in North America and Kraus Global has been a world leader in the development of CNG dispensers and metered time-fill systems for over 30 years. Clean Energy and Kraus are working closely with GTI to develop a commercially viable smart filling solution that integrates seamlessly with new and existing vehicles and dispensers. The team also includes Ozinga Brothers, Inc. (Ozinga) to demonstrate fuller fills onboard their fleet of concrete mixers and support vehicles. Ozinga is a major concrete provider in the Chicago area, with many light- and heavy-duty CNG vehicles. These vehicles consume large amounts of fuel in a variety of weather conditions, making them an excellent test bed for collecting baseline filling data and comparing that to the improved fills received from a smart filling solution.

The first step in demonstrating and achieving full fills is to establish a diverse dataset of baseline dispenser performance. GTI has previously demonstrated underfilling using two commercial dispensers at GTI headquarters, but will expand on that data by collecting at least a year of filling and operations data on multiple vehicle platforms across the US. This will be accomplished by leveraging Clean Energy and Ozinga fleet vehicles instrumented with data acquisition units collecting mileage, fuel consumption, CNG pressure and temperature, as well as other relevant data points. The demonstrations will be strategically located at two sites in California, and one each in Illinois, Texas, and Colorado, to provide the team with a wide variety of gas compositions and climate conditions. The selected sites are known to experience extremely high and low temperatures throughout the year, as well as wide deviations in gas composition caused by high ethane or propane-air mixing. The team will collect baseline and smart-filling data for at least a year at these sites. This will ensure the performance of the baseline and smart station systems are fully characterized and quantified over a wide range of environmental conditions. The vehicles used in the demonstration will range from vans and pickups to Class 8, heavy-duty trucks. By ensuring an extreme mixture of fleet vehicles and locations the team will evaluate the impact these variables can have on a fill.

Concurrent to the baseline data collection, the team will build on GTI's extensive previous work to develop a prototype smart refueling system for CNG stations and vehicles. The team will design a smart vehicle module to fit within a vehicle and interface with temperature and pressure sensors onboard the fuel system. In addition to temperature and pressure, the smart vehicle module will be programmed to detect the CNG fuel system volume, tank quantity and type, tank age, last date of inspection, and other relevant information, which will be very useful to fleets and maintenance technicians. The vehicle module will have the option of connecting to the onboard computer or Controller Area Network (CAN) bus to access information such as total fuel consumption and usage rate. It will be integrated with wireless communications to transmit data to the fleet operator at its base or to the dispenser during filling.

The smart dispenser module will be designed to be fully compatible with any smart vehicle module it detects, while also being able to operate with new and existing commercial dispensers. The device will be installed within the dispenser cabinet and will be designed with multiple input and output interfaces to enable communications between the smart module and the existing dispenser logic. Future dispensers could have the smart software and communications hardware directly integrated into the dispenser; however, GTI sees the need for a near term, universal solution to ensure industry-wide adoption. Therefore, the proposed design will interface with the dispenser software and override the existing filling logic when a smart vehicle is detected. The vehicle's state of fill will be actively calculated using the information transmitted from the vehicle. In the case where communications are lost, the smart dispenser module will indicate that the dispenser should revert to its existing non-communications-based filling algorithm.

The first budget period focuses on developing vehicle and dispenser data acquisition systems (DAS) and smart module prototypes loaded with GTI's advanced dispenser control algorithm and integrated into a test dispenser provided by Kraus. Upon verification that the algorithm and controls are working in a laboratory environment, the team will integrate the prototype smart modules into an operational dispenser and vehicle fuel system. Kraus will undertake extensive testing to ensure the seamless and reliable integration of the smart components into their dispenser, while also ensuring the advanced full fill algorithm continues to perform as designed, safely and accurately filling vehicles. Following the successful integration of the smart modules, the team will prepare for deployment of the hardware to multiple sites in the field.

The field deployment will include the fabrication of the final smart vehicle and dispenser modules, the fabrication of five upgraded smart dispensers (one for each of the selected demonstration sites), and installation of the new dispensers at each site. Fabrication and installation will take approximately six months and then the systems can be tested in the field. While the smart dispensers and sites are being prepared, the team will install the smart vehicle modules to collect baseline data regarding filling at the stations.

Following installation of the equipment at the selected sites and onboard the vehicles, the team will verify each of the systems is operating correctly, resulting in a seamless connection between the vehicle and dispenser, and filling according to the smart filling algorithm. These sites will be operated for at least a year to capture the smart CNG station results across a wide range of filling conditions and to compare performance to the baseline. The team expects the addition of the smart components will significantly improve full fills on their own. However, pre-cooling will also be tested to achieve full fills on hot days. One of the California sites will include a gas conditioning system that can be safely used by the advanced algorithm to achieve an improved fill on a hot day, with the ultimate goal of getting a full fill on a >90°F day.

By the end of the project, the team anticipates the prototype smart components integrated with the advanced full fill algorithm will have shown a significant improvement in filling performance across all filling conditions. In addition, the smart components will enable the seamless addition of pre-cooling to a fleet or public station, enabling those vehicles to achieve year-round full fills. The anticipated improvements will enable the complete utilization of the CNG storage system, allowing fleets to reduce the volume and cost of CNG storage by up to 25%. The project will occur over 36 months.

Results

The major technical activities during this period included finalization of the requirements and specifications for the Data Acquisition Systems (DAS) that will be installed on vehicles under this project. A diagram showing the conceptual design of the DAS is shown in Figure I.22-1.

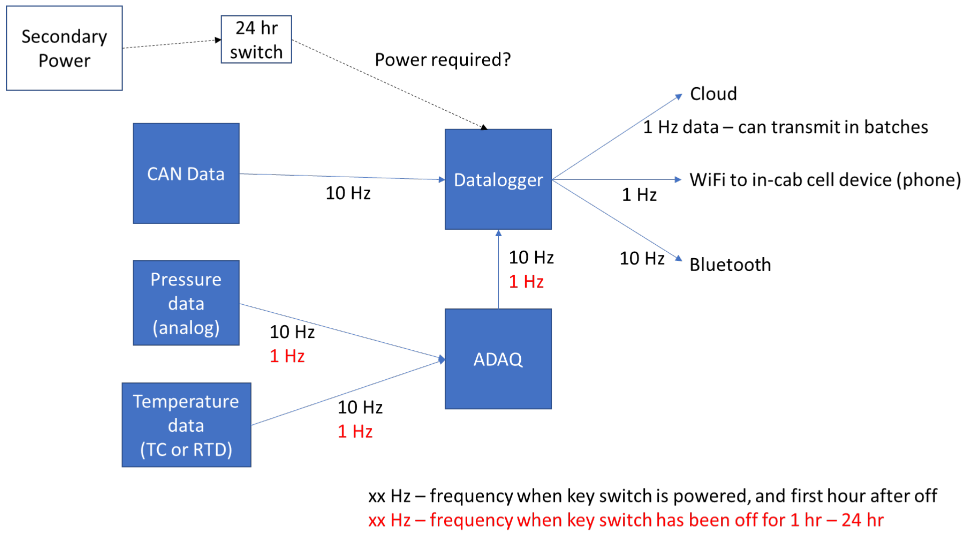

Figure I.22-1. Data Acquisition System conceptual design

The team agreed that two different systems would be built and tested at GTI before selecting one system to replicate and install on multiple vehicles. GTI wants to evaluate differences in cost, performance, ease of programming, and communication format before committing to one system. During this period, we completed design, assembly, and testing of two DAS in the laboratory and installed them on trucks for preliminary testing. The systems include a module that will be connected to temperature and pressure sensors in the CNG fuel system on the truck. Figure I.22-2 shows a schematic of the mounting system for these sensors and a photograph of where they will be installed on the tank. The design and installation of the sensors is on-going.

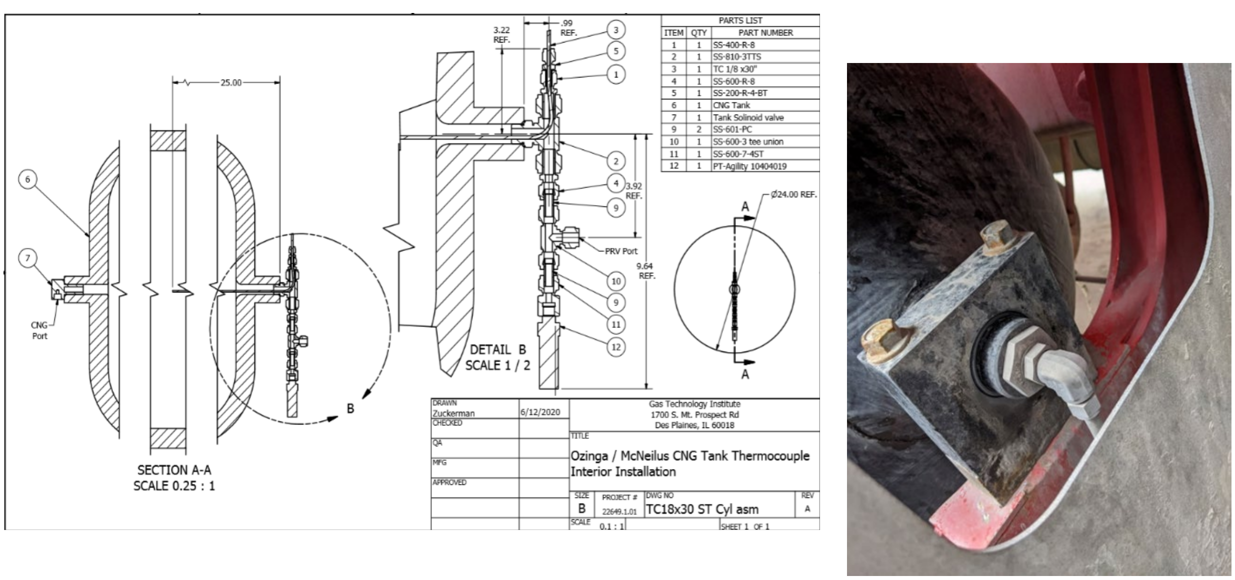

Figure I.22-2. Diagram of pressure and temperature probe mount (left) and photo of mounting location on tank (right)

The first DAS was assembled using parts from HEM Data (HEM). After successful testing in the laboratory, Ozinga Brothers, GTI's field test partner, installed the system on a truck. Data from these sensors and the CAN bus will be transmitted over Wi-Fi and cellular networks. The cell connection will be used to send all recorded data to a cloud server for analysis by GTI engineers. The Wi-Fi data streams will send real-time data to local devices such as the smart dispenser during fueling. This system is attractive because all vehicle and fuel system data can be consolidated on the CAN bus and then transmitted to various locations. Ozinga Brothers technicians then installed the HEM DAS in a Pelican Case and then mounted it on a cement truck for initial shakeout testing. Photographs of the HEM system in the case and the case in the truck are shown in Figure I.22-3. This system is sending data for storage and review over the cellular interface as designed. GTI is evaluating the amount of data that will be transmitted and best ways to store and manipulate that data. We are also evaluating the cost of the components to conduct a cost-benefit analysis.

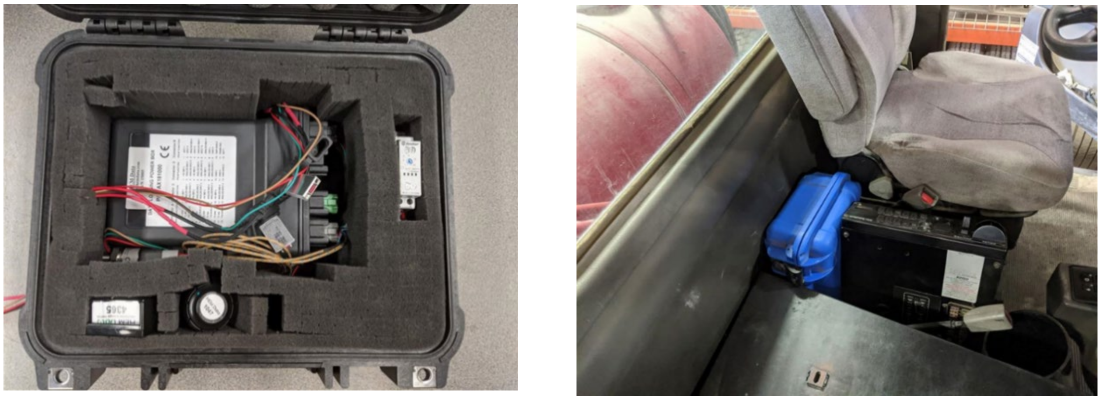

Figure I.22-3. HEM Data Acquisition System components in pelican case and mounted in a truck for testing

The team also assembled and tested a second system with parts from Campbell Scientific. The major components are shown in Figure I.22-4 during bench-top testing at GTI laboratories. Unlike the HEM system that sends all data to the CAN bus and then transmits, the Campbell system records select CAN bus data and then combines that with the measured pressures and temperatures from the truck's fuel system. The Campbell system can both filter and process that data onboard the unit and can also be programmed with additional data about the vehicle, such as the VIN number, tanks sizes, etc. These are all benefits of the Campbell system. However, the data converter and Campbell hardware have bandwidth limitations that are preventing the system from capturing all the CAN bus data at the full rate that it is broadcast over the CAN bus. Data filtering is being implemented to reduce the amount of data that is transmitted and thereby resolve the bandwidth issue.

Figure I.22-4. Campbell system components - battery pack, 12-18V boost converter, CR6-WIFI, CELL210 cellular module

Technical progress during this Budget Period was delayed by the Coronavirus pandemic, because GTI's laboratories were closed for over two months and were only slowly reopened with access restrictions after that. The decision to design, build, and test two competing data acquisition systems increased the scope of some tasks while longer-than-expected subcontract negotiations delayed the start of other tasks. The result of these changes and difficulties is that the project is 3 to 6 months behind the originally proposed schedule. The team will take steps over the next budget period to accelerate progress and get back on schedule.

Conclusions

GTI has proven in previous research that a more sophisticated algorithm, employing strategic temperature and pressure data from onboard sensors, can be used to control a CNG dispenser and provide more complete fills of NGV fuel systems. GTI has assembled a highly capable team to develop, test, and deploy smart station dispensers that utilize this algorithm and controls. This project will provide real-world data from a wide range of vehicles operating in a variety of weather conditions to confirm the applicability and benefits of the approach. Testing on five dispensers and multiple vehicles will confirm that a simple, cost-effective system can provide consistently fuller fills at CNG Smart Stations, which will give NGV designers the confidence they need to stop oversizing NGV fuel storage systems.

I.23 Next Generation NGV Driver Information System (Gas Technology Institute)

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Start Date: October 1, 2019 End Date: December 31, 2022
Project Funding: $1,600,000 DOE share: $600,000 Non-DOE share: $1,000,000

Project Introduction

Measuring the amount of fuel contained in the tank of a natural gas vehicle (NGV) is not as straightforward as it is for a liquid fueled vehicle. The fuel in an NGV is a compressed gas, and the pressure changes with temperature. If the gas temperature goes up – for the same amount of gas in a tank – then the pressure goes up. If the temperature goes down, then the pressure goes down. To complicate matters further, the temperature of the gas does not simply vary in response to the ambient temperature, but it also changes as a function of filling or emptying the tank through what is called the heat of compression. Whereas knowing a liquid level in a gasoline or diesel vehicle will provide an accurate measure of the volume of fuel (and energy) on-board the vehicle at any time, there is no corresponding single-value indicator of NGV fuel volume or energy content.

The current state-of-the-art, which is used on most NGVs, is a simple pressure gauge as a rough guide for remaining fuel. This presents a high degree of error because pressure varies widely depending on temperature. Immediately following fueling, the temperature in the vehicle cylinders is often greater than 150°F. The pressure gauge indicates a 'full' cylinder even though the vessel is under-filled compared to the target fill density. As the driver pulls out of the fueling station and begins consuming gas, the pressure drops at a very fast rate due to isentropic cooling of the gas. This pressure drop appears to the driver to be a very rapid decrease in fuel level, reducing trust in the fuel level indication and leading to concern about the distance the vehicle can travel before refueling again, which is known as "range anxiety."

The cost of range anxiety is difficult to quantify due to the dependency on driver experience. However, initial discussions with vehicle owners indicated they return for fueling when their vehicle tanks are still 20-40% full. Decreasing the remaining fuel content to below 10% before refueling would result in significant time and cost savings. The simplest way to quantify this savings is with fuel system costs. NGV fuel systems are typically oversized in response to full fill difficulties and range anxiety issues. By increasing confidence in the fuel status of the vehicle, the vehicle fuel storage capacity can be reduced, which can lower fuel system cost by as much as 20%.

Objectives

The objective of this project is to develop and demonstrate a more accurate and effective Driver Information System for any NGV that includes a prediction of the remaining miles-to-empty, within 5% or 25 miles (whichever is greater) at any time during vehicle operation. The predictive model of miles-to-empty requires knowing the amount of fuel energy on the vehicle and the required fuel for the route, based on real-time traffic conditions, speed profile, and weather, among other parameters. Increasing the driver's confidence in the remaining range of the vehicle will allow a reduction of on-board fuel capacity and frequency of fueling stops.

Approach

The calculation of the remaining miles-to-empty depends on the usable fuel quantity in the vehicle and on the average fuel economy along the upcoming route. These two values must be properly measured and predicted, respectively, to accomplish the goal of this project. The Gas Technology Institute (GTI) is addressing the estimation of the usable fuel remaining on the vehicle with the development of a new model relating CNG (Compressed Natural Gas) tank pressure to ambient temperature, on-board gas temperature, and estimated future fuel consumption rate. Fuel consumption rate is an often-overlooked factor, but it dramatically affects the temperature, and hence pressure, of the remaining gas due to the cooling effects of gas expansion. To predict the expected average fuel economy for a given route, GTI's partner, Argonne National Laboratory (ANL), is developing a second, predictive model of the required fuel based on powertrain efficiency, real-time traffic conditions, speed profile, and weather, among other parameters. These models make use of the fundamental thermodynamics of the problem and employ machine learning tools that will continually improve the calculated results. Once the two models are developed, they will be implemented in a turn-by-turn navigation mobile app to display a real-time miles-to-empty prediction to the driver. This app will also be used for driver guidance and fleet management.

The usable fuel status model utilizes a heat balance between the tank and the atmosphere to predict the amount of fuel that will remain stranded in the vehicle tank when the minimum operating pressure is reached. As fuel is consumed, the gas in the tank expands and cools. This isentropic expansion cooling causes a reduction in tank pressure and results in more gas stranded on board the vehicle as the low pressure lacks the driving force to provide sufficient gas flow to the engine. Fortunately, the CNG storage vessel walls act as a thermal buffer, providing heat from the atmosphere to the gas, which mitigates some of the pressure drop effect.

Two processes are being modeled to accurately predict the usable fuel status of the vehicle:

1. Isentropic decrease in gas enthalpy as the pressure is reduced
2. Heat transfer from the atmosphere to the vessel and from the vessel to the gas.

The first of these issues, the isentropic enthalpy decrease, determines how much the gas cools as it expands and how much heat needs to be transferred from the atmosphere (and through the wall of the vessel) to bring the gas back up to ambient temperature. Although enthalpy decrease for isentropic expansion is a well-studied and understood phenomenon, the amount of cooling varies with the composition of the gas. The team will determine how much variability is possible in this cooling as well as the impact it has on the fuel status prediction. Real-time estimation of gas composition using micro-electromechanical sensors (MEMS) will be considered if the variability is high enough to significantly impact the fuel level prediction.

The second process, heat transfer, occurs in several steps and requires modeling the heat flow between the tank liner, carbon-fiber wrapping, and the outer tank wall, which absorbs heat from the atmosphere. Previously developed modeling for hydrogen tanks, based on fundamental physics, are being used as a starting point for predicting heat transfer from the wall of the cylinder to the gas during fuel consumption. A natural convection heat transfer correlation is used to estimate heat transfer between the ambient air and the external surface of the vessel.

Significant spatial and temporal variations in gas temperatures have been observed. However, controlled experimentation coupled with real-world fleet testing will ensure that an accurate model of gas temperature is developed. Recent experimental work at GTI found the cylinder centerline temperature could predict the gas density within 1.5% at any time during a fill, when the gas is warming. The accuracy of predictions based on this centerline temperature is likely to be even better for the much slower fuel-consumption-driven cooling process.

Previous research at GTI measured the average temperature of the vessel wall and compared it to the gas temperature and ambient temperature during a fuel-consumption process over the course of three hours. Figure I.23-1 shows these temperatures. As expected, the vessel wall temperature sits between the gas and ambient temperatures. The temperature of the gas in the vessel depends on both the starting conditions and on how fast the gas in the tank is being consumed. If the vehicle is traveling at high speeds and consuming fuel quickly, the temperature will decrease faster, resulting in a more drastic pressure decrease and leaving more fuel stranded in the vessel below the minimum operating pressure. The mobile app that is being developed uses turn-by-turn navigation to determine how fast the fuel will be consumed and how fast the temperature will decrease. The modeling will be validated with data from several different types of fleet vehicles to ensure accuracy for a broad range of NGVs.

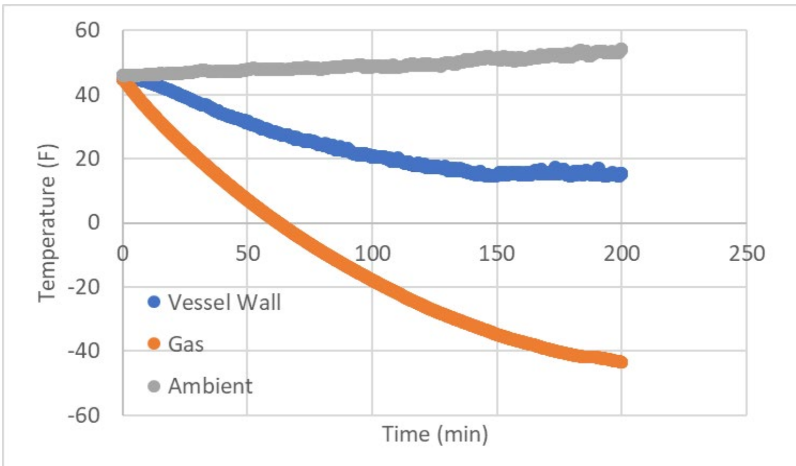

Figure I.23-1. Test result showing CNG and tank cooling during de-fueling over 3 hours

Once the usable fuel status on-board the vehicle is obtained, the miles-to-empty are calculated by dividing the amount of usable fuel by an estimation of the fuel economy. The fuel economy strongly depends on the route to follow, which is characterized with data collected by the mobile app. The route to follow is divided into different segments according to traffic conditions, and the fuel economy is calculated for each one. The overall estimated fuel economy of the route is the average value of the segments. Each segment is characterized by predicted values of average speed, weather (including ambient temperature and wind speed), and use of vehicle accessories (A/C, lights, etc.) among other factors. Using these inputs, fuel economy in the segment is calculated with two different approaches, an analytical approach estimating the impact of each parameter and an empirical approach based on machine learning. The two values obtained from these models are then averaged to obtain the fuel economy estimate of the segment. The process is summarized in the schematic shown in Figure I.23-2.

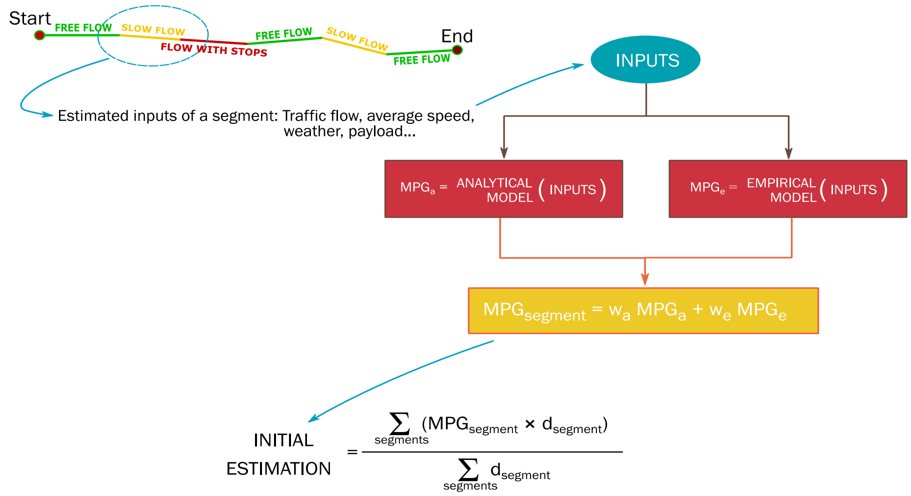

Figure I.23-2. Schematic representation of fuel economy calculation

The values of the parameters in the analytical model, the training of the machine learning model, and the weighting of each model on the average final fuel economy estimation are calculated from the fuel economy data collected during the baseline stage of the project. Twelve vehicles are being instrumented with temperature and pressure sensors in their fuel tanks and with data acquisition systems (DAS) to collect these and other data on the vehicle's performance and location. These values are used to validate the models with the aim of improving the accuracy of the predictions. In practice, as the machine learning model receives more input and improves its predictions, its relative weight in estimating the final fuel economy will be increased.

Two other corrections to the fuel economy models will be introduced on-road: a driving style correction and a recalculation of the overall fuel economy value. The driving style correction is a machine learning model that computes the effect of parameters such as hard braking, acceleration, or deviation from the estimated average speed. Recalculation of the overall fuel economy is done in response to significant changes, such as a change in the route, a change in the traffic, or a variation of the payload, among others. Data from the twelve trucks will be collected for over one year to help test the models in various driving conditions. GTI will provide several graphical user interface options for the driver, offering varying levels of data and analysis.

Results

Parametric modeling of CNG tank filling and emptying has been started in conjunction with lab testing. There are two main requirements to accurately determining the usable fuel left on the vehicle: 1) determining the total amount of gas contained on board the vehicle, and 2) predicting how much of that gas will be 'stranded' or unusable. We satisfy the first requirement with the real gas equation ($PV = ZnRT$), but difficulties can arise with variability in the composition of natural gas, which determines the compressibility factor Z and the molecular weight that is needed to convert gas quantity into a mass. GTI conducted a survey of gas composition across the US in 2013. The extremes from this analysis were used as boundaries to the model. With these inputs, a surface plot and equation were created to calculate compressibility factor as a function of pressure and temperature (Figure I.23-3). The surface created from these data is very accurate at temperatures above -60F but requires monitoring at -80F to -100F.

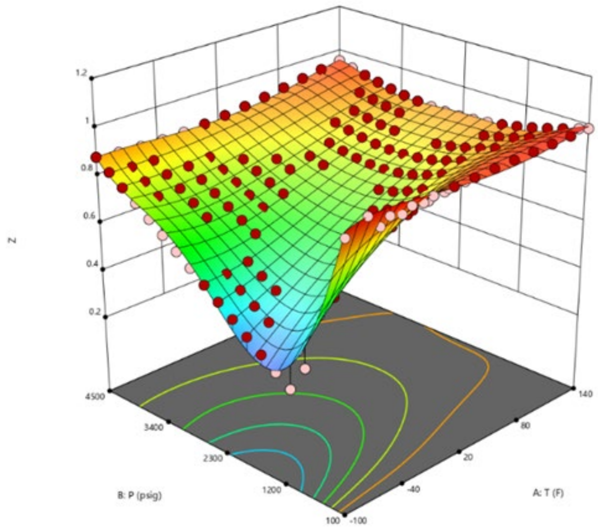

Figure I.23-3. Dependency of compressibility factor on pressure and temperature

GTI conducted experiments to determine the impact of heat transfer between the tank and the environment on the temperature inside the tank at the ‘empty’ condition. Figure I.23-4 shows the temperature inside the tank (relative to ambient) for several different de-fueling experiments. While the temperatures are very different from ambient, they are similar for widely different de-fueling rates. The ultimate temperature is dependent on the tank size, positioning, whether a shroud is present around the tank, and other factors. These data are being fed into a model to calculate the amount of un-usable fuel stranded in the tank below a given pressure.

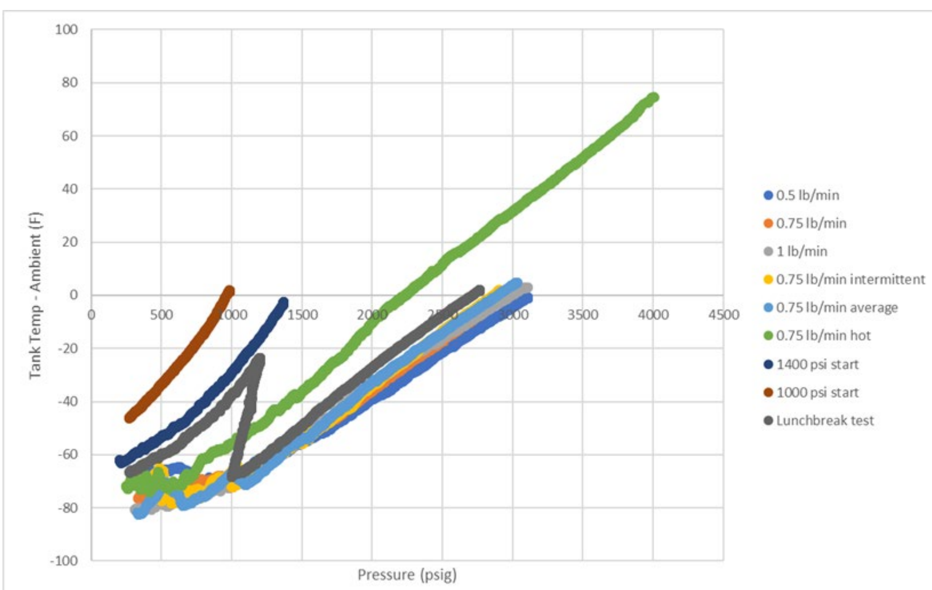

Figure I.23-4. In-tank temperature behavior during de-fueling

In the first Budget Period the major field test activities included designing and testing two DAS in the laboratory and installing each system on a truck. The GTI team decided to build and test two different DAS before selecting one to replicate and install on multiple trucks. One system uses parts from HEM Data that were designed for vehicle applications but have data-handling limitations. The other system uses parts from Campbell Scientific Inc. (CSI) that are commonly used in industrial applications and have more programming capability that provides data handling flexibility. GTI is evaluating differences in cost, performance, communication format, and ease of programming before committing to one system. A photograph of the HEM system during testing in the laboratory is provided in Figure I.23-5.

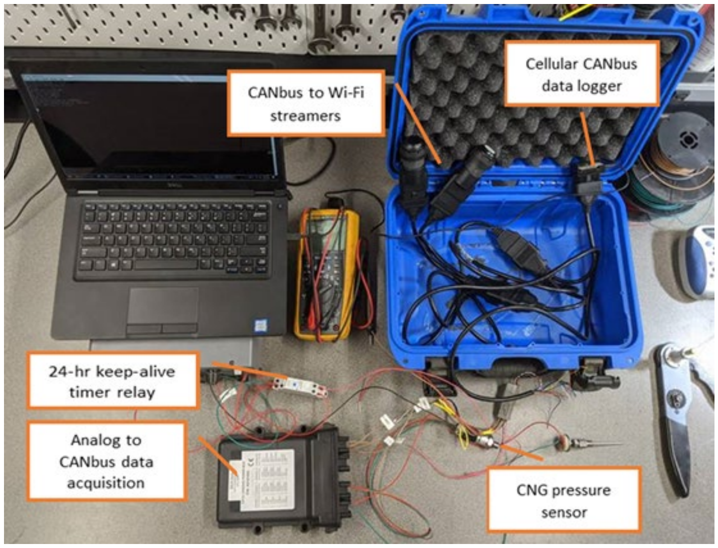

Figure I.23-5. HEM data acquisition system hardware on laboratory bench

Both DAS include a module that will be connected to the vehicle's Controller Area Network (CAN) Bus and to temperature and pressure sensors attached to the CNG fuel system on the truck. GTI has been evaluating options for data logging and transfer from the vehicle to other devices. Wi-Fi will be used for real-time, short-range data transfer to local devices, such as a smart dispenser during fueling or a driver interface. A cellular connection will be used to send data to a Cloud server that will be used to store and organize the data collected from each truck. During Budget Period 1, the data management strategy was determined. With the large amount of data generated, a cost-effective way to collect and store that data is required. The CAN Bus transmits more messages than are needed for the Driver Information System. The data need to be filtered so that only the needed data are stored and analyzed, but whether that filtering takes place on the vehicle (prior to transmission to the Cloud) or takes place in the Cloud (prior to storage and analysis) has not yet been determined.

Conclusions

GTI and its partner, ANL, have confirmed that more accurate estimations of usable remaining fuel and miles-to-empty for NGVs are possible if well-defined information about CNG pressure and temperature is known and combined with information about upcoming vehicle use (route, speed, stops, etc.). On this project, GTI is developing the models to make these predictions and testing them against real-world data in a wide range of duty cycles and weather conditions. The models and data acquisition systems were designed during this budget period. Testing on twelve trucks will confirm that a simple, cost-effective system can provide NGV drivers with the information they need to overcome range anxiety, and will provide NGV designers with the confidence they need to stop oversizing their fuel storage systems.

Key Publications

Because this project was just starting with the design of the data acquisitions system during this first year of activity there are no publications yet.

Acknowledgements

GTI would like to acknowledge the technical contributions of our partners at Argonne National Laboratory, Dr. Thomas Wallner and Dr. Michael Pamminger. We would also like to acknowledge the participation of our industry partners, Mr. Jeffrey Bonnema of Ozinga Brothers, Inc. and Ms. Samantha Bingham of the Chicago Area Clean Cities Coalition.

I.24 Carolina Alternative Fuel Infrastructure for Storm Resilience Plan (E4 Carolinas, Inc.)

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Start Date: October 10, 2019 End Date: December 31, 2022
Project Funding: $1,683,052 DOE share: $826,593 Non-DOE share: $856,459

Project Introduction

North Carolina and South Carolina are highly susceptible to severe weather, ranked among the top six states for hurricane occurrence by the National Hurricane Center (data for 1851 – 2010). Tropical storms and hurricanes occur frequently along their Atlantic Coast. Since 2000, North Carolina has experienced 62 such storms, of which 28 were hurricanes. South Carolina has experienced 32 such storms, of which 12 were hurricanes. Recent examples of how disruptive to infrastructure these storms can be are Hurricane Joaquin (2015) impacting South Carolina, and Hurricane Matthew (2016) and Hurricane Florence (2018), both impacting North Carolina and South Carolina.

This project engages appropriate Carolina alternative fuel vehicle stakeholders. They will undertake planning, training and implementation to create an integrated Carolina plan to employ alternative fuel vehicles in enhancing resilience during, and recovery from, infrastructure disruption. The plan will establish emergency procedures, training, and best practices for the diversification of, and access to, alternative fuels to expedite storm recovery, increase disruption resilience and ensure that alternative fuel supplies are reliable during times when conventional fuel supplies are susceptible to disruption.

The project partners are:

- Advanced Energy
- Centralina Regional Council/Centralina Clean Cities
- Dominion Energy
- Duke Energy/Piedmont Natural Gas
- Electric Cooperatives of South Carolina

- North Carolina Department of Environmental Quality
- ONEH2
- Savannah River National Laboratory
- Southeast Alliance for Clean Energy
- Triangle J Council of Governments/Triangle Clean Cities
- University of North Carolina Clean Energy Technology Center.

Objectives

This project will produce a plan augmenting the content of both states' emergency preparedness plans by clearly identifying 1) alternative fuel vehicle (AFV) fleets which can be employed in storm, disaster, or petroleum fuel disruption recovery, 2) alternative fuel resources for such fleets, 3) means by which alternate fuel vehicles can better serve in recovery actions, and 4) communication of information regarding fleets and alternate fuel systems to facilitate increased utilization.

Approach

Year 1/Task 1: Research

A great deal of data exists relevant to the proposed project. However, it resides with a variety of organizations and exists in a variety of formats not immediately useful to addressing alternate fuel vehicle storm resilience and recovery. Fortunately, much of this data resides with many of the project team members and supporters; specifically, the Clean Cities programs, the State Energy Offices, the State Emergency Preparedness Offices, private sector companies and the utilities. The project team members have formulated a work plan for gathering the required data and have established a uniform format for data storage and maintenance. The minimum data believed to be required includes:

- The incidence of damaging Carolina storms and specifically when, where and the duration of each
- Storm-caused disruption of infrastructure affecting transportation fuel supply, including the fuel distribution and utility networks
- Storm-caused damage requiring response involving vehicles
- A cataloging of best practices utilizing alternative fuels and AFVs for storm resiliency
- The existence of alternative fuel infrastructure, its locations and suppliers
- The existence of AFVs and fleets now used by storm first responders, utilities and government organizations and their plans for additional AFVs.

Year 1/Task 2: Inventory

The project partners are using research results to develop data inventories, which will be used in assessing the current value of, and need for, additional AFV fleets and fueling infrastructure for storm resilience and recovery. Some of the inventory data may become part of a resource used during storm recovery. All is planned to be displayed via geographic information system (GIS) technology. The inventories at minimum are thought to be:

- Alternative fuel infrastructure, including electric, natural gas, hydrogen and other alternative vehicle fuels (which may contribute to the databases of current fuel apps for use in the Implementation phase)

- Existing and planned AFV fleets, including electric, natural gas, propane, and hydrogen, and types of alternative fuel fleets
- Conventional petroleum fuel resources.

Year 2/Task 1: Assessment

From information gained in the Research phase and contained in the inventories, the project team will assess the disruption of petroleum, natural gas and alternative fuel infrastructure from severe storms, and the impact on existing and planned AFV use during infrastructure disruption and recovery. If the assessment finds that disruption of fuel availability significantly affects storm recovery and increased resilience, or that providing additional alternative fuel infrastructure will appreciably improve storm recovery, the project team members will proceed to develop and implement the Storm Resilience Plan.

Year 2/Task 2: Plan

The Carolina Alternative Fuel Infrastructure for Storm Resilience Plan will have as its foundation the research, inventory and assessment findings previously completed. The resilience and recovery opportunities identified in the assessment will be established as plan objectives and each will be the subject of a "solution" process. At minimum, the solutions will address alternative fuel infrastructure coordination plans for electricity, natural gas and hydrogen, to facilitate shared use of back-up fueling/vehicle charging facilities during outages and emergencies. This solution process will survey national and global best practices with regard to specific resilience or recovery practices and will contribute to the project team crafting each objective's solution. The individual solutions will be consolidated into a single plan and socialized with appropriate stakeholders. Following appropriate stakeholder input, the project team will offer the plan to various government agencies, utilities and others, for approval.

Year 3/Task 1: Plan Testing and Implementation

Project partners will undertake virtual testing of the approved plan. Some testing may be undertaken via computer simulation, role play, "dress rehearsal" and other means. Testing will reveal any plan adjustments needed, the adjustments will be made, and the plan tested again. Upon validation through testing, government agencies, utilities and alternative fuel providers may implement the plan by incorporating plan elements into their operating processes. Implementation may involve the addition of alternative fuel data to the data bases of various apps used by government agencies, utilities, first responders, etc.

Year 3/Task 2: Training

As the project partners initiate plan implementation, they will conduct training on the plan elements. Project partners will acquaint parties involved with managing and recovering from infrastructure disruption, including government agencies, utilities, first responders, etc., with the new data. Project partners will review new processes and procedures documented in the plan with them, and may hold dress rehearsals in some instances, so they know where alternative fuel infrastructure (including at least electric, natural gas and hydrogen) is located and how it operates. The project partners will present plan findings regarding the potential value of AFVs or fleets in storm recovery to policy makers, utilities and agencies responsible for emergencies and infrastructure disruption recovery, and will connect them with resources that can support them in exploring the opportunity.

Results

At this early stage the project partners have amassed a great deal of raw data that will be transformed into complex maps of Carolina energy infrastructure during the planning stage. An example of such mapping appears below in Figure I.24-1 and is produced from U.S. Department of Energy, Energy Information Administration data.

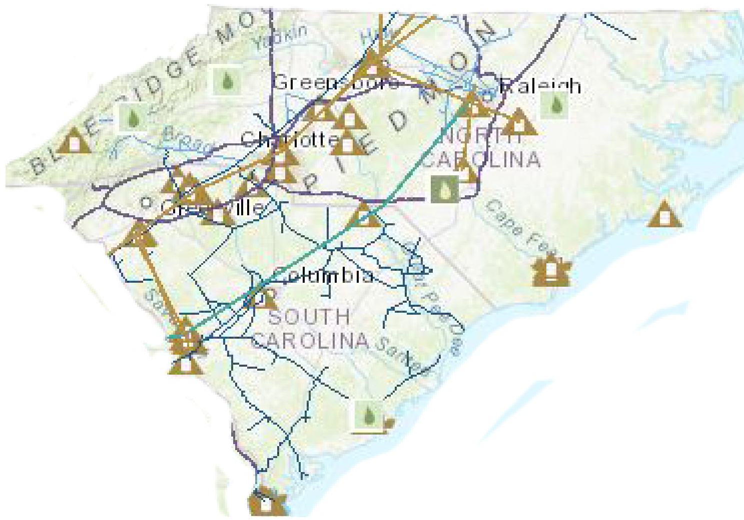

Figure I.24-1. Carolina Petroleum Products Pipelines and Terminals (source: USDOE Energy Information Administration)

Conclusions

The project partners even at this early stage of the project appreciate the value of the final plan. Utility, fuel, communication, water and highway infrastructure maintenance is exceptionally complex, being the responsibility of literally hundreds of separate organizations. The Carolinas are served by two major investor-owned utilities (Dominion Energy and Duke Energy), many electric cooperatives (26 in North Carolina and 20 in South Carolina) and nearly 100 Carolina municipal/public power authorities. None have plans for the coordination of alternative fuel vehicles to provide resiliency of their operation or effective use when critical infrastructure is disrupted. This project's plan will provide that.

Acknowledgements

E4 Carolinas recognizes its project partners for their collaboration during the first 9 of the project's 36 months and resolves to produce the project's Year 1 objectives on time.

I.25 Statewide Alternative Fuel Resiliency Workplan (Florida Office of Energy)

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Start Date: October 1, 2019 End Date: December 31, 2022
Project Funding: $1,728,300 DOE share: $700,000 Non-DOE share: $1,028,300

Project Introduction

Florida experiences the most hurricane landfalls, third most tornado events, and fifth most wildfires by acreage in the country. Because of this, the State Emergency Operations Center is very experienced in responding to emergency events. Prior to this project, however, very little preparation had occurred in the area of alternative fuels, even as alternative fuel vehicles (AFVs) and generators are beginning to be used by local emergency operations centers, first responders, and a growing number of private citizens. This study is being conducted by the Florida Department of Agricultural & Consumer Services Office of Energy (FDACS OOE), National Renewable Energy Laboratory (NREL), the University of Central Florida's (UCF) Florida Solar Energy Center (FSEC) and Tampa Bay Clean Cities Coalition/ University of South Florida (TBCCC/USF).

Objectives

The objective of the project is to complete a comprehensive Statewide Alternative Fuel Resiliency Plan (Plan) that utilizes multiple alternative fuels to provide redundancy, and therefore resilience, in Florida's transportation fuels. The project will develop a best practice resiliency guide for alternative fuels for transportation as well as stationary alternative fuel generators, and will share lessons learned. The best practice guide will provide insight regarding using AFVs as emergency response vehicles, alternative fuel supply chain strengths and weaknesses, and utilizing alternative fuel generators for emergency management facilities.

During the budget period, the project team focused on data collection, analysis and development, and identifying relevant stakeholders. The project team conducted visits to key facilities, and held a workshop to determine the necessary data and parameters to complete the Plan.

Approach

Stakeholder Engagement

Gathering information from stakeholders is vital to understanding the performance of the existing infrastructure, as well as planning needed for future infrastructure. Towards that end, on September 23, 2020, the project team organized and presented a virtual stakeholder meeting to discuss project goals and preliminary work, and to collect feedback on alternative fuel practices and protocols from stakeholders. The workshop included presentations by FDACS OOE, NREL, FSEC and TBCCC/USF. The virtual stakeholder webinar also featured polling questions and a facilitated discussion.

The team identified relevant statewide stakeholders, including representatives from local governments, state agencies, utilities, vehicle manufacturers, electric vehicle supply equipment providers, emergency management agencies, ports, airports, National Laboratories, transit agencies, private fleets, county school districts, Metropolitan Planning Organizations/Transportation Planning Organizations (MPO/TPOs), industry, and Clean Cities coalitions. OOE and TBCCC/USF compiled a list of more than 290 stakeholders from around the state to invite to the workshop. The team promoted the webinar through email communications to stakeholders, and there were 63 attendees. Following the webinar, OOE and USF made the registration list, attendees list, transcription of the chat box, poll responses, recording, and slide deck available to stakeholders online and via email.

Web-based Electric Vehicle Supply Equipment (EVSE) Tool

The USF team started reviewing relevant existing EVSE tools, identifying challenges and gaps in the existing tools, and began work on designing its own web-based EVSE tool.

Data Gathering

UCF/FSEC performed the following reviews during this time period:

- Two sample building facilities in Brevard County, indicating that diesel is a dominant fuel choice for emergency/resiliency generators in those buildings not plumbed for natural gas
- Alternative fuel data on fleet vehicles in the Cities of Cocoa and Melbourne and in Brevard County
- Data from Waste Management Florida on heavy duty fleet vehicles, indicating that approximately 64% of the fleet utilizes natural gas for its operations
- Recent reports and papers from NREL, the Joint Institute for Strategic Energy Analysis, and the American Council for an Energy Efficient Economy on electric vehicles, plug-in electric vehicle infrastructure and fuel choice for backup generators
- On-line data reports on plug-in hybrid and electric vehicles
- Status of alternative fuel corridors and stations in Florida
- Specifications and consumption data on dual & tri-fuel generators, with the intention of disseminating information on these alternative fuel products if found suitable for buildings resiliency
- Discussions with a manufacturer of solar charging stations (EVArc) for information on stand-alone grid independent product /battery storage choices.

UCF/FSEC is also developing a brochure for informing stakeholders about hurricane resiliency, entitled "Resilient Florida Buildings: Alternative Fuel Options for Maintaining Power During Outages."

TBCCC/USF also collected data on AFV fleets in the Tampa Bay region, including garage locations and fuel stations, as well as critical infrastructure geodata. They conducted site visits at a CNG facility operated by Waste Pro and propane stations operated by Seminole County Public Schools.

NREL conducted a literature review of hurricane resiliency methods, to inform Task 5 of the Florida Statewide Alternative Fuel Resiliency Plan. Specifically, the literature review assessed information from 21 resources, including reports, articles, and websites, and notes from one phone interview, on vehicles and their ability to withstand hurricanes, standing water, and flooding.

Results

The following considerations and determinations resulted from discussions with the webinar participants. Stakeholders are actively taking measures to incorporate AFVs into their fleets, preparing their fleets before hurricanes, and communicating between fleets and dispatch during disasters. Natural gas has especially been implemented for the medium- and heavy-duty fleet sector. Resiliency is important to organizations, and they are actively taking these steps:

- Installing EV charging infrastructure
- Adding natural gas vehicles to fleets
- Developing partner agreements for the use of existing propane storage tanks
- Updating resiliency plans with specific focuses on light, medium, and heavy-duty vehicles
- Certain cities reported setting goals for implementing 100% AFV fleets.

The literature review found a sufficient amount of information regarding common vehicle damages, as well as how to assess and repair them, if possible. All the information identified, except for some information on EVs, was for conventionally fueled vehicles. Therefore, there is a gap in knowledge for how AFVs fare in hurricanes, standing water, and floods.

Conclusions

None at this time.

Acknowledgements

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I.26 Integration of Smart Ride-Sharing into an Existing Electric Vehicle Carsharing Service in the San Joaquin Valley (University of California, Davis)

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Start Date: January 1, 2020 End Date: December 31, 2023
Project Funding: $1,502,688 DOE share: $750,000 Non-DOE share: $752,688

Project Introduction

In California's Central Valley, high auto ownership costs, limited transit service, and increasing housing costs are an accessibility triple threat for low-income populations in rural communities. These residents need more affordable, clean, safe, and reliable travel modes that fill the wide accessibility gaps between existing transit service and personal vehicle ownership. Many of these residents struggle to access essential opportunities (education and jobs) and essential services (health care, recreation, and healthy food).

In rural communities, high-quality transit services (fixed route and dial-a-ride) are challenging to provide because of low-density, dispersed development patterns. Moreover, the revolution in shared mobility services and electrification has left rural communities behind. In contrast, major urban areas have benefited from these same services. Private venture-funded startups focus on affluent urban communities, while public-private partnerships focus on incremental innovations (i.e., introduction of a smartphone application). Neither business model takes a systemic approach to introducing new mobility options and expanding service in communities with the greatest need, which would provide an affordable alternative to owning a personal vehicle.

Objectives

To meet the challenges described above, the project will launch a volunteer ride program (Míoride) that uses electric vehicles from a local electric vehicle carsharing organization (Míocar). This carsharing organization was created as the first phase of a concept that was identified in a planning and scoping study conducted by UC Davis, the eight San Joaquin Valley Metropolitan Planning Organizations (MPOs), transit agencies, and the California Department of Transportation. This volunteer ride component represents the second phase. The pilot will achieve the following:

1. Reduce energy use and greenhouse gas (GHG) emissions by replacing internal combustion engine (ICE) trips with electric vehicle (EV) trips and by reducing ICE vehicle ownership
2. Improve mobility in target communities by making it easier for customers to travel to new destinations and for different purposes

3. Demonstrate a path towards cost-effective non-profit operations of volunteer EV ridesharing in low-income rural communities
4. Provide direction and lessons learned about how best to scale the full pilot or elements of the pilot as other communities come online with investments towards the expansion the carsharing service.

Approach

The pilot project will integrate a volunteer ridesharing program (Míoride) with a community-operated non-profit 501(c)(3), San Joaquin Community Shared Mobility (doing business as Míocar) in the Central Valley. Míocar is an electric carsharing program with eight hubs in affordable housing complexes in six rural communities in Tulare and Kern counties. The program is available to people who live in the complexes and the surrounding communities at an affordable rate ($4 per hour and $35 per day). Míoride will reward Míocar members with free personal Míocar carsharing use when they volunteer to drive people who need transportation in Míocar vehicles.

Míoride will overlay Míocar's current operation, leveraging Míocar's fleet, staffing, and membership network, and allowing this program to emerge in a region where such a program would be more challenging to build and sustain. Should the program continue beyond the pilot period, Míocar may provide a long term home for Míoride.

Riders in need of transportation will be identified by participating agencies that are seeking to fill a segment of their current transportation service to their clients. The following agencies are participating, or may participate, in the pilot:

- Adventist Health (Visalia and Orosi locations): Release rides home
- Anthem Blue Cross Medical: Rides to appointments
- Family Health Network locations from Pixley to Dinuba: Fleet augmentation
- Greenline Call Center, City of Visalia: Long-distance after-hours transportation
- Kern Transit Dial-A-Ride: Trips that do not require a wheelchair accessible vehicle
- Health and Human Services Agency- 99 Palms Transitional Housing Project: Trips to access services and employment.

The DOE funds and ongoing Míocar operations will support the start-up of the Míoride volunteer network, including the administrative costs (dispatch, insurance, volunteer management) and partial fleet costs (insurance and fleet maintenance for five vehicles).

In addition to implementation, we will evaluate the pilot over a one and a half-year period using integrated survey data and observed user data provided by Mobility Development (MD) and Volunteer Transportation Center (VTC), for each volunteer driver and rider of the service. The data will be used to conduct a full pilot evaluation that integrates all stated and observed data using statistical methods to understand the effects of the program on factors including change in vehicle ownership (shed, deferred, postponed), change in the use of personal vehicles, change in frequency and use of mode, and unmet travel demand (transit, destinations, purpose). The data collected through the surveys will also be used to determine the scalability and cost-effectiveness of the program in achieving reductions in GHG emissions and energy usage.

The results of the study will provide direct support for policy makers and professionals as they consider cost-effective modal alternatives that employ new mobility technology and shared use services to expand travel opportunities to low-income populations in low-density and rural areas, and reduce GHG emissions.

Results

The key technical result, at the end of year one of the project, is the decision to move forward with launching the Míoride pilot based on the project planning and program design phase. Many decisions related to the design and implementation of Míoride are dependent on the results of the Míocar program.

Míocar experienced several program-level outcomes over the course of its pilot period that informed the timing and planning efforts for Míoride. Míocar originally operated through a partnership that included a local vanpool operator (California Vanpool Authority), an affordable housing developer (Self-Help Enterprise), and an experienced carsharing operator (Mobility Development). Míocar has transitioned into a non-profit, San Joaquin Valley Community Shared Mobility, Inc. (doing business as Míocar), that now owns, insures, and maintains the fleet and has assumed management of carsharing operations.

The member and user data show that Miocar membership levels grew to 153 active members as the 27 EVs were gradually added over a 10-month ramp-up period through January 2020. Míocar operated for approximately one year before the service paused at the beginning of the COVID-19 pandemic, in late March of 2020. Míocar relaunched at the end of July 2020, with the program's fleet housed in the new non-profit structure, and has been rebuilding its membership base since that time. As of the end of October 2020, Míocar had 160 active members, which is sufficient to recruit the first five volunteer drivers for Míoride.

Based on findings from the initial Míocar pilot period, continued market forecasts, and feedback from project partners, the project team developed a business plan for Míoride as part of the planning and program design phase. Additionally, the project team revised existing data collection procedures to more effectively capture the perspectives of Míocar drivers who will be driving for Míoride, and developed new surveys that will be administered to Míoride riders when they join the service, at the end of the pilot, and after individual rides. The project team also worked with VTC to refine the format of the telematics data collected for individual trips, to allow for a thorough evaluation of how riders are using Míoride. With the data collection instruments and data sets in place, the team is prepared for the launch and evaluation of the pilot program.

Conclusions

As part of the project planning and design phase, the project team developed assumptions and forecasts for program operations and used these to develop the pro forma financial materials for the program. The assumptions and forecasts we developed during this period include:

- There will be a slow ramp up over 12 months from 3.5 trip legs per volunteer driver weekly to 6 trip legs per volunteer driver weekly. Initially, volunteers are expected to participate only occasionally. However, as the program grows, it may not be uncommon for a portion of the volunteer base to operate at nearly a full-time level. This average accounts for varying levels of participation and for scheduling, attrition, etc.
- The average driver will increase service hours from ten volunteer days/month to 14 days/month by mid-2021.
- The average trip leg is 20 miles plus five "deadheading" miles. This estimate is based on distances to key destinations common in volunteer transportation operator networks in counties of similar size and with similar characteristics as Tulare and Kern counties.
- Trip requests coming from participant agencies start in March 2021.

Based on the project design and planning efforts the project team concludes that our initial projection of 200,000 miles of trips over the project's life is reasonable and achievable. The team anticipates that Míoride will utilize an estimated 50 volunteers over the course of the project, with ride reservation requests coming from at least six participating agencies.

The project team has also determined that to meet the above forecasts and overall performance targets, a special focus must be placed on overcoming challenges of recruitment that are common to volunteer ride services, and has identified the following activities as key components of a strong recruitment strategy:

- Hiring a recruitment and dispatch manager locally who will develop partnerships with agencies that can refer rides, including Medi-Cal, logisticare, and local clinics
- Recruiting initial drivers from the Míocar membership pool as members return to the program (depending in large part on COVID-19 impacts)
- Identifying and highlighting how the program can complement the use and availability of the EV carsharing fleet.

Incorporation of these recruitment efforts is based on the project team's experience and expertise from VTC and MD, which have had continued success in operating and replicating volunteer transportation services and building member networks in new service areas.

While the project team is not yet able to develop conclusions related to the performance of Míoride, conclusions from the initial Míocar pilot period provide insight into driver behaviors and needs, and our evaluation of the Míoride pilot will allow us to refine these findings into conclusions and actionable recommendations. For example, the initial Míocar pilot evaluation provided some tentative findings that suggest the need for, and potential sustainability of, the rural EV carsharing model in its current format, but also provided findings suggesting that there may be a need for additional carsharing hubs to better serve members who are several miles away from the nearest existing hub. These and other findings will be further assessed during the Míoride pilot and evaluation.

Acknowledgements

The project team would like to acknowledge the assistance of Brett Aristegui, National Energy Technology Laboratory Project Manager.

I.27 The Clean Rural Shared Electric Mobility Project (Forth)

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Start Date: October 1, 2019 End Date: December 30, 2022
Project Funding: $1,054,020 DOE share: $548,540 Non-DOE share: $605,480

Project Introduction

Forth is a nonprofit whose mission is to advance electric, smart, and shared transportation through demonstration projects, policy advocacy, and engagement. There is tremendous potential to benefit from supplemental mobility services such as carsharing; however, due to low population density, lack of charging infrastructure, lack of familiarity with carsharing or electric vehicles, and longer driving distances, carsharing has not been well established in rural communities. The Clean Rural Shared Electric Mobility Project (CRuSE) will introduce an all-electric carshare program in Hood River, Oregon. The carshare, consisting of five electric vehicles placed with dedicated electric vehicle charging stations at five distinct sites, will provide access to several groups of users including City employees, affordable housing residents, tourists and the general community population.

Objectives

The objective of this project is to develop, demonstrate, and refine an affordable, accessible, sustainable, and replicable financial model for electric carsharing in rural Hood River, Oregon. The overall project goals of the CRuSE Project are to demonstrate that round trip electric vehicle carsharing can serve rural communities – including low income residents – in an effective and financially sustainable way, and to develop the tools and voice to educate, encourage and replicate carsharing in other rural communities. Critical success factors will include the CRuSE project's ability to (i) entice Hood River's low-income residents, government, businesses, townspeople, and tourists to first try, then grow, their carsharing use; (ii) obtain qualitative and quantitative data from users, and on operations and revenue streams, so data analytics can inform our understanding of what is/is not working, leading to ongoing design improvements and the development of a replicable, financially viable model; and (iii) encourage other rural regions to implement similar carsharing projects.

Approach

The CRuSE Project seeks to significantly reduce many upfront cost challenges and other barriers to electric carsharing deployment at five sites in Hood River, to achieve the following targeted improvements:

- Initiate and grow electric vehicle carsharing usage among each of three market segments (i) low-income residents, (ii) business, government and townspeople, and (iii) tourists, over the 3-year project period, with data and feedback from user surveys, operations, and economics, to enhance understanding and inform iterative project refinements
- Document electric carsharing's energy efficiency, air quality and greenhouse gas benefits
- Enhance Envoy Technologies' carsharing app to increase accessibility for low-income residents via:

  - Spanish language translation of the software application
  - Tiered pricing structure, creating an opportunity for subsidies to qualified users
  - Alternate payment mechanisms to increase access for unbanked individuals
- Identify key success factors and develop a financially sustainable carsharing model
- Produce and document best practices through interim reports and a final case study
- Encourage replication in other rural communities through webinars and workshops
- Provide hands-on technical assistance to help three other rural regions around the country to implement similar carsharing projects in partnership with local Clean Cities coalitions.

As planned, the first year and Budget Period of the project would consist of project initiation and a project launch. This would include site assessment and selection for charging station installation, preparation of each site with an installed charging station and vehicle, outreach and education to the community about the program, technology upgrades to the software app, and data collection through surveys and charging and travel behavior. Budget Period 2 would consist of project refinement, continued outreach and marketing, additional technological upgrades to the app, and initial assessments of the model's financial viability. Budget Period 3 would consist of final project refinements, continued outreach and marketing, additional technological upgrades to the app, refining the financial viability model, and producing a final case study. Throughout this project, one of our partners, Columbia-Willamette Clean Cities Coalition, would be supporting the project team in disseminating results to other Clean Cities coalitions through workshops and conferences.

For this project, Forth partnered with a number of local and national partners to fulfill its deliverables and objectives, including Envoy Technologies, Pacific Northwest National Laboratory, Columbia-Willamette Clean Cities Coalition, American Honda, OpConnect, Pacific Power, City of Hood River, Port of Hood River, Columbia Cascade Housing Corporation, Mid-Columbia Economic Development District, Columbia Area Transit, and Ride Connection.

Results

The major tasks in the first year of this project were to:

1. Identify the five sites to host the electric vehicles and charging stations throughout the project period
2. Secure vehicles
3. Secure and install charging stations
4. Survey the community around transportation behaviors
5. Build public awareness of the program's public launch.

The CRuSE project award was under definitization by the U.S. Department of Energy for the first six months of the year, with the award being fully granted in March 2020. Between the period of October 1, 2019 and March 2020, the project team began work toward the major deliverables, although these efforts were limited with local community partners.

Progress toward the major tasks during the first year was as follows:

Identify Host Sites

The team has identified all five sites, which include a mix of public and privately-owned sites to provide access to City employees, affordable housing residents, tourists, and the general public.

Secure vehicles

Forth has secured vehicles for the duration of the project from American Honda. The project will utilize five off-lease Honda Clarity electric vehicles.

Secure and install charging stations

The team has acquired the charging stations to be utilized during the project and has secured a contractor to complete the installations. There have been a number of delays in the installation due to a variety of factors. COVID-19 has impacted this task because site hosts have been prioritizing community needs and recovery efforts from the economic downturn the pandemic has created. Additionally, wildfires affecting Oregon in September 2020 caused further delays from key partners in the installation project, including electrical contractors and Pacific Power, the electric utility company. This task is a priority for the project team to move toward a public launch.

Community Survey

The team developed a survey in English and in Spanish to distribute to Hood River community members toward the beginning of a public launch. The goal of the survey is to better understand the transportation behaviors and mobility challenges of Hood River residents. It also seeks to capture the community's awareness of electric vehicles and carsharing. Forth distributed the survey digitally beginning in September 2020, through community partner e-mail and newsletter channels.

Public Outreach

This task has been limited due to other delays in building up to a public launch. The team planned public outreach strategies toward the end of August and September 2020. Those strategies would include a media press release, radio advertisements and interviews, and direct outreach from community partners through e-mail and newsletter channels. Additionally, the project team has prepared a document outlining precautions being taken to clean and sanitize the vehicles to protect against the spread of COVID-19.

COVID-19 Impacts

As described above, work toward meeting project goals and deliverables began in earnest following the definitization and granting of the award in March 2020, which coincided with the timing of the COVID-19 pandemic, forcing Oregon into stay-at-home orders. The most notable consequence was that the attention of some project partners, including the site hosts for the vehicles and charging stations, shifted toward responding to community needs during the crisis. In addition, due to government regulations, these partners were required to work remotely indefinitely, which presented its own set of challenges. The impact to the project overall was that communications between Forth and several partners slowed significantly or halted. More specifically, COVID-19 has contributed to delays around securing sites and installing charging stations for this project. As the pandemic persisted through September, the project team acknowledged the need for continued flexibility around a project launch. Forth intends to remain conscious of the challenges our communities are facing and is proceeding cautiously with moving this project forward. Concern for public health and safety will continue to influence decisions made by the project team.

Conclusions

Given the status of the project, there are not yet any major conclusions to make regarding the goals and objectives.

Acknowledgements

Forth would like to acknowledge and thank National Energy Technology Laboratory Project Manager Dan Nardozzi for the valuable insights and support throughout the first year of this project. We are also grateful for our many partners that together are making this project possible:

- Pacific Power
- Columbia-Willamette Clean Cities Coalition
- Pacific Northwest National Laboratories
- Envoy Technologies
- American Honda
- OpConnect
- City of Hood River
- Port of Hood River
- Mid-Columbia Economic Development District
- Columbia Cascade Housing Corporation
- Columbia Area Transit
- Ride Connection.

I.28 Holistic and Energy-efficient Rural County Mobility Platform (RAMP) (Carnegie Mellon University)

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Start Date: January 1, 2020 End Date: December 31, 2022
Project Funding: $2,037,781 DOE share: $1,000,000 Non-DOE share: $1,037,781

Project Introduction

Rural America, representing 97% of the U.S. land area, is home to 15% of the total U.S. population. Rural trips for commuting, shopping, health care and community-based services have become increasingly longer in the past few decades. Unfortunately, mobility services to rural areas are insufficient, inefficient, unaffordable and inaccessible, with highly limited resources. Often rural trips are made by solo-driving in private vehicles with low fuel economy. Very little public transit or shared mobility is utilized. Those rural trips are likely to be long, expensive, with a single trip purpose, and thus energy inefficient. More importantly, because rural trips are extra burdensome to households both financially and physically, it makes resources, facilities and other communities more inaccessible to rural populations.

Greene County is a typical rural county in Southwestern Pennsylvania bordering West Virginia, with about 39,000 in population. Waynesburg, the County seat, is home to Waynesburg University (WU), a partner with Carnegie Mellon University (CMU) in research and educational projects. Recently a group of faculty and students probed the difficult issue of food insecurity in the County. Over 13% of the county's population is food insecure, and one third of those individuals are children. The primary finding of the study focused on the transportation barriers to dealing with the issue, i.e., getting food to people or people to food.

In Greene County, 57% of households report at least one member with high blood pressure. A number of their non-emergency doctor appointments, especially among children and the elderly, are delayed or missed due to insufficient and inefficient mobility services. There is no public transit in Greene County, nor are there shared mobility services, such as taxis, Uber or Lyft. The only mobility service available is through the Greene County Transportation Program where residents are required to book a ride in advance. The Program provided 40,323 trips in 2017, and 26% were associated with seniors. The average trip time was more than one hour, at an average cost of more than $26/ride. A recent survey by Greene County Human Services shows there are local residents who have no other choice than to pay more than $50 for riding the shuttle into the City of Pittsburgh, the closest major city. Mobility service in Greene County is clearly insufficient, inefficient, and unaffordable, affecting access to not only healthy food, but healthcare, work, and community services.

Waynesburg University (WU) of Greene County enrolls approximately 2,500 students and offers shuttle services to transport students to and from bus and train stations outside Greene County, local hospitals, and shopping retailers. Despite students finding it a challenge to get around the City of Waynesburg, the shuttle service ridership is low and has been dropping over the past years, due to inefficient service not fulfilling student demand. WU has Bonner student volunteers (10 hours per week service for a Bonner scholarship) to drive those shuttle services, but clearly those volunteering resources could be optimally allocated to facilitate a more efficient rural mobility service.

Objectives

We propose developing a holistic approach to address the mobility challenges in Greene County, and this approach can be replicable to all rural counties in the U.S. Key will be developing a capability that does not now exist in the U.S., namely a "Rural County Mobility Platform" (RAMP) consisting of both an online platform and phone-based system for trip reservations, structured shuttle services, volunteer management, volunteer-request matching, and mobility information dissemination. This project will support developing methods and algorithms to pilot a new hybrid service consisting of two complementary components: a volunteer-based ridesharing system and a highly-structured shuttle service (not a typical fixed-route, with flag stops). It will also include a new capability for more efficient data-driven operations of the existing Greene County Transportation Program and WU shuttle services. This holistic approach will primarily target four types of rural trip access: work, food, health care, and community-based services. There are three main features of RAMP that are distinct from general mobility services: a hybrid service design tailored for rural trips, data-enabled matching/routing among rural riders and services, and outreach to the rural population.

Approach

As an initial and ongoing activity, the team will engage Greene County residents in a process of "human-centered design" to ensure that the pilots are developed with the input of the targeted clientele. On an ongoing basis, we will collect data from riders, volunteers and shuttle services, and conduct surveys of local residents, with the aim of improving the system design throughout the project. We will also reach out nationally to both share our experiences and to benefit from the experience of others addressing rural mobility issues.

Indicative of many rural counties, Greene County residents have a strong culture of volunteer service, ranging from volunteer fire departments to volunteer service by WU students (e.g., Bonner volunteer program). However, matching an individual's need for mobility with a volunteer who is willing to meet that need is problematic and inefficient. As part of the hybrid rural mobility service, we will design an online system to manage and check in volunteers, provide incentives and develop a method to optimally match volunteers and pick-up/drop-off requests (for both people and goods). The proposed Rural County Mobility Platform (RAMP) would allow volunteers to report their service time windows, locations and possible routes. This will be complemented by an additional incentive program to encourage volunteers to fulfill on-demand pick-up/drop-off requests. Incentives include public acknowledgements, vouchers for community shopping, free shuttle rides, Bonner scholar hours (for WU students only), etc. Not everyone in a rural area like Greene has ready access to either internet or cell phone service. Thus, it is mandatory to design RAMP to be a landline phone-based service as well as internet and mobile phone accessible.

The hybrid system is designed to be demand responsive point to point. We will initiate a highly structured shuttle service in partnership with WU and the Greene County Department of Human Services. Primary destinations for work, shopping, health care and community services will be selected through interviews, surveys and data collection, and further mapped along with residential patterns. With community input and using geographic information system (GIS) mapping capabilities, we will design potential main points of interest, also known as hubs, along with initial fixed routes with daily trips scheduled between those hubs. Routes are fixed in terms of schedules and planned routes/zones, but are flexible in terms of making actual stops at potential hubs on a daily basis. This shuttle service will differ from conventional public transit buses since it will require riders to confirm the trips in advance via RAMP, and the shuttle can pass by (or skip) stops/hubs if not requested by riders in advance. At least two shuttle buses will provide service for this pilot study, one from the existing Greene County Transportation Program or existing WU shuttle service, and the other from additional rental vans. The team will install Global Positioning System (GPS) sensors, dashboard cameras, and automated passenger counter sensors on the shuttle buses to collect service data and information on road conditions.

In addition, RAMP serves the hybrid system via volunteer registration, volunteer non-monetary incentives, and mobility service requests. The hybrid system is analogous to hub-and-spoke networks, where the shuttle service runs between center hubs, but most volunteer trips meet the demand from the main hubs to scattered origins or destinations. The system will collect anonymous data from both volunteers and rider requests. Those data together will be analyzed on a monthly basis to identify system inefficiencies, so as to develop solutions to improve the hybrid service design and the online system.

Another barrier to efficient rural mobility service is the inability to adapt to incidents or events in the rural areas. Rural trips have very limited choices in routes and points of interest. If roads or points of interest are subject to planned events or unplanned incidents, trips are likely to be substantially impacted. Therefore, RAMP will leverage existing data sources (from public agencies and social media, e.g., PennDOT and Twitter/Waze) to monitor traffic conditions in real-time, and then take them into account when optimizing mobility services and disseminating trip/traffic information to residents.

The performance of the mobility services is measured and optimized in terms of travel time, vehicle-miles traveled, fuel use, emissions, accessibility, affordability, 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. DOE's SMART Mobility team and NREL's rural-to-urban mobility dynamics team will explore the data that is collected, integrated, and analyzed for this pilot study, along with optimized models and algorithms, to identify potential replicability of analytical/modeling insights in other rural regions.

Results

The research team designed two surveys, one for faculty/staff/students in Waynesburg University and the other for the general public in Greene County. The surveys are designed to understand the mobility needs of Greene County residents, including a relatively large population of Waynesburg University affiliates. The research team then conducted two focus groups on the Waynesburg University campus that consisted of over 40 faculty/staff/students representatives. The team conducted a sample survey to seek comments and feedback from those potential survey responders. The team then modified and improved the surveys, and the Institutional Review Board (IRB) for human subject research approved them. We also conducted a literature review regarding volunteer-led mobility services, interviewing six local non-profit organizations and several volunteers, and developed general guidelines for establishing a transportation volunteer program for Greene County.

This project was scheduled to kick off on January 1, 2020, but the official award of this project was delayed to March 10, 2020. Due to the impact of COVID-19, the research team has been unable to make progresses since Mar 15, 2020. We were unable to conduct any field surveys or any interviews with our partners, due to a state lockdown. We are not sure when we will be able to resume work on this project. Another main concern is that the current travel demand and travel behavior in Greene County may vary substantially from a 'typical' day prior to the pandemic. We may have to wait until the pandemic is over and most travel demand resumes before we can start our surveys and data collection. The team has requested a 12-month no-cost extension.

Conclusions

This research advances the technology and practices of mobility services in rural areas in the following aspects: holistic rural transit mobility system, data-driven modeling approach, and MEP-based management. A door-to-door service in rural areas would be very expensive because not many users have the same origin and destination, but it can provide the first/last-mile connectivity at a high level of service. Volunteers with non-monetary incentives keep the costs low and ensure availability of drivers locally. We propose to leverage the certainty of fixed-route transit by having fixed stop locations (or hubs) for the shuttle service, determined by identifying common use patterns from rider surveys using data-driven methods. The system will collect anonymous data from both volunteers and requests for service. Those data will be analyzed on a monthly basis to identify system inefficiencies, so as to develop solutions to improve the hybrid service design and the

RAMP system. Tailored specifically for rural counties, the hybrid system utilizes the information technology and system-level optimal design to balance its operational cost and service efficiency/quality. The new rural mobility service design incorporating rural travel demand characteristics and multi-source data has great potential to be widely deployed in practice for rural agencies that are responsible for providing rural mobility services. After the completion of this project, we plan to transfer the technology to further develop and deploy rural mobility systems in other rural regions. 412 Food Rescue, a non-profit organization, will benefit directly from this project, as they expand their volunteer services from food to passengers, and from urban areas to rural areas.

I.29 R.O.A.D.M.A.P: Rural Open Access Development Mobility Action Plan (Rural Action)

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Start Date: October 1, 2019 End Date: March 31, 2023
Project Funding: $1,782,603 DOE share: $880,724 Non-DOE share: $901,879

Project Introduction

Rural communities are disproportionately impacted by current gaps in the transportation system, which limit access to opportunities such as healthcare, jobs, and social services. There is also a high concentration of poor, elderly, and zero-vehicle households in rural areas. Current mobility gaps plaguing rural communities include: insufficient rural public transit operations; insufficient countywide affordable services; limited non-emergency medical transportation (NEMT) providers available to the public; and limited weekend, early morning and late-night services.

The R.O.A.D.M.A.P. project aims to better understand how advanced vehicle technologies function in these rural settings, and to enhance awareness of innovative solutions with the potential to fill transportation gaps sustainably. Rural Action leads a project team that consists of Clean Fuels Ohio (CFO), The Transportation Research Center, Inc. (TRC), Hocking Athens Perry Community Action (HAPCAP), and The Ohio Department of Transportation's DriveOhio Initiative. Additional partners include the City of Athens, Ohio, Columbus Yellow Cab, regional Clean Cities Coalitions, the Joyce Foundation, and the Southeast Ohio Public Energy Council.

Objectives

The objective of R.O.A.D.M.A.P. is to develop, demonstrate, and refine affordable, accessible, sustainable, and replicable mobility service-enabled electric vehicle shuttle service applications in rural Appalachian Ohio. The team will analyze data from several deployments of electric and automated vehicles across transit and private vehicle operations and develop insights that will inform the team's Rural Mobility Action Plan.

The National Renewable Energy Laboratory (NREL) is a key end user of the data and reporting generated by R.O.A.D.M.A.P. The project also aims to share best practices, lessons learned, and infrastructure recommendations with a variety of other stakeholders, to accelerate rural adoption of advanced and sustainable mobility solutions in Ohio and nationwide.

Approach

The objectives of R.O.A.D.M.A.P. are supported through data collection, analysis, sharing, and public dissemination of results. The project is being carried out over several interconnected task areas:

Task 1: Individual Motorist Data

Led by CFO, the partners are working to better understand the unique characteristics of rural Electric Vehicle (EV) owners and the rural market for EV sales and service. Data sources include the Ohio Bureau of Motor Vehicles, local EV driver clubs, and regional dealer networks. Insights gleaned can be used to help guide future infrastructure planning and incentive programs.

Task 2: EV Shuttle Pilot

HAPCAP is conducting this pilot with technical assistance from other partners; it will gather data from field tests of a battery electric shuttle bus purchased as part of the project and operating in a rural public transit fleet, Athens (Ohio) Public Transit. Following a driver and maintenance training program, the shuttle will be deployed daily in all seasons on a mixed urban/rural route, and data from vehicle telematics and maintenance will be used to evaluate its performance against a baseline supplied by existing gasoline-powered vehicles in the fleet.

Task 3: Transportation Service Provider (TSP) Analysis and Education Program

CFO and Rural Action are developing a program for education and technology transfer between TSPs with EV experience and TSPs seeking to add EVs to their operations, as well as providing local Electric Vehicle Supply Equipment (EVSE) infrastructure support in the project territory. The task spans participant recruitment, presentations and breakout sessions at a range of clean transportation conferences, a series of ride and drive events, and peer-to-peer mentorship.

Task 4: Automated Vehicle (AV) Feasibility Study

An EV equipped with commercially available automated driving capabilities is being deployed under a variety of rural seasonal and roadway conditions by TRC, Inc. A Tesla Model 3 sedan equipped with Tesla's Navigate on Autopilot feature was chosen for testing, assumed to display SAE Level 2 autonomy. Controlled environment testing at TRC's facility in East Liberty, OH is an input to formal test planning, and will be followed by a series of test deployments on a fixed rural loop in Athens County. Results of testing will help inform state and local government infrastructure strategies for enhancing automated driving adoption.

Task 5: Outreach

This task prepares and disseminates the information gathered. R.O.A.D.M.A.P. has a Project Advisory Committee with membership from Clean Cities Coalitions in Kentucky, Ohio, Pennsylvania, Virginia and West Virginia, and progress is being shared regularly through a series of events hosted by the Appalachian Clean Transportation (ACT) Forum, a complementary outreach initiative administered by Rural Action and funded by the Joyce Foundation. Final summary reports and technology transfer plans will be distributed to all stakeholders at the conclusion of the project.

Results

Complications connected with the global COVID-19 pandemic caused delays in operational startup lasting until mid-June, 2020. The project team submitted, and DOE approved, a No-Cost Time Extension (NCTE) to shift each project budget period later by one quarter. Rural Action finalized contracts with partners and assembled a Project Management Plan and virtual shared work environment during July and August. DriveOhio completed a draft Performance Measurement Plan in consultation with all major partners.

CFO worked with technical partners (DriveOhio and NREL) to identify the full Bureau of Motor Vehicles (BMV) data set and create a detailed analysis framework; they created a filter to remove all personally identifiable information (PII) from BMV data to ensure anonymity and motorist privacy, as well as a VIN decoding filter to detail the Original Equipment Manufacturer make, model, year, and other vehicle-specific details, and a 5-digit zip code filter to sort data by county and zip code.

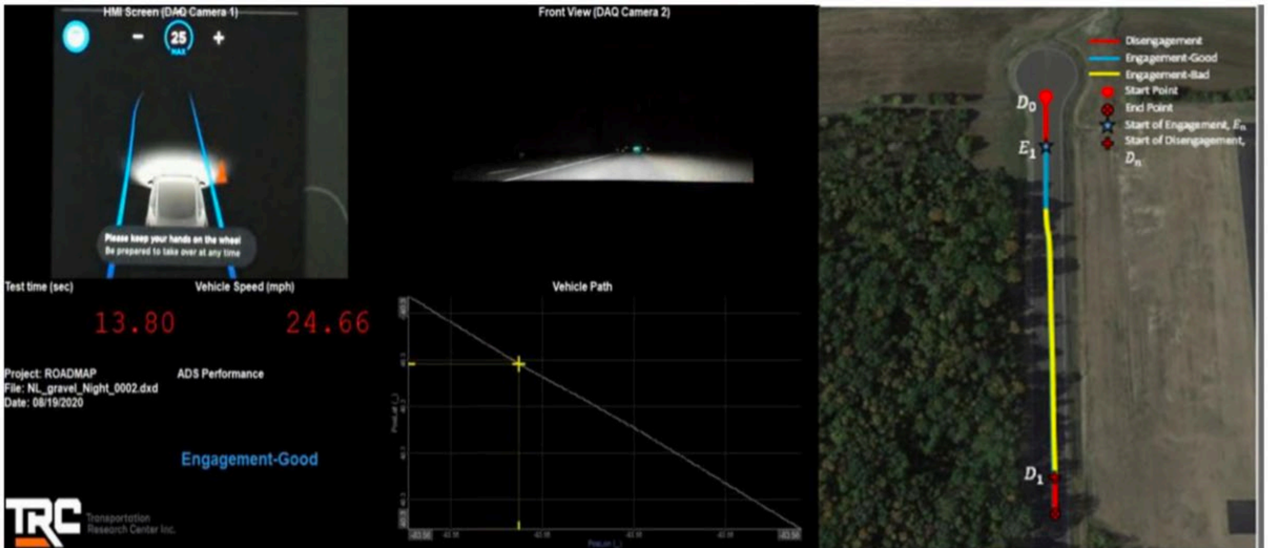
As preparations for procurement of an electric shuttle bus were made, project partner HAPCAP began gathering baseline telematics data from its Athens Public Transit fleet running portions of the proposed pilot route, and met with CFO and DriveOhio to discuss plans for analysis and metrics to employ.

With assistance from CFO, the City of Athens applied for funding for a direct current (DC) fast charging station through an American Electric Power charging incentive program. The station is now launched; it is the first DC fast charger in Athens County and one of only five public DC fast chargers in use across the 32-county Appalachian Ohio region at the time of writing. The station will be available for the deployment phases of both the EV and AV tasks. See Figure I.29-1.

Figure I.29-1. City of Athens DC Fast Charger Installation (Photo: Sarah Conley-Ballew)

Rural Action began recruiting activities for the TSP Analysis and Education Program by sending invitations to member organizations of the Athens City-County Coordinated Transportation Group; a variety of public and private fleets and operators are participants. During the 2020 Midwest Green Transportation Forum and Expo, which it successfully pivoted to a fully virtual interactive event on the Whova platform, CFO offered panels and workshops designed to educate TSPs on fleet electrification options, incentives and support available in the Midwest region. Educational sessions will continue during the first edition of the ACT Forum, to be held virtually on November 17 and 18, 2020. The ACT Initiative, a two-year project funded by The Joyce Foundation, seeks to engage a network of economic development partners, industry specialists, and statewide policy experts to plan implementation strategies that bring clean transportation infrastructure and development to Appalachian Ohio. Forum events function as opportunities for peer sharing, planning and data collection.

TRC began work by modeling the rural environment for the AV deployment and categorizing anticipated challenges, which included faded or obscured lane lines, signage missing or askew, unpaved roads, uncontrolled intersections and animal crossing events. The engineering team outfitted the Tesla Model 3 with an additional sensor suite to enhance monitoring capabilities, and conducted controlled environment testing using eight different challenge scenarios. Following evaluation of the controlled environment test results, the team revised and finalized the test plan, with the first on-site test deployment scheduled for late October, 2020.



Conditions: Night time testing starting after light is <2Lux ~10:15 PM

"Events"	Description
Start of Engagement- E_n	$E_1 \rightarrow Category$ 1, Speed = 25mph.
Engagement Sector – *Good*	For a small stretch (Blue), ADS was able to keep lane on gravel covered lane lines.
Event which impacts ADS Performance	In this case, vehicle was able to engage in the first segment with no gravels on lane lines. If otherwise there is an uncertainty of AP engagement due to gravel covering the lane lines.
Engagement Sector – *Bad*	ADS makes a lane change and drives in the on-coming lane (wrong-way) of a two lane bi-directional road. The ADS continues to perform wrong-way driving, posing a risk to oncoming traffic.
Disengagement – D_n	$D_1 \rightarrow Category3$. The vehicle was traveling in the opposite lane and it shows unsafe behavior. Hence, the safety operator has to take over.

Figure I.29-2. A sample of data insights from AV controlled environment testing (Photo: TRC, Inc.)

Several insights emerged from controlled environment testing that were flagged for further attention in the live deployment. For example, a range of factors may obscure the visibility of lane lines, and these can exert a direct and critical impact on safe AV performance. In Figure I.29-2, above, the Autopilot feature positively engaged during a stretch of clear lane lines but remained engaged and moved the vehicle to the oncoming side of the test track when it encountered a stretch of lines covered with gravel. TRC will share these and other initial insights at the upcoming Intelligent Transportation Society Midwest 2020 Annual Meeting, scheduled for November 3, 2020. They underscore the need for further study and recommendations regarding rural road infrastructure investment and planning.

Conclusions

Though still in the project development period and hampered by COVID-related delays, R.O.A.D.M.A.P. has already made some significant progress towards its project objectives. Of particular note is the expansion of regional EVSE capacity represented by Southeast Ohio's first DC fast charging station, the educational and outreach activities conducted as part of the Midwest Green Transportation Forum and Expo, and the initial results generated by TRC's AV testing. Budget Period 2 contains the bulk of demonstration and data collection activities, and the project partners are excited to begin generating further insights.

Acknowledgements

The R.O.A.D.M.A.P. team wishes to thank NETL Project Officer Erin Russell-Story and Contract Specialist Patrick Mayle for their invaluable advice and support throughout an eventful first project year.

I.30 Electric First/Last Mile On-demand Shuttle Service for Rural Communities in Central Texas (Lone Star Clean Fuels Alliance)

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Start Date: October 1, 2019 End Date: January 31, 2023
Project Funding: $1,523,176 DOE share: $711,588 Non-DOE share: $811,588

Project Introduction

The baseline for rural transportation in Bastrop, Texas and in many other rural communities, is the limited mobility services available to connect rural residents and visitors to existing rural transit, and destinations within their communities. Rural communities do not have the suite of mobility options typically found in urban areas, and this is an opportunity to tailor Low Speed Electric Vehicle (LSEV) based Mobility as a Service (MaaS) to provide an affordable, practical, efficient, zero-emission, and fun way to enhance access. LSEVs use a fraction of the energy of conventional vehicles, yet are capable of providing the same level of service for the intended market and service area. LSEVs run on 72V systems that can be charged with 110V outlets.

Objectives

The objective of this project is to develop, demonstrate, and refine affordable, accessible, sustainable, and replicable mobility service-enabled electric vehicle shuttle service applications in rural Central Texas, supported by dataset collection, analysis, sharing, and public dissemination of results.

Approach

Lone Star Clean Fuels Alliance (LSCFA) oversees the project, and facilitates communication among the stakeholders and project partners to ensure timelines and accountability, and create the shared sense of purpose and commitment critical to success. Grant subrecipients are Electric Cab of North America (eCab), Wheels & Water (W&W), and the National Renewable Energy Laboratory (NREL).

eCab will provide the vehicles and drivers, and manage the service, interfacing with the Capital Area Rural Transportation System (CARTS), NREL and W&W to generate the appropriate robustness of data and analysis. W&W's expertise is in research, interpreting traffic and parking counts, and analysis.

NREL's contributions include an analysis of data collected; assisting with data sharing; estimating and assessing overall lessons learned, including energy and mobility benefits; serving in an advisory role; taking the lead documenting and disseminating lessons learned; and making data generated from the project available through the Energy Efficient Mobility Systems (EEMS) Program's data sharing platform, *Livewire*.

The key partner is CARTS, the local rural transit providing service to the City and County of Bastrop, within a much larger regional footprint. CARTS has a variety of services including a circulator route, and a phone-in on-demand country bus. CARTS will launch its demand response service, which includes eCab and another microtransit, under the CARTS *NOW* brand using a Via developed application.

Additional partners of note are the City of Bastrop, and the County of Bastrop, in particular its Planning, Tourism and Economic Development Departments. These partners provide local input on vehicle use opportunities, and assist with promoting the vehicles and community outreach.

Our three-year plan is as follows:

Budget Period 1: Planning, Data Collection System Design, Finalize Paratransit Low Speed Electric Vehicle

eCab will procure the LSEVs, and integrate and install the data collection systems on the vehicles. LSCFA will work with CARTS and partners to plan and hold Show and Ride events to introduce the eCabs as part of the CARTS *NOW* program. CARTS and Via, with input from eCab, will design the zones for the CARTS *NOW* app. CARTS and eCab will complete the route planning for implementation. eCab will deploy its vehicles in designated areas with full data collection from the eCab data collection application and driver input through observation.

Budget Period 2: Data Collection and Demonstration, Analysis & Reporting

eCab will be operating its vehicles and data collection systems in designated areas with adjustments made as needed to improve both service and data. eCab's data collection will be on-going and assimilated and NREL, W&W, LSCFA and eCab will disseminate the data for community replication efforts.

Budget Period 3: Data Collection and Demonstration, Analysis and Evaluation

Lone Star and eCab will continue to measure project goals. eCab will continue to adjust vehicle operations to provide robust data. eCab and CARTS will wind down the vehicle operations and data collection. W&W and NREL will increase data analysis and disseminate findings. All project partners, including LSCFA, W&W, eCab, CARTS, and local partners, will assist in project end reporting.

Results

At this stage of the project in Budget Period One, eCab has procured three Polaris Gem E6 Low Speed Vehicles, one of which has been upfitted by eCab to a paratransit vehicle (Figure I.30-1).

Figure I.30-1. eCab paratransit LSEV (Photo Credit: Chris Nielsen)

The eCab service zone was created within the CARTS dynamic response zone, which is specifically for "on demand" vehicles, using a Via developed demand response application for shared and individual rides. The CARTS zone is limited to the size that fits the Via algorithms to ensure the anticipated response time while including key neighborhoods and trip generators. The eCab zone is a smaller subsection of the CARTS zone which considers the 45-mile an hour or lower speed limits for LSEVs.

eCab designed and installed its data collection systems on the vehicles. eCab has been working with NREL on the data integration with the EEMS Livewire platform. As this project began in advance of other rural mobility projects under the same award, eCab has agreed to serve as a test case for data flow integration with Livewire. NREL's Livewire representatives will continue to work with this project team to facilitate data access and flow and an understanding of how data streams interact with Livewire. This information will help to inform other projects.

Figure I.30-2 is a partial section of the preliminary eCab data collection dashboard.

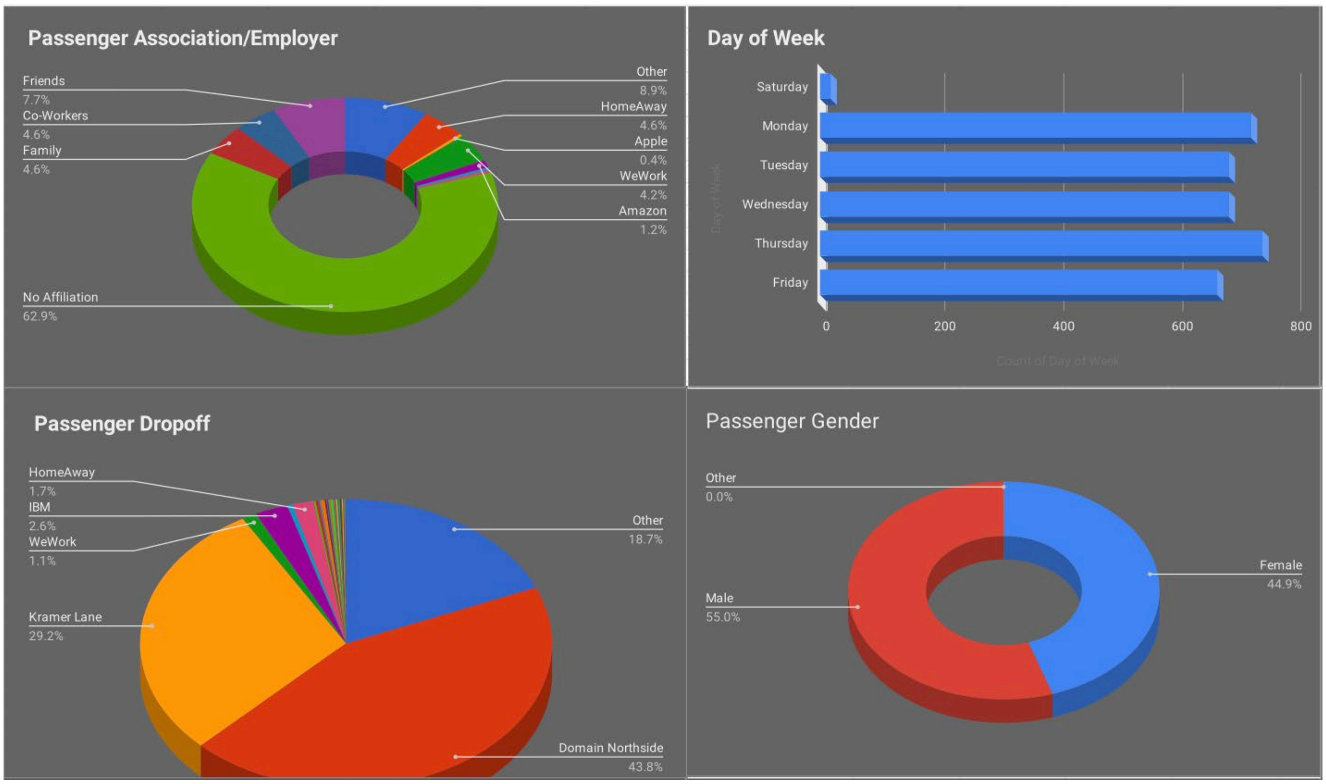

Figure I.30-2. Sample eCab data dashboard (Photo Credit: Chris Nielsen)

The onboard telematics collects information on pick up time and date. The eCab driver collects other information through observation and direct questions as passengers enter, and inputs it into a tablet. Currently the dashboard is set up to collect the following information: passenger associations with each other (family, friends, co-workers, individual), passenger employer, passenger pick up and drop off points, reason for trip, age, gender, first time or repeat user, and, if applicable, Americans with Disabilities Act - type user (more specific than just needing the wheel chair lift). All data will be used to refine route offerings to better accommodate passengers and anticipate their needs.

Conclusions

We are in the first year of the project and due to disruptions from the pandemic, segments of our timeline have been delayed: customer engagement, route design and vehicle deployment, data generation and analysis. While we will be deploying our vehicles during Budget Period One, as of this writing we have not yet generated data. The following observations are worth noting:

Flexibility and communication have been key to keeping this project on track. The initial focus was for the eCab routes to handle primarily downtown and tourist traffic. Downtown Bastrop is known for its down-home country flavor and has numerous events attracting locals and tourists. Due to the pandemic, events and tourist traffic are significantly reduced.

eCab's demonstrations of the LSEVs to key CARTS staff showed the breadth of the vehicle abilities. Although CARTS staff was familiar with the Polaris GEMs, they hadn't actively thought of the possibilities the eCabs could provide CARTS, and they identified additional market segments the eCabs could service if pandemic restrictions continue to hamper tourists and nightlife.

I.31 EVZion - East Zion National Park Electric Vehicle Shuttle System Plan (Utah Clean Cities Coalition)

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Start Date: October 1, 2019 End Date: December 31, 2022
Project Funding: $1,436,568 DOE share: $655,000 Non-DOE share: $781,568

Project Introduction

EVZion will demonstrate a small-scale environmentally sound, zero-emission, electric vehicle (EV) shuttle system through a small gateway community and the east entrance of Zion National Park (ZNP). This high-tech, electric shuttle pilot and demonstration project will involve National Laboratory data collection, industry partner extreme road testing in extreme climate fluctuations, and local community leadership. This nationally recognized project is intended to support the sustainability goals of Zion National Park, along with the economic and environmental resilience objectives of rural gateway communities. EVZion is designed for universal scalability, with deployment in other high-traffic, environmentally sensitive National and State Parks throughout the United States. This pilot will propose positive strategies and smart mobility solutions through the design of an electrified and resilient park touring transportation system.

Objectives

The objectives of this project are to conduct a small-scale proof of concept Electric Vehicle (EV) shuttle demonstration targeted at connecting the City of Kanab, Utah to ZNP; collect and share usage data with a Department of Energy (DOE) Federally Funded Research and Development Center (FFRDC) for further analysis; develop lessons learned and best practices; and conduct outreach with other fleets to assist with technology adoption decisions.

Approach

The project will reach the objectives by achieving several initiatives across all budget periods, with different levels of effort, including the following:

Assessment and Electric Vehicle Supply Equipment (EVSE) Shuttle System Planning:

The first budget period includes collection of input from stakeholders, identification of key transportation strategies, mapping the shuttle system and issuing a Request for Proposal (RFP) to potential EV and EVSE vendors.

EVSE and Shuttle Stop Development:

The second budget period includes selection of vendors, purchase and installation of infrastructure, and development of shuttle stops.

EV Shuttle Demonstration:

The third and final budget period includes purchase, acquisition and deployment of shuttles, completion of a technology pilot study and creation of a National Park EV Development Concept Plan.

Achievement of overall project objectives is dependent upon tasks performed by the National Renewable Energy Laboratory (NREL), a National Laboratory funded under a separate DOE award. Utah Clean Cities Coalition will coordinate and collaboratively conduct work with NREL on tasks integral to the completion of the project. The results of this collaborative effort will be included in all project reporting. NREL will collect, test, and assess data for this project, including infrastructure development and vehicle deployment evaluations.

Results

Through 2019 and into 2020, the project team assembled a Steering Committee and engaged them through monthly virtual meetings/calls. The Steering Committee is integral to project success because the members are actively engaged in developing, deploying, evaluating, and educating on EV charging infrastructure. Additionally, the Steering Committee oversaw all tasks accomplished throughout the first year, as outlined below. The Steering Committee members are shown in Table I.31-1. Further, the key community members that are following the project are shown in Table I.31-2, Community Partners.

Table I.31-1. Steering Committee Members

Organization	Category
Utah Clean Cities Coalition	Primary Invesigator, Clean Cities Coalition
National Renewable Energy Laboratory	FFRDC Laboratory
Kane County	Government
Kanab City	Government
Garkane Energy	Utility
Zion National Park	National Park
Zion National Park Foever Group	Non-profit
Kane County Utah Office of Tourism and Film Commission	Office of Tourism
Utah Department of Transportation	Department of Transporation
Zion Mountain Ranch	Private
Zion Ponderosa Ranch Resort	Private

Table I.31-2. Community Partners

Organization	Category
Denver Metro Clean Cities Coalition	Clean Cities Coalition
Northern Colorado Clean Cities	Clean Cities Coalition
Southern Colorado Clean Cities	Clean Cities Coalition
Treasure Valley Clean Cities Coalition	Clean Cities Coalition
Land of Enchantment Clean Cities Coalition	Clean Cities Coalition
Valley of the Sun Clean Cities	Clean Cities Coalition
Yellowstone-Teton Clean Cities	Clean Cities Coalition
Utah State University, ASPIRE Center	University
Utah Transit Authority	Transit Agency
Salt Lake City	Municipality
Springdale	Municipality
Five County Association of Governments	Government

Organization	Category
Bureau of Land Management	Government
Department of Administrative Services	Government
Washington County	Government
Rocky Mountain Power	Utility
Dominion Energy	Utility
Utah Governor’s Office of Economic Development	Utah Governor's Office
Utah Governor's Office of Energy Development	Utah Governor's Office
Utah Governor’s Office of Tourism	Utah Governor's Office

Data Logging:

The project team acquired a data logger from NREL to collect initial data from a traditional diesel shuttle bus through the route. The data collected was as follows:

1. To and from Zion Empty – 3 passes of route
2. To and from Zion Loaded – 3 passes of route, fully loaded or at least 500-1000 lbs.
3. Idle – no air conditioning (AC) for 1 hour
4. Idle – AC for one hour with door closed
5. Idle – AC for one hour with door open.

The team then sent the data back to NREL to be analyzed. The full report and recommendations for the RFP are scheduled for internal review mid-November, and the RFP will be fully released at the end of December 2020.

EVSE at Kanab:

The project team coordinated with Kane County to finalize the Environmental Questionnaire and procure the EVSE infrastructure for Kanab. This is the first scheduled installation of EVSE in the project; additional infrastructure will follow in Applecross Junction, and outside of Zion National Park West side.

Conclusions

During the first year of the EVZion project, the project partners successfully developed the working group of the Steering Committee, finalized all administrative documents, and started the process for the RFP, with the collection of data from a similar conventional diesel vehicle. Finally, Verdek Green Technologies Co. installed EVSE at Shuttle Depot in Kanab.

Acknowledgements

The team would like to recognize the efforts of Daniel Nardozzi, the project’s NETL manager.

I.32 Electrifying Terminal Trucks in Un-Incentivized Markets (Metropolitan Energy Center)

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Start Date: October 1, 2019 | End Date: December 31, 2022
Project Funding: $1,781,776 | DOE share: $780,000 | Non-DOE share: $1,001,776

Project Introduction

Metropolitan Energy Center (MEC) is a nonprofit organization with a 37-year history of transforming energy use in the building and transportation sectors in the Kansas City region and beyond. MEC houses both the Kansas City Regional and Central Kansas Clean Cities Coalitions. Through the coalitions, MEC has brought together public and private stakeholders to promote clean fuels, fuel efficiency, and new transportation technology. We also have over 20 years of experience working with alternative fueled vehicles of all types. This project, Electrifying Terminal Trucks in Un-Incentivized Markets, will simultaneously fulfill aspects of MEC's energy transformation strategy and meet the objective to accelerate the deployment of commercial electric vehicles, as well as supporting infrastructure.

Despite being a commercially proven concept, electric vehicles are still demonstrating financial and technical viability in a variety of markets, including manufacturing and distribution settings. The electrification narrative often cites total cost of ownership (TCO) as lower with an electric vehicle due to lower maintenance and fueling costs, but the long-term vision of TCO is not a convincing argument for fleets with limited cash flow. This project will demonstrate all-electric terminal tractors manufactured specifically for that duty cycle by Orange EV. Through observation, interviews and data capture, MEC will validate the speed with which fleets earn back the capital costs of replacing diesel terminal tractors with electric models, generate case studies that can be used throughout industrial markets in Clean Cities territories, and put four Orange EV T-Series pure electric terminal trucks into permanent service within the regional territory.

Objectives

The objectives of this project are to demonstrate the feasibility of electrification for freight yard and terminal fleets through pilot projects with three fleets, and to generate outreach documents that can be used regionally and nationally to promote electrification in other terminal fleets. Project partner, Missouri University of Science and Technology, will analyze telematics and charging data, supported by fleet interviews and operational analysis. Ultimately, MEC will create a deployment guide based on the real-world data and experiences of our pilot fleets in Chicago and Kansas City, so fleet operators across the country can make the move to clean, efficient freight handling.

The technology being put into service by the pilot fleets is manufactured by Orange EV. Based in the Kansas City metro, in Riverside, Missouri, Orange EV designs and manufacturers all-electric yard trucks in the heartland. They are also the first American company to commercially build, deploy, and service 100% electric Class 8 trucks into container handling operations. The pilot fleets are described below:

- Firefly Transportation Services provides clients a one-stop-shop for yard services solutions – utilizing 100% electric vehicles – delivering sustainability, safety, service, and continuous improvement. Firefly will deploy two trucks in the Chicago metropolitan area. One of their deployments will include Orange EV's all new T-Series Tandem pure-electric terminal truck.
- Johnson County Wastewater Department will deploy their truck at their new wastewater treatment facility located in Leawood, KS. The facility is currently under construction in a multi-year expansion project. Johnson County is one of fourteen counties in the Kansas City metropolitan area.
- Hirschbach Motor Lines, a private long-haul carrier with emphasis on refrigerated and other specialized services, will deploy their truck at a client site in Wyandotte County, Kansas, which is also located in the Kansas City metropolitan area.
- Orange EV will also take possession of a demonstration truck that will be available for use by interested fleets across the U.S. at no cost except for a shipping fee of $500.

Approach

Figure I.32-1. Jason Dake, Vice President of Legal & Regulatory Affairs at Orange EV and Emily Wolfe, Program Specialist with Metropolitan Energy Center, are pictured with Firefly Transportation Services' T-Series extended duty electric terminal truck

In addition to telematics and data collection, the project team will hold quarterly roundtables during the three-year duration of the project, allowing the pilot and demo fleets to share lessons learned and best practices in their unique deployment settings. Feedback collected from the roundtables will inform key message refinement, identify project champions, and provide content for outreach documents and the final project report. These meetings will also provide a basis of relationships across the region with the goal of demonstrating the feasibility of battery-powered terminal trucks. See Figure I.32-1.

Year two of the project will focus on community outreach. Pilot fleets will work with MEC and Orange EV to host at least one community workshop. Presenters will share the benefits of electrification and other alternative fuels in freight applications, and the pilot fleets will reveal their experiences and best practices with fleet electrification. Successful workshops with follow-up surveys and meetings should generate new strategic deployment opportunities.

In the final year of the project, MEC will work with Orange EV and the pilot fleets to present the project case study for at least one regional or national conference, providing a reliable and replicable basis (and resources) for more companies to choose electric terminal trucks in the future. A successful conference presentation should also generate new strategic deployment opportunities and apply a multiplier effect on project outcomes.

Results

MEC has onboarded all project partners, all procurements are well underway, and one of the four trucks was recently deployed by the pilot fleets, in addition to the deployment of the Orange EV demonstration vehicle.

Conclusions

Data collection has just begun for the project. We have yet to draw any conclusions.

Acknowledgements

Report content and project leadership primarily provided by Emily Wolfe, Program Specialist at Metropolitan Energy Center.

I.33 Developing an EV Demonstration Testbed in the Upper Cumberland Region of Tennessee, an Economy Distressed Rural Region (Tennessee Technological University)

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Start Date: October 1, 2019 End Date: December 31, 2022
Project Funding: $1,559,686 DOE share: $779,823 Non-DOE share: $779,863

Project Introduction

Electric vehicles (EVs) are promising solutions for rural mobility due to the lower fuel cost and lower maintenance cost. Rural areas and associated rural clusters in the U.S. are facing numerous challenges in adopting EVs and developing EV charging station networks due to low population density, lack of EV charging infrastructures, limited to no EV experience, and low consumer awareness. The overall goal of this project will be to create a proof-of-concept demonstration testbed for EVs and fueling infrastructure in the Upper Cumberland (UC) region in Tennessee (TN), which is a representative rural and economically distressed region, to provide the experience, research, demonstration and educational opportunities needed to address EV adoption issues.

Objectives

The objective of this project is to develop a rural EV testbed to demonstrate and evaluate the applications of EVs over a diverse range of activities, serving the rural and largely economically depressed UC region in TN, to help potential fleet owners and the public at large make informed decisions about EV adoption before making significant financial investments. This project will serve as a proof-of-concept implementation to support knowledge gaining, transfer, outreach and education on EVs for rural applications, and to compliment DOE Vehicle Technology Office’s existing EV data set with detailed EV operation and use data dedicated specifically to the challenges and needs associated with rural communities.

Approach

For this project, Tennessee Tech University (TTU) has teamed with a large number of stakeholders including East Tennessee Clean Fuels (ETCF) coalition, The University of Texas at Austin (UT-Austin), Nissan North America, Phoenix Motorcars as a Ford-authorized Qualified Vehicle Modifier, Upper Cumberland Human Resource Agency as the primary public transit provider in UC region, ChargePoint as one of the leading EV supply equipment (EVSE) suppliers in the United States, Seven States Power Corporation (Seven States) as EV charging service provider, LYFT, and Oak Ridge National Laboratory (ORNL) as informal technical advisor of the Project Team.

The demonstration testbed will consist of a small EV fleet (five EVs) including three Nissan Leaf EVs (one with a 40-kWh battery pack and two with 60-kWh battery packs), one plug-in hybrid pickup truck (F250), and one battery-electric transit bus, along with a supporting EV charging station network across the UC region, including one direct current fast charging (DCFC) station and eight Level-2 charging stations.
The project objectives are to address the challenges of adopting EVs into rural regions via the following five primary components:

- EV Fleet Demonstration and Charging Network Development: This project will serve as an open demonstration of the use of EVs and charging infrastructure within the UC region. Our project targets five user communities (general residents in the UC region, faculty/staff/students at TTU, new economy transportation service providers such as LYFT drivers, farming, and other businesses) which collectively cover most of the residents within the UC region. An EV charging station network will be established to support EV operations in UC region.
- Data Tracking and Collection: The project will strongly focus on collecting comprehensive data from the proposed plug-in electric vehicles (PEVs), charging infrastructure, and the served communities. The PEV data will include key information related to vehicle speed, energy consumption, charging dates, times and durations, driving and charging patterns. The team will collect comprehensive charging station data. In addition, the team will conduct pre-demonstration and post-demonstration surveys and interviews with the served rural communities, as well as early EV adopters in rural areas.
- Data Analysis: The key questions regarding EV adoption in rural areas will be: 1) What are the costs, operational issues, and performance attributes for EV operation in rural areas? 2) What are the key factors for different potential vehicle fleets and communities in rural areas to make EV adoption decisions? 3) What best practices and lessons can be learned and shared for EV adoption in rural areas in this project? The project will focus on detailed data analysis to answer these critical questions. In addition, the team will develop a PEV readiness model for assisting with EV adoption.
- Information Sharing & Outreach: The team will exchange information such as new findings, observations, best practices, and lessons learned with various stakeholders including rural communities, fleet managers, and government agencies, via diverse outreach activities (e.g., EV ride-and-drive/show-and-tell events), EV chapter development, sustainable transportation forum, expo and conferences.
- Education: The project will integrate EV demonstrations into a newly-formed Vehicle Engineering program at TTU. This degree program educates new engineers to use the latest technologies to design and manufacture modern vehicles, including EVs. The project has integrated EV demonstrations into TTU's vehicle engineering curriculum. Further, the project has created public education opportunities for the rural communities in the UC region via reoccurring public events.

Results

During the first year of the project (FY 2020), the project team has had the following accomplishments:

As of September 30, 2020, the project partner, Seven States Power Corporation, has identified all 9 public charging station hosts and successfully installed three Level-2 charging stations and one DC fast charging station in the UC region, as shown in Figure I.33-1. The DC fast charging station is only the second DC fast charging station in the entire UC region. These four public charging stations are ready to serve the EV communities in the rural UC region. As of September 30, 2020, the developed charging stations have supported 43 charging events across four counties (Macon, Smith, Overton, and Putnam) in the UC region. Five additional Level-2 public charging stations are currently under site preparation, and it is expected that they will be completed by December 31, 2020.

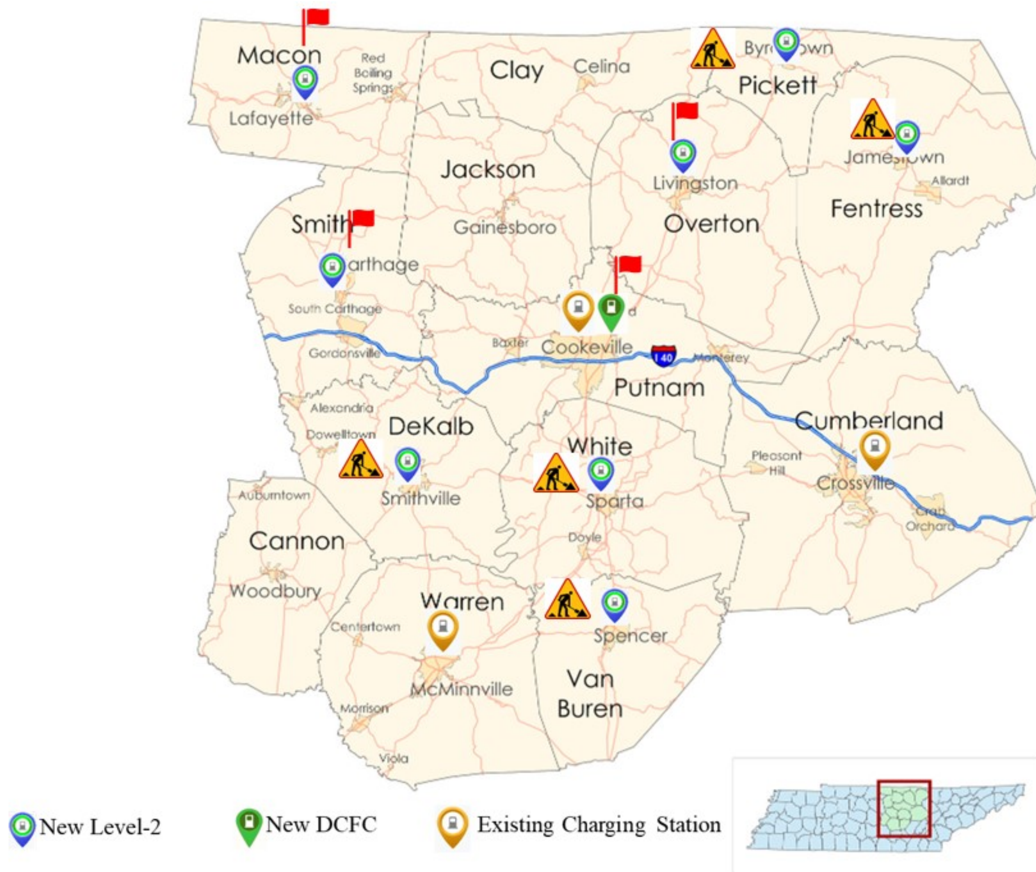

Figure I.33-1. EVSEs installed (flag symbol) and in preparation (construction symbol)

The project team has acquired a small fleet of EVs (three compact EVs) in the first year for demonstration. As a project partner, Nissan North America has donated a 2019 Nissan Leaf SL Plus, which features a 62-kWh battery pack and a 215-mile EV range. TTU has acquired two additional Nissan Leaf EVs (one Nissan Leaf SV with a 40-kWh battery that supports a 149-mile EV range, and one Nissan Leaf SV Plus with a 62-kWh battery that supports an EV range of up to 225 miles). The project team has installed on-board diagnostics (OBD) data loggers on all three Nissan Leaf EVs to collect comprehensive vehicle operation data during the demonstration. The photos of the three Nissan Leaf EVs are shown in Figure I.33-2.

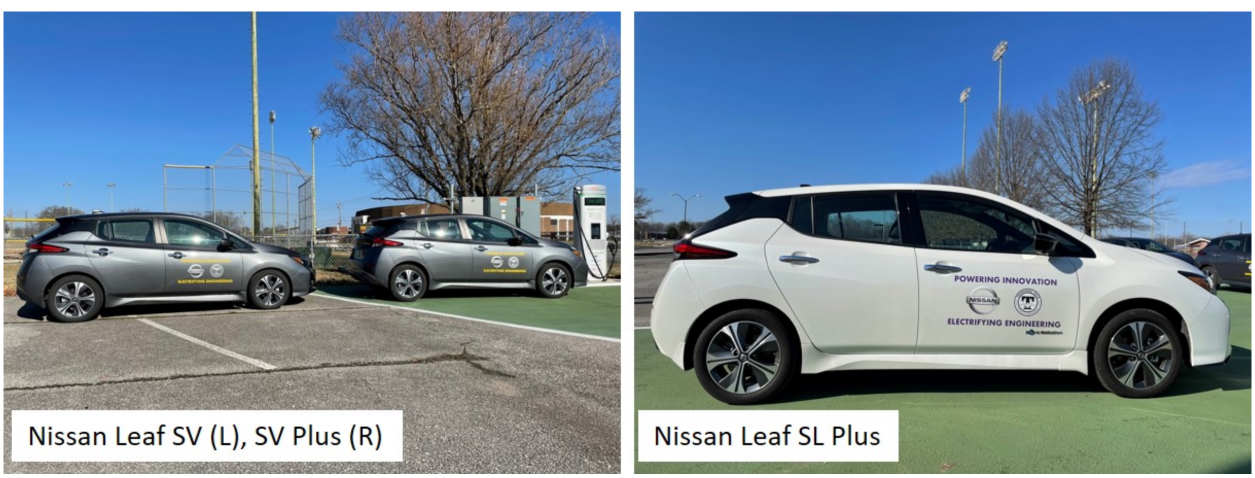

Figure I.33-2. Photos of three Nissan Leaf EVs

TTU spent the first several months in preparing the information needed for a smooth EV demonstration, including institutional review board (IRB) application, characterization of project vehicles, testing of data acquisition system, preparing the data management plan and project management plan, preparing the recruitment materials, designing survey/interview tools, developing EV demonstration protocols, purchasing additional insurance for project vehicles, and preparing basic handouts for participants. TTU also identified a group of internal drivers to test drive the three Nissan Leaf EVs to test the proposed EV demonstration protocol. Note that, due to the COVID-19 pandemic, the preparation step is taking longer than originally planned. Each of our vehicles is thoroughly cleaned between every test drive. This includes washing, vacuuming, general wipe down, and sanitizing with a disinfectant, with particular attention to high-touch points.

After all the preparation steps were completed, the formal EV demonstration started on August 10, 2020. As of September 30, 2020, the project team has received more than 113 pre-screening applications from 8 counties (Putnam, Cumberland, DeKalb, Overton, Smith, Warren, Jackson, Macon) in the UC region, which indicated strong interest in EVs from the rural UC region. Seventeen applicants have submitted all the requested application materials to TTU for review. More than 10 participants have been approved for 2-week EV demonstrations. The electric vehicles have been demonstrated to 7 approved participants, in addition to 3 internal participants, with each participant driving an EV for two weeks as a daily commute vehicle, to learn EV performance, EV charging, benefits, cost, issues, and best practices. The EV demonstration has reached Putnam County, DeKalb County, and Macon County in the UC region. Participants have logged more than 6,000 EV miles in the demonstration of the EV testbed.

Key findings through the EV demonstration program are summarized are as follows:

1. In the rural UC region, there is a large group of people showing strong interest in EVs. It is very important to take an ecosystem approach to accelerate EV adoption in rural areas. Local auto dealers are a critical part of a rural EV ecosystem. Due to the lack of access to EVs for test drives from the auto dealerships, it is very difficult for rural communities to gain experience and knowledge about EVs. This project will fill in the gap to provide the rural communities in the UC region with much-needed test-drive opportunities and EV knowledge.

2. Public EV charging stations are rarely found in rural areas like the UC region. Without appropriate access to EV charging stations (in-home Level-2 or public charging stations), it is still difficult for the participants to behave like normal EV users in the test drives. By making project EVs (including residential charging equipment) available to the rural communities at no cost and building a charging station network in the region, the rural communities will be able to test drive EVs and charge EVs at home or at public charging stations when needed. This is critical to understanding how EV charging typically works, and to establishing comfortable charging patterns. The DC fast charging station is much more heavily utilized than Level-2 charging stations in rural areas.

3. The analysis of vehicle operation and charging data from the test drives, conducted by TTU and UT-Austin, found that EVs with ranges from 150 to 230 miles can meet the needs of most rural applications. In the case of long daily commutes, EVs with larger battery packs are preferred, and EVs need to be charged frequently. Therefore, it is critical to have an in-home charging station ready for convenient EV charging without significantly relying on public charging stations, which are limited in rural areas. In the case of short daily commutes, EVs with smaller battery capacities can meet the needs. Charging strategies are very flexible in this case as the users may use Level-1, Level-2, DCFC stations, or a combination. In addition, driving behaviors (such as cruise speed on the highway) can significantly impact EV driving ranges and the user experience. To extend EV driving range on the highway, the team recommends that the participants operate at a lower speed, 55 to 60 mph, if travel time and traffic conditions permit [1].

TTU has coordinated with ETCF on various outreach activities to promote EV awareness in the rural UC region in Tennessee, including:

1. Two TTU 2020 Spring Showcase events on February 5, 2020 and March 7, 2020, to promote EV awareness and education to prospective TTU students and their family members, who typically live in rural areas across Tennessee.

2. DCFC infrastructure unveiling event on July 22, 2020, to inform the rural communities and stakeholders about the project, and charging station availabilities

3. An EV "Ride-and-Drive/Show-and-Tell" event in Cookeville TN (the largest city in the rural UC region) on September 26, 2020 during National Drive Electric Week (NDEW) [2]

The key numbers of the TTU showcase events, the DCFC infrastructure unveiling event, and EV ride-and-drive event in Cookeville, TN, are summarized in Table I.33-1. The photos of the DC fast charging station unveiling event and EV ride-and-drive event in Cookeville TN, are shown in Figure I.33-2.

Table I.33-1. Key Numbers of DCFC Unveiling Event and EV Ride-and-Drive Event

Event and Location	Number of People Targeted in the Event	Number of People Exposed to the Event	Number of Plug-in Vehicles at the Event	Number of Test Ride and Drives in the Event
TTU Spring Showcase Events, Cookeville, TN	260	260	2	1
DCFC Unveiling Event, Cookeville, TN	10,500	45	6	0
EV Ride-and-Drive Event, Cookeville, TN	22,540	25	6	20

Figure I.33-3. Photos of DCFC station unveiling event (left) and EV Ride-and-Drive event in Cookeville TN (right).

The Principal Investigator (PI) presented a poster about this project in the 2019 Tennessee Sustainable Transportation Forum and Expo, to promote EV awareness in the rural areas. Our project partner, Upper Cumberland Human Resource Agency, gave a presentation titled "Electrifying Public Shuttle Bus in Upper Cumberland, TN" in the 2019 Tennessee Sustainable Transportation Forum and Expo.

TTU and ETCF have initiated discussions with the different stakeholders in the rural UC, including Cookeville and regional leadership, local car dealers, local Tennessee Department of Environment and Conservation staff, local power corporations, and the local transit agency, as part of the project's rural community engagement. The goal is to establish an EV ecosystem with all the necessary stakeholders involved. TTU and ETCF have also started developing an EV Club at TTU, and a Cookeville/Upper Cumberland EV chapter.

TTU has incorporated EV education in the newly launched vehicle engineering program. In Fall 2019, the PI used the EVs in this project to educate vehicle engineering students on EV powertrains, EV charging, and benefits and limitations. In addition, over 20 vehicle engineering students participated in a short-term EV ride-and-drive event to understand the EV performance on the road.

Conclusions

Developing proof-of-concept EV demonstration testbeds in rural areas like the UC region in Tennessee is critical to understanding the performance, benefits, limitations/lessons of EVs in meeting the needs of rural communities and fleet operation. Through the demonstration of the testbed and associated outreach activities, the EV experience, knowledge and awareness in the rural communities can be significantly improved. This can be very beneficial for rural communities and fleet owners to make informed decisions in adopting EVs for their applications. DOE funding provided through this project made it possible to build and demonstrate such a valuable EV testbed.

Through the first year of the project, the initial data sets suggest that the affordable EVs deployed in this project can meet the needs of rural applications. In-home charging stations are critical to making EV operation sustainable in rural applications, which makes EV users less dependent on the limited public charging stations in the rural UC region. Charging patterns and driving behaviors can potentially be optimized to allow the best use of EVs in rural areas.

Key Publications

Maxavier Lamantia, Zifei Su, Pingen Chen, "Remaining Driving Range Estimation Framework for Electric Vehicles in Platooning Applications," accepted in 2021 American Control Conference.

References

[1] https://www.fueleconomy.gov/feg/driveHabits.jsp
[2] See https://driveelectricweek.org/event.php?eventid=2541 for details

Acknowledgements

The project team is grateful to DOE NETL program manager Trevelyn Hall for valuable feedback and guidance that help improve this project. The project team is also grateful to NETL Contract Specialist Shane Buchanan for his time and efforts on the budget management. Finally, the project team would like to thank the following organizations for their contributions to the project: East Tennessee Clean Fuels Coalition, The University of Texas at Austin, Nissan North America, Phoenix Motorcars, Upper Cumberland Human Resource Agency, ChargePoint, Seven States Power Corporation, Lyft, and Oak Ridge National Laboratory.

I.34 Heavy Duty EV Demonstrations for Freight & Mobility Solutions (Clean Fuels Ohio)

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Project Introduction

While adoption of light-duty electric vehicles (EVs) has increased and more models have become commercially available, medium-duty (MD) and heavy-duty (HD) EVs have not seen the same widespread success. MD and HD EVs offer tremendous potential economic benefits to fleets, and wider energy and environmental benefits to communities. This project confronts that disparity to highlight the importance and uses of MD and HD EVs.

Clean Fuels Ohio designed this project to prove the operational and financial effectiveness of MD and HD EVs in fleets and communities that had not previously used this technology. Through diverse partnerships, the project will utilize commercially available EVs, electric vehicle supply equipment (EVSE), facilities, and app-platforms to ensure seamless technology deployment and showcase significant return on investment. Clean Fuels Ohio will partner with Orange EV, SEA Electric, and Lightning Systems to operate three demonstration projects of MD and HD EVs. We anticipate this will lead to Class 4-8 EV adoption in various fleet applications across the country.

Objectives

This project aims to demonstrate the viability of MD and HD EVs in new fleets and communities. The project partners include highly visible fleets in freight/goods movement and mobility solutions, such as DHL Supply Chain, Two Men and a Truck, and Columbus Yellow Cab, a new project partner. (An original partner, Empower Bus, shut down as a result of COVID-19).

Approach

The project will enable and speed up Class 4-8 EV adoption by making targeted improvements in each of the four major areas of activity:

1. Real-world deployments of MD and HD EVs by highly visible fleets in key vehicle segments, designed to showcase EVs in vehicle platforms with opportunities for adoption across a wide range of use cases in freight, service, and mobility fleets

2. Improved MD and HD EV datalogger analysis and reporting capabilities - This will be led by partner Sawatch Labs, working in conjunction with EV Original Equipment Manufacturers (OEMs) involved in the three demonstration projects

3. Operational & financial performance analysis tools informed by OEM end-user data on real world vehicle deployments

4. Analysis of key fleet prospects and a distribution of replication resources to fleets – The project team, in partnership with Clean Cities Coalitions from across the country, will identify fleet stakeholders with similar vehicle operations, share case studies, and perform individualized analysis. The project team will use these results to demonstrate how the pilot vehicles can be adopted by additional fleets to improve economic and environmental performance.

Results

Clean Fuels Ohio, in conjunction with project partners, completed a series of milestones in the first year of the project, as follows:

1. Developed a data collection and analysis plan to inform a demonstration fleet deployment plan
2. Convened and supported a Project Advisory Committee (PAC)
3. Developed a fleet deployment plan
4. Designed engineering plans for the fleet deployment
5. Completed specifications for EV/EVSE, and purchased and deployed vehicles and equipment.

The Go/No Go decision point for the first year of the project was to confirm operation of demonstration EVs and EVSE.

First, Clean Fuels Ohio worked with Sawatch Labs to draft a comprehensive "Data Collection and Analysis Plan" that covers the following topics in detail: project schedule, data diversity, data partner recruiting, data parameters and other collected information, data collection process, data storage methodology and security, and data analysis. Sawatch Labs added MD and HD EVs to their data analysis platform and performed the data analysis, visualization, and key reporting functions.

Subsequently, Clean Fuels Ohio convened and supported a PAC, made up of a diverse coalition of organizations and fleet owners to participate in and advise on the project, shown in Table I.34-1.

Table I.34-1. Heavy Duty EV Demonstrations for Freight & Mobility Solutions: PAC Members

Organization	Point of Contact	Relevance
Mid-Ohio Regional Planning Commission (MORPC)	Dina Lopez	Strategic Projects Manager responsible for freight and transportation policy that supports freight at MORPC, the metropolitan planning organization for central Ohio
Sawatch Labs	Mary Till	Director of Business Development, project technical lead whose mission is to use data to inform and accelerate the adoption of EVs and charging infrastructure through their ezEV analytics platform
AEP Ohio	Julie Volpe-Walker	Energy Efficiency Program Manager at major national utility
North American Council for Freight Efficiency (NACFE)	Dave Schaller	Industry Engagement Director at NACFE, works to drive the development and adoption of efficient, environmentally beneficial, and cost-effective technologies in freight industry
DHL Supply Chain	Emily Davis	Fleet Demonstration Partner; DHL Supply Chain is the world's largest contract logistics provider.

Organization	Point of Contact	Relevance
Two Men and a Truck	Christian Irkens	Fleet Demonstration Partner; the fastest growing franchised moving company in the US
SEA Electric	David Brosky	OEM project partner, provider of electric-powered system technology for delivery and distribution fleets
OrangeEV	Don Jalbert	OEM project partner, provider of 100% electric Class 8 trucks
Adomani Electric	Doug Lollar	Director of Sales, provider of zero-emission Class 3-5 electric vans, trucks, and drivetrain systems
Utah Clean Cities	Tammie Bostick	Clean Cities project replication partner, DOE Clean Cities coalition for the State of Utah
New Jersey Clean Cities	Chuck Feinberg	Clean Cities project replication partner, DOE Clean Cities coalition for the State of New Jersey

Next, Clean Fuels Ohio developed a fleet deployment plan. The demonstrations in this project focus on freight and goods movement and mobility solutions, including:

1. DHL Supply Chain (Class 8 EV for transfer/yard hostler truck)
2. Two Men and a Truck (Class 6 EV for local delivery)
3. Columbus Yellow Cab (Class 4 EV shuttle for local transit transportation/mobility services; this aspect of the project is pending final DOE approval as the original project partner, Empower Bus, closed due to COVID-19). Clean Fuels Ohio worked with DHL and Two Men and a Truck to develop fleet deployment and EV equipment selection plans.

Finally, Clean Fuels Ohio completed purchase specifications for EV/EVSE for the three project partners, in conjunction with three OEMs – Orange EV, SEA Electric, and Lightning Systems, respectively. Orange EV and Clean Fuels Ohio worked with DHL, SEA Electric and Clean Fuels Ohio worked with Two Men and a Truck, and Lightning Systems and Clean Fuels Ohio worked with Columbus Yellow Cab. These conversations determined final EVSE charging equipment, installation locations on site, site prep needs, and plans for installation, parking, and charging to prepare each company to launch their respective EVs.

Conclusions

Clean Fuels Ohio and the project team are largely proceeding as planned with project set up and deliverables for budget year one. The team did not expect to find any significant conclusions currently, and there is nothing considerable to report.

The global COVID-19 pandemic remains the biggest development impacting the project to date. Clean Fuels Ohio staff are working remotely for the foreseeable future to comply with CDC and State of Ohio Guidelines pertaining to COVID-19. We plan to continue work on our DOE funded projects, as do all contracted project partners.

The main impact of the COVID-19 pandemic has been on the project fleets that are deploying the vehicles. As noted above, Empower Bus, an original project partner, closed its business due to COVID-19. Clean Fuels Ohio has found an adequate replacement able to perform all original project deliverables in time to keep the project on track, pending final approval from DOE. Otherwise, the other project partners can move forward, as they are essential services and experience continued business during the pandemic.

I.35 Electric Vehicle Widescale Analysis for Tomorrow's Transportation Solutions (Akimeka, LLC)

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Start Date: October 1, 2019 End Date: December 31, 2022
Project Funding: $3,999,370 DOE share: $3,999,370 Non-DOE share: $0

Project Introduction

With the rapid increase in vehicle electrification, there is a need for up-to-date, publicly available national data on the usage of plug-in electric vehicles (PEV) and electric vehicle supply equipment (EVSE), also referred to as charging stations. This data must be analyzed to understand end-user charging and driving patterns, as well as vehicle and infrastructure performance, to inform DOE's research planning. Energetics is working with project partners to collect PEV and EVSE usage data from a wide range of fleet types and charging venues from across the United States. Energetics will analyze the data and make summary results publicly available. All data sets and reported results will anonymize data to protect sensitive information. Partners include ChargePoint, Sawatch Labs, Clean Fuels Ohio, Dallas-Fort Worth Clean Cities, Middle-West Tennessee Clean Fuels, Kansas City Regional Clean Cities, Denver Metro Clean Cities, Empire Clean Cities, Columbia-Willamette Clean Cities, Palmetto Clean Fuels, Virginia Clean Cities, and Clean Cities – Georgia.

Objectives

The objectives of this project are to collect, validate, collate, analyze, summarize, and publicly release real-world use data and datasets from PEVs and EVSE, to inform future research and deployment planning efforts. The team will provide project data to Department of Energy (DOE) National Laboratories for additional analysis on a quarterly basis and will make a dataset publicly available at the end of the project. Personally Identifiable Information (PII) will not be distributed or released to the National Laboratories or the public. The critical success factors for achieving these objectives are:

- Building strong collaborative partnerships with existing PEV and EVSE deployment initiatives; Clean Cities coalitions across the country; ChargePoint, an EVSE network provider; and Sawatch Labs, a telematics analytics company
- Securing diverse and representative PEV and EVSE data from various vehicle deployments and charging station host sites from across the country
- Developing robust and secure data management and analytics based on the Energetics team's extensive experience with PEV, EVSE, and other fleet data analyses
- Using multifaceted dissemination channels to ensure widespread stakeholder access to the datasets, including distribution through Clean Cities coalitions; Project Advisory Committee members from state energy offices, utilities, telematics providers, academia, and vehicle Original Equipment Manufacturers; state and local organizations; and industry partners.

The project's nationally scaled anonymized dataset and analysis summaries are expected to be highly valuable for a range of entities, including state and federal organizations, regulatory agencies, vehicle manufacturers, electric utilities, universities, National Academies of Science, and fleet operators. The primary goals of this project are to:

- **Provide anonymized PEV and EVSE data** that augments existing National Laboratory datasets. This data, formatted to leverage National Laboratory capabilities, will be representative of nationwide PEV and EVSE operation.
- **Develop and regularly share high-level data summaries** that provide stakeholders and the public with a snapshot of current PEV and EVSE operations and trends
- **Apply data analytics to answer the project's key research questions, designed with industry expert panel input**, and provide new insights on PEV and EVSE uses that will inform the next generation of policies and investments. Key research questions include, but are not limited to:
    - How are EVs and EVSE being used today?
    - Is EV and EVSE use changing over time with higher adoption and technological advancements (e.g., faster charging and longer electric ranges)?
    - What are the barriers or challenges to wider adoption for electrified transportation solutions?

Approach

The usage datasets will encompass at least 1,600 PEVs and 10,000 EVSE charging ports, representing a diverse set of vehicle sizes, vehicle types, applications, settings, and operating conditions across the United States. The project will apply proven data collection and analysis methodologies to collect, validate, clean, anonymize, analyze, and summarize data from both existing and new PEV and EVSE deployments using a nationwide network of partners. The EV WATTS dataset will consist of three distinct databases with varying access levels, due to the nature of PII or sensitive information.

1. A raw database (multiple tables with utilization and characteristic information for both vehicles and charging stations) and internally generated data tables used to determine sensitivities, PII, anonymization levels, and global statistics. This database will be restricted to a small number of personnel at Energetics for security purposes.
2. A database filtered to remove PII for parties held under a non-disclosure agreement such as the National Laboratories. These tables will be used to transfer quarterly datasets to DOE and National Laboratories (via the DOE Vehicle Technologies Office's LiveWire platform) and to develop associated summary reports published by the project.
3. A database filtered of PII and sensitive information, with categorizations of critical data with less specific detail to provide anonymity. The team will publish this database on LiveWire upon project completion and closeout, for widespread public access and use.

Results

The team identified raw input data parameters, and others may be added as more data providers and sources are brought into the project. Only a few of these parameters may be considered PII and likely only when used in combination with other fields in the database; however, some fields present sensitivities to owners and manufacturers/providers if disclosed. Therefore, many fields that do not add value to the study's purpose will be removed and other fields will be used to establish standard categorizations before being removed.

The goal of anonymization is to provide privacy without sacrificing the value of the data. Two distinct areas for anonymization are: 1) location and 2) time. Removing these fields shields the data providers from potential privacy breaches. The team is considering multiple strategies for anonymization of data, as described below:

- Resolution limitation. An example of this is to limit the resolution of a physical location to an acceptable level of magnitude by rounding coordinates or truncating zip codes. Another example is to force timestamps to 10-minute intervals.
- Use of differential data rather than absolute data can also provide valuable anonymization without sacrificing the value of the data. An example of this is determining the distance of a trip using precise Global Positioning System (GPS) coordinates but only keeping the absolute distance so the coordinate level data can be removed. Another example is determining the trip duration prior to rounding the timestamps, then removing the absolute timestamps.
- Categorization of sensitive information also decreases the potential misuse of this data without sacrificing pertinent information to any analysis performed with this dataset. Examples of this include labels of "Home" or "Work" for the start or end of a vehicle trip instead of an address, venue type instead of the specific name of the charging station location, and land use type (urban, suburban, or rural) instead of the zip code of the charging station location.

The data analysis approach and data management strategy are outlined in Figure I.35-1 and Figure I.35-2.

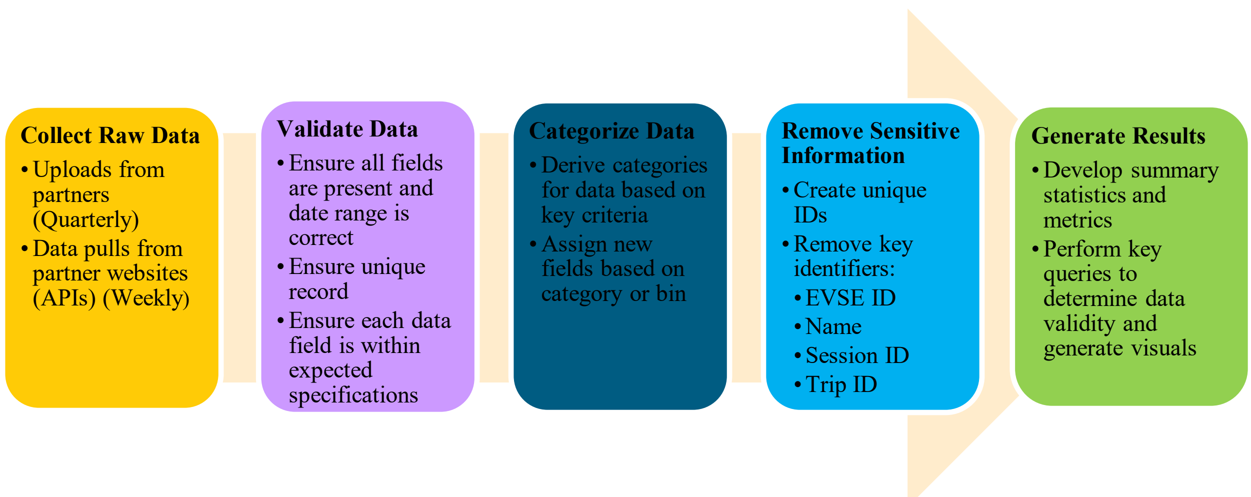

Figure I.35-1. EV WATTS process steps from raw data to results

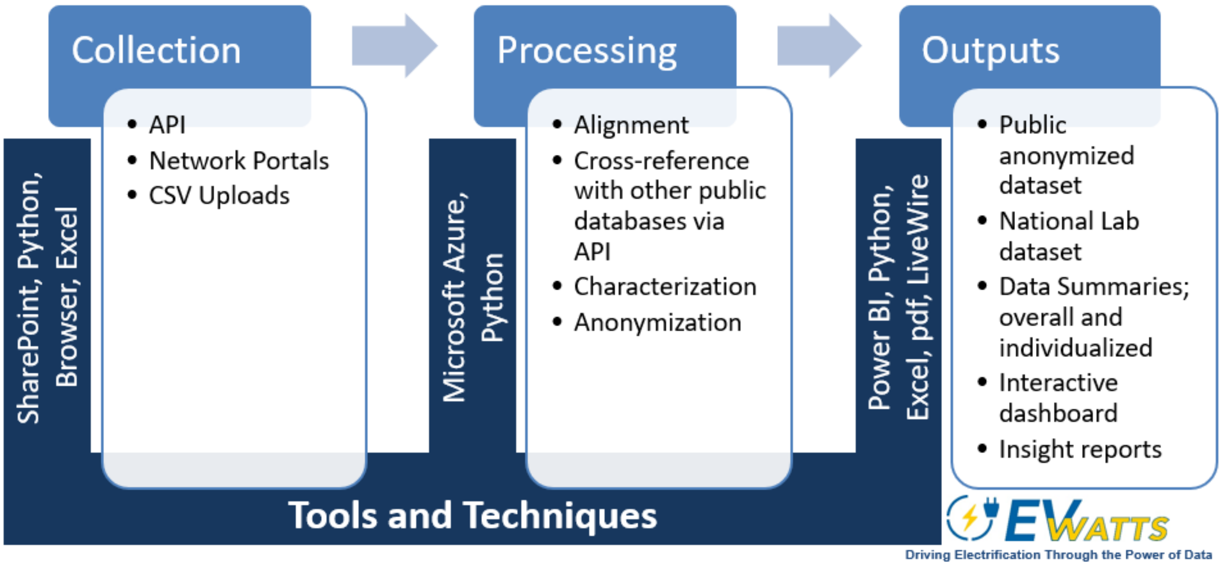

Figure I.35-2. EV WATTS data management structure

The team developed a separate version of the Data Sharing Agreement (DSA) template for 1) partners providing charging station or vehicle data they already have, 2) partners willing to have telematics devices installed on their PEVs that will share data with the project, and 3) partners that had existing data and will have new telematics devices installed. Energetics and the Clean Cities partners have engaged numerous potential partners to introduce the project, gauge their interest in participating, document the potential data available through that partner, and review the DSA. Table I.35-1 and Table I.35-2 indicate the total of secured, pending, and potential data sources.

Table I.35-1. EV WATTS Current Status of Charging Station Data Partners

Region	Secured DSAs	Secured Charging Ports	Pending DSAs	Pending Charging Ports	Potential DSAs	Potential Charging Ports	Total DSAs	Total Charging Ports
New England					1	3,500	1	3,500
Middle Atlantic	2	2,100	2	16	4	160	8	2,276
East North Central			1	675	1	165	2	840
West North Central	1	6	2	2,000	2	65	5	2,071
South Atlantic					5	350	5	350
East South Central			1	86	1	50	2	136
West South Central	1	62			6	350	7	412
Mountain	2	466			4	90	6	556
Pacific			2	300	10	5,000	12	5,300
Total	**6**	**2,634**	**8**	**3,077**	**34**	**9,730**	**48**	**15,441**

Table I.35-2. EV WATTS Current Status of PEV Data Partners

Region	Secured DSAs	Secured PEVs	Pending DSAs	Pending PEVs	Potential DSAs	Potential PEVs	Total DSAs	Total PEVs
New England	2	25	1	1	10	15	13	41
Middle Atlantic	1	2			25	220	26	222
East North Central					20	185	20	185
West North Central	1	1			10	50	11	51
South Atlantic	1	35	2	25	25	300	28	360
East South Central			2	2	10	50	12	52
West South Central			1	1	15	210	16	211
Mountain					26	200	26	200
Pacific			2	385	25	510	27	895
Total	**5**	**63**	**8**	**414**	**166**	**1,740**	**179**	**2,217**

Conclusions

The primary focus to date has been on initiating the project and setting up the processes and approaches to collect, manage, analyze, and deliver the data. No significant findings or conclusions from project specific aspects were expected at this time, but a few observations based on the project progress are listed below.

- The COVID-19 pandemic, and to a lesser extent some natural disasters such as wildfires and hurricanes, had an impact on the project progress. All project staff have been able to continue working remotely without impact on standing-up the project and setting-up the data management structure. However, the pandemic has impacted the team's ability to engage data partners. The data partners have not been able to devote much time to learning about EV WATTS and reviewing the DSA because of more pressing priorities, limited staff availability, and remote work challenges (not being able to attend in-person conferences and meetings limits our ability to connect well with some prospective data partners). Some organizations have also seen plans to install charging stations or acquire PEVs be put on hold due to budget constraints.

- The analysis and sharing of data are starting to be viewed with more scrutiny. One concern raised by data sharing partners has been regarding privacy, as they want to ensure their information is not used maliciously, or in a way that could negatively impact them. While we can outline our approach and expected results, our final deliverables are not yet publicly available, so it is difficult to provide data partners with clear examples as to how the data will be used and presented. Another aspect is the increasing recognition that this kind of data has value and many companies, such as the charging station network providers, are becoming reluctant to offer it for free (or allow their customers to share it for free). The charging station network providers also have concerns about how these data might be used and whether the data could potentially give some advantage to their competitors.

Key Publications

Project materials are available on the project website: www.ev-watts.com

I.36 Medium and Heavy-Duty Electric Vehicle Deployment – Data Collection (CALSTART)

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Start Date: October 1, 2019 End Date: December 31, 2022
Project Funding: $2,166,871 DOE share: $2,166,871 Non-DOE share: $0

Project Introduction

Data on medium-and heavy-duty (MD and HD) battery-electric vehicles (BEVs) are lacking and yet very much needed as the trend towards transportation electrification is expected to accelerate. This project directly addresses this problem by collecting, consolidating, organizing, and making available to DOE National Laboratory researchers a large set of data from a wide range of electric MD and HD vehicles operating under different conditions.

The primary focus is data collection and analysis for electric MD and HD vehicles (transit buses, school buses, trucks, and off-road equipment). This project is an effort to leverage any recently collected data while strategically planning for and collecting new data from upcoming electric vehicle deployment projects across the nation. The data and the extensive research that will be facilitated by consolidating it will help inform the industry, legislators/regulators, researchers, planners, and end-users about future deployments, energy demands, and user trends. There are many potential benefits of having such a comprehensive data source. The impacts the data and the summary analysis could have for the industry are wide-ranging and will likely prove valuable for years to come. CALSTART will work in partnership with University of California, Riverside, Clean Cities Coalitions, TetraTech, ViriCiti and GeoTab.

Objectives

The objective of this project is to collect, validate, analyze, and provide summary analysis of real-world use data and datasets from electric MD and HD vehicles and electric vehicle charging infrastructure. The use data and datasets will encompass approximately 200 diverse vehicle sizes, types, settings, and operating conditions. Project data will be provided to a Department of Energy National Laboratory.

Approach

This project will be conducted in three phases:

Phase 1: Establish the Framework of Data Collection: Establish the data collection framework, including confirming the details of the types of data, storage, and transfer protocols. Confirm the number and type of vehicles and associated data, obtaining any remaining agreements on data from individual project partners from the three dataset categories. Set up the hardware, software and any technical connectivity needed to effectively collect, store and analyze project data.

Phase 2: Implement Data Collection: Implement the data collection processes; perform quality control of data collected; and compile, store, and validate the data.

Phase 3: Data Analysis, Reporting and Sharing: Complete the data collection, perform analysis, and provide summary results, making them publicly available. Complete the final report and provide the compiled raw dataset collected to a national laboratory to be determined.

The data types that will be collected through the course of this work will include Vehicle Data, Charger Data, Facility Data, and Maintenance Data. See Table I.36-1.

Vehicle Performance Data

Vehicle data will be collected using on-board data loggers and established data collection protocols based on the extensive experience of the project team. Different types of data loggers may be used depending on the project source. Previously acquired and new data loggers alike will be available for use in this project. The data loggers read vehicle performance data directly from the vehicle's Controller Area Network (CAN) network and either store it locally until it can be retrieved or send it over cellular or Wi-Fi networks to a remote, secure server. This allows the data to be checked throughout the data collection process to ensure the data logger is operating properly. In addition, the data loggers can record Global Positioning System (GPS) data, including the vehicle's location (latitude and longitude, from which speed and road grade can be derived) and altitude. For some projects, no additional hardware will be required if the vehicle manufacturer includes data logging equipment as a standard feature. In these cases, a software interface will allow raw data to be transmitted from the manufacturer to the project team's servers for storage and analysis. This transfer may be automated or manual at regular intervals. Every effort will be made to seek participation from the manufacturers to ensure that data is successfully and accurately captured from their on-board systems. Data collection test plans and protocols will be standardized, as much as possible, to maximize uniformity across the projects.

Regardless of the specific device collecting the data, the principal data generated by this project is electric vehicle performance data. This includes a wide variety of parameters describing the operation of the vehicle. For example, parameters like distance travelled, vehicle efficiency, idle time, total energy consumed, etc. will all be collected from each vehicle included. These data will be collected in addition to vehicle description data such as make, model, year and battery capacity. Data will be collected over varying periods, depending on the specific project and vehicle availability. Data storage will utilize CALSTART's and/or University of California, Riverside's (UCR) secured data servers. The project team will verify, clean, anonymize, and analyze the data using clearly defined steps and uniform processes across all vehicles. CALSTART will collaborate with UCR to inform the definitions of parameters and format of the raw data, ensuring alignment with existing system requirements, before providing it to the designated DOE National Laboratories. The project team will perform analyses to provide summarized results, including tables, charts, and other visuals.

Table I.36-1. Example Subset of Different Data Sources and Types to be Collected

Vehicle Data	Charging Data	Maintenance Data
Speed	Date/Time	Repairs Performed
Trip Mileage	Energy Charged	Preventive Maintenance
Latitude	Average Charging Rate	Source of Repair
Longitude	Max Charging Rate	Down Time
Start and Stop State of Charge (SOC)	SOC Charged	Service Calls
Date & Time	Utility Rate Structure	
Vocational Use	Demand Charges	
GVWR	Electricity Consumption	
Vehicle Model Year		

Vehicle Data	Charging Data	Maintenance Data
VIN Number		

Charging Data

The project team will collect data on charging sessions and energy used for each session from the Electric Vehicle Service Equipment (EVSE) using the charging management software provided on the majority of equipment. In the cases where a fleet does not have a smart charger, the team will use utility sub-meters to track the energy charged. Vehicle data loggers may also provide measurements on charging sessions and energy charged. In addition, the team will retrieve facility data, including information on electrical consumption, to understand energy throughput. This shall include electricity consumption, utility rates and demand charges, and duration for all sites selected for inclusion in this project.

Maintenance Data

The maintenance data will include all electric vehicle-related maintenance information, including maintenance work details, service calls, and vehicle and equipment availability. The project team will be responsible for collecting and analyzing this data, whether from charging infrastructure or the vehicles themselves.

Results

This year was focused on establishing the data collection framework, including confirming the details of the data, storage and transfer protocols. The team agreed with the National Laboratories on using the Livewire Data Platform for easy and secure data sharing.

The projects are grouped in the following three categories:

- Category A – recently completed projects with collected datasets that need to be validated and uploaded
- Category B – upcoming projects the team is aware of and has plans to collect data from
- Category C – new projects to be identified through outreach by all project partners.

During this first year the focus was on developing data sharing agreements with the Group A projects (Table I.36-2) and conducting outreach to Group B (Table I.36-3) and Group C (Table I.36-4) projects. Table I.36-5 shows a summary of all categories. The first set of data from Group A projects will be uploaded by the end of the year. In support of the outreach, the team created a public landing page with basic information on the project.

Table I.36-2. Status of Projects and Vehicles within Category A

	Identified		Confirmed		Data Collection Status		
	Projects	Vehicles	Projects	Vehicles	Completed	Active	Not Started
HD	-	-	6	24	24	-	-
MD					-	-	-
LD	-	-	2	12	12	-	-
Off Road					-	-	-
Category A Total	-	-	**8**	**36**	**36**		

Table I.36-3. Status of Projects and Vehicles within Category B

	Identified		Confirmed		Data Collection Status		
	Projects	Vehicles	Projects	Vehicles	Completed	Active	Not Started
HD	10	116	2	40	-	23	17
MD	2	7	-	-	-	-	-
Off Road	5	46	1	38	-	38	-
School	4	86	-	-	-	-	-
Category B Total	**21**	**255**	**3**	**78**	-	**61**	**17**

Table I.36-4. Status of Projects and Vehicles within Category C

	Identified		Confirmed		Data Collection Status		
	Projects	Vehicles	Projects	Vehicles	Completed	Active	Not Started
HD	1	6	-	-	-	-	-
MD	-	-	-	-	-	-	-
Off Road	-	-	-	-	-	-	-
School	2	4	-	-	-	-	-
Category C Total	**3**	**10**	**-**	**-**	-	**-**	**-**

Table I.36-5. Summary Counts of Projects and Vehicles within all Categories

	Identified		Confirmed		Data Collection Status		
	Projects	Vehicles	Projects	Vehicles	Completed	Active	Not Started
HD	11	122	8	64	24	23	17
MD	2	7	-	-	-	-	-
LD	-	-	2	12	12	-	-
Off Road	7	50	1	38	-	38	-
School	4	86	-	-	-	-	-
Total	**24**	**265**	**11**	**114**	**36**	**61**	**17**

References

Project Landing Page, https://calstart.org/doe-info/

Acknowledgements

We would like to acknowledge the support from the National Laboratories including researchers from Idaho National Laboratory, Argonne National Laboratory, National Renewable Energy Laboratory, and Pacific Northwest Laboratory, that have been providing advice on the data types. We also would like to acknowledge the close coordination with the EV WATTS project team that was funded in parallel and is led by Akimeka (or Energetics).

I.37 Mid-Atlantic Electric School Bus Experience Project (Virginia Clean Cities at James Madison University)

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Start Date: October 1, 2019 End Date: December 31, 2024
Project Funding: $1,668,349 DOE share: $670,000 Non-DOE share: $998,349

Project Introduction

The Mid-Atlantic Electric School Bus Experience Project (MEEP) is working with school bus manufacturers, Clean Cities coalitions and other partners to provide free electric school buses for 6 to 8-week demonstrations in selected school fleets in Virginia, Maryland, Washington DC, Pennsylvania, and New Jersey over the next two years. Electric school buses are an exciting tool for school districts to: reduce operating costs; improve local air quality; achieve sustainability goals; and protect the health of children.

These short-term demonstrations are a fantastic opportunity for school administrators, mechanics, drivers, faculty and students to experience electric school buses firsthand without any cost or long-term commitment.

Partners Include: Virginia Clean Cities at James Madison University (lead), Greater Washington Region Clean Cities Coalition, Eastern Pennsylvania Alliance for Clean Transportation, Maryland Clean Cities, New Jersey Clean Cities Coalition, VEIC, National Association for Pupil Transportation, Al Pollard of the Energy Foundation, Generation 180, bus manufacturers (Thomas Built, Proterra, and Blue Bird), state air agencies (Virginia Department of Environmental Quality (DEQ), Maryland Department of the Environment, New Jersey Department of Environmental Protection, and regional electric utilities (Dominion Energy, BGE, PEPCO and Exelon).

Objectives

The objective of the project is to provide local school districts with experience operating electric school buses in their fleets, as well as generating detailed, in-use data and information to allow other school districts to make future procurement decisions.

The project will provide a user level introduction to electric school bus technology in the region; provide a wide range of stakeholders with needed information about electric school buses; allow school districts to gain experience with electric school buses from multiple manufacturers for an extended period of time; evaluate vehicle performance (including comparison to baseline conventional fuel buses); and provide findings that can be used to intelligently advance the domestic fuel technology.

These elements are critical to advancing electric school bus technology in the Mid-Atlantic region, which, to date, has not seen any deployments sufficient to inform decision-making.

Approach

The MEEP project team is seeking schools, school districts and/or school transportation contractors interested in deploying one or more electric school buses into their regular transportation service for a 6 to 8-week demonstration in the multi-state project region.

First, the project will conduct kickoff activities, and bring together the team to prepare for and initiate the experience placements. This will include developing plans to address implementation issues, identifying school district selection criteria, conducting initial stakeholder engagement events, starting to sign up school districts to participate, conducting training for the first placement, and starting the first placement.

Then, the project will conduct a coordinated set of activities focused on continuing to elicit stakeholder interest, including identifying participating school districts, signing up those districts, conducting pre-placement training, holding outreach events during placements, and collecting and analyzing data from the placements.

In the final stage, the experience placements, outreach events, and data collection and analysis will all be completed, and the project team will prepare a final report documenting project results.

The MEEP project team will support school partners before, during and after the demonstration period, helping to facilitate the process and providing technical assistance, including staff training to support operations and data collection. Participating school partners will also be eligible to receive a free Level 2 charging station (including installation) for charging the bus during the demonstration project, and for use by the school after the project.

School administrators, fleet managers and school boards throughout the Mid-Atlantic region will identify opportunities for bus experiences on real routes, drivers will receive greater exposure to the technology, and these partners will gain confidence and data ensuring that the vehicles will perform in a range of conditions. For each state partnered in this project, and with national distribution, this project will present “on the ground” use studies and success stories for local, state, and national deployment of electric school bus technologies.

The project team will address major hurdles of design, specification, infrastructure, education, and operations . The project provides a transformational opportunity for this technology to emerge successfully into application in pupil transportation. This is critical to providing confidence for future decision-making that will fully consider the cleaner electric school bus option.

Results

As school districts throughout the mid-Atlantic project region continue to operate in a mostly remote status, after being closed or operating in remote-only status for the previous school semester, opportunities to reach project milestones and goals have been limited. This became very clear in August 2020 as school operations throughout the Mid-Atlantic region were scheduled to begin operations.

Examples of this difficulty throughout the project area have been widespread in the mass media, as sampled here in clips below from each state:

- (MD) School District Reveals Plan to Let Go of Bus Drivers, Cafeteria Workers over COVID-19, https://www.wusa9.com/article/news/education/frederick-staff-reductions-over-covid-19/65-604b08eb-0819-40f9-a2bc-f4c7cbce89b1

- (MD) Montgomery County Public Schools Move Online for First Semester Amid COVID-19 Pandemic, https://baltimore.cbslocal.com/2020/07/21/montgomery-county-public-schools-virtual-learning-coronavirus-latest/
- (NJ) More Schools Switch to Remote Learning Amid Positive COVID-19 Cases, https://www.njspotlight.com/video/many-schools-are-closing-after-positive-covid-19-cases/
- (PA) Pennsylvania Extends School, Business Closures "Indefinitely" as COVID-19 Cases Grow, https://www.fox29.com/news/pennsylvania-extends-school-business-closures-indefinitely-as-covid-19-cases-grow
- (DC) Schools Closing Due to COVID-19 Even Before Students Return, https://www.fox5dc.com/news/schools-closing-due-to-covid-19-even-before-students-return
- (VA) Virginia State Department of Education Snapshot showing fully remote in much of VA, and only 10 school systems operating fully in person. See Figure I.37-1. http://www.doe.virginia.gov/support/health_medical/office/reopen-status.shtml.

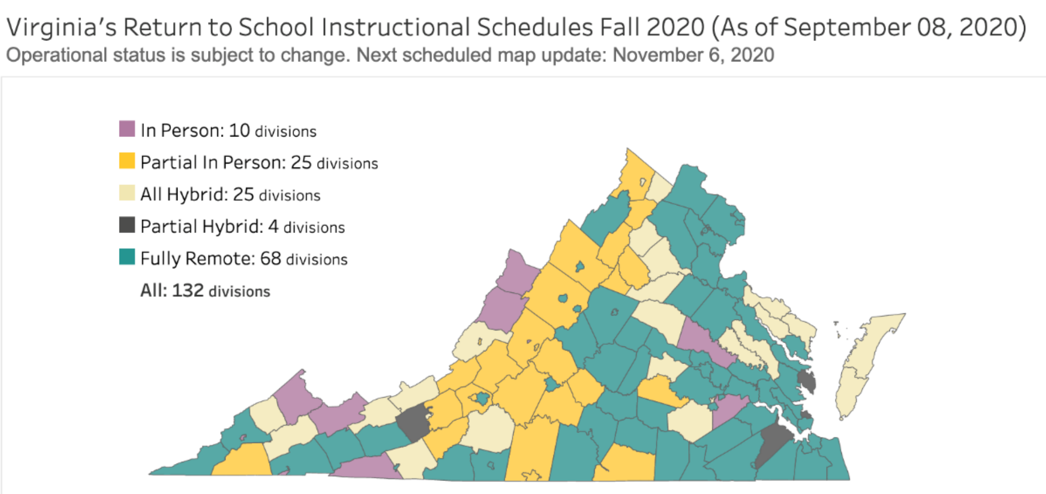

Figure I.37-1. Virginia State Department of Education snapshot

In Virginia, some delays have impacted the Virginia DEQ demonstration and experience vehicle, and the state program announced publicly in the fall of 2019 has not yet been published due to delays from the pandemic in the Commonwealth of Virginia. However, some vehicles have arrived on the Dominion Energy partnership projects and progress is underway for school bus deployments to begin, as we close FY2020.

Public events for the program, including school bus demonstration events, have been fully canceled and virtualized. Despite these challenges, the project has had a number of accomplishments at this stage of operations.

- Project scoping activities being completed remotely in accordance with COVID-19
- School district selection and implementation challenges documents finalized
- Kickoff and promotional activities underway
  - Project bi-weekly calls initiated
  - Project recruitment flyer, incentives inventory, and educational materials under production

- School bus and additional manufacturers engaged (Motiv, Bluebird, IC, Thomas)
- Financing companies engaged for exploring finance options (Highland Electric)

- Billing arrangements configured and invoicing initiated.

Conclusions

Opportunities to more fully implement the vehicle demonstrations, and gain audience with the school systems are expected to continue to expand as pandemic guidelines are revised for the second semester of the 2020-2021 school year, early in 2021.

Key Publications

Project Selection Criteria
Electric School Bus Challenges Document

Acknowledgements

This work is a collaborative effort and progress has been due to the collective effort of Virginia Clean Cities, VEIC, and the other regional Clean Cities Coalitions involved with this project: Greater Washington Region Clean Cities Coalition, Eastern Pennsylvania Alliance for Clean Transportation, Maryland Clean Cities, and New Jersey Clean Cities Coalition.

I.38 CORWest - Supporting Electric Vehicle Infrastructure Deployment along Rural Corridors in the Intermountain West (Utah Clean Cities Coalition)

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Start Date: October 1, 2019 End Date: December 31, 2022
Project Funding: $1,340,000 DOE share: $670,000 Non-DOE share: $670,000

Project Introduction

CORWest is a highly collaborative eight state partnership working with Clean Cities networks and state agencies to do the following:

- Design and expand the existing alternative fuel corridors with electric charging in the Intermountain West, as shown in Figure I.38-1
- Support electric vehicle (EV) access into high visitation areas throughout rural America
- Offer regional transportation solutions to gateway communities through public/private partnerships.

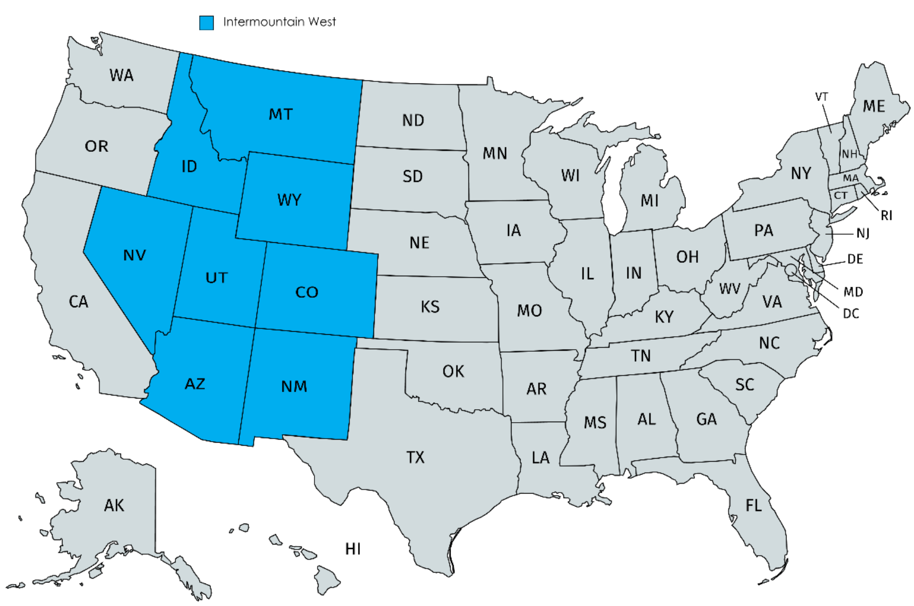

Figure I.38-1. Intermountain West

Objectives

The objective of the project is to increase transportation efficiency and enable widespread access to affordable alternative fuels, by supporting the EV market and Electric Vehicle Service Equipment (EVSE) throughout the Intermountain West.

The main objectives of the project are the following:

- Apply past project lessons learned and tools at a regional scale and develop novel strategies to overcome technology integration challenges and unique geographic barriers to infrastructure deployment
- Assess needs and barriers in the region, target policy and planning solutions, and leverage local networks to engage the public and private sector through marketing and education
- Update and customize tools for rural modeling to ensure best practices for all project stakeholders to correctly install, manage and maintain EVSE stations.

These coordinated strategies applied at a regional scale will support targeted infrastructure deployment, ensure EVSE and EVs are accessible throughout the Intermountain West, and make the region more attractive to private and public infrastructure investment.

Approach

The project will achieve the objectives by undertaking several initiatives across all budget periods, including the following:

- Conduct Needs Assessment, Aggregate Tools, and Develop Strategy
- Remove Barriers to Station Deployment and Develop Outreach Strategy
- Deploy Infrastructure, Develop Public and Private Partnerships, and Expand Corridors

Needs Assessment, Tool Aggregation, and Strategy Development

Utah Clean Cities (UCC) will assemble and engage stakeholders through an advisory committee. UCC will identify key barriers inhibiting EV market development, and specific needs for the region. UCC will also aggregate existing tools, such as those within the Alternative Fuel Data Center (AFDC), to ensure past efforts are utilized to the greatest extent possible to enable focus on novel solutions.

Remove Barriers to Station Deployment and Develop Outreach Strategy

UCC will develop the demand charge assessment, the signage principles, and the off-grid EV charging solutions in select rural areas. New station investments in all states will continue with further work on connecting rural areas through scenic byways. To address the Intermountain West's geographic challenges, efforts will focus on rural regions with an emphasis on gateway communities that are close to national and state parks, recreations areas, monuments and other points of interest, to host EVSE site(s). Several new initiatives will start to raise the overall awareness of electrified transportation and decrease range anxiety regarding travel to rural areas. UCC will continue maintenance of the online repository and will update the website with new station openings, tools and resources created, such as the Needs Assessment and Demand Charge Assessment. UCC will develop and implement the branding and marketing strategies. UCC will also begin outreach to dealerships and used vehicle exchanges to ensure EV options are available.

Infrastructure Deployment, Public and Private Partnerships, and Corridor Expansion

UCC will review and report on all current and pending station investments; prepare and submit to the team the recommendations for enhancing EVSE and EVs in underserved markers; and further develop educational outreach to foster awareness and meet generated demand for EVs. Finally, UCC will ensure the public facing tool website portal is updated with the most current tools and that the project partners, stakeholders and future information seekers find user-friendly access to the tool suite.

Results

During Budget Period 1, the project team assembled an Advisory Committee, as shown in Table I.38-1, and engaged them through monthly virtual meetings/calls, and quarterly webinars. The Advisory Committee is integral to project success because the members are actively engaged in developing, deploying, evaluating, and educating on EV charging infrastructure. The Advisory Committee oversaw all tasks accomplished throughout the first year, as outlined below.

Table I.38-1. Advisory Committee Members

Organization	Category
Utah Clean Cities Coalition	Primary Invesigator, Clean Cities Coalition
National Association of State Energy Officials (NASEO)	State Agency Lead
Denver Metro Clean Cities Coalition	Clean Cities Coalition
Land of Enchantment Clean Cities Coalition	Clean Cities Coalition
Northern Colorado Clean Cities	Clean Cities Coalition
Southern Colorado Clean Cities	Clean Cities Coalition
Treasure Valley Clean Cities Coalition	Clean Cities Coalition
Valley of the Sun Clean Cities	Clean Cities Coalition
Yellowstone-Teton Clean Cities	Clean Cities Coalition
Arizona Department of Administration- Office of Grants and Federal Resources	State Agency
Colorado Energy Office	State Agency
Idaho Governor's Office of Energy & Mineral Resources	State Agency
Idaho Transportation Department	State Agency
Montana Department of Environmental Quality	State Agency
Nevada Department of Transportation	State Agency
Nevada Governor's Office of Energy	State Agency
New Mexico Department of Transportation	State Agency
New Mexico Energy, Minerals, & Natural Resources Department	State Agency
Utah Department of Transportation	State Agency
Utah Governor's Office of Energy Development	State Agency
Utah Associated Municipal Power Systems (UAMPS)	State Agency
Wyoming Department of Transportation	State Agency

Questionnaire/Needs Assessment:

The project team accomplished the first part of the Needs Assessment, dissemination of the questionnaire of electric vehicle readiness. The purpose of the questionnaire is to assess barriers to, and opportunities for, EV adoption in rural and underserved areas of the Intermountain West. The project team developed a questionnaire with questions tailored to four specific audiences: local governments; parks and tourism agencies/organizations; electric service providers; and automobile dealerships. The team sent a fifth "general" questionnaire to additional stakeholders in the region. Each questionnaire included a set of universal general questions; unique questions were included for each stakeholder group. The project team sent the questionnaire to over 500 individuals in the Intermountain West, and received 227 responses across eight states, including: 65 from local governments; 73 from parks and tourism; 29 from electric service providers; 13 from automobile dealerships; and 47 responses to the general questionnaire. The project team will include a summary of responses to the questionnaires in the Needs Assessment. In addition to collecting questionnaire responses, the project team gathered EVSE station locations from the Alternative Fuels Data Center and REV West DCFC Station Map during this reporting period. Information from these tools will be used to identify EV charging station gaps along key corridors – particularly those located at or near national parks – and will be used to inform analysis and recommendations within the Needs Assessment. The National Association of State Energy Officials (NASEO) and UCC also explored options to collect EV registration data during this reporting period.

Demand Charge Assessment:

The project team began research for the Demand Charge Assessment in support of CORWest. At the direction of several REV West agencies/CORWest project partners, NASEO engaged the Western Interstate Energy Board (WIEB) to join he Demand Charge Assessment team as a research partner. WIEB staff have extensive expertise in electricity policy development and will be an excellent addition to the research team. Supporting activities undertaken by NASEO during this reporting period include engaging WIEB via email and phone calls to discuss the Assessment's scope and each partner's role; drafting a preliminary outline of the Demand Charge Assessment research methodology; and refining the methodology. In the coming weeks NASEO expects to identify electric service providers (ESP) that should be contacted in each state and to engage the state teams to identify data sources and ESP contacts.

Webinars/Education:

As outlined in the project plan, the CORWest partners facilitated two CORWest webinars in the first year: Alternative Fuels Data Center Corridor Tools, and EVSE Infrastructure Presentation and Panel. These webinars focused on key tools and information vital to the CORWest project. The first webinar demonstrated how to find alternative fueling stations in the United States and Canada. The presenters reviewed data by state and demonstrated how to plan for future expansion of alternative fuel corridors, as defined by the Federal Highway Administration (FHWA), in the Intermountain West. The second webinar, the EVSE Infrastructure Presentation and Q & A Panel from FreeWire, Black & Veatch and ChargePoint, focused on the newest updates to EV charging infrastructure, for EV Corridor development.

Branding:

The CORWest team, led by UCC, also started the branding process by creating a logo and a Request for Proposals for the online repository/CORWest webpage, to be updated with news, resources, and DOE tools.

Conclusions

During the first year of the CORWest project, the project partners successfully developed statewide partner relationships with state agencies and Clean Cities coalitions. UCC finalized all administrative documents and started the process for the Needs Assessment and Demand Charge Assessment. Finally, UCC started EV education and branding, which will continue through the next phase of the project.

Acknowledgements

The team would like to recognize the efforts of Daniel Nardozzi, the project's National Energy Technology Laboratory manager.

I.39 Decentralized Mobility Ecosystem: Market Solutions for 21st Century Electrified Mobility (Clean Fuels Ohio)

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Start Date: October 1, 2019 End Date: December 31, 2022
Project Funding: $1,341,999 DOE share: $619,999 Non-DOE share: $722,000

Project Introduction

This project demonstrates an operationally and economically successful model for electric vehicle (EV) adoption and charging station deployment by transportation service fleets (taxis, car-sharing fleets, transportation network companies (TNC), etc.) and by major parking providers (universities, airports, hotels, corporate campuses, etc.). The Decentralized Mobility Ecosystem hubs deployed in this project will provide solutions to minimize the financial risks of EV usage for drivers (both commercial drivers and the general public) while strategically locating mobility hubs to maximize EV utilization across multiple use cases (taxi, TNC, delivery, car-sharing). Clean Fuels Ohio designed this innovative project to demonstrate solutions that address the main barriers to vehicle electrification in the mobility and transportation services sectors. Additionally, the project is designed to create and disseminate a complete "Replication Playbook," geared toward transportation fleet or parking service providers, that includes a fully framed business plan; design and engineering plans; new commercialized software applications and tools for turn-key scaling; marketing tools; and more.

Objectives

This project will create a decentralized and electrified mobility ecosystem, leveraging Columbus Yellow Cab's growing fleet of electric vehicles (EVs) to bring mobility hubs to three quadrants of the Columbus Region. Each of these mobility hubs will offer a small fleet of EVs and associated charging infrastructure, including Level 2 and DC Fast Chargers (DCFC), for use by any licensed drivers.

In the first year of the project, the team began analyzing Columbus Yellow Cab's data to inform the mobility hub deployment plans; supporting PAC member feedback and information sharing; finalizing mobility hub deployment plans; and creating specifications for purchasing EVs and electric vehicle supply equipment (EVSE).

Approach

While many companies have transformed a segment of their business or provided a single novel service, this project offers a new, integrated mobility platform with 21st century transportation services for all use cases, designed for replication by other taxi or transportation service provider fleets nationwide. This project demonstrates how a decentralized mobility platform will leverage the success of a current taxi business to implement increased services and environmental benefits for users, and provide lower per mile operational costs, lower fleet total cost of ownership, and multiple new vehicle-use cases to supplement a traditional taxi business – all while complementing other regional transportation service providers. Clean Fuels Ohio is partnering with Columbus Yellow Cab, HNTB Corporation (HNTB), MobiKit, Greenlots, and the Smart

Columbus Program to implement this project. This project's key differentiators and innovative solutions include: Fleet Electrification; Decentralized Vehicle Network; Vehicle Fast-Charging Network; Unified, Neutral Platform for All Users; Environmental Sustainability; Economic Sustainability; and Scalable & Replicable.

Results

Clean Fuels Ohio partnered with MobiKit, a company that provides ways to integrate telematics into your products and processes, to analyze taxi data and create a web-based geospatial planning app to identify ideal EVSE/Mobility Hub locations. Since February 2, 2020, MobiKit has collected telematics records at 1-minute frequency, inside a secure virtual machine, using Tesla Application Programming Interface credentials obtained from Columbus Yellow Cab's leadership. The team extracted, transformed, and loaded this data into the MobiKit SaaS platform. MobiKit then pulled data from the platform to conduct the initial analyses, generated summary statistics of data collection, and reported the results to Clean Fuels Ohio.

Columbus Yellow Cab conducted data analyses internally to facilitate the development of the geospatial planning app. They developed a prototype and presented it to Clean Fuels Ohio (see Screenshots in Figure I.39-1, Figure I.39-2, and Figure I.39-3). The geospatial planning app allows urban planners and fleet owners to upload fleet activity data, specify a region of interest for mobility hub planning, and finally choose the number of mobility hubs desired. After piloting and test driving several EV models over a four-year period, Columbus Yellow Cab had determined that the Tesla Model 3 would be the best vehicle for this project. The app dynamically generates the most effective potential mobility hub site, with existing sites of Tesla superchargers in mind, in terms of the average distance from fleet activity to a potential mobility hub site. All source code for the prototype geospatial planning app was made available to Clean Fuels Ohio, by Yellow Cab under an open-source development license.

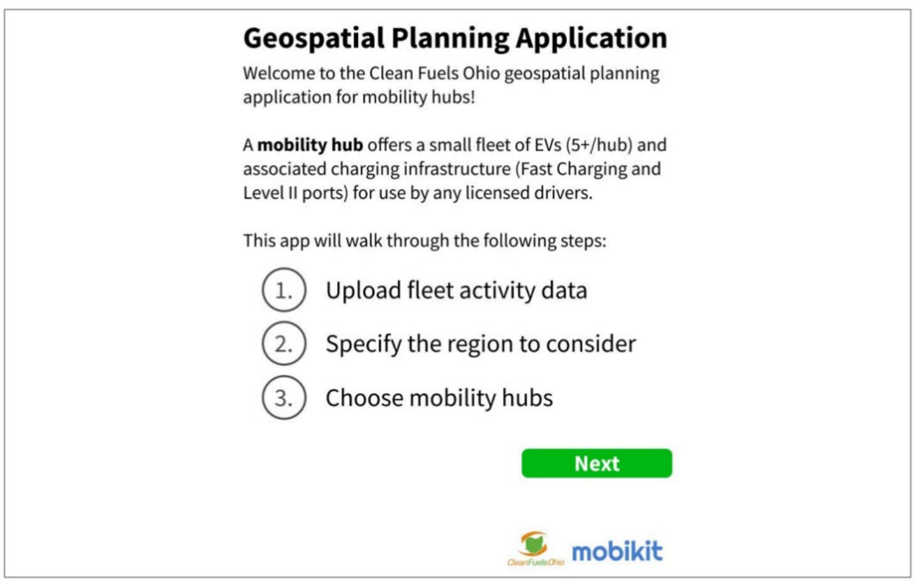

Figure I.39-1. Welcome screenshot from Columbus Yellow Cab's Geospatial Planning Application

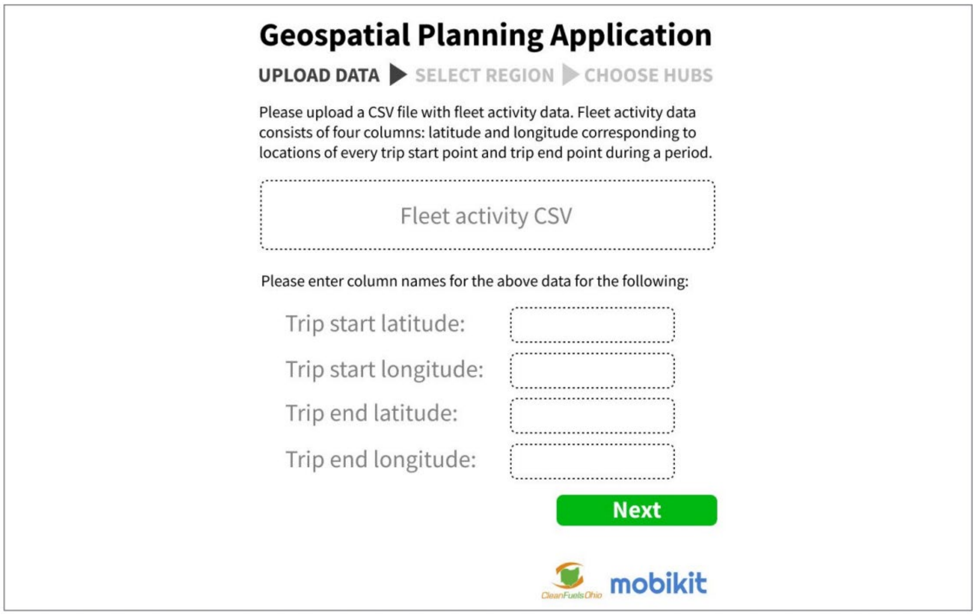

Figure I.39-2. Upload data screenshot from Columbus Yellow Cab's Geospatial Planning Application

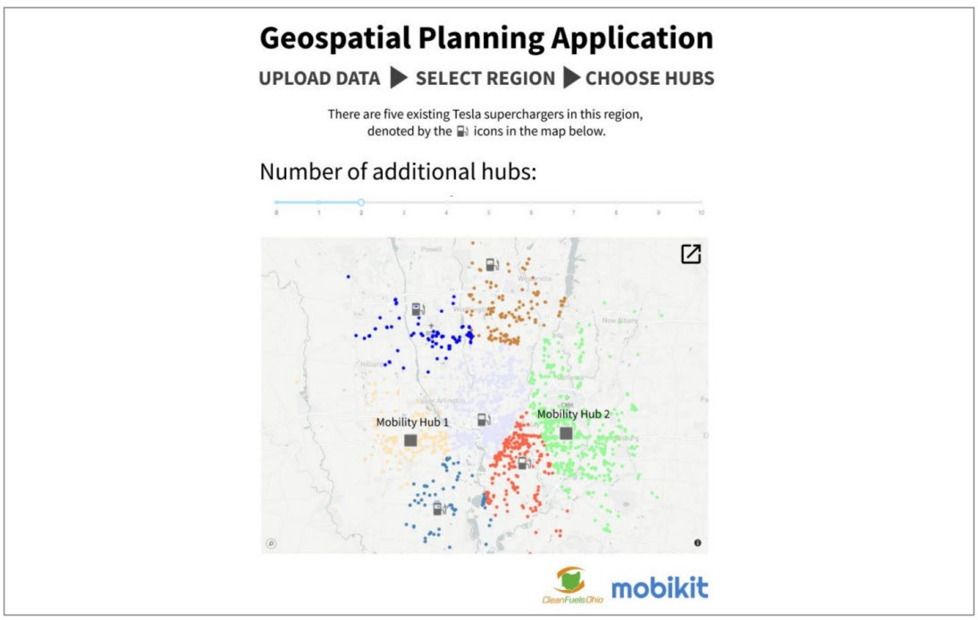

Figure I.39-3. Screenshot map from Columbus Yellow Cab's Geospatial Planning Application

Clean Fuels Ohio subsequently completed the specifications for electric vehicle purchases and EVSE. Columbus Yellow Cab worked with Tesla and is currently operating 20 Tesla Model 3 sedans as the main vehicle for the mobility hubs.

Clean Fuels Ohio recruited a diverse Project Advisory Committee (PAC) to participate in and advise on the Decentralized Mobility Ecosystem project. The project Statement of Project Objectives and plans call for quarterly meetings of the PAC, to advise on a range of project topics. In addition to quarterly meetings, PAC members volunteered for routine follow up and additional information sharing in a one-on-one setting with key project team members. Clean Fuels Ohio conducted significant continued recruitment to solidify the PAC for this project and hosted and convened virtual meetings with the PAC members on June 23 and Sept. 28, 2020, to discuss this project in detail. The goal was to brief all PAC members on the core details of the project and solicit key feedback. The first critical project topic discussed with the PAC members was benchmarking the Decentralized Mobility Ecosystem project against other projects across the United States, to avoid obstacles and replicate best practices.

Columbus Yellow Cab completed deployment plans for its three mobility hubs, as detailed below, with a slight modification of the Short North location from 33 Eden Alley to 1159 N. High St., 0.8 miles north on the main N. High St. thoroughfare, due to better existing utility service to provide power for DCFC.

HNTB and Columbus Yellow Cab have completed designs for the Camaro Drive mobility hub for Level II and DCFC, and submitted draft designs for the Short North mobility hub for Level II. See Figure I.39-4. DCFC plans are currently under review as part of the contractual agreement process with the City of Columbus. Columbus Yellow Cab plans to use these two hub designs as templates for future locations, including the third hub for this project targeted for Essex and Cleveland Avenues in the Milo Grogan neighborhood. The EVSE for these locations is specified in partnership with Greenlots, which is serving as the main hardware, network, and reservation system vendor/partner for Columbus Yellow Cab in this project. A summary snapshot of the formal HNTB design plan for the 1159 N. High St. location is pictured below and has been approved by AEP and the City of Columbus.

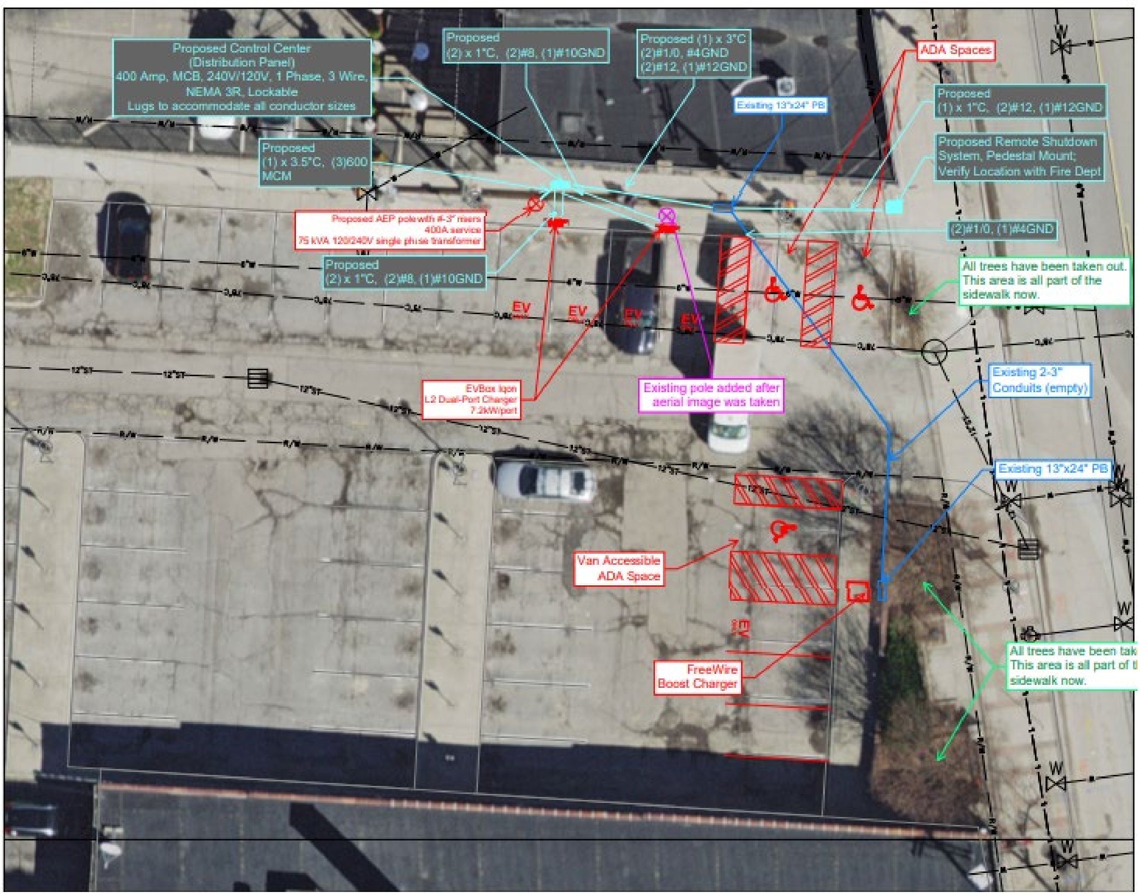

Figure I.39-4. HNTB Design Plan for the Project

Tesla established special warranty terms with Columbus Yellow Cab, and worked out a partnership where Columbus Yellow Cab can perform maintenance on these vehicles. Columbus Yellow Cab has a working partnership with Greenlots for EVSE related to this project and has worked with Greenlots on the plans and specifications for the mobility hubs to date. In addition, Greenlots is the EVSE hardware supplier for the Level and DCFC stations currently operational at the Columbus Yellow Cab Camaro Drive location, and the EVSE included in the designs for the remaining two mobility hubs incorporated into HNTB's formal engineering design plans above.

Conclusions

Clean Fuels Ohio and the project team are largely proceeding as planned with project set up and deliverables for budget year one. No significant findings or conclusions from project specific aspects were expected at this time, and there is nothing significant to report.

The global COVID-19 pandemic remains the biggest development impacting the project to date. Clean Fuels Ohio staff are all working remotely for the foreseeable future to comply with CDC and State of Ohio guidelines regarding COVID-19. We plan to continue work on our DOE funded projects, as do all contracted project partners.

Columbus Yellow Cab, as an essential service, has continued to operate uninterrupted throughout the pandemic. While rides for travel, tourism, and entertainment purposes have certainly declined for Columbus Yellow Cab, other contracts and needs for rides have increased, particularly rides for medical appointments, food deliveries, and other essential services. Despite the pandemic, the Decentralized Mobility Ecosystem project team is still on target to meet all project goals and is on track with Budget Period 1 timelines and milestones.

II. National Laboratory Projects

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

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Start Date: October 1, 2019 End Date: September 30, 2020
Project Funding (FY20): $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 performance data. Since that time, it has evolved to become an indispensable resource for fleets, fuel providers, policymakers, Clean Cities coalitions, and others working to improve efficiency, cut costs, and reduce emissions in transportation. Armed with the AFDC's data, information, and tools, these transportation stakeholders are increasing the use of domestic alternative fuels and advanced vehicle technologies every year, resulting in substantial benefits to the country's economy, energy security, and environment. The AFDC has achieved this level of engagement because of the many successful public and industry partnerships built in the past 29 years that have contributed to the quality and quantity of information contained on the AFDC website.

Based on expertise from the National Renewable Energy Laboratory (NREL) and partnerships with Argonne National Laboratory (ANL) and Oak Ridge National Laboratory, the AFDC provides extensive information about alternative and renewable fuels, including biodiesel, electricity, ethanol, hydrogen, natural gas, propane, and other emerging fuels. Users can find out about fuel properties, production, distribution, prices, station locations, emissions benefits, and more. The site features information on the vehicles and engines that use these fuels and the corresponding fueling infrastructure. Fuel-saving strategies like idle reduction, fuel economy improvements, and efficient driving habits are also included on the AFDC.

The site's large suite of online tools and vast collection of vetted data empower fleets and drivers to identify the strategies and technologies that will best help them meet their environmental and energy goals in the most cost-efficient manner. Users can examine long-term trends, estimate costs, project emissions benefits, compare multiple strategies, and identify fuels and technologies that are appropriate for their operational needs and geographic locations.

In sum, the AFDC provides a wealth of information and data on alternative and renewable fuels, advanced vehicles, fuel-saving strategies, and emerging transportation technologies. With interactive tools, calculators, and mapping applications that aid in the implementation of these fuels, vehicles, and strategies, the AFDC functions as a dynamic online hub that enables thousands of stakeholders in the transportation system to interact with one another.

Objectives

The AFDC's primary objective is to be a leading, trusted site that provides information, tools, and resources for transportation decision makers seeking domestic alternatives that diversify energy sources and help businesses and government agencies make wise economic choices. The site also facilitates critical-mass market adoption of alternative fuels and advanced vehicle technologies by fleets and consumers. The AFDC is strategically designed to attract and serve decision makers in all areas of the transportation system, including fuel suppliers, policymakers, Clean Cities coalitions, fleets, and early-adopter consumers. As one of the most popular DOE websites, 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. To ensure the AFDC keeps pace with the rapidly evolving transportation arena, NREL cultivates partnerships with industry leaders and innovators, which fosters intrastate and international collaboration. 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 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.

Effective Delivery

Delivering information through a diversified strategy ensures it 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:

- **Website**: Information and data 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.

- **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 load 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 mobile 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.

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 the AFDC's value to the market and industry partners.

Annual Content Review

To ensure the integrity of the information and data, the AFDC undergoes an in-depth annual content review. Each year, subject-matter experts at NREL and ANL conduct a comprehensive review of more than 150 web pages to ensure the AFDC continues to provide accurate, relevant, and up-to-date information for transportation decision makers. This deep dive into the content results in critical thinking about what information is presented and how to continue providing content that helps shape the future of transportation. NREL works closely with other National Laboratories, agencies, and industry partners to identify gaps and tap experts for content contributions and reviews.

Results

The AFDC continues to grow as a relevant and trusted resource. In fiscal year (FY) 2020, the AFDC boasted a 31% increase over FY 2019 in page views, with more than 3.8 million visitor sessions and 2.9 million unique visitors. Those visitors accessed pages on the AFDC website more than 11.9 million times. Visits to the site included an average of 14% returning visitors and 86% 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, 41% of all EERE website page views are from AFDC pages. Additionally, 16 of the top 30 most-viewed pages in the EERE portfolio are AFDC pages. Figure II.1-1 illustrates the AFDC's steady growth in FY 2020 compared to FY 2019. The dip in page views between March and May is likely a result of COVID-19, with a shift in national attention near the beginning of the pandemic.

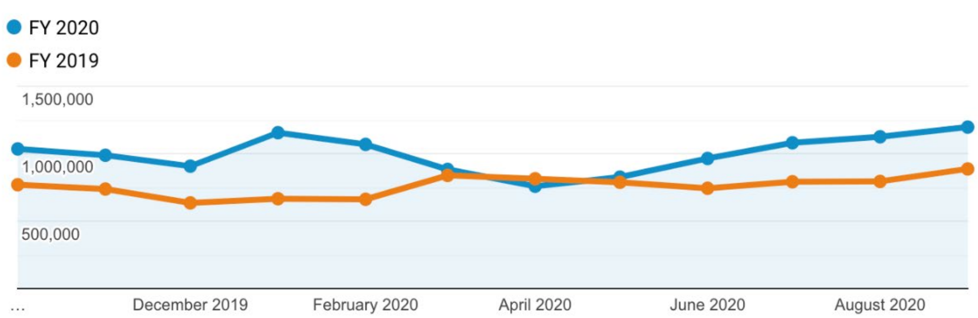

Figure II.1-1. Page views in FY 2020 compared to FY 2019

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 2020 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.

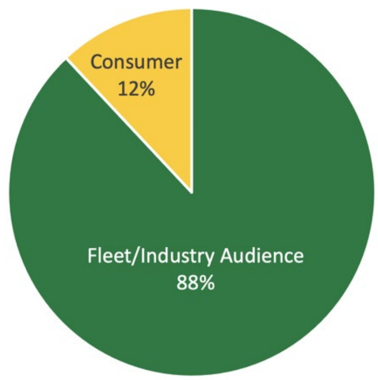

Figure II.1-2. Sources of AFDC visits based on the top 40 referrals

Some of the top referrers in FY 2020 included several vehicle Original Equipment Manufacturer (OEM) sites linking to the laws and incentives information, with Toyota leading the referral count. In FY 2020, the Federal and State Laws and Incentives pages were viewed more than 2.1 million times, particularly via referrals from numerous vehicle manufacturers. During FY 2020, there were more than 7,100 websites linking to the AFDC, resulting in more than 620,000 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 for the top 20 referrers in FY 2020.

Table II.1-1. Top 20 Referrers to the AFDC Website in FY 2020

Referrer	Sessions
toyota.com	73,808
automobiles.honda.com	41,278
accessrvrental.com	30,399
bmwusa.com	30,374
subaru.com	28,855
ford.com	28,525
tesla.com	17,525

Referrer	Sessions
search.usa.gov	13,447
energysage.com	12,571
chevrolet.com	12,075
fueleconomy.gov	11,994
m.facebook.com	10,038
easy-website-traffic.com	9,512
vw.com	9,472
drivegreen.nj.gov	9,342
cleanngreenfuel.com	6,383
kandiamerica.com	5,974
baidu.com	5,790
easyorganictraffic.com	5,695
easyuniquevisitors.com	5,688

While referrals are a tangible way to measure part of the AFDC's impact, this metric does not tell the whole story. Referrals provide an idea of how many people see AFDC information on other websites when the organization using the data chooses to link to the AFDC as a source. The referral statistics don't include sites that use AFDC data without reference. More importantly, referrals do not quantify how the AFDC data impacts organizations in the transportation industry. For example, the National Conference of State Legislatures (NCSL) depends on the AFDC laws and incentives data to provide a summary of policies by state that promote hybrid and electric vehicles. By relying on this AFDC dataset and the effort that NREL spends researching and disseminating the data, NCSL provides valuable information for its audience while saving significant time and effort that would otherwise be spent collecting the data on its own. DOE and NREL partner with many organizations in the transportation sector to ensure the AFDC datasets provide ongoing value as the market evolves.

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 2020, interest in fuels and vehicles information accounted for 32% of the total page views on the AFDC, compared to 31% in FY 2019. Historical data shows that the most frequently accessed pages by fuel type vary from year to year. In FY 2020, ethanol was the most popular topic in terms of page views for fuels and vehicles information with 31% of the total traffic followed closely by electricity with 30% of the total page views.

Figure II.1-3 depicts the breakdown of interest in content by fuel type in FY 2020.

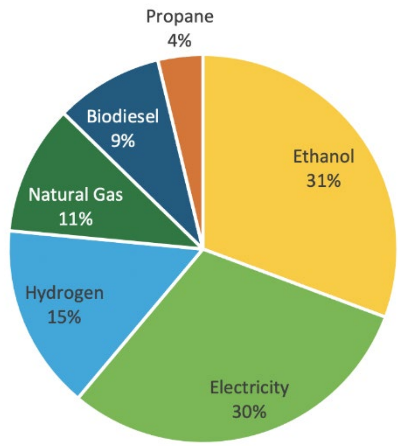

Figure II.1-3. Interest in fuels and vehicles information by subject based on page views in FY 2020

As shown in Figure II.1-4, 41% of the queries for fueling station locations involved ethanol. This is a decrease over ethanol's 46% share in FY 2019.

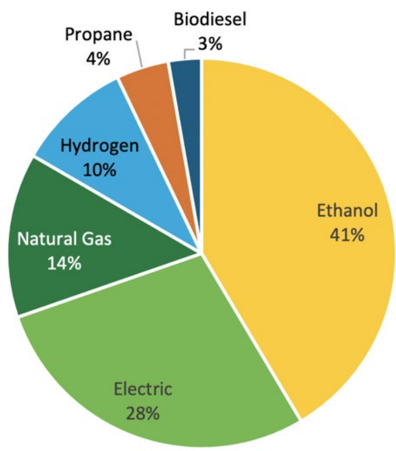

Figure II.1-4. Interest in stations information by subject based on page views in FY 2020

Tools

The tools available 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 13,700 views in FY 2020; 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 2020, the Fuel Properties Comparison saw an 80% increase in page views compared to FY 2019. The Alternative Fueling Station Locator, the Laws and Incentives Search, and the Maps and Data Search each saw a significant increase in page views compared to FY 2019. On the other hand, the Publications Search saw a modest decrease in page views. Together, the tools accounted for 67% of the total page views on the AFDC in FY 2020, which was the same percentage as in FY 2019.

Table II.1-2. Page views for the Primary Tools on the AFDC Website

Tool	FY 2020 Page Views	FY 2019 Page Views	% Change
Alternative Fueling Station Locator	4,396,841	3,266,514	35%
Laws and Incentives Search	2,122,904	1,570,229	35%
Maps and Data Search	623,395	501,717	24%
Vehicle Cost Calculator	558,298	487,338	15%
Vehicle Search	137,559	120,774	14%
State Information Search	56,232	51,745	9%
Case Studies Search	41,569	37,124	12%
Publications Search	31,710	32,641	-3%
Fuel Properties Comparison	28,182	15,619	80%
EVI-Pro Lite	8,714	7,321	19%

Several of these tools are available as widgets that allow users to embed the tools on their own websites. In FY 2020, the Alternative Fueling Station Locator widget was the most popular widget, with more than 461,000 page views while embedded on other websites, accounting for 10% of the total stations traffic.

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 2020 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 2020

Data	API Requests	Unique API Users	Downloads
Alternative Fueling Stations	25,669,936	9,690	2,865
Laws and Incentives	273,359	39	2,712
Vehicles	18,107	35	2,071

Stations data downloads and requests via the web service, also known as an API, have expanded the use of AFDC data over time. The alternative fueling stations API (a live data feed of stations data) received more than 25.6 million requests in FY 2020, which was up from about 20.2 million requests in FY 2019.

The laws and incentives API received more than 273,000 requests in FY 2020. Many OEMs now link to the laws and incentives site. This is an 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 2020 was the fuel properties comparison chart, with more than 40,000 downloads, followed by the Alternative Fuel Price Reports with more than 26,000 downloads. The high-resolution images for vehicle illustrations had more than 183,000 downloads, and the diagram of vehicles by weight class had more than 41,000 downloads.

Stations Database Redesign

In FY 2020, NREL designed a new structure for the stations database, to align with Open Charge Point Interface (OCPI), an industry standard for organizing data on electric vehicle charging stations. While these database changes do not affect what people see in the Alternative Fueling Station Locator, they improve and simplify NREL's data collection process. Compared to the previous database structure, the OCPI design is simpler; by combining the data for charging ports and posts into a single model, this update makes it easier for NREL to manage the dataset. Adopting the OCPI standard also makes it easier and more efficient for NREL to add charging networks that also use the OCPI standard for their data.

Stations Data in Geospatial Formats

Although NREL has provided stations data in a number of formats in the past, through data downloads and web services, the dataset has never been available in a geospatial format that can be used easily in geographic information system (GIS) tools. In FY 2020, NREL revamped the stations web service to provide the data in two geospatial formats: GeoJSON and KML. These open source formats for geographic data are standard in the information technology industry. Providing the stations data in these formats was an important accomplishment because it increased the usability and value of the data. With a fair amount of effort, savvy GIS experts could have used NREL's original web service to visualize the data. The new web service, on the other hand, allows even GIS novices to quickly import the data into GIS tools, shifting their focus away from simply accessing the data to planning fueling infrastructure.

Alternative Fuel Corridors

Through a long-standing partnership with the Federal Highway Administration, NREL added a new feature to the Alternative Fueling Station Locator in FY 2020 that is dedicated to helping states nominate alternative fuel corridors. The tool helps people measure the driving distance along highways between stations that meet the criteria for corridors. The long-term goal is to show current corridors, potential corridors, and gaps on one map to help with fueling infrastructure planning.

EVI-Pro Lite Charging Load Profiles

In FY 2020, NREL expanded the Electric Vehicle Infrastructure Projection (EVI-Pro) Lite tool by adding more analytic capabilities. Previously, the tool was limited to letting users estimate how many and what kind of electric vehicle chargers a city, region, or state might need to support an influx of EVs. Through an added section of the tool, users can now take the analysis a step further, to predict how that added EV charging will impact electricity demand, or load shapes, in their area at any given time. This project was funded through EERE's Vehicle Technologies Office and the Strategic Priorities and Impact Analysis Team.

Electricity Sources and Emissions Tool

NREL refined the Electricity Sources and Emissions Tool to help transportation decision makers and Clean Cities coordinators gauge vehicle emissions by state more accurately. The updated tool includes graphic improvements to distinguish tailpipe emissions from grid emissions, revised assumptions to account for evolving travel patterns and a changing vehicle market, and a more precise approach to accurately measure the emissions of EVs and plug-in hybrid-electric vehicles at the state and national level. Instead of using a national average for the fuel mix used to generate electricity, the calculator now uses U.S. Energy Information Administration data to calculate the weighted average emissions for all energy consumed in each state, to account for possible differences in generation technology across the country. In addition to these updates, NREL made a widget of the tool, to allow individuals and organizations to share the tool and provide value for their audiences by embedding it on their own websites or blogs.

Dynamic PDF for Light-Duty Vehicles

NREL developed an automated, dynamic PDF with data from the Vehicle Search Tool for light-duty alternative fuel and advanced technology vehicles on the market. The data in the dynamic PDF is updated from the database automatically each time someone downloads the file. Offering the light-duty vehicle data in this format enables Clean Cities coordinators to access up-to-date information on vehicles sooner than they could before, and in a format that can be shared easily with stakeholders.

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 and renewable 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

AFDC home page: afdc.energy.gov

Alternative Fueling Station Locator: afdc.energy.gov/stations

Laws and Incentives Search: afdc.energy.gov/laws

Maps and Data Search: afdc.energy.gov/data

Vehicle Cost Calculator: afdc.energy.gov/calc

Vehicle Search: afdc.energy.gov/vehicles/search

Publications Search: afdc.energy.gov/publications

State Information Search: afdc.energy.gov/states

Case Studies Search: afdc.energy.gov/case

Fuel Properties Comparison: afdc.energy.gov/fuels/properties

EVI-Pro Lite: afdc.energy.gov/evi-pro-lite

Data Downloads: afdc.energy.gov/data_download

Widgets: afdc.energy.gov/widgets

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, 2019 End Date: September 30, 2020
Project Funding (FY20): $250,000 DOE share: $250,000 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) 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. AFLEET also includes a calculator to estimate the environmental impacts of public electric vehicle charging.

Argonne had previously updated AFLEET and included changes that matched results to Argonne's Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) 2019 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 9,400 individuals for the spreadsheet and 4,700 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) 2020, the AFLEET Tool had several factors that needed updating. Similar to the 2019 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 cost data on factors such as insurance, maintenance, repair, and fees, for a wide range of light-duty and heavy-duty vehicles, for 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 and cost analysis.

Approach

Argonne used the GREET 2020 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 2020 results from the EPA MOVES

2014b version. In addition, Argonne used EPA MOVES to update national emission factors for off-road gasoline, diesel, natural gas, and propane equipment. Electric off-road equipment emissions are estimated using data from GREET. AFLEET uses 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 2020 to account for the latest data.

Argonne used data from a variety of sources, including national surveys and automotive cost databases, to update the insurance, maintenance, repair, and fee data for light-duty and heavy-duty vehicles. In previous versions of AFLEET, default insurance costs were aggregated for light-duty and heavy-duty vehicles. In AFLEET 2020, heavy-duty insurance costs were separated by vehicle type for vocational trucks, delivery trucks, commercial freight trucks, and buses. Both commercial freight trucks and commercial buses have federal requirements to have significant liability coverage, resulting in much higher insurance costs than other heavy-duty vehicle types. Argonne included updated maintenance schedule data for conventional, hybrid, and electric vehicles in AFLEET, detailing service intervals and service costs for each powertrain. As many states have additional registration fees for advanced vehicles, most frequently for plug-in electric vehicles, Argonne also added those costs to AFLEET.

In AFLEET 2020, Argonne incorporated cost data for off-road equipment, such as forklifts and airport ground support equipment, to enable users to perform simple payback calculations. Argonne also collected and analyzed purchase price data for available off-road equipment, for different fuels types. This effort required analyzing the specifications by fuel type to make sure the costs represent technologies with equivalent capabilities. Argonne incorporated average annual hourly operation, rated horsepower, load factor, and equipment lifetimes for each off-road type into AFLEET based on EPA MOVES. This data will allow fleet stakeholders to examine the costs and benefits of purchasing alternative fuels for both on-road vehicles and off-road equipment, as seen in Figure II.2-1 and Figure II.2-2. In these figures, HEV is hybrid-electric vehicle, PHEV is plug-in hybrid electric vehicle, EV is electric vehicle, and G.H2 FCV is gaseous hydrogen fuel cell vehicle.

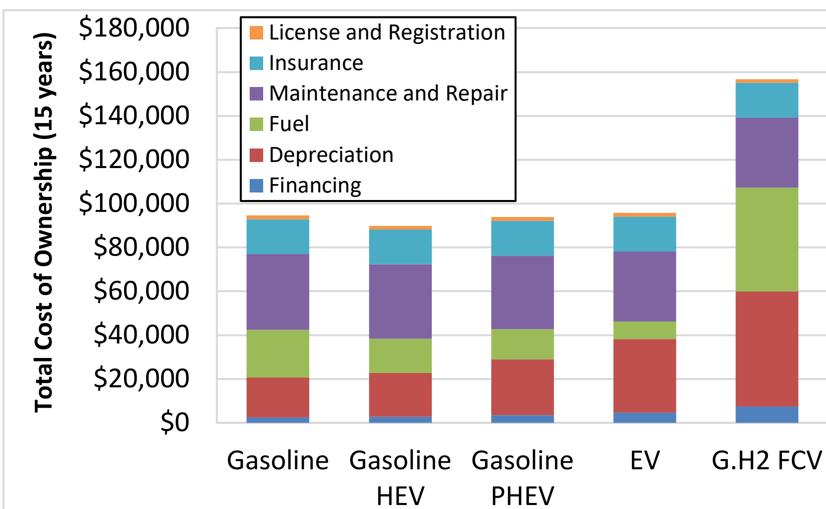

Figure II.2-1. AFLEET Total Cost of Ownership passenger car results

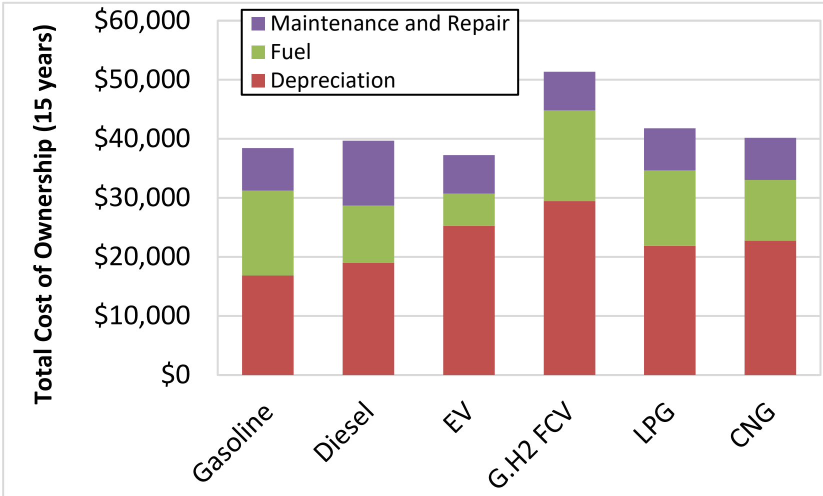

Figure II.2-2. AFLEET Total Cost of Ownership forklift result

Results

During FY 2020, the AFLEET Tool was downloaded about 900 times, and the accompanying AFLEET user manual about 2,200 times. To date, 9,400 individual users have downloaded the tool. The user-friendly AFLEET online tool released in FY 2019 had more than 4,700 new users.

Conclusions

In FY 2020, 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 prices, and vehicle costs. In addition, Argonne developed a calculator to help stakeholders estimate the cost impacts of alternative fuel off-road equipment.

References

[1] National Renewable Energy Laboratory, Alternative Fuels Data Center, https://afdc.energy.gov/

[2] Argonne National Laboratory, 2020. GREET Model - 2020 version, http://greet.es.anl.gov.

[3] Environmental Protection Agency, 2018. Motor Vehicle Emission Simulator (MOVES) - MOVES2014b version. http://www.epa.gov/otaq/models/moves.

[4] Bourbon, E., 2020. Clean Cities Alternative Fuel Price Report, https://afdc.energy.gov/publications/.

[5] Energy Information Administration, 2020. Annual Energy Outlook 2020, https://www.eia.gov/outlooks/AEO/.

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

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Start Date: October 1, 2019 End Date: September 30, 2022
Project Funding (FY20): $4,686,330 DOE share: $ 3,000,000 Non-DOE share: $1,686,330

Project Introduction

The U.S. Department of Energy, MathWorks, and General Motors (GM) 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 11 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
- Balance energy efficiency needs with the consumer acceptability, safety and cost considerations EcoCAR teams are following GM's 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 concluded its second year, culminating with a virtual awards ceremony in July 2020 where government and auto industry representatives presented teams with 22 awards in various categories. The virtual event had nearly 2,900 views on YouTube.

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
- Develop a highly-skilled workforce, knowledgeable in advanced technology vehicles
- Incorporate current industry codes and standards into the testing and evaluation of the competition vehicles
- Develop safety practices and procedures for university competitors to ensure a safe competition

- Develop real-world, multi-year training and education programs focused on advanced vehicle technologies for university competitors, with subject matter experts from government and industry
- 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) 2020 roughly aligned with the second 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 current series in a more than 32-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 are focused on CAV systems. AVTC competitions have always had a strong element of consumer acceptability. These changes, among various other shifts, represent the largest paradigm shift for the AVTC program in its over 32-year history.

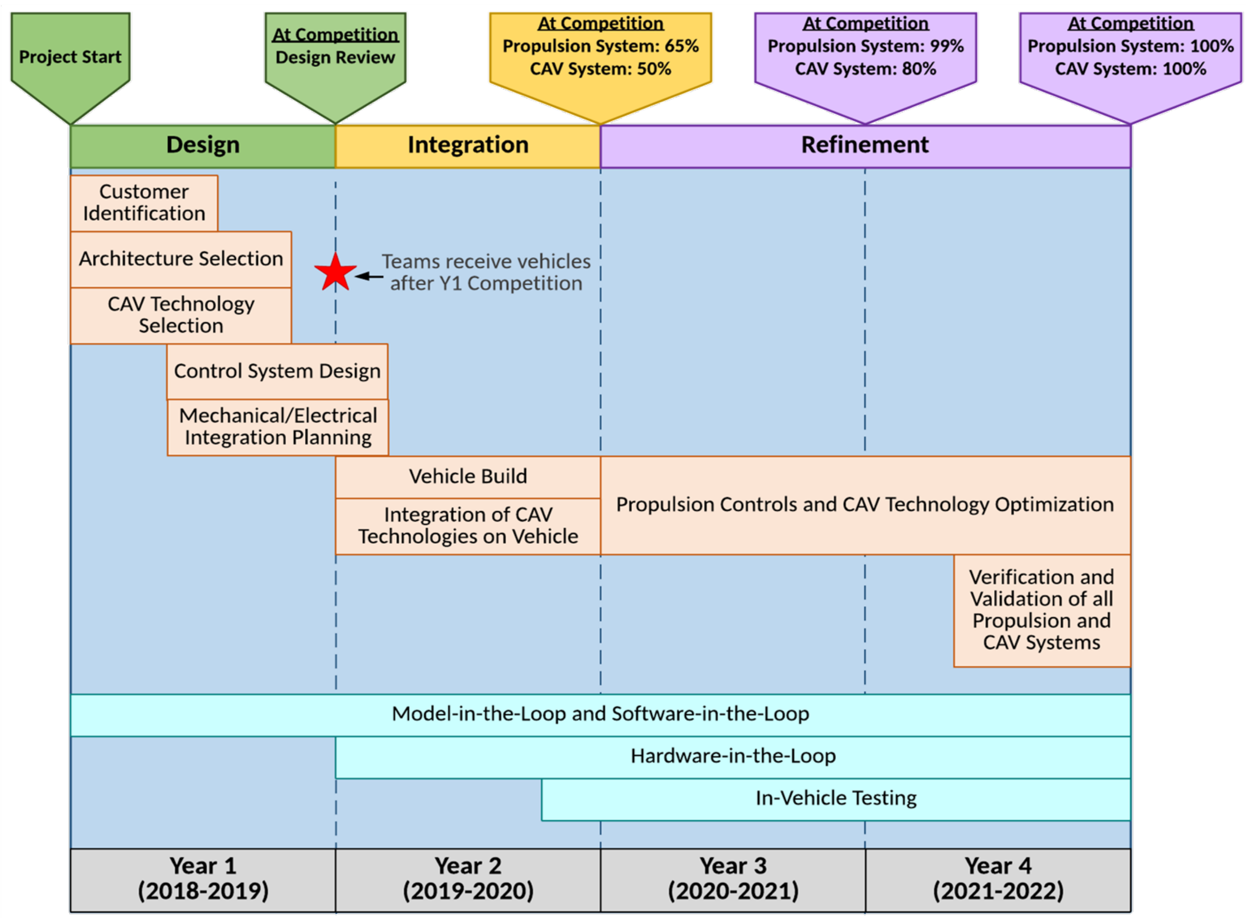

Figure II.3-1. EcoCAR Vehicle Development Process

Over the four years of the EcoCAR competition, each team will design, build, and test an advanced technology vehicle. Teams receive milestones for each year of the competition to guide them through the full development process, covering multiple academic years. 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.

To facilitate the new emphasis on 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.

Table II.3-1. Technical Goals for Each Annual Competition

Year	Propulsion System Goals	CAV Goals
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	• Propulsion system components and auxilary systems are fully integrated • Propulsion system components are able to safely produce torque • Vehicle propulsion system can attempt all planned dynamic events	• Sensor integration for longitudinal control • Sensor simulation and fusion algorithm development • Longitudinal control algorithm development
Year 3	• Complete and reliable integration of all vehicle components • Vehicle propulsion controller developed with basic energy management strategy • Reliable and expected propulsion system • Calibration not yet refined to customer's satisfaction	• Baseline functional sensor fusion algorithm on vehicle • Baseline functonal longitudinal control demonstrated on vehicle (limited speeds) • Vehicle-to-Everything (V2X) system integration on vehicle and able to send basic safety message • Simulations for lateral control and energy consumption in connected corridor
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

The impacts of the COVID-19 pandemic required EcoCAR organizers to adjust the Year 2 and Year 3 VDP goals for both propulsion systems and CAV systems. The adjustments are shown in Table II.3-1. For the propulsion systems, the primary adjustments were pushing back the VDP milestone for complete and reliable integration of all vehicle components, while pulling ahead vehicle simulation and modeling activities that could be accomplished virtually.

For CAV systems, the primary adjustments were rescoring the rate of development for sensor fusion and longitudinal systems, which required in-person vehicle development with various CAV sensors. Universities were able to accomplish these new goals with amplified efforts from the organizing committee to enable increased EcoCAR work that was executed virtually.

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

Results

During FY 2020, all 12 teams successfully completed the following technical goals:

- Integrated primary propulsion system components in the competition vehicles, performed subsystem level testing for propulsion system components, and refined vehicle models in simulation
- Implemented hardware-in-the-loop (HIL) testing methodologies, developed software requirements, and developed an initial supervisory controls strategy
- Completed bench testing of sensors, collected data on a mule vehicle, and started development of sensor fusion and longitudinal control algorithms
- Performed System Functional Interface Analysis (SFIA) and developed a requirements traceability matrix for vehicle systems safety.

The program was also successful in achieving its core objective: training the next generation of automotive engineers, communicators, and business leaders. In Year 2, a total of 907 students participated in the competition. Table II.3-2 summarizes student participation by major.

Table II.3-2. EcoCAR Mobility Challenge Year 2 Student Participation by Major

	Total	% of Total	STEM?
Mechanical Engineering	349	38.5%	Y
Electrical/Computer Engineering	219	24.1%	Y
Mechatronics Engineering	72	7.9%	Y
Computer Science	54	6.0%	Y
Aerospace Engineering	30	3.3%	Y
Industrial/Systems Engineering	28	3.1%	Y
Software Engineering	25	2.8%	Y
Automotive Engineering	15	1.7%	Y
Nanotechnology Engineering	13	1.4%	Y
Biomedical Engineering	13	1.4%	Y
Chemical Engineering	9	1.0%	Y
Informatics	6	0.7%	Y
Physics	5	0.6%	Y
Civil Engineering	4	0.4%	Y
Mathematics	1	0.1%	Y
Agriculture Engineering	1	0.1%	Y
Geomatics	1	0.1%	Y
Other	36	4.0%	N
Communication/Public Relations	10	1.1%	N
Business/Economics	7	0.8%	N
Human Factors/Human-Centered Design	4	0.4%	N

	Total	% of Total	STEM?
Management	3	0.3%	N
Marketing/Advertising	1	0.1%	N
Accounting/Finance	1	0.1%	N
Total	907	100%	--

Based on data reported by EcoCAR universities, a total of 44 employers hired an EcoCAR student during the 2019-2020 academic year (Aug 2019 – Aug 2020). Thirty-six employers hired at least one student for an internship or co-op position and 19 employers hired at least one student for a full-time position. EcoCAR students that accepted full-time jobs during this time period out-earned their peers by $2400-$15600 depending on major and degree, as shown in Figure II.3-2.

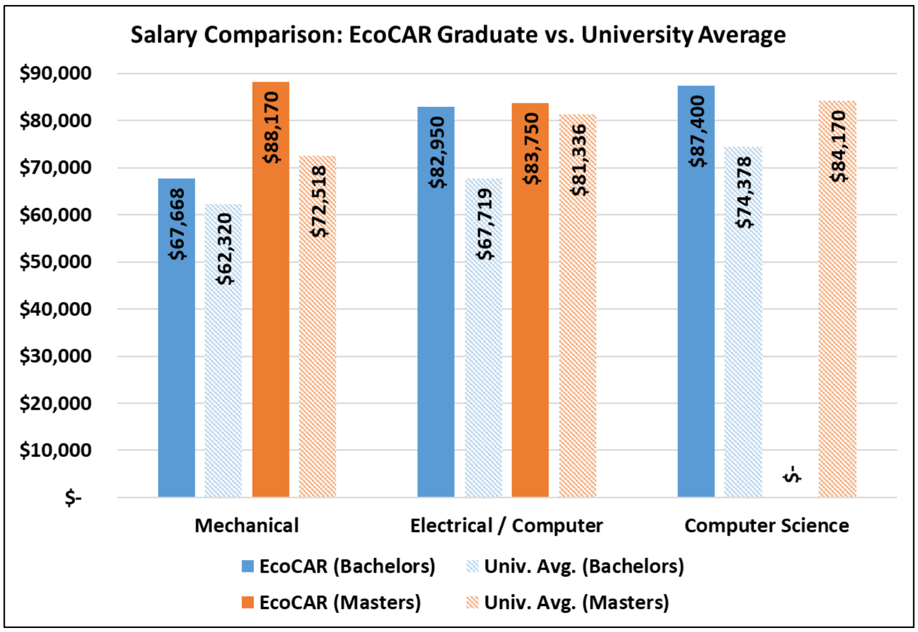

Figure II.3-2. Salary comparison of EcoCAR graduates and their peers

In Year 2 of the EcoCAR Mobility Challenge, the communications outreach focus was scaled back significantly compared to previous years, due to COVID-19. Up until March 2020, the 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 2 of the EcoCAR Mobility Challenge, teams conducted 34 total youth outreach events, reaching more than 10,235 youth in grades 6 to 12. Table II.3-3 summarizes the overall youth impacts from the second year.

Table II.3-3. Youth Impacts of the Program in Year 2

Metric	#
No. of youth outreach events	34
No. of students at those events	10,235

In addition, teams had an increased focus on raising awareness of the program at their university campuses. Teams conducted 46 events on campus and reached more than 3,133 other college students.

EcoCAR also brought awareness to the general public, stakeholders, sponsors and participants through social media and the Green Garage Blog, where students wrote and submitted 48 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, LinkedIn, and Twitter. Public relations and media outreach efforts included issued press releases and earned placements. Total media impressions for Year 2 reached 91 million and landed in more than 100 publications.

In conjunction with the Year Two Virtual Awards Ceremony, EcoCAR Mobility Challenge launched a month-long organic social media campaign on Facebook, Twitter, LinkedIn and Instagram. The campaign reached 150,336 impressions and nearly 4,000 likes/shares. See Table II.3-4. The website saw a 7% increase in page views (310) just in the day following the virtual event. In addition, this year's strategy to boost EcoCAR's LinkedIn presence was very successful and added 366 new followers (541 total). In addition, there were 138 referrals from LinkedIn to the website in July of 2020 alone.

Table II.3-4. EcoCAR Mobility Challenge Organic Social Media Results - Virtual Awards Ceremony Campaign

	Total Tweets/Posts	Total Shares	Impressions/Reach
Twitter	59 tweets	N/A	63,397
Facebook	42 posts	1043	23,000
Instagram	16 posts	278 likes	3,034
LinkedIn	44 posts	2,655	60,905

The Virtual Awards Ceremony also featured remarks by Argonne Director, Paul Kearns. As a result, multiple sponsors promoted EcoCAR on their social platforms, and the program was featured on Argonne's Twitter (451 views) and LinkedIn (1,441 views) handles.

Conclusions

During Year 2, the EcoCAR Mobility Challenge leveraged the unique public-private partnership of more than 20 government and industry organizations to facilitate the continued development of the competition vehicles towards the Year 2 VDP goals. While the introduction of COVID-19 in March of 2020 required Argonne to adjust the EcoCAR VDP, the competition was able to maintain a VDP that still provided stakeholder value while balancing student and university constraints. The effort made to pivot in Year 2 has enabled universities and the competition to enter Year 3 well prepared to adapt to the increased virtual environment.

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 sectors. 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 on campus and within local, state and regional communities about advanced technology vehicles.

Key Publications

The EcoCAR program funded student assistant positions on each EcoCAR team. This included engineering graduate research assistants (from multiple disciplines), as well as a Project Manager and a Communications Manager. The publications produced in FY 2020, as a result of this funding, are summarized in Table II.3-5.

Table II.3-5. EcoCAR Team Publications (to date)

Team	Publication/Presentation Title	Lead Author Name	Conference / Journal
CSU	Synchronous and Open, Real World, Vehicle, ADAS, and Infrastructure Data Streams for Automotive Machine Learning Algorithms Research	Aaron Rabinowitz	SAE WCX 2020
CSU	Vehicle Velocity Prediction Using Artificial Neural Network and Effect of Real World Signals on Prediction Window	Tushar Gaikwad	SAE WCX 2020
ERAU	Impact of Automated Lane Change Assist on Energy Consumption	Casey Troxler	SAE International
MSU	Design of a Mild Hybrid Electric Vehicle with CAVs Capability for the MaaS Market	Amine Taoudi	SAE International
OSU	Learning Simulation in the Academic Environment	Shawn Midlam-Mohler	NAFEMS Simulation in the Automotive Industry: Creating the Next Generation Vehicle
OSU	Benchmarking Computational Time of Dynamic Programming for Autonomous Vehicle Powertrain Control	Wilson Perez	SAE World Congress Experience
OSU	Model-Based Design of a Hybrid Powertrain Architecture with Connected and Automated Technologies for Fuel Economy Improvements	Mahaveer Satra	SAE World Congress Experience
OSU	Fault Insertions into Hardware-in-the-Loop Simulation	Tyler Martin	The Ohio State University
OSU	Active Aerodynamics Control for Hybrid Thermal Systems	Phillip Dalke	The Ohio State University
OSU	Research, Design, and Implementation of Virtual and Experimental Environment for CAV System Design, Calibration, Validation and Verification	Shlok Goel	The Ohio State University
OSU	Full-Vehicle Model Development of a Hybrid Electric Vehicle and Development of Framework for Controls Testing	Mahaveer Satra	The Ohio State University
OSU	System Level Approach for Controller Development for a Hybrid Electric Vehicle Focused on Drive Quality	Kristina Kuwabara	The Ohio State University
OSU	Modeling and control of automotive energy storage systems	Jacqueline Karl-DeFrain	The Ohio State University
OSU	Design and Validation of Perception System Algorithms for a Semi-Autonomous Vehicle	Akshra Narasimhan Ramakrishnan	The Ohio State University
OSU	Design, Validation and Integration of a Rear Subframe	Leala Longmire	The Ohio State University
OSU	Human Centered Design process using Systems Modeling Language for CAV Driver Education	Kriti Gena	The Ohio State University

Team	Publication/Presentation Title	Lead Author Name	Conference / Journal
UA	A Study of Using a Reinforcement Learning Method to Improve Fuel Consumption fo a Connected Vehicle with Signal Phase and Timing Data	Ashley Phan	WCX 2020
UA	Scalable Simulation Environment for Adaptive Cruise Controller Development	David Barnes	WCX 2020
UW	On Implementing Optimal Energy Management for EREV Using Distance Constrained Adaptive Real-Time Dynamic Programming	Aman V. Kalia	mdpi.com open access journal Electronics Volume 9 Issue 2 specail topic "Optimization Base Energy Management Stategy for Hybrid-Electric Vehicles"
UWAFT	Sensor Fault Detection and Isolation for Degrading Lithium-Ion Batteries in Electric Vehicles	Manh-Kien Tran	UWSpace (Thesis)
UWAFT	Sensor Fault Detection and Isolation for Degrading Lithium-Ion Batteries in Electric Vehicles Using Parameter Estimation with Recursive Least Squares	Manh-Kien Tran	Batteries
UWAFT	A Review of Lithium-Ion Battery Fault Diagnostic Algorithms: Current Progress and Future Challenges	Manh-Kien Tran	Algorithms
UWAFT	High Reynold's Number Turbulent Model for Micro-Channel Cold Plate Using Reverse Engineering Approach for Water-Cooled Battery in Electric Vehicles	Manh-Kien Tran	Energies
UWAFT	Nonlinear Optimal Control of Automated Vehicles in a Connected Environment	Derrick Tan	UWSpace (Thesis)
UWAFT	Hybrid Electric Mobility: Design Considerations for Energy Storage Systems and Fuel Economy Optimization of Shared Semi-Autonomous Vehicles	Mobaderin (Bade) Akinsanya	UWSpace (Thesis)
WVU	RoAdNet: Robust Adaptive Network for Information Diffusion in VANET	Priyashraba Misra	WVU Research Repository
WVU	RoAdNet: A Multi-Resolution Transmission Strategy for Long Range Information Diffusion in VANETs	Priyashraba Misra	Vehicular Technology Conference 2019
WVU	Generation and Analysis of Hybrid-Electric Vehicle Transmission Shift Schedules with a Torque Split Algorithm	Nicholas J. Connelly	Journal of Transportation and Technologies

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, 2019 End Date: September 30, 2020
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) 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 2020, 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 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, 2019 covered MY 2019 vehicle acquisitions. In reports submitted at the end of 2019, 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 2019 acquisition requirements by more than 35%. 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 2019 petroleum use reduction requirements by more than 7%.

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. Fleets reporting biodiesel usage report amounts that typically exceed the amount of biodiesel that could be counted toward credits. The amount of biodiesel use reported rose from just over 7.9 million gallons in MY 2018 to a little less than 8.3 million gallons in MY 2019. The biodiesel gallons reported by alternative fuel provider fleets was a program high. DOE also saw a rebound in total biodiesel credits earned, approaching the previous program high, in 2016, of over 2,500 credits. Fleets earned a total of 2,414 credits in MY 2019 for using biodiesel, an increase from 1,108 credits earned in MY 2018.

Fleets reported an increase in the number of reported creditable light-duty vehicles acquired (18,053) in MY 2019, which includes light duty AFVs, non-AFV hybrid-electric vehicles (HEVs), and neighborhood electric vehicles (NEVs), when compared to MY 2018 (16,747). MY 2019 marked the seventh 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 629 credits for partial-credit vehicles and 295 credits for investments in alternative fuel infrastructure and non-road equipment in MY 2019 (a 28% increase, for the two categories combined, over MY 2018 (231)).

Conclusions

The data for MY 2019 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.

II.5 Fuel Economy Information Project (Oak Ridge National Laboratory)

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Start Date: October 1, 2019 End Date: September 30, 2020
Project Funding (FY20): $2,525,000 DOE share: $2,525,000 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 43,000 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 (1) providing information about light-duty vehicle fuel economy and fuel costs, (2) educating consumers on the benefits of improved fuel economy, and (3) 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 an electronic version of the *Guide* in the fall and distributes it 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.

The *2020 Fuel Economy Guide* currently contains information for more than 1,240 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 leverages the power of computers and the internet to reach more consumers and provide more functionality than possible within the limitations of a paper booklet. The website can be viewed on PCs, smart phones, and other mobile devices, allowing consumers to have fuel economy information at their fingertips while shopping. FuelEconomy.gov has become the FEI Program's most effective tool for reaching consumers and providing them with fuel economy information.

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 43,000 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.

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

- Federal tax credit information for advanced technology vehicles (e.g., plug-in electric vehicles)
- 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.

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.

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

- *Trip 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 candidate vehicles. 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.* Allows users to compare the fuel costs of two vehicles with different fuel economies. The FEI Program has enhanced the tool to include vehicle purchase and financing/lease costs. 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.
- "*Can a Hybrid Save Me Money?"* Compares 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 re-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.
- *Used Car Label Tool*. Generates printable fuel economy labels that sellers can affix to their vehicles or electronic images they can include in on-line ads. 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. Two DOE website tools (Find EV Models and the Vehicle Cost Calculator) use FuelEconomy.gov's data, as do EPA's Green Vehicle Guide and the joint DOE/EPA ENERGY STAR website. 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. FuelEconomy.gov provides users with fuel-saving tips and allows consumers to personalize these tips to see how much money and fuel they can save by following them. The FEI Program compiles the fuel-saving tips based on available literature from U.S. government agencies, auto experts, and other credible sources. In recent years, the FEI Program has supported research projects aimed at quantifying factors that can increase or decrease fuel economy. Research has focused primarily on aspects of fuel economy that can be improved by driver behavior. Past research topics include (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 effects of cold and hot 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 hybrids and plug-in vehicles, and (8) 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 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 consumers that prefer to use mobile apps rather than the FuelEconomy.gov website. The Find-a-Car app has similar functionality to the website's Find-a-Car feature, but it can be downloaded to a personal device and accessed with the touch of a button. It also 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 fuel economy, alternative fuels, and advanced vehicle technologies. MotorWeek airs on 92% of PBS stations nationwide, as well as 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.

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 and inquiries. Consumers and media contacting FuelEconomy.gov can expect a response within a few business days (or sooner).

Results

In model year 2020, the FEI Program continued to help DOE meet its statutory requirement to produce an annual *Fuel Economy Guide* for light-duty vehicles. Model year 2020 was the third 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 new car dealers, public libraries, and credit unions. The FEI Program now mails letters inviting these parties to register for routine email communications about the new *Guide* for 2020, 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 2020 *Guide*, which the FEI Program updates weekly, is available on-line at FuelEconomy.gov. In addition, the FEI Program has made a preliminary, data-only version of the 2021 *Guide* available to the public on FuelEconomy.gov, as of the second quarter of FY 2020. This preliminary version contains data for model year 2021 vehicles already released by manufacturers. The 2021 *Guide* will be finalized and distributed in the first quarter of FY 2021.

Since its launch in 1999, FuelEconomy.gov has hosted more than 490 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 (Figure II.5-1). In FY 2020, FuelEconomy.gov hosted more than 22 million user sessions, more than 276 million page views, and more than 62,000 daily visits on average.

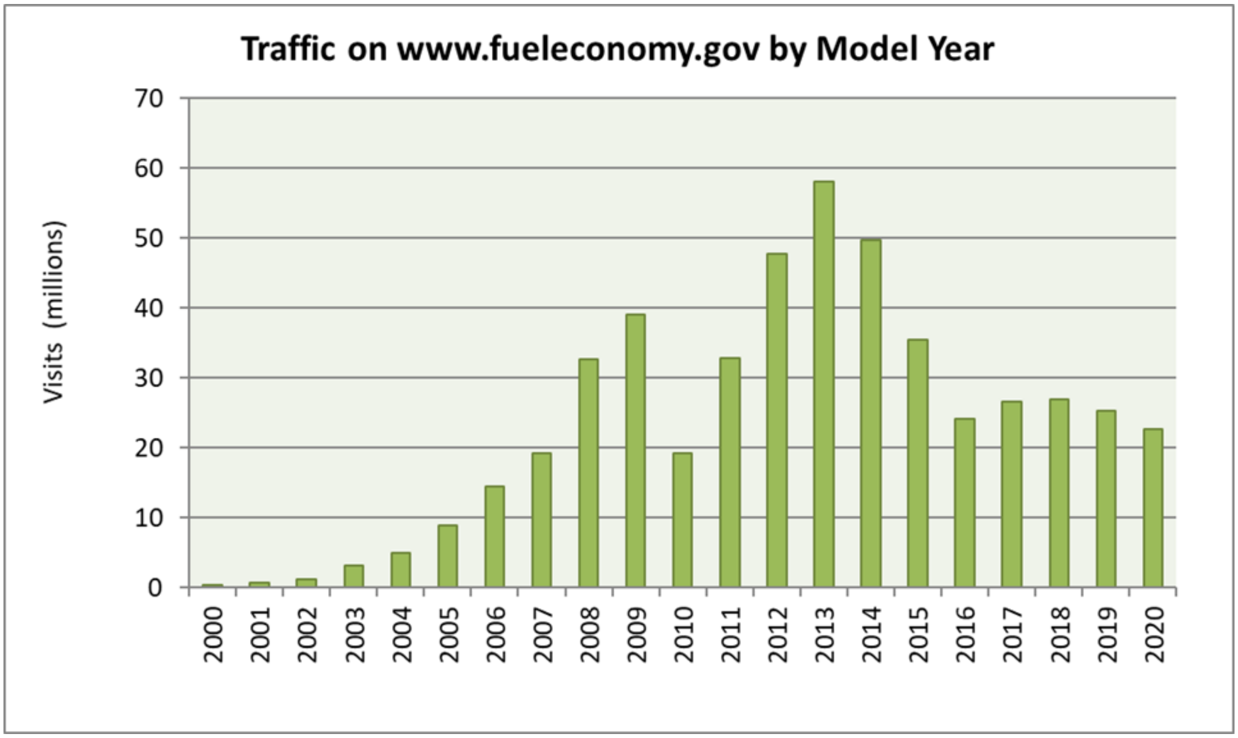

Figure II.5-1. Traffic on FuelEconomy.gov grew steadily after its initial launch in 1999, peaking in 2013 when fuel prices were high.

FuelEconomy.gov's My MPG tool continues to be popular with consumers. More than 35,000 drivers have shared fuel economy estimates for more than 50,000 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 team recently redesigned the tool and plans are to launch this upgrade in FY 2021. Enhanced features include an improved, mobile-friendly user interface; more graphs and tables for user analysis; and the ability to enter data for all-electric vehicles.

The Find-a-Car mobile app has been successful. At the end of FY 2020, over 53,000 users had installed the app on Apple and Android devices. The app has a combined user rating of over 4.0 out of 5.0. A new Find-a-Car app has been developed and will be launched once approvals are in place.

Not only were the data updated weekly on the FuelEconomy.gov website in FY 2020, but other parts of the website were also improved. Power Search was updated with additional search capabilities, such as stop-start, turbocharging, and detailed cylinder classifications, as well as additional vehicle classifications. The Beyond Tailpipe Calculator pages were redesigned to be more explanatory. The cold weather tips and the Federal tax incentive data were updated with new information, along with other routine content updates. Changes were also made to the website in response to user feedback.

MotorWeek segments completed in FY 2020 included three related to electric vehicles (Electric Vehicles Charge up the Police Force, New Flyer Buses Go Electric, and Living with an EV), one segment on the Michigan to Montana Alternative Fuel Corridor, and two Clean Cities Success Stories (Indiana Cleans up with Natural Gas Trucks, and USA Hauling and Recycling).[4]

Two fuel economy research projects began in 2020: a fuel stabilizer study and a stop-start fuel economy study. Gasoline is stored in plug-in hybrids much longer than in conventional vehicles, which may lead to fuel stability problems. ORNL is conducting a study to assess the effectiveness of three popular off-the-shelf fuel stabilizers over extended time periods. The study will examine gum formation, oxidation stability, Reid vapor pressure, and other fuel attributes. The second study evaluates the effects of the auto stop-start feature on fuel economy using two vehicles that allow the feature to be disabled. Results from both studies will be documented through journals and on FuelEconomy.gov in future years.

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 1,700 times in the technical literature. Finally, the FEI Program responded to over 600 email inquiries submitted by media and users through FuelEconomy.gov.

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 2020, 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 its 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. In fact, these tips, which are used widely by many media sources, are one of the reasons FuelEconomy.gov is considered a trusted and authoritative source of 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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Start Date: October 1, 2019 End Date: September 30, 2020
Project Funding (FY20): $1,225,000 DOE share: $1,225,000 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 across multiple technologies to a wide cross section of stakeholders. 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 greenhouse gas reductions, and transformed fleet managers into 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. The technical assistance made available also helps with planning, implementation and operational challenges facing end users. Through these trusted, time-tested methods, DOE has helped fleets and other stakeholders make informed decisions to deploy hundreds of thousands of alternative fuel vehicles (AFVs) and fueling stations that serve a growing market. The project is continually evolving to identify and 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 information and expertise that enables informed decisions and helps 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 challenges and barriers that should be addressed
- Using results to guide Technical Assistance objectives and inform future research and development efforts.

Approach

The Technical Assistance project makes varying levels of technical assistance available, 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 in-house and subcontracted experts, based upon the type of assistance requested and the required depth of response. As appropriate, NREL will collaborate with other National Laboratories to identify solutions and provide the needed level of expertise. 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 current issue.

NREL offers a base level of Technical Assistance 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, industry trends, 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 on and access 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.

Results

A sampling of fiscal year (FY) 2020 TRS and Technical Assistance projects includes the following:

Technical Response Service Inquiries

A robust inquiry tracking system allows each inquiry to be tracked, which also means trends can be identified. Recent questions with a high rate of multiple inquiries include: What are the best resources for owning and operating a DC fast charger? How much does each fuel type in the transportation sector contribute to overall emissions? What resources compare the cost and emissions of compressed natural gas (CNG) and propane paratransit shuttle buses? Where can I find an overview of federal alternative fuel tax credits that were retroactively extended?

An Original Equipment Manufacturer (OEM) inquired as to whether the Emissions from Hybrid and Plus-In Electric Vehicle tools could be used to estimate the change in PEV emissions if the grid shifted to include more renewable energy. The TRS suggested using Argonne National Laboratory's Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) tool to estimate PEV emissions from various grid mixes. Additional guidance on how to update the default grid mix was included.

A representative from the propane industry asked about projections for AFVs in operation in the United State. The TRS staff referred the individual to Energy Information Administration (EIA) data available on the EIA website, and also included estimates for AFVs in 2025 and 2050. Additionally, TRS staff pointed the individual to fuel-specific vehicle projections referred to in statements from industry associations.

A stakeholder approached the TRS with a question about which emissions certifications were required in New York state. The stakeholder's client had conflicting information about which certification, from the Environmental Protection Agency (EPA) or the California Air Resources Board (CARB), was required for medium duty vehicles, and the client was unable to order vehicles until definitive information was provided. ICF provided definitive information about New York's Low Emission Vehicle (LEV) standards, specifically which standards apply to which vehicle classes.

An individual from the University of California inquired about whether information on when stations first went into service was available for EVSE in California. The TRS accessed the AFDC Station data and provided a spreadsheet with EVSE opening dates, and the historical monthly station counts by state. Detailed information on data caveats was also provided.

A federal agency inquired looking for information about what other agencies have successfully implemented a Level 2 workplace charging program for employees, and asked how payments are handled in a manner that adheres to federal requirements. Following input from NREL staff who manage federal fleet efforts, the TRS provided detailed information on pricing structures and payment options for various Level 1 workplace charging programs at federal agencies. The TRS also included a list of contacts who could provide additional information.

A utility representative requested information about the average cost to "make ready" a home for EVSE, and about what the market trends are for public and workplace EVSE. The TRS provided an overview of costs to wire homes for EVSE, sourced from ENERGY STAR, Southwest Energy Efficiency Project (SWEEP), and local government and university resources. For trends on public and workplace EVSE, TRS referred the client to various publications from the AFDC database.

Technical Assistance Activities

Technical assistance frequently requires cooperation among agencies. U.S. DOT's Volpe center requested that NREL provide technical expertise to Grand Canyon National Park. The park operates buses with liquefied natural gas (LNG) systems and identified the need for redundancy in fueling stations to ensure continued operation. NREL worked with the park to determine the best path. The park chose a dual pump skid which provides redundancy, but also considerably more confidence in their ability to use LNG flashed to CNG to fuel their buses moving forward.

CNG Tank Testing report. NREL received the final results and data report from subcontractor Digital Wave on the investigation of structural integrity of CNG fuel tanks under routine operating conditions at the defined end of their useful lives (EOL). NREL compiled the results and finalized the report to allow the industry to better identify, understand, and mitigate safety risks, and address barriers and opportunities related to CNG storage onboard vehicles. This study evaluated the structural integrity of Type III and Type IV CNG fuel tanks from the Los Angeles Metropolitan Transportation Authority, to characterize the fuel tank conditions after experiencing a full-service life of 15 years in transit bus application. The data produced provides insight about the condition of the CNG fuel tanks at the conclusion of their defined EOL and potential risks of continued operation of the CNG vehicles without replacement of the expired fuel tanks.

The Natural Gas Vehicle Technology Forum, coordinated by the Technical Assistance project, took place in February 2020, at SoCalGas Energy Resource Center in Downey, California. More than 60 stakeholders attended the meeting, including representatives from industry, government, utilities, and regulatory bodies. High interest topics included continued work on increasing vehicle efficiency, and reducing component failure rates. Additionally, attendees discussed fuel system and container safety standards, chiefly the evolving fuel system integrity requirements for medium- and heavy-duty natural gas vehicles. Challenges that need to be addressed include the ongoing need for training for technicians, drivers and first responders; supply chain challenges, fuel storage tank issues (packaging, pay load, and life expectancy), and range anxiety.

Codes and standards work is an important part of proactive technical assistance. Subcontract expertise is being used to help address differences between current National Fire Protection Association (NFPA) and International Fire Codes (IFC). Developing consistent codes will smooth the path for fleets that are working with an Authority Having Jurisdiction (AHJ) toward adopting CNG vehicles.

Conclusions

The ready availability of industry experts, through the TRS and the Technical Assistance project, makes it possible for fleet managers to understand, select and integrate new transportation technologies into their fleets. 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.

II.7 Technologist-in-Cities (National Renewable Energy Laboratory)

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Project Funding (FY20): $400,000 DOE share: $400,000 Non-DOE share: $0

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 mobility systems that are automated, connected, efficient, shared (ACES), and fully integrated across modes. 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 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 Technologist in Cities (TIC) with Columbus, Ohio, after the City of Columbus' Smart Columbus project won the DOT Smart City Challenge in 2016. TIC works with the City and its partners throughout the life of the Smart Columbus project, beginning this relationship in 2016, with plans to continue technology advisement through the end of FY 2022, pending continued Vehicle Technologies Office (VTO) support.

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, and truck platooning. Complementing the DOT grant is a $10-million grant from Paul G. Allen Philanthropies (formerly Vulcan) to accelerate adoption of plug-in electric vehicles (PEVs), enhance charging infrastructure to support PEV adoption, and provide a cleaner and more efficient electric grid.

In its final year of the DOT grant, many of the projects—particularly with respect to PEV adoption—are highly developed, and many of the mobility-based projects are nearing full implementation. Smart Columbus is working toward identifying funding sources and designing subsequent phases of activity beyond the initial grant-funded projects to sustained initiatives within the city.

Objectives

TIC supports the City of Columbus in its Smart City endeavors, serving as a liaison on energy and mobility issues. The TIC program advises the city's innovation and technology team on transportation energy efficiency and connects the City to experts throughout the DOE National Laboratory system. 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 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 that are encouraged by the Smart Columbus initiative, though not directly funded by the grants.

Approach

TIC support of Smart Columbus includes a variety of activities, methods, and approaches as outlined below:

- Maintain a physical presence at adequate frequency to maintain a working relationship and serve as a liaison. In 2020, physical visits were conducted monthly through March 2020, and thereafter virtually, when all DOE travel was postponed, due to the pandemic.
- 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 (AV) and automated electric shuttle (AES) demonstrations
- Support the Smart Columbus Operating System (the centralized, modern data repository and exchange that supports Smart Columbus initiatives), promote access to vital regional data sets housed at the City and with the City's partners, and integrate data into the DOE EEMS Livewire data-sharing system
- Provide communications between the City and its partners to DOE and the National Laboratories
- Promote opportunities for collaboration between Smart Columbus and the DOE VTO EEMS programs, such as SMART research and Technology Integration (TI) projects.

Near the end of the formal DOT grant period, many of the grant-funded projects have transitioned to operational programs within Smart Columbus, including the Smart Columbus Operating System, 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, with initiatives to efficiently solve employer labor access issues and to streamline payments and user experiences, especially for the disabled community; at Ohio Department of Transportation, with the formation of DriveOhio to promote ACES and workforce mobility 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 2020, but the momentum generated by the grant has also begun to sprout other significant EEMS initiatives within the community.

Since March 2020, the COVID-19 pandemic has had significant impact on cities as they struggle to maintain services during severe economic downturns. The TIC effort has maintained communications with Smart Columbus through webinars and phone calls, as all non-mandatory travel has been suspended at the laboratory. The National Renewable Energy Laboratory's (NREL's) data expertise has also been diverted to assist with the COVID-19 response, providing insights and analysis on the impact of COVID-19 on mobility and quantifying the reduction in travel, particularly for shared modes such as public transit, air travel, and transportation network companies (TNCs). As the United States emerges from the pandemic in 2021 with the introduction of vaccines and the return to normal, or perhaps a new normal, Smart City priorities with respect to sustainable mobility will have the added challenge of ensuring the safety of their mobility systems in the face of the current disease and restoring the confidence of its riders.

Results

In fiscal year (FY) 2020, the TIC program was able to carry out its objectives in a variety of ways. Select project accomplishments include:

- **Columbus Electrification Program Final Report** – Collaboratively, the City of Columbus and the Smart Columbus team worked to support transportation electrification. The team issued a final report on its electrification program, with details on parameters and partnerships, as well as measurements and other outcomes resulting from the work accomplished over the course of the program. The report presents a roadmap for other smart cities efforts to follow and provides in-depth learning and knowledge from years of hard work and experience of being a community forging new pathways for mobility.

  In the Lessons Learned section of the report, a lesson is noted that "early coordination with your utility provider and NREL is encouraged. Involvement from AEP Ohio and NREL greatly strengthened our document, specifically the calculation methodology." The DOE Technology Integration program's support of the TIC effort facilitated this connection and has grown multiple opportunities to learn from many implementation projects within the Smart Columbus catalog. These interactions with Smart Columbus have led to the exchange of information on key DOE programs, including the EVI-Pro analytical tool, the Alternative Fuels Data Center, and the Mobility Energy Productivity (MEP) metric, a central mobility measure for analysis within DOE.

  Dividends of the investment in smart cities support and research continue with emerging relationships. The New York State Energy Research and Development Authority (NYSERDA) is among the leaders in this mobility area and has engaged the NREL team for programmatic support based on TIC findings and experience. Progress continues in preplanning and program development for smart cities programs to support NYSERDA.

- **Next Stage Columbus Electrification Program – Climate & Smart Growth** – Thinking ahead to objectives beyond the end of the grant period, Smart Columbus conducted a workshop to set a course for the Smart Columbus Electrification Program 2.0. From January 28–30, the Smart Columbus program hosted a workshop to celebrate the accomplishments of the first 3 years of the project. Invited speakers present at the workshop included several nationally prominent figures in the area of electric vehicles (EVs), including practitioners, industry operators, and researchers, along with three members of the NREL TIC team and a researcher from Argonne National Laboratory, who reflected on the progress made in Columbus and beyond. Leaders from the City of Columbus, the Columbus Partnership, local and national industry, and numerous community groups gathered to learn about the progress toward transportation electrification that has been achieved to date, as well as to envision and plan for the next phase. Since 2017, Columbus has reached EV sales of more than 1.6%, which is double the projected estimate without Smart Columbus efforts. This accomplishment is in part through the efforts of Smart Columbus, including setting a record of conducting more than 12,000 ride-and-drives with prospective EV buyers and strong connection and coordination with area dealerships.

  To track progress toward goals, TIC initiated and supported the Performance Metrics Plan (PfMP) during the first year of the program. In the second year, TIC transferred responsibility for maintaining and updating the PfMP to internal Smart Columbus staff. The PfMP in its third year is fully supported internally by Smart Columbus and reports progress toward electrification goals, including the number of EVs adopted and the greenhouse gas (GHG) and energy reduction benefits resulting from various activities and projects in the Columbus Electrification Program, such as education and incentives for EV purchases. This initiative has helped to inspire and support the Transportation Energy Analytics Dashboard, a DOE VTO TI research project updated in a subsequent highlight. The quantitative tracking of electrification goals as embodied in the PfMP is now part of the "DNA" of the Smart Columbus initiative and shared broadly in the Smart Columbus outreach activities.

- **Columbus Neighborhood Linden LEAP Automated Electric Shuttle** – On February 5, 2020, the Linden Empowers All People (LEAP) AES launched, the first such implementation in the United States to serve a residential neighborhood. Two LEAP shuttles from equipment vendor EasyMile began service, linking residents in the Linden neighborhood to a transit hub via a 2.9-mile route, which takes 24 minutes to make a complete circuit. City and community leaders and a group of citizens from the neighborhood gathered to celebrate the launch.

  However, a few weeks after the LEAP shuttles began operating, an incident in which one of the vehicles stopped abruptly to avoid an object in its path caused a passenger to be ejected from a seat to the floor of the vehicle. Though no serious injuries were reported, in an abundance of caution on the part of the operators and EasyMile, service was temporarily suspended to investigate the cause and response of the vehicle's sudden stop. Subsequently, the shuttle service was suspended due to the COVID-19 pandemic, with some service later resuming, serving a modified food delivery role.

- **City of Columbus EV Fleet: Energy Savings Performance Contract Case Study** – Calvin Spanbauer, a graduate from the Ohio State University (OSU) business program and intern on the TIC project, submitted a paper co-authored with Andy Duvall titled, "Applying Energy Performance Contracting to Vehicle Fleet Transitions" to the Transportation Research Board (TRB). The paper explores the potential for the application of energy savings performance contracts (ESPCs) for mobility investments. ESPCs in the past have been used by corporations and other organizations to improve energy efficiency for buildings and other stationary assets. For example, in 2017, OSU entered a comprehensive energy management partnership (CEMP) with ENGIE (an energy management service provider) and investment firm Axium Infrastructure. OSU's CEMP is the largest energy-related deal of its type, with OSU receiving a $1.015-billion upfront payment. The CEMP includes four main components: (1) operation of all of OSU's energy-related facilities, (2) significant energy efficiency targets (with a goal to improve OSU's energy use intensity by 25% over the first decade via ESPC), (3) enhancement of OSU's procurement process for energy sources, and (4) establishment of an academic collaboration plan.

- **Columbus Application of the Transportation Energy Analytics Dashboard (TEAD)** – Continuing development of work envisioned through the TIC program and funded through a DOE VTO 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, D.C., as test cases. The team is integrating real-time and historic traffic volume and speed data with detailed roadway information and vehicle powertrain models to estimate the gasoline gallon equivalents 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, which services over half of all states. The TEAD project is moving forward on schedule, and full update on progress is available through its normal reporting system. When fully deployed, TEAD will enable energy and GHG metrics to be incorporated into traffic operations, planning, and research, ultimately providing a more comprehensive tool for transportation decision-making. In the past quarter, the TEAD project was able to validate its energy models to be implemented, exercise models for both Columbus and Washington, D.C., and remains on track for full implementation.

- **Columbus Travel Data: Leveraging Emerging Mobility Data Sources – Traffic Signal Performance Analysis Using Trip Trajectory Data** – In support of the special projects around understanding mobility patterns and changes related to the pandemic, progress continues in exploration of INRIX trip data. As shared in previous quarters, NREL—through partnership with Wayne State University—leveraged an investment by the Ohio Department of Transportation of a cutting-edge transportation planning and analysis data set to demonstrate traffic signal performance assessment without the need for deploying sensors.

That work was presented at the 2020 annual meeting of the Transportation Research Board, where it was shared widely with others in research and industry. This methodology has been extended to the Regional Mobility research initiative, in which a digital twin for the city of Chattanooga was used as a corridor. INRIX partnered with academia to provide a version of the new capability in their tools. Discussions and proposals are ongoing to scale this capacity to state and national levels, in essence performing signal optimization at the national scale. All of this was seeded and promoted through investment in the TIC initiative in Columbus.

- **Columbus Parking and Curbside Management** – Coordination with Robert Ferrin, Parking Lead for the city of Columbus, continues to be fruitful. Columbus has taken a lead role in developing curb space monitoring and management and has received good press on an initial report and pilot with vendor partner curbFlow. A report on the initial pilot project conducted from November 2019 to May 2020 is available here: https://www.columbus.gov/publicservice/parking/curbFlow-Final-Report-June-2020/.

  As noted in the report: "Despite rapidly rising demand, the supply of the city's curbs is largely fixed, creating a supply/demand imbalance that was leading to increased congestion and unsafe operating environments." Though conditions of curb space utilization have changed as a result of the pandemic, intentional coordination of activities dependent on the curb zone is becoming more crucial for cities to actively manage and represents opportunities as cities look to future funding strategies beyond the standard parking model.

- **Columbus as Civic Development Leader: Fostering Activities with DriveOhio and The Fund NEO (Northeast Ohio) –** As a result of an introduction fostered by DriveOhio, key partner with Columbus in monitoring regional travel patterns, the NREL team met with members of The Fund for Our Economic Future (the Fund NEO) effort. The Fund NEO coordinates several mobility projects, including the Paradox Prize competition. The Paradox Prize is framed around developing sustainable mobility solutions to address the paradox of '*no car, no job; no job, no car*' with regard to employment challenges in the chronically economically underperforming communities of Northeast Ohio. The Paradox Prize initiative aligns closely with efforts to improve mobility access and equity that have been a part of the Smart Columbus effort, as well as workforce mobility research within EEMS programs. The Fund NEO's program has supported about $1 million in strategic workforce mobility projects since starting in June 2019. The Fund NEO, in collaboration with area universities, asked the NREL team to serve as a sub-partner and to support development of a proposal to the National Science Foundation Civic Innovation Challenge, a funding opportunity in collaboration with DOE and the Department of Homeland Security. The concept is aiming for Track A: Communities and Mobility: Offering Better Mobility Options to Solve the Spatial Mismatch Between Housing Affordability and Jobs.

- **Columbus EV Metrics and 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 program, initiated discussions with the Ohio Bureau of Motor Vehicles (BMV) to obtain direct access to vehicle registration data. Since 2018, Smart Columbus and the Ohio Department of Transportation have begun 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) natively within the state's 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. BMV, Ohio Department of Transportation, and Smart Columbus collaborated to develop a process for 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. This process came to fruition in mid-2020, with the group presenting EV information through the BMV Alternative Fuel Vehicle Registration Data web dashboard. TIC will continue to monitor this tool, and data from the initiative is targeted for inclusion in the TEAD project.

Conclusion

As the TIC program enters a final stage of the project, the NREL team remains engaged with the City of Columbus and the entities comprising Smart Columbus and continues to provide support as current projects wind down and subsequent phases are designed. During FY 2020, the TIC program continued to frequently engage with Columbus, yet as with the rest of the world, impacts of the COVID-19 pandemic disrupted regular field visits to Columbus. However, ongoing TIC efforts were maintained to explore and collaborate with several entities in Columbus and the surrounding region. As the initial grant funding support for the Smart Columbus effort draws to a close, the initiative is shifting toward new phases. Columbus continues to become more established as a municipal leader in smart mobility and serves as a valuable resource for other communities aiming to learn from and improve upon the work implemented in Columbus and the region. More broadly, the state of Ohio appears to be becoming the location of several new-era mobility efforts, still concentrated largely in Columbus but emerging as new iterations in other parts of the state. The DriveOhio program, under the Ohio Department of Transportation, has emerged as a leading voice for Smart Communities and EEMS statewide, and is among the most innovative state-level mobility efforts in the country. The expansion of TIC work into other geographic areas and into new and emerging topics is enabling transference of methods and findings to be of value outside the initial project area. In the current age of highly altered mobility trends and practices, such as how best to maneuver public transit during a time of pandemic, highly knowledgeable partnerships, exemplified by that with the Central Ohio Transit Authority, greatly augment the ability of DOE researchers to quickly gain on-the-ground insight to inform timely research work. Numerous professional and agency connections, access to unique and valuable data, and collaborative relationships enabled through the TIC program are all strong returns on the investment made to support the efforts in Columbus.

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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