U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Technology Integration

2021 Annual Progress Report

Vehicle Technologies Office

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Disclaimer

Acknowledgements

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Acronyms

AAR	Association of American Railroads
ACEP	Alaska Center for Energy and Power
ACES	automated, connected, efficient and shared
ACFC	Alabama Clean Fuels Coalition
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
AI	artificial intelligence
ANL	Argonne National Laboratory
API	Application Programming Interface
ATSPM	automated traffic signal performance metric
AV	autonomous vehicle
AVTC	Advanced Vehicle Technology Competition
BEV	battery-electric vehicle
BID	business improvement district
BMS	Behavioral Micro-simulation
BSSD	Blue Springs School District
CACC	Cooperative Adaptive Cruise Control
CAN	Controller Area Network
CARB	California Air Resources Board
CARTS	Capital Area Rural Transportation System
CAV	Connected and Automated Vehicle
CBO	community-based organization

CC-G	Clean Cities Georgia
CCoD	City and County of Denver
CCOG	Centralina Council of Governments
CCWNY	Clean Communities of Western New York
CDF	cumulative density function
CDTC	Capital District Transportation Committee
CFD	Computational Fluid Dynamics
CFO	Clean Fuels Ohio
CMIC	Cummins Machine Integration Center
CMU	Carnegie Mellon University
CNG	compressed natural gas
CO	carbon monoxide
CO2	carbon dioxide
COOL EVs	Cold-Weather Operation Observation and Learning with Electric Vehicles
CPU	central processing unit
CRuSE	Clean Rural Shared Electric Mobility Project
CTE	Center for Transportation and the Environment
CTS	Contract Transportation Services
DAS	data acquisition system
DC	direct current
DCC	Drive Clean Colorado
DCFC	direct current fast charger
DER	Department of Environmental Resources
DERST	Distributed Energy Resources Safety Training
DEUSA	Drive Electric USA
DNL	Dynamic Network Loading
DOE	Department of Energy
DOT	Department of Transportation

DRIVE Electric USA	Developing Replicable, Innovative Variants for Engagement for EVs in the USA
DSRC	dedicated short-range communication
EEL	energy-efficient logistics
EEMS	energy efficient mobility systems
EERE	Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EISA	Energy Independence and Security Act
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
ESS	energy storage system
ETCF	East Tennessee Clean Fuels
EV	electric vehicle
EV-EMCB	Electric Vehicle Energy Management Circuit Breaker
EVI-Pro	Electric Vehicle Infrastructure Projection
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
EZMT	Energy Zones Mapping Tool
FCEV	fuel cell electric vehicle
FDACS OER	Florida Department of Agriculture and Consumer Services Office of Energy Resources
FE	fuel economy
FEI	Fuel Economy Information
FEMP	Federal Energy Management Program
FFNN	fast-forward neural networks
FFRDC	Federally Funded Research and Development Center

FSEC	Florida Solar Energy Center
FtC	Fort Collins, Colorado
FTG	freight trip generation
FY	fiscal year
GCKS	Garden City, Kansas
GGE	gasoline gallon equivalent
GHG	greenhouse gas
GIS	geographic information system
GM	General Motors
GMU	George Mason University
GPS	Global Positioning System
GPU	graphics processing unit
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation
GT	Georgia Tech
GTFS-RT	General Transit Feed Specification - Realtime
GTI	Gas Technology Institute
GVSD	Grain Valley School District
GVW	Gross vehicle weight
H2	hydrogen
HAPCAP	Hocking Athens Perry Community Action
HD	heavy duty
HDV	heavy duty vehicle
HEV	hybrid-electric vehicle
HPC	high performance computing
ICE	internal combustion engine
ICV	intelligent connected vehicle
IEEE	Institute of Electrical and Electronics Engineers
IRB	Institutional Review Board

ITS	intelligent traffic system
KCI	Kansas City International Airport
KCMO	Kansas City, Missouri
KDOT	Kansas Department of Transportation
KPI	key performance indicator
KU	Kansas University
kW	kilowatt
kWh	kilowatt-hour
L2	Level 2
LDDV	light duty diesel vehicle
LDV	light duty vehicle
LNG	liquefied natural gas
LSCFA	Lone Star Clean Fuels Alliance
LSEV	low speed electric vehicle
LSTM	Long Short-Term Memory
LT	lead truck
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
MAE	mean absolute error
MAP	manifold absolute pressure
MC3	Minnesota Clean Cities Coalition
MD	medium duty
MDE	Maryland Department of the Environment
MEC	Metropolitan Energy Center
MEEP	Mid-Atlantic Electric School Bus Experience Project

MEP	Mobility Energy Productivity
METS-R	Multimodal Energy-optimal Trip Scheduling in Real-Time
MMDUE	Multi-modal Dynamic User Equilibrium
MOU	memorandum of understanding
MOVES	Motor Vehicle Emission Simulator
MPC	model predictive control
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
MY	model year
NAFA	National Association of Fleet Administrators
NACFE	North American Council for Freight Efficiency
NAPT	National Association for Pupil Transportation
NASEO	National Association of State Energy Officials
NCAT	National Center for Asphalt Technologies
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NGV	natural gas vehicle
NGV UPTIME	NGV Updated Performance Tracking Integrating Maintenance Expenses
NHTSA	National Highway Traffic Safety Administration
NJDEP	New Jersey Department of Environmental Protection
NOx	oxides of nitrogen
NREL	National Renewable Energy Laboratory
NYC	New York City
NYSERDA	New York State Energy Research and Development Authority

OCCP	Open Charge Point Protocol
OEM	original equipment manufacturer
OPC	Office of Public Council
ORNL	Oak Ridge National Laboratory
OSU	Ohio State University
PAC	Project Advisory Committee
PDF	Probability Density Function
PEV	plug-in electric vehicle
PHEV	plug-in hybrid-electric vehicle
PII	personally identifiable information
PM	particulate matter
PNNL	Pacific Northwest National Laboratory
POEMS	Predictive Optimal Energy Management Strategies
POI	point of interest
PSCFC	Palmetto State Clean Fuels Coalition
PSU	Penn State University
RAMP	Rural County Mobility Platform
RBE	Roads, Bridges and Engineering Department
RFP	request for proposals
RNG	renewable natural gas
RNN	recurrent neural networks
ROADMAP	Rural Open Access Development Mobility Action Plan
ROG	reactive organic gases
RPI	Rensselaer Polytechnic Institute
SACE	Southeast Alliance for Clean Energy
SAE	Society of Automotive Engineers
SAFP	State and Alternative Fuel Providers
SCAQMD	South Coast Air Quality Management District

SEAFDP	Southeast Alternative Fuel Deployment Program
SiLVERS	St. Louis Vehicle Electrification Rides for Seniors
SLAAA	St. Louis Area Agency on Aging
SLCFP	Southeast Louisiana Clean Fuels Partnership
SLRCC	St. Louis Regional Clean Cities
SME	subject matter expert
STEM	Science, Technology, Engineering and Mathematics
SWS	Solid Waste Services
TAZ	traffic analysis zone
TBCCC	Tampa Bay Clean Cities Coalition
TCO	total cost of ownership
TI	Technology Integration
TIC	Technologist in Communities
TMS	traffic management strategy
TNC	transportation network company
TOG	total organic gases
TPO	transportation planning organization
TRB	Transportation Research Board
TRS	Technical Response Service
TSP	transportation service provider
TTCI	Transportation Technology Center, Inc.
TTU	Tennessee Tech University
UA	University of Alabama
UAV	unmanned aerial vehicle
UC	Upper Cumberland
UCC	Utah Clean Cities
UCF	University of Central Florida
UCHRA	Upper Cumberland Human Resource Agency

UIPA	Utah Inland Port Authority
ULSD	ultra-low sulfur diesel
UNC	University of North Carolina, Charlotte
USPS	United States Postal Service
UT	University of Tennessee, Knoxville
UT-Austin	University of Texas at Austin
UTA	Utah Transit Authority
UW	University of Washington
UWAFT	University of Waterloo Alternative Fuels Team
V2V	vehicle to vehicle
V2X	vehicle to everything
VADEQ	Virginia Department of Environmental Quality
VDP	Vehicle Development Process
VIN	vehicle identification number
VMRS	Vehicle Maintenance Reporting Standards
VoICE-MR	Vocation Integrated Cost Estimation for Maintenance and Repairs of Alternative Fuel Vehicles
VRP	vehicle routing problem
VSP	vehicle specific power
VT	Virginia Tech
VTO	Vehicle Technologies Office
WestSmart EV	Western Smart Plug-in Electric Vehicle Community Partnership
WU	Waynesboro University
WVU	West Virginia University
ZNP	Zion National Park

Executive Summary

The 2021 Technology Integration Annual Progress Report covers 51 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 12 billion tons of freight—more than $38 billion worth of goods each day[1]—and move people more than 3 trillion vehicle-miles.[2] Growing our economy requires transportation, and transportation requires energy. The transportation sector accounts for approximately 27% of total U.S. energy needs[3] and the average U.S. household spends over 17% of its total family expenditures on transportation,[4] making it, as a percentage of spending, the most costly personal expenditure after housing. Transportation is critical to the overall economy, from the movement of goods to providing access to jobs, education, and healthcare.

The Vehicle Technologies Office (VTO) funds research, development, demonstration, and deployment (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. VTO leverages the unique capabilities and world-class expertise of the National Laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies (including automated and connected vehicles as well as innovations in efficiency-enhancing connected infrastructure); innovative powertrains to reduce greenhouse gas and criteria emissions from hard to decarbonize off-road, maritime, rail, and aviation sectors; and technology integration that helps demonstrate and deploy new technology at the community level. Across these technology areas and in partnership with industry, VTO has established aggressive technology targets to focus RDD&D efforts and ensure there are pathways for technology transfer of federally supported innovations into commercial applications.

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 advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

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 Technologies 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) 2021. The APR presents descriptions of each active project in FY 2021, including funding, objectives, approach, results, and conclusions.

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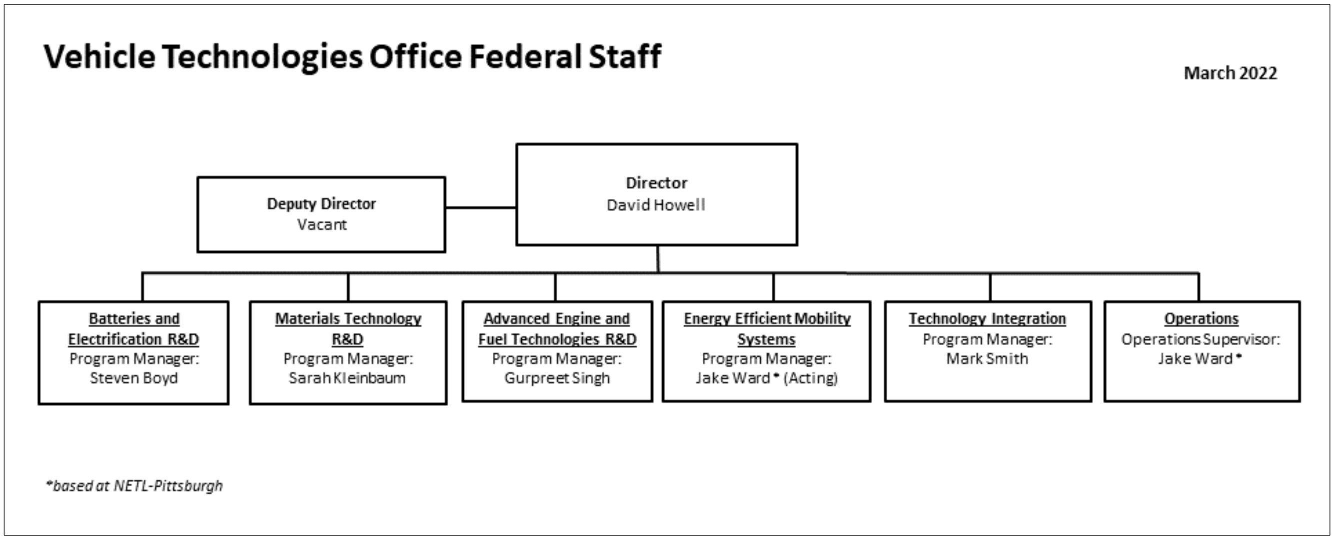
[1] U.S. Department of Transportation, Freight Analysis Framework Version 5.0 Data Tabulation Tool.
[2] U.S. Department of Transportation, March 2022 Traffic Volume Trends, Figure 1.
[3] U.S. Energy Information Administration. Monthly Energy Review, 2022, https://www.eia.gov/totalenergy/data/monthly/index.php .
[4] Davis, Stacy C., and Robert G. Boundy. Transportation Energy Data Book: Edition 39. Oak Ridge National Laboratory, 2020, https://doi.org/10.2172/1767864.

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, 2022
Project Funding: $ 10,003,633 DOE share: $ 4,999,983 Non-DOE share: $ 5,003,650

Project Introduction

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 (AFVs) that are commercially available today. To establish a Michigan to Montana (M2M) Alternative Fuel Corridor, Gas Technology Institute (GTI) established a project team comprised of alternative fueling infrastructure/transportation deployment partners and Clean City Coordinators from I-94 states. Since the kick-off of this project, this team has been guiding the creation of a planning and implementation framework to provide outreach, commission additional vehicle charging and fueling stations, deploy alternative fuel vehicles, and provide the education and training necessary to establish a sustainable market for alternative fuel vehicles along Interstate 94. This will hopefully 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 and sustainability of these technologies.

As prime, GTI brings over 80 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. Team members include Greater Lansing Area Clean Cities, South Shore Clean Cities, Chicago Area Clean Cities, Wisconsin Clean Cities, Minnesota Clean Cities, North Dakota Clean Cities, ZEF Energy (ZEF), Ozinga Ready Mix (Ozinga), Veriha Trucking, Contract Transportation Services (CTS), Time Transport, Blink Charging, and Energy Hunters.

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 20 electric vehicle (EV) DC fast chargers, 2 publicly accessible CNG fueling stations, 1 propane station, and 78 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 EV owners to travel longer distances, while also expanding commercial fleets' abilities to utilize EVs and AFVs for regional and long-haul applications.

The project team will collaborate with several community-based stakeholders in all phases of this project. To achieve the 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. The project team uses a variety of methods to coordinate efforts on this project. There is near-constant communication between team members on specific activities as well as monthly Coordination Conference Calls on which the team reviews important initiatives and objectives.

Results

EV Charging and Alternative Fueling Stations Infrastructure

Using results from a Needs Analysis completed at the outset of the project, the M2M team continued efforts to close gaps in alternative fueling and EV charging stations infrastructure along I-94. To identify these gaps, 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.

Figure I.1-1. Infrastructure gap analysis and station locations. Note: Red ovals denote major gaps in fueling infrastructure on I-94

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 (see 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 so that identified gaps are addressed.

At the initiation of the project, GTI had secured industrial partners committed to support the deployment of electric charging, CNG and propane fueling infrastructure, as well as new CNG long haul trucks that would traverse the I-94 corridor. Over the course of the past four years, some of these partners withdrew from the project for business reasons. This forced GTI and the Clean Cities coordinators to identify and secure commitments from new infrastructure and CNG truck deployment partners. The following discussion identifies the project's current deployment partners along with progress achieved in FY 2021:

EV Fast Charging Station Deployment

To date, EV charging station partner, ZEF Energy, has installed and commissioned seven DC fast charging stations along the I-94 corridor, and has four additional stations under construction with commissioning planned by 1Q 2022, with one remaining site with target completion in 2Q 2022. Table I.1.1 is a reporting of the number of vehicles using the seven commissioned ZEF charging stations (located in Tomah and Hudson, WI; St. Cloud, Alexandria, Fergus Falls and Moorhead, MN; and Dickinson, ND) along with kilowatt hours supplied. Some of the station locations include both DC fast chargers and Level 2 chargers. The Level 2 option was funded by others outside of this project.

Table I.1.1. ZEF Charging Stations Tracking Report: January - June 2021

kW-hr supplied		1/2021	2/2021	3/2021	4/2021	5/2021	6/2021
1	Moorhead DCFC	1050	850	450	450	450	450
2	Moorhead Level 2	40	15	231	229	210	242
3	Fergus Falls DCFC	401	429	578	503	578	1205
4	Alexandria CCS/CHAdeMO DCFC	48	232	529	519	318	106
5	Alexandria L2	7	10	7	2	2	8
6	Saint Cloud CCS/CHAdeMO DCFC	3565	390	522	598	429	469
7	Hudson CCS/CHAdeMO DCFC	455	485	72	200	237	267
8	Hudson L2	137	114	129	131	414	576
9	Eau Claire*						
10	Tomah	600	840	960	1320	1200	1800
Vehicle Count							
1	Moorhead DCFC	36	28	2	1	0	0
2	Moorhead Level 2	9	4	30	51	34	23
3	Fergus Falls DCFC	20	27	41	33	41	60
4	Alexandria DCFC	5	14	36	29	21	62
5	Alexandria L2	2	1	4	4	9	11
6	St. Cloud DCFC	216	59	37	45	45	93
7	Hudson DCFC	25	43	13	14	24	17
8	Hudson L2	9	9	21	22	28	31
9	Eau Claire*						
10	Tomah	8	13	20	40	33	67

* Project civil and electrical are completed. Project is awaiting a code review scheduled July 2021

From the data provided in Table I.1.1, one can see that the use of the chargers varies among stations and by month. On June 30, 2021, the Eau Claire station was not fully connected to the ZEF monitoring system, so there was no data available. The charger at Moorhead was damaged by a vehicle, and usage was impacted because of spare part unavailability due to the global component shortage. Following delivery of a new power supply at this station in July 2021, we understand that usage has improved. GTI and ZEF continue to evaluate the usage data and will attempt to better understand factors that might be influencing the values reported. ZEF provided this photo of the charging station recently commissioned in Dickinson, ND (Figure I.1-2).

Figure I.1-2. ZEF DC fast charger at Dickinson, ND

While Ozinga Energy has primarily supported deployment of CNG fueling station infrastructure, they more recently began installing EV public charging stations, as well. When the CNG station in New Buffalo, MI was constructed, the city requested and supported the installation of a public EV charging station, shown in Figure I.1-3.

Figure I.1-1. EV charging station installed and commissioned by Ozinga Energy at New Buffalo, Michigan

GTI executed a contract with Blink Charging to purchase, deploy, install, commission, operate, maintain, and manage three networked DC fast chargers located in the following cities/states: 1) Fargo, ND, 2) Rothsay, MN and 3) Mauston, WI. For each of the three proposed locations Blink has specified the installation of two Tritium Veefil RT 75kW dual port DC fast chargers with simultaneous charging capabilities. Blink shall provide a configuration of two parking spaces designated for EV parking only for each of the two DC fast chargers. This allows for two electric vehicles to charge simultaneously at each DC fast charger. With site host consent the configuration of chargers and footprint can be expanded as needed.

GTI also executed a contract with Energy Hunters, LLC to purchase, deploy, install, commission, operate, maintain, and manage three networked DC fast chargers located in the following cities/states: 1) Ashby, MN 2) Barnesville, MN and 3) Jamestown, ND. For each of the three proposed locations, Energy Hunters will install two 100kW electric Charger Power Units. Each Charger Power Unit will feature two charging ports that provide universal compatibility with all EVs and open-source software. Each of the three sites will have the capability of charging four EVs at the same time. Furthermore, each station installation will include a solar collector roof panel to augment grid supplied electricity and minimize the station's impact on the local and regional grid. Energy Hunters will provide a configuration of two parking spaces per charger designated for EV parking only. This allows for two electric vehicles to charge simultaneously at each charger. With site host consent the configuration of chargers and footprint can be expanded, as needed.

Propane Station Deployment

As shown in Figure I.1-4, ALCIVIA (formerly Landmark Services Cooperative) completed construction of a new public propane fueling station at Cottage Grove, WI. ALCIVIA will fuel its propane vehicles at this station and is prospecting for additional fleets in the area that could fuel here. They are also working with Wisconsin Clean Cities to modify Wisconsin state law to make public fueling at propane stations more convenient.

Figure I.1-4. ALCIVIA propane fueling station

CNG Truck Deployment

The project began CNG truck deployment with Contract Transport Services (CTS) out of Green Bay, WI. Established in 1985, CTS is a leader in providing dedicated and Midwest regional transportation services to many Midwest Fortune 500 companies. CTS travels the I-94 corridor on a daily basis, hauling freight to Chicago. With support from the project, CTS deployed 30 new CNG trucks. These new trucks are Kenworth Model T680. Of their 68 trucks, 61 are currently natural gas-powered. To date, the CTS trucks deployed under this project have traveled well over 15,000,000 cumulative miles and used over 3,000,000 gasoline gallon equivalents (GGE) of CNG.

Veriha Trucking received grant support to purchase an additional ten CNG trucks to add to its existing 39 trucks. This increase in the "anchor fleet" is critical to growing and sustaining an Alternative Fuel Corridor along I-94. Veriha's CNG fleet travels through most of the I-94 corridor states. Through 2021, the 10 trucks deployed by Veriha (with grant funding support) have accumulated over 800,000 miles along the corridor and have displaced almost 156,000 GGE.

In January 2021, Time Transport Inc. requested project support to purchase an additional 8 new CNG trucks. Time Transport, Inc. is headquartered in Franksville, Wisconsin, directly along the I-94 corridor. They made their first 12 compressed natural gas-powered vehicle purchases in 2013. Now, nearly 90 percent of Time Transport's fleet is powered by compressed natural gas (60 out of 67 units). The majority of their operation is along the I-94 corridor. Time Transport is reviewing a draft contract agreement and DOE has allocated and approved funds for the purchase of these 8 new 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. With M2M Project support, Chicago Area Clean Cities commissioned a study titled "Alternative Fuel Corridor Readiness Study for Northeastern Illinois". The objectives of this study were to map the current locations and usage patterns of petroleum alternatives, evaluate criteria for siting, and communicate the factors that lead to successful refueling station installations – including both construction and market-based factors. The study concentrated on the main transportation corridors in the Chicago Area Clean Cities region (Cook, DuPage, Kane, Lake, McHenry, and Will counties in Illinois). Alternative fuels include CNG, liquefied natural gas (LNG), propane, 20% biodiesel/80% diesel blends (B20), 85% ethanol/ 15% gasoline blends (E85), electricity, and hydrogen (H2). The report can be accessed at: https://chicagocleancities.org/alternative-fuel-corridors-study/.

Outreach and Coordination

New alternative fuel stations have been promoted via targeted "grand opening" events and marketing campaigns developed by project partners and Clean Cities coordinators for their respective locations. Partners and new station site operators also promote the program through internal communications. Project partners are encouraged to provide quality information by using alternative fuel vehicle market experts to deliver engaging presentations, to grow the I-94 Alternative Fuel Corridor. Project partners can utilize DOE tools such as calculators, interactive maps, and data searches, which will assist fleets, fuel providers, and other transportation decision makers in their efforts to reduce petroleum use.

Several studies have shown that until fleet managers and the general public experience a vehicle and fuel themselves, they will hesitate on the decision to use these cleaner burning fuels and are more likely to believe popular myths and misconceptions. By filling in the gaps along the I-94 Alternative Fuel Corridor with natural gas, propane and electric vehicle infrastructure, new fleets will have an opportunity to meet with local fleets currently using alternative fuels.

Partners in the M2M Project are also working to develop new educational and marketing materials and graphics for the I-94 corridor and develop multimedia promotions to advertise the new stations and promote driver visits. An excellent example of this effort is the video found at: https://www.motorweek.org/features/auto_world%20/national-alternative-fuel-corridor-michigan-to-montana

M2M Flyers – Each of the M2M Clean Cities coordinators has developed state-level flyers. The first page of the flyer includes general information about the I-94 corridor and the M2M Project. The second page provides a state-level 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 that assist in searches regarding project partners, progress, events, and available resources.

Events- Provided below is a listing of M2M Project Team sponsored and led workshops and webinars that have been conducted during FY 2021:

- Webinar: Clean Fuels Corridor Project Stretches 1,500 Miles Along I-94; Webinar to Showcase Successes, October 26, 2020: https://chicagocleancities.org/clean-fuels-corridor-project-stretches-1500-miles-along-i-94-webinar-to-showcase-successes/
- Webinar: Michigan to Montana Alternative Fuel & EV Corridor Project, November 10, 2020: https://chicagocleancities.org/event/webinar-michigan-to-montana-alternative-fuel-ev-corridor-project/
- Webinar: Propane Autogas Answers Webinar, February 10, 2021: https://chicagocleancities.org/event/propane-autogas-answers-webinar/
- Webinar: Powering Vehicles with Compressed Natural Gas, April 8, 2021: https://chicagocleancities.org/event/webinar-powering-vehicles-with-compressed-natural-gas/
- Webinar: Intro to Renewable Fuels Webinar, August 6, 2021: https://chicagocleancities.org/event/intro-to-renewable-fuels-webinar/

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

Social Media – Interns at several Clean Cities partners collaborated on social media messaging communications related to the M2M project. They launched these communications on Facebook and Twitter. For each of the monthly Coordination Conference Calls, the team reviews important metrics regarding Facebook and Twitter followers, posts, and impression. By the end of September 2021, there were 63 followers on Facebook with an average post reach of 24 and 88 followers on Twitter with 568 impressions.

Conclusions

The M2M Corridor Project remains on track to accomplish all of its goals and objectives within the planned budget. Unfortunately, a number of factors have impacted the project schedule in FY 2021 resulting in the need to request a project extension. Every effort is being made to limit overall project schedule slippage as the team expands to complete infrastructure deployment efforts. While most of the planned live outreach efforts by the team members from the Clean Cities coalitions continued to be "virtual" in FY 2021, the results are impressive and are paving the way to establishing a sustainable alternative fuels corridor along I-94.

Acknowledgements

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I.2 Collaborative Approaches to Foster Energy-Efficient Logistics in the Albany - New York City Corridor (Rensselaer Polytechnic Institute)

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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 achieve EEL.

Objectives

Reaching this goal will require achieving several objectives: First, 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 EEL. Second, broaden the focus when assessing energy scenarios, to consider both demand and supply, and the roles played by all participants in supply chains. Third, exploit the synergies and mutually reinforcing effects among EEL initiatives. Fourth, 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. Fifth, 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 to EEL; (2) identify ways to overcome those barriers; and (3) demonstrate the real-life benefits of EEL initiatives to stakeholders.

The project consists of four major thrusts. During 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. During thrust 2 the team will develop tools and algorithms to assess the initiatives and develop an energy management guidebook. For thrust 3 the team will assess the impacts of collaborative measures on initiative adoption, assess the initiatives' effectiveness, and design pilot tests. Lastly, for thrust 4 the team will conduct and assess the pilot tests. All thrusts are going to be completed throughout the duration of the project.

The practical impossibility of collecting fine resolution global positioning system (GPS) data during the COVID-19 pandemic had a number of impacts. Most notably, it prevented George Mason University (GMU) from developing truck-specific procedures to estimate the second-by-second speed profiles needed by AUTONOMIE to estimate fuel consumption. As an alternative, GMU tried to develop procedures to estimate the speed profiles using average speeds estimated by RPI using GPS archival data. Recently, GMU informed RPI that the development of these procedures was not successful. RPI, GMU, and ANL are setting a meeting to discuss options. In this context, a decentralized Integrated Transport Energy Model—instead of a single piece of software, the various pieces of software will be run separately, with a set of procedures that enable the user to run the BMS-EEL to prepare the inputs for AUTONOMIE—seems to be the most practical option.

Results

During the past year, the team worked on the development of simulation tools to model supply chains. In parallel, the team also developed computational systems and algorithms to characterize baseline conditions in terms of supply chain practices and energy use in the Albany - New York City Corridor. The team also worked on behavioral research by surveying households and establishments to assess the effectiveness of possible initiatives that would increase EEL. Lastly, the team has been engaging the private and public sectors for the development of potential pilot tests for the project.

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 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.

During the last year, the team worked on the BMS-B2C module that simulates ecommerce delivery tours to households. This module is necessary to account for the freight activity associated with deliveries of internet purchases to households, since the current BMS-EEL code only considers freight flows between commercial establishments (BMS-B2B module). The BMS-B2C module has dedicated code due to the different dynamics of household deliveries. Therefore, the final outcome of this task consists of two simulations, one dedicated to freight deliveries to commercial establishments (BMS-B2B) and the other dedicated to household deliveries (BMS-B2C).

The development of the BMS-B2C module took the previous year, and it had the following sections: (1) split the demand according to market shares and companies; (2) Construct tours for each company; (3) assign delivery areas to Distribution Centers (DCs); (4) optimize to output the sequence of traffic analysis zones (TAZs). Each section and the entire module were rigorously tested, obtaining satisfactory results.

Section1: Split the demand according to market shares and companies: The BMS-B2C module models tours taking into consideration that carriers have dedicated vehicles that serve different market segments. This module of the BMS-B2C takes the total demand of household deliveries by TAZ, and market shares percentages for each carrier company, and it splits the demand of each TAZ according to company and market segment.

Section 2: Construct tours for each company: The second section of the code constructs the tours performed by each company to fulfill all deliveries. To mimic the logic that carriers use to construct their tours, this section uses a districting algorithm. The districting or clustering consists of dividing the territory into areas that are going to be served by a single vehicle. The purpose of the clustering is to create the delivery tours of each carrier by grouping deliveries into TAZs within the study area with three main goals in mind: (1) Demand of each TAZ must be met. (2) The truck's tour cannot exceed its maximum tour time. (3) If a truck serves multiple TAZs, these serviced TAZs must be adjacent, to create a compact service area for each truck.

Section 3: Assign delivery areas to DCs: In this section, the origin DC of each simulated tour is selected based on the proximity of the DCs to the delivery area of the tour. This section is used only when one company has multiple DCs to serve the study area. When a company has only one DC, that DC serves the entire area.

Section 4: Optimize to output the sequence of TAZs: The last section consists of the optimization routines to determine the order in which each tour visits its TAZs. The optimization routines are the same ones used in the BMS-B2B module: 2-opt and 3-opt algorithms.

The team started working on the input-data preparation for the assessment of initiatives and policy measures with a study case in the Albany metropolitan area. Three major tasks were carried out for this purpose. First, the team used the results from the baseline conditions to produce travel times and speeds. Second, the team investigated the carriers, markets shares, market segments, and distribution centers in the study area. Third, the team used the results from the household surveys together with population data from the capital district at the finest level (CDTC Zones), to estimate the household deliveries.

During the last year the team also built a test case of the City of Troy, New York with establishment-level data to further test the BMS-B2B module. The objective of this new test case was to check the results produced for a smaller and more disaggregated case. The City of Troy was chosen due to the familiarity of the team with the area. Establishment level data were used to estimate freight trips produced and attracted in the study area using FTG models developed as a part of the National Cooperative Freight Research Program 25 report. [2]

Baseline Conditions

This section presents the results of the estimation of baseline conditions for the Albany-NYC corridor. The main objective of this task is to use archival GPS data to produce a quantitative analysis about the current patterns of energy use, emissions, and costs associated with freight activity in the area. The team worked on a geographical analysis to identify hot spots of emissions in the NYC-Albany Corridor, and opportunities to apply EEL initiatives. The main challenge of this task is the large size of the data, which totals around 500GB of CSV files, and therefore surpasses the capacity of any Geographical Information System (GIS) software available on the market. To overcome this challenge, the team created a custom code that aggregates the GPS data points into a raster with cells of 500 by 500 meters. This way the geographical analysis can be conducted with a precision of 500m, or approximately 0.31 mi. Considering that the Albany-New York City Corridor covers an area of approximately 4,900 sq. mi., the raster provides an adequate precision for a geographical analysis of the entire area. In addition to spatial analysis, the rasters also allow for a temporal analysis as the GPS data points can be aggregated not just based on location but on time periods as well. The team produced 24 rasters accounting for 24 hours of a typical business day to analyze how traffic patterns changed through the course of a day.

Figure I.2.1 shows an example of the raster created for a typical business day in the New York City area; on the left it shows average travel speeds, and on the right, fuel consumption rates. Manhattan is a hot spot of congestion, and for that reason fuel consumption rates are higher in that region.

Through the spatial-temporal analysis, the team identified a strong opportunity to apply demand management strategies in the Port Newark-Elizabeth Marine Terminal, NJ. The port is a large traffic generator and the analysis showed that the area around it is a hot spot of congestion. Currently, the port working hours are from 6:00 AM to 6:00 PM, which coincides with the peak of traffic congestion in the area. The team used the archival GPS dataset to estimate possible savings in fuel consumption and pollutant (CO_2, CO, NOX, ROG, TOG, $PM_{2.5}$, PM_{10}) emissions if the port shifted or extended its work hours 3 hours before and after the current period, to allow delivery/pick-up vehicles to access the terminal at alternative hours with less traffic congestion. Results show that vehicles traveling to the port at an earlier hour could reduce emissions rates by up to 12%. This shift in time of travel would not only provide social benefits with the reduction of emissions but also provide vehicle operational cost savings of up to 23% in terms of cost per unit distance traveled. Similar benefits would be achieved with vehicles traveling to the port after their current working hours;

however, emissions are expected to be reduced by 3.8% on average, a lower reduction than in the morning period prior to the current working hours.

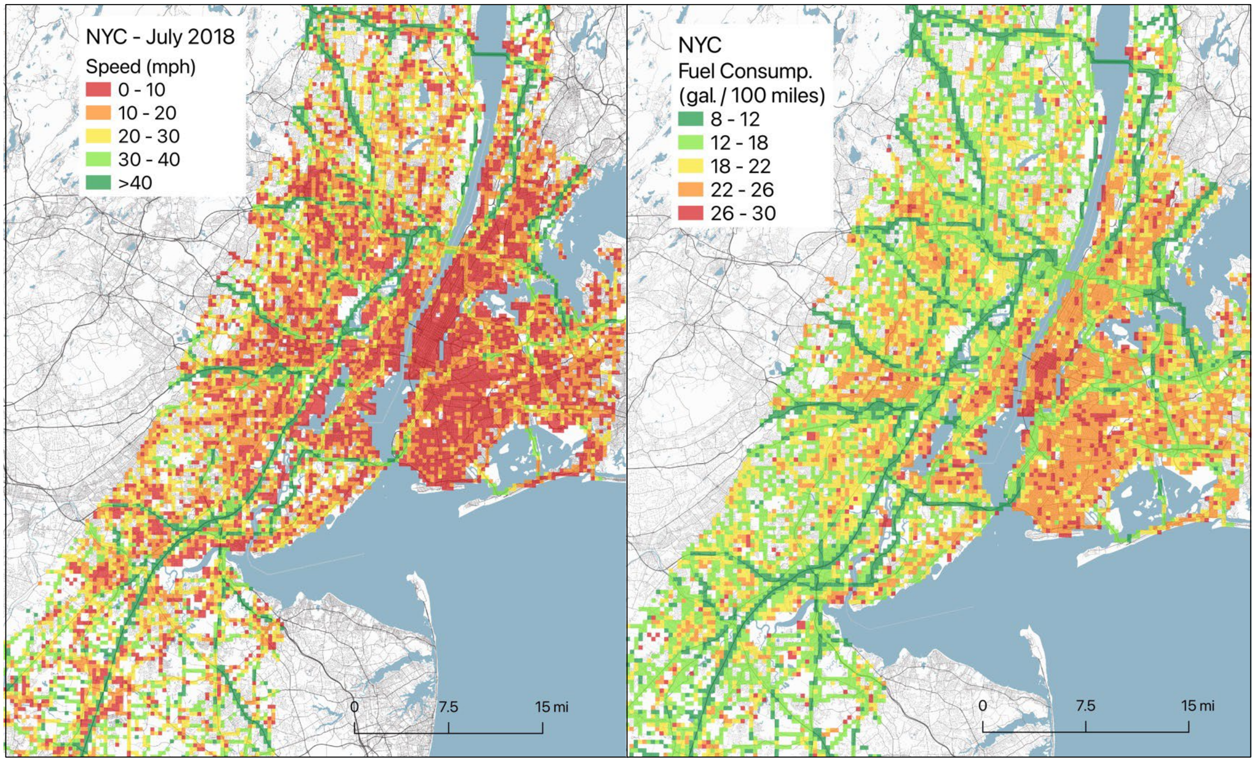

Figure I.2-1. Average travel speeds and fuel consumption in the New York City area

To complement the analysis of inbound trips to the Port Newark-Elizabeth Marine Terminal, the team aggregated the trips by origin and by time of arrival at the port; eleven areas were identified as main origins of trips with the port as destination. Figure Figure I.2-1 shows the percent reduction of CO_2 across the day with respect to the hour of the day with maximum emissions for each origin. For prompt visual assessment, the percentage reductions are color coded from red to green; red is 0% reduction, meaning the hour of the day with maximum emissions, and the hours of the day with higher percentage reductions in comparison to the hour with maximum emissions are darker green. The results show that the largest reductions occur in the areas closer to the port, such as the cities of Elizabeth, Newark, and Bayonne, which during port working hours (6:00 AM to 6:00 PM) could reduce emissions by 36%. Note the vehicles coming from Elizabeth, NJ, and arriving at the port at 2:00 PM. This result supports staggering deliveries/pickups at the port to reduce energy consumption and emissions. In addition, the results confirm that reductions in emissions, and consequently in fuel consumption, can be achieved if vehicles could arrive at the port earlier (before 6:00 AM) or later (after 6:00 PM) than the current working hours, regardless of their origin. See Figure I.2-2.

Arrival Time at the Port	Elizabeth NJ	Newark NJ	Bayonne	Carteret NJ	I-280	West of Hudson	I-287	East of Hudson	I-78	I-95 South	NY North	Average
Midnight		-22%		-30%					-24%	-11%		-24%
1AM		-30%						-30%	-28%			-28%
2AM	-39%	-23%		-29%			-25%	-30%	-33%	-9%		-27%
3AM		-20%		-32%		-21%			-25%	-12%		-25%
4AM		-10%		-31%					-16%	-7%	0%	-22%
5AM	0%	-19%		-18%				-30%	-25%	-10%		-13%
6AM	-20%	-6%		-12%		-19%			-26%	-8%		-5%
7AM	-18%	-13%	0%	-9%	-24%	-24%	-18%	-20%	-26%	-9%		-1%
8AM	-16%	-19%	-4%	0%		-20%	-18%	-14%	-26%	-6%	-5%	-5%
9AM	-22%	-26%	-5%	-14%		-16%	-17%	-19%	-21%	-5%	-9%	-13%
10AM	-31%	-18%	-11%	-9%	-9%	-21%	-19%	-15%	-16%	-4%	-7%	-12%
11AM	-37%	-15%	-24%	-11%	-17%	-25%	-12%	-25%	-22%	-5%	-6%	-11%
Noon	-29%	-16%	-19%	-6%		-26%	-12%	-27%	-24%	-1%	-4%	-7%
1PM	-31%	-23%	-5%	-16%	-16%	-24%	-14%	-16%	-23%	-5%	0%	-9%
2PM	-36%	-20%	-14%	-17%		-21%	-18%	-14%	-23%	-4%	-4%	-12%
3PM	-34%	-10%	-17%	-17%	-17%	-15%	-16%	-14%	-21%	-1%	-3%	-6%
4PM	-33%	0%	-5%	-14%	0%	0%	0%		-20%	-4%		-7%
5PM	-31%	-18%	-13%	-21%	-10%		-15%	0%	-17%	-11%		-9%
6PM	-29%	0%		-21%		-6%		-11%	0%	0%		0%
7PM	-22%	-18%		-25%					-22%	-10%		-17%
8PM	-21%	-25%		-31%					-27%	-3%		-16%
9PM		-33%		-27%	-21%	-29%		-21%	-30%	-7%		-27%
10PM		-17%		-17%	-11%		-25%	-22%	-31%	-8%		-24%
11PM	-50%	-38%								-6%		-28%
Average	-31%	-17%	-14%	-12%	-14%	-21%	-15%	-18%	-22%	-5%	-5%	-10%

Figure I.2-2. CO_2 percent reduction of trips going to the Port Newark-Elizabeth Marine Terminal with respect to the maximum emission hour, by time of origin of the trip

Behavioral Modeling: Internet Surveys

In late January 2021, the project team conducted the second round of the household survey. The central goal of the survey was to ascertain how Americans shop online and the factors influencing this activity. The COVID-19 pandemic had been ongoing for approximately 10 months at the time of survey administration, with the study area hit particularly hard, and the team wanted to learn how consumers had changed their online shopping patterns due to the pandemic, as well as how people expect to shop online going forward. A parallel goal was to assess the willingness of consumers to utilize environmentally friendly delivery strategies that were found to be popular in the first round of the household survey, conducted in Summer 2019. The assessed strategies were delivery lockers, delivery consolidation, and eco-friendly delivery methods.

With this survey, the team collected 500 responses from throughout the United States, with stratification to ensure an even demographic distribution. Respondents tended to be younger and better educated than the general population, while ethnic and racial minorities were underrepresented. To account for these discrepancies, sampling weights were used to assign a higher weight to underrepresented demographics. Among all types of goods, respondents greatly increased their online shopping during the COVID-19 pandemic. In all categories, respondents expect to receive fewer deliveries once the pandemic is over, but in no category did the respondents expect deliveries to fall to pre-pandemic levels, with post-pandemic expectations twice the pre-pandemic level in some cases.

To assess the innovative delivery strategies, the survey presented a series of stated preference scenarios to respondents. Each respondent was presented with a set of six scenarios (three delivery locker, two delivery consolidation, one eco-friendly delivery) and asked to rate their likelihood of using the strategy under the given conditions on a scale of 1 (very unlikely) to 5 (very likely). Generally, respondents were more willing to use delivery lockers if a higher cost savings was provided and the locker was close to home. For consolidation, a higher cost savings was linked to higher acceptance. For eco-friendly delivery, respondents were unwilling to pay extra to have their items delivered in an eco-friendly manner.

Once data was collected, the team generated models to estimate number of home deliveries and acceptance of various home delivery initiatives. For home deliveries, negative binomial regressions were used to estimate deliveries before and during the COVID-19 pandemic using respondents' stated home delivery frequencies. There was also a third set of estimates which predicted post-pandemic home deliveries, using respondents' predictions for how often they would shop online after the pandemic. These models considered a respondent's age, race, education level, employment status, and income, as well as the median household income in their ZIP Code of residence. Models for acceptance of alternative delivery strategies were ordered choice regressions predicting one's likelihood of using each strategy on a scale of 1 (very unlikely) to 5 (very likely).

Behavioral Modeling: Receivers Surveys

Collection of data from surveys of commercial establishments is critical to gain insights about the acceptance of energy-efficient initiatives. The original plan was to implement surveys during 2020. However, the COVID-19 pandemic created an unprecedented scenario of uncertainty, in which behavioral data collection was inadvisable. During the last year, with the extensive rollout of vaccines, the economy has begun to normalize. During this time, the team finalized the survey for establishments, focusing on how they would react to the implementation of EEL initiatives, updating the original survey to include questions regarding the impacts of COVID-19. The questionnaire is divided in two sections. The first part is a revealed preference survey in which operational characteristics are asked (e.g., number of stops, average tour length or load factors). The second part is a stated preference survey which focuses on assessing the willingness to participate in EEL initiatives. The Rensselaer Institutional Review Board (IRB) approved the receivers' survey questionnaire. Once the questionnaire was approved the team got access to the Qualtrics software where the survey was implemented. The questionnaire was quickly implemented, and pilot tested by several members of the industry advisory group, obtaining positive feedback.

During the last year the team finalized the sampling framework of the survey. The sample is focused mainly on the Freight Intensive Sectors (FIS) of the economy. These types of industry sectors are *industry sectors for which the production and consumption of freight is an indispensable component of the economic activities* [1]. The decision to inquire specifically in these industry sectors was driven by the fact that most establishments that receive commercial deliveries belong to these industry sectors. Hence, it is critical to shed light on the demand management initiatives that could induce behavior changes in their supply chain. Once the sampling framework was finished, the team started working on the distribution plan for the survey. The team selected a dual approach in which postcards and letters were either mailed or handed personally to the establishments. The motivation for this dual approach came after meeting with two Business Improvement Districts (BIDs) of New York City i.e., Grand Central Partnership BID and the SOHO BID. The team received approval from New York City DOT and the Capital District Transportation Committee (CDTC) to use their logos on the postcard to increase the likelihood of the responses. The team obtained addresses of possible establishments from a major data provider company. Using these addresses, the team delivered over 370 postcards to establishments in the cities of Cohoes, Troy, Latham, Schenectady and Colonie. The selected locations where postcards were delivered have in common that they are clusters of establishments e.g., main streets, commercial malls, or plazas. Future locations to deliver postcards include Albany, Clifton Park, Saratoga Springs, and Amsterdam. In addition, the team has been working closely with the Business Improvement District (BID) of SOHO in New York City to carry out a joint data collection effort using an in-person survey to commercial establishments in the SOHO area.

Pilot Tests

The team has been working this past year on scheduling several pilot tests in collaboration with the private sector. The objective of these pilots is to test the most promising EEL initiatives. The motivations to do a pilot test are to: (1) provide real-life experiences of EEL initiatives to the stakeholders involved, (2) help identify the potential issues the initiative could have, before a full-scale implementation, (3) gain new insights that are only possible when implemented in real life, and (4) attract attention and support from the stakeholders in doing a full-scale implementation of EEL initiatives.

The pilot tests would take place within the study area—the NYC metro area, the Albany, NY region, and the 150-mile freight corridor that connects them. In some other cases pilot tests outside of the study area might be considered as long as the results are transferable to the study area. The proposed pilot tests are intended to assess the performance of EEL that reduce emissions, congestion, vehicles miles traveled, and delivery times. Some of the pilot tests may focus on consolidating deliveries or shifting delivery times and/or locations to ensure carriers can deliver the goods during less congested times, i.e., off-hours, or deliver the goods to locations that can reduce the number of last mile deliveries to residential areas by using delivery lockers and/or workplace deliveries. Other proposed pilot tests may help achieve energy efficiency by improving the loading/unloading process of delivery trucks through targeting the parking spaces segregation to improve their turnover rates.

The team is in conversations with multiple partners to identify possible pilot tests to conduct as part of this project. Some potential pilot tests include:

- Assessing alternatives for consolidation of cargo in or near ports of entry. This case study aims to reach logistical efficiency by reducing the number of vehicle trips between the ports and the final destinations.
- Collecting data and performing analysis to assess the impact on tandem trailer operations of the recent switch of NYS Thruway Authority to cashless tolling and the reconfiguration of many of the tandem trailer staging areas along the NYS Thruway. Tandem trailer operations are more economical and environmentally friendly since they require only one power unit to pull two trailers when operating long distances; hence, the need to assess the impacts of this switch.
- Evaluating the introduction of electric trucks within truck rental fleets, to be used by companies that contract out for their last mile delivery. In this possible pilot test case a well-recognized retailer is leading an effort to subsidize the rental company when the trucks are not being rented. If this pilot test is chosen the team will document the lessons learned from this novel approach to foster energy efficient deliveries.
- Evaluating a series of demand management strategies, e.g., off-hour deliveries, delivery consolidation and scheduled delivery slots, to improve the impacts of deliveries in facilities that attract a large number of daily truck trips.
- Evaluating electric class 8 trucks in the urban delivery environment.
- Assessing impacts of several sustainable urban freight initiatives: 1) reducing double parking on narrow residential streets by providing space at the curb for truck delivery activities and taxi and car service pick-up and drop-off, 2) designing green loading zones, 3) segregating parking spaces for service and freight vehicles.

During the next year, the team will continue working with the public and private sectors to pursue the different pilot tests.

Conclusions

Even though the project team encountered major setbacks due to the financial impacts generated by the COVID-19 crisis, the team has made substantial progress on the project and has advanced in multiple tasks. The team tested the module of the BMS-B2B that models freight tours among commercial establishments, and drafted the module of the BMS-B2C that simulates e-commerce delivery tours to households. The team created rasters with cells of 500 by 500 meters for the Albany-NYC corridor by time of day. Using these rasters, the team estimated the average speed and fuel consumption rates throughout the whole day within the study area. The results suggested that by shifting/extending port operation hours there could be a reduction in emissions of up to 36%. Hence, there is a major opportunity for possible savings in fuel consumption and reduction in pollutant emissions by shifting/extending port operating hours.

As for behavioral modeling, the team has collected 500 responses from household surveys and has been analyzing the results in the last year. The data were used to generate models to estimate both home deliveries and acceptance of home delivery initiatives that can promote energy efficiency. The team tested three different demand management initiatives. Respondents mentioned that they were more willing to use delivery lockers if a higher cost savings was provided and the locker was close to home. A higher cost savings for consolidation was also linked to higher acceptance. Lastly, for eco-friendly deliveries, respondents mentioned that they would be unwilling to pay extra to have their items delivered in an eco-friendly manner.

For the receivers' surveys, the team finalized the survey questionnaire and started implementing it by distributing 370 postcards in the capital region. The team has started discussions about collaborating with potential partners in both public and private sectors on pilot tests to assess the impacts of various energy-efficient initiatives.

Summarizing the efforts done last year:

- Finalized households' surveys and estimated models.
- Currently implementing receivers' survey in both the Capital Region and NYC.
- Finished rasters of baseline conditions by time of day, which can be used for analysis of different initiatives. It has been tested on shifting/extending New Jersey port operating hours.
- Finished BMS-B2B and tested it on multiple cases in Albany and Troy.
- Finished BMS-B2C; currently being tested. it would be used to test the scenarios obtained from the households' surveys models.

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I.3 Southeast Alternative Fuel Deployment Partnership (Center for Transportation and the Environment)

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Start Date: October 1, 2017 End Date: March 31, 2022
Total Project Cost: $10,881,211 DOE Share: $4,621,781 Non-DOE Share: $6,259,430

Project Introduction

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

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 this often 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. Funding from 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 will 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
- Increase the size of the AFV market, increase volume of sales, add competition, and drive 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 (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 approximately 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 work with 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.
- 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) 2021, CTE conducted the following key activities towards the completion of this objective:

- Developed and issued a Request for Proposal (RFP) for deployment of battery-electric vehicles, charging infrastructure, compressed natural gas (CNG) vehicles, and CNG infrastructure in Alabama, Georgia, and South Carolina. The RFP was issued due to additional funding available when other SEAFDP project partners were unable to carry out their original scopes of work. CTE received four (4) proposals and selected Waste Management for the full funding amount during 1Q21.
- Continued Key Performance Indicator (KPI) reporting, which estimates fuel economy, fueling requirements, and emissions reductions for each partner. This information helps project partners conceptualize the impacts of each vehicle and infrastructure deployment. Figure I.3-1 represents the overall fuel and tailpipe emissions reductions from April 1, 2019 through September 30, 2021.
- Conducted site visits to confirm delivery and deployment of 221 alternative fuel vehicles, as outlined in Table I.3.1.

Figure I.3-1. Overall fuel and tailpipe emissions to date

Table I.3.1. Fleet Partner Vehicles – Revised

SEAFDP Partner	Expected # of Vehicles	Vehicles Delivered to Date	Percentage of Vehicle Share Delivered	Percentage of Project Total Vehicle Share	Completion Date
City of Atlanta	6	6	100%	2.5%	N/A
DeKalb County	32	32	100%	13.5%	4Q19
McAbee Trucking	0	0	0%	0%	N/A
UPS	150	150	100%	63%	3Q19
Waste Management – Hardeeville, SC	25	25	100%	10.5%	1Q21
Waste Management – AL, GA, SC	25	8	32%	10.5%	4Q21
SEAFDP Project Total	**238**	**221**	**93%**	**100%**	**1Q22**

- 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

City of Atlanta

The City of Atlanta took delivery of two (2) CNG refuse trucks, three (3) Nissan LEAFs, and one (1) Chevrolet Bolt before dropping out of the project. 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 were utilized in the replacement RFP issued by CTE.

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

McAbee trucking was unable to meet the required provisions of this grant related to the purchase of 4 CNG trucks. The reason for this dropout was due to the partner's lack of participation and provision of required documentation. McAbee Trucking delivered vehicle quotes to CTE during the procurement phase of the project but subsequently failed to send proofs of purchase and vehicle data. CTE made many attempts to reconcile the situation and to understand the reason for the failure to submit required information, however, no correspondence was received. As a result, CTE issued a project closeout letter to McAbee Trucking in August 2021 due to its lack of response and effort to process the reimbursement.

UPS

UPS has received all 20 Workhorse PHEVs and all 130 Ford CNG delivery trucks. CTE continued to collect operational data from UPS to support a 12-month KPI study. The original scope included KPI reporting for an additional 10 all-electric Workhorse trucks. Due to internal restructuring, UPS elected not to take delivery of these all-electric trucks during the reporting period and CTE was no longer able to include them in the 12-month KPI reporting period.

Waste Management – Hardeeville, South Carolina

To date, Waste Management has taken delivery of the following CNG-fueled vehicles: seven (7) roll-off refuse trucks, six (6) automated side loaders, ten (10) front-end loaders, and two (2) rear end loaders, in addition to the CNG refueling station. CTE and Waste Management continued collecting operational data to support a 12-month KPI study.

Waste Management – Birmingham, Alabama

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

Waste Management – Alabama, Georgia, South Carolina

In FY 2021, the project team selected Waste Management for the full funding amount available from the RFP issued by CTE, to significantly add to the CNG vocational trucks currently operating throughout the Southeastern U.S. The deployment of 25 vehicles resulting from this RFP began in April 2021 and is expected to be completed by November 2021. Upon deployment, CTE and Waste Management began to collect operational data to support a 12-month KPI study.

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 to 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
- Providing consultation for organizations as they enter the market.

The final scope of work, GIS mapping activity, and stakeholder surveys in the region are complete. During FY 2021, CTE continued work on a case study draft that includes the results from vehicle network surveys and feedback from project site deployments. The case study will also examine the benefits to disadvantaged communities resulting from the vehicles and infrastructure deployed in the region. The project team intends to finalize and publish the case study during the fourth quarter of 2021. Figure I.3-2 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 highway exit and signage data into the mapping to provide users with visibility around signage coverage, effectiveness, and gaps.

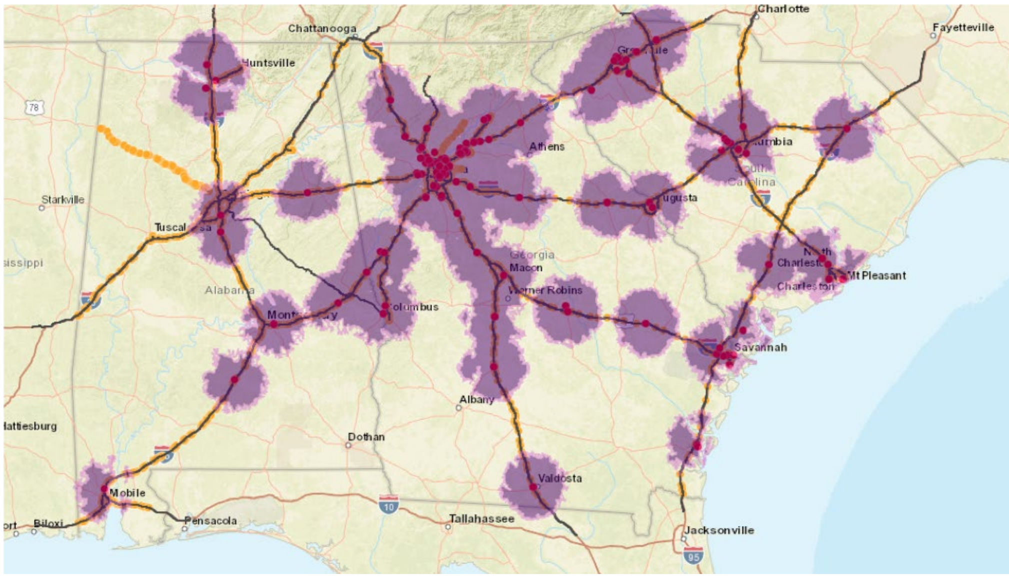

Figure I.3-2. EVSE drive-time area function

Preparation of Hydrogen Infrastructure Integration Study

CTE authored and published the hydrogen infrastructure integration study during FY 2021. This study examines the similarities and differences between CNG and hydrogen equipment and infrastructure, specifically as it pertains to the two Waste Management CNG locations in Birmingham, AL and Hardeeville, SC. This study focuses on the equipment and knowledge-based resources that can be built upon at existing CNG sites to support deployment of hydrogen infrastructure at the same or similar sites. The effort for this study began with a thorough analysis of previous works, research, and publications on the topic of comparing CNG equipment and infrastructure with hydrogen equipment and infrastructure. Over the course of three project quarters, CTE conducted interviews with subject-matter experts from academia, private, and public sectors to incorporate into the study. The publication was submitted to DOE for distribution during FY 2021.

Conclusions

The four-year project began on October 1, 2017, and after a six-month no-cost extension and an additional one-year time extension, it is currently scheduled for completion in March 2022. Most of the tasks in Year 1 were dedicated to contracting, project planning, and finalizing purchase orders for alternative fuel vehicles and associated infrastructure. Years 2 and 3 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, which have higher capital costs compared to diesel or gasoline equivalents. This is especially true for small- to medium-sized organizations and municipalities, where local funding may be scarce, and budgets are based on historic, conventional vehicle prices.

- 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 should be adjusted accordingly. 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. The project team recommends developing relationships with individuals from various levels and departments of the project partners early in the project to obtain everything needed throughout the project. This includes vehicle data, station and vehicle specifications, and operational profiles.

- To help streamline processes and increase the reliability of data, allocate proper funding and general planning to support the use of technology (e.g., telematics systems) in data collection and reporting activities. Additionally, the nature of the vehicles' fixed route profiles, or lack thereof, makes it difficult to track precisely where and how they operate and relate to performance metrics.
- Federal funding through the SEAFDP project was key to the deployment of two (2) CNG fueling stations and 221 CNG, hybrid-electric, and electric vehicles across Alabama, Georgia, and South Carolina. These vehicles and stations have reduced diesel consumption in the region by 391,650 gallons over the period from April 2019 to September 2021, which translates into a reduction of 3,987 tons of carbon dioxide emissions.
- For Clean Energy to proceed with the construction of a CNG station in Alabama, it required utilization commitments from regional fleets. Clean Energy never received sufficient commitments, which led to the closeout of its scope to construct a CNG station as part of this project. CTE proceeded to issue a new RFP to utilize this funding.
- CTE did not receive any proposals for battery-electric technology, indicating a lack of demand in the region. Despite low demand, given the federal incentives, CTE selected a new project partner, Waste Management, to demonstrate its commitment to CNG technology.
- CNG fleets reported difficulties in finding maintenance staff that are experienced and knowledgeable about CNG technology. Also, CNG operators have expressed their need for additional training support for the technology. Incentives and funding opportunities will drastically help offset the burden of finding and retaining maintenance staff that are equipped with supporting CNG technology.
- Allocating funding towards studying alternative methods to deploying new technologies will help entities determine how to adopt them in an innovative and strategic manner. There will be a high demand for hydrogen fueling in the coming years and CNG operators will need to explore ways to utilize the technology already in use.

Key Publications

Hanlin, Jason, Cory Shumaker, and Chase Stell. "Hydrogen Infrastructure Integration Study". 2021.

I.4 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; the Kansas City Public Library; the City of Olathe; and DS Bus Lines. DOE funding covers 45% of the incremental costs of purchasing alternative fuel vehicles, and 45% of total costs of purchase and installation of fueling 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 tracking and reporting 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 while navigating through it, and was able to adapt in many areas to meet the needs of the sub-recipients.

Grain Valley School District (GVSD): Grain Valley School District's (GVSD) construction project was completed in 2018, and they are now in the tracking and performance phase of the project. Leftover funding allowed for the addition of two new propane special needs lift buses in 2021, bringing the fleet to 23 propane buses out of 49 total buses. MEC published a Propane School Bus Fleet Case Study on the Grain Valley School District in late 2020, highlighting the district's real-world experiences integrating 21 propane buses into the fleet and discussing how they worked with Clean Cities throughout the entire process. Aside from continuing fuel and fleet tracking, this subproject is now essentially completed.

The City of Garden City, KS (GCKS) received and deployed two CNG garbage trucks with Cummins 8.9L engines in 2019 and two in 2020 with Cummins 11.9L engines. The city is now in the tracking and performance phase of the project. A goal of this project was to reduce the noise pollution of trash trucks running their routes. This goal has been accomplished by switching to CNG trucks, as they run quieter. Another benefit of CNG is avoiding diesel gelling in extreme cold. Garden City had hoped to save money by using CNG, but diesel prices have remained low (at least until mid-2021) so they are not seeing the savings they expected. One problem with the 2019 deployment is that they lack power and there are issues getting in and out of the landfill with the trucks when the ground is wet or snowy. For the 2020 trucks, they have gone with larger engines, and this seems to have solved the power problems at the landfill. Garden City reported that they did not experience this issue with diesel trucks. Another issue reported by the fleet is lower than expected miles per gallon for the CNG trucks. The fleet reported that they achieved their goal to reduce emissions but did not achieve their goal of financial savings.

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 airport installed direct current fast charger (DCFC) stations in the fourth quarter of 2017, deployed 3 CNG shuttles in the first quarter of 2019 and replaced other CNG vehicles with four EVs in the third quarter of 2020.

At the beginning of this project, KC Airport (KCI) was fielding a 100% CNG fleet of 33 shuttles and was planning a move to near 100% electric shuttles. The electric shuttles were significantly more expensive than the CNG shuttles, however, and KCI has since determined it wants to maintain about 50% CNG and is reducing its fleet size in line with an airport redesign. With that in mind, it ordered 4 additional CNG buses in Q4 2019. Due to the COVID-19 pandemic manufacturing delays, delivery was delayed until mid-2021. MEC also plans to work with the airport on a separate DOE-funded project to install telematics software on all EV buses, including units ordered under this project. KCI will install additional inductive charging EVSE outside the new parking garage, in front of the new terminal. This inductive charging EVSE is part of a different project but will be used by vehicles deployed under this project. KCI will be retrofitting the existing EV buses previously deployed under this project so that they can also use the new inductive charging, or wireless charging parking pads. The plan is for the shuttle buses to use the inductive charging while they are loading and unloading passengers.

The City of Kansas City, MO (KCMO) has completed deployment of all CNG and electric vehicles and infrastructure. The city deployed 16 new CNG trucks in 2019 and the remaining 7 CNG trucks in 2021. In 2020, KCMO deployed 10 electric sedans and charging infrastructure. The chargers and 7 of the sedans are assigned to Neighborhood and Housing Services. The first three sedans are operating at different locations and will continue to use wall outlets to charge when not in use. Two have been deployed to Water Services and one to General Services. All sedans are equipped with telematics software. Feedback from KCMO has been very positive so far. The electric sedans' range of 280 miles is high enough that the units can sufficiently charge for their duty cycle by plugging into a 110-volt outlet overnight and during the weekends. KCMO's drivers report that they appreciate the quieter engine, roomy interior, and electric display screen. The incremental cost of KCMO's CNG work trucks was higher than anticipated and as a result MEC worked with KCMO to authorize additional funding under this project. In Q2 2021, KCMO worked on a city ordinance to allow for additional funding and formally amended their contract with MEC. KCMO plans to invoice out their final purchases at the end of 2021, then continue tracking and reporting for the remainder of the grant project period.

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 in 2020. A small terminal on site feeds that station and provides truckloads of blended biodiesel fuel to other 24-7 Travel Store locations. 24/7 successfully supplied seven of their locations (N 9th Salina, West Crawford Salina, Russell, WaKeeney, Abilene, McPherson, and Maple Hill) with biodiesel blends during 2021. 24/7 has installed or plans to install DCFC at 4 locations (McPherson, Goodland, Colby, and Russell).

To support the DCFC development, a group of stakeholders led by the state Petroleum Marketers Association developed legislation that would allow third-party owners/managers of EV charging stations to charge customers on a kWh basis in the state of Kansas. MEC provided subject matter input as needed, but MEC's primary role is to advocate to the utility commission (Kansas Corporation Commission) and the utility ratepayer board (Citizens' Utility Ratepayer Board). This legislation was reintroduced when the new legislature reconvened in January 2021, and it was passed and signed by the governor.

Construction and deployment were completed at the McPherson DCFC site with 2 public 100kW stations installed in March 2021. See Figure 1.4.1. Each unit supports 1 car to charge at 100 KW (or the car's limitation) or 2 cars charging at 50 KW (or the cars' limitations). This is a major corridor between Wichita and Salina with multiple commuting populations in between. 24/7 held a ribbon-cutting ceremony in Q2 2021 with Kansas Department of Transportation (KDOT) and McPherson Chamber of Commerce participating in the event. Attendees included staff from U.S. Senator Marshall's office. In Q3 2021, 24/7 completed construction on the new Goodland, KS, store. There is now a 12,000-gallon biodiesel tank and inline blender to supply retail biodiesel blends, along with the chargers.

Throughout 2021, 24/7 continued to experience supply chain delays as a result of increased tariffs and supply shortages due to the COVID-19 pandemic. As a result, installations at the Colby and Russell sites are delayed. Work at the Colby site is expected to begin in spring 2022. The timeline for the Russell site is still uncertain. 24/7 is working on getting timelines from its suppliers but is facing difficulties due to uncertainties over pricing and availability. This ongoing delay is considered a project risk, since our final installations must be completed prior to the end of Sept 2022.

Winter weather is a challenge for biodiesel blends, as biodiesel gels at significantly higher temperatures than ULSD. In February 2021, Kansas experienced lows that haven't been reached in decades. The inline blender at the Salina location allows 24/7 to stop blending in biodiesel instantaneously, but inventory must be rotated to reduce the blend at splash blended sites; 24/7 was able to stop splash blending early enough to rotate in enough straight ULSD, #1 ULSD, and anti-gel treatment to avoid any gelling. 24/7 was one of few retailers in Kansas that managed through the cold front with no onsite gelling and minimal customer complaint. Their independent lab testing along with the organization's experience were key to managing through the event. To date, 24/7 reports that the biodiesel side of their business has been profitable; however, due to the price of soybeans, the price for biodiesel was forecast to surpass that for diesel this fall, which could have affected the blend ratio. In reality, the price of diesel has risen enough for 24/7 to continue blending biodiesel for a financial advantage. 24/7 utilized the sales lines they developed and the Kansas Soybean Commission's biodiesel rebate (administered by MEC) to get fleets to at least try biodiesel for 2000 gallons. See Figure I.4-1.

Figure I.4-1. The 24-7 Travel Store in McPherson, Kansas installed DCFC (Photo Credit: Tami Alexander)

Blue Springs School District (BSSD) originally planned to add time-fill CNG stations to its bus lot; however, the Superintendent and Assistant Superintendent for Operations of BSSD both retired, and new leadership was more focused on cost cutting, including for pupil transportation. 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. MEC has reassigned the $180,000 of federal funding originally slated for BSSD's fueling expansion to other projects described herein.

Kansas University (KU) Biodiesel Program does not receive direct funding from the project but benefits from technical assistance and relationship facilitation. As COVID-19 shut down the KU campus, biodiesel production ground to a halt in March of 2020. MEC had brokered an agreement with the City of Lawrence to use biodiesel produced by the Chemical Engineering Department's biodiesel program to fuel Parks and Recreation Department equipment, and to gather data from that deployment. This basic plan for deployment and data collection with the city remains unchanged, though delayed. COVID forced KU to close all dining halls, the main source of feedstock. As a result, KU partnered with local restaurants for limited feedstocks, even as COVID impacts slowed local restaurants' business to a crawl during winter 2020-21. In addition, the KU campus shutdown meant that only a skeleton crew of faculty and advisors was on hand for biodiesel production even as restrictions began to ease during the spring of 2021. Limited production resumed during the fall and winter 20-21 semesters, but a spring 2021 batch *just* failed to meet ASTM specs.

During early 2021, KU Chemical Engineering upgraded its blending station for KU fleets to meet fuel specs and reset its testing process. The City of Lawrence confirmed interest in proceeding, and KU is on track to set up its B20 fueling system in early 2022, with fueling of Parks and Recreation Department equipment beginning in March as seasonal work starts. There is also a possibility that blends lower than B20 may be used earlier in 2022 during colder weather, though MEC is awaiting confirmation. City staff confirm that expanding biodiesel use fits the City's new sustainability goals and has support of the City Council. The Parks and Recreation Department is willing to start with at least one big diesel mower and a tractor or two. In addition, MEC is exploring the possibility of an Optimus engine system upfit to allow one vehicle (city or university) to run on B100, though securing funding will take additional work. Our hope is that positive outcomes from the Parks and Recreation Department test will encourage this move by project partners, should funding come through.

In late 2021, MEC expanded KU's scope of work to include hydrogen infrastructure integration research and began negotiations to bring them on as grant subrecipient. The study will be focused on the potential conversion of compressed natural gas (CNG) filling stations to hydrogen. To support this effort, a graduate student working at the University of Kansas in conjunction with MEC will research the literature and provide a 20-page report documenting the findings, including information on the use of natural gas as a bridge fuel to hydrogen and specific siting requirements for hydrogen safety. MEC plans to submit the completed study to DOE in early 2022.

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 and was added as a subrecipient under this project in Q1 2021. DS Bus bought 30 late-model used CNG buses from Midwest Bus Sales for deployment in Olathe using the City of Olathe's existing natural gas fueling facility. These buses were then leased to the Olathe School District. DS Bus completed purchasing, inspection, and transferring of the buses in June 2021. DS Bus deployed the buses in mid-August at the beginning of the fall semester. DS Bus and Clean Energy Fuels had planned a public event to mark the rollout of the CNG fleet but concerns over COVID-19 intervened. Though the deployment is already complete, reimbursement to DS Bus has been delayed. MEC is awaiting a reference from DOE on whether DS Bus' financing arrangement meets regulatory requirements for grant projects. DS Bus will pay off their financing arrangement as directed by MEC upon DOE's determination.

The City of Olathe, KS, was added as a subrecipient under this project in early 2021. Olathe installed six mobile solar-powered electric charging stations at three popular community destinations: a library, a community center, and a lakeside park. The stations are not connected to the grid and required no construction. The City of Olathe held a public ribbon-cutting ceremony with MEC and Olathe's mayor and City Council in attendance. The stations are open and free for public use. See Figure I.4-2 for an image of Olathe EVs charging at the solar-powered EVSE station during the City's community workshop.

Figure I.4-2. The City of Olathe KS new EV and EVSE. (Photo credit: Jeff Windsor)

The city is also adding six electric Chevy Bolts to the City's fleet. These vehicles were deployed mid-July 2021 after vehicles were upfitted for City service, but shortly after initial deployment Chevrolet recalled the Bolts due to fire hazards. The vehicles are currently out of service as the city waits for Chevrolet to replace the affected parts. Due to continuing production delays caused by the COVID-19 pandemic, the city is uncertain when Chevrolet will be able to repair the vehicles so that they are safe to redeploy.

The city has been conducting outreach about the project, including via social media, local news media, and presentations to community organizations. The city held a community workshop and invited local fleet managers to showcase the project's accomplishments, impacts, and lessons learned.

The Kansas City (KC) Public Library was added as a subrecipient under this project in Q3 2021. The project scope is for the KC Library to purchase one electric bookmobile. The KC Library plans to charge the vehicle using existing outlets and does not anticipate installation of any infrastructure. The KC Library is currently working on allocating funding for the cost-sharing and selecting vehicle technology. Contract execution and procurement is expected in early 2022 with deployment in summer 2022.

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. 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, due to cost concerns and return on investment, as diesel prices have been low in comparison to CNG. Recent volatility in the price of diesel may encourage renewed interest in CNG station installation, however. MEC is seeing much more successful outcomes in 2021, since making the shift. MEC is also increasing electrification of municipal fleets and is in the early stages of assisting the cities of Olathe, KS, and Kansas City, MO, with electrifying their fleets. 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 2022 and the final months of the project.

Lessons Learned

- Financial returns and technology performance are some of the top concerns of fleet managers when considering alternative fuel projects. While the City of Garden City overcame the technological difficulties with the vehicles, they did not see their expected financial savings and expressed little interest in future CNG investments. In contrast, the City of Kansas City saw a lower than anticipated vehicle and infrastructure cost for the electric sedans, with high technology performance. Kansas City's successful pilot under this project paved the way for a 2021 commitment towards full fleet electrification. Kansas City also reports success with their CNG trash trucks and CNG water services trucks, however, and the city will likely continue with CNG medium and heavy-duty vehicles until the cost of electrifying those vehicles is more reasonable.

- COVID-19 certainly has made an impact that continues, likely with long-term negative effects. The pandemic caused supply chain and equipment delivery delays. The disrupted schedules and impacted budgets will take on a new shape. It might take a few years to fully understand the impacts and paths forward for economic recovery, including for AFV investments. Counterbalancing this cluster of negative pandemic impacts is the recent passage of the federal infrastructure bill and new funding starting to come online in 2022.

- An additional notable 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.

Key Publications

Metropolitan Energy Center. Case Study: Propane School Bus Fleet. https://metroenergy.org/wp-content/uploads/2021/04/FINAL_AFV17_Grain-Valley-School-District-Case-Study.pdf. 2021.

I.5 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: $2,140,200 DOE share: $1,500,000 Non-DOE share: $640,200

Project Introduction

We are living at the convergence of the rise of e-commerce, ride-hailing services, connected and autonomous vehicle technologies, and fast-growing cities. In addition, the COVID-19 pandemic has had significant disruptive impacts on urban freight, emphasizing the need to better understand new operational strategies. 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 (PNNL), and project partners developed, pilot tested, and improved upon technologies supporting new operational strategies to optimize use of urban load/unload spaces, as well as business efficiencies, in the final 50 feet of the goods delivery system.

Objectives

The objectives of this project were 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 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 sensors and common-carrier parcel lockers 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 parking app to display real-time load/unload space availability, as well as the commercial vehicle load/unload space behavior model.

In Year 2, the team focused on implementing the planned technologies. This included overseeing installation of the parking occupancy sensors and collecting and processing data. The project team tested the prototype parking app with initial data streams and developed and tested a commercial vehicle parking behavior simulation model. The team also continued to manage installation, marketing and operations of three common-carrier lockers in the pilot test area.

In Year 3, the project team evaluated the impact of these tools and technologies on urban freight operations in the test area. The team continued to measure results of the parking app and better understand parking overstay behavior (excess parking time from a given maximum allowed parking duration). An evaluation of the effect of common carrier parcel lockers on delivery efficiency showed the lockers significantly reduced dwell time at the curb and the time delivery drivers spent inside the building dropping off packages.

Results

Key accomplishments and associated key findings of the project over the past fiscal year (October 1, 2020 through September 30, 2021) 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 – Continued to make improvements to parking application displaying real-time data and predicted parking occupancy information

PNNL addressed usability issues with the parking app (Open Park) and fixed some critical bugs. They upgraded the backend service of the prediction server that generates parking predictions and displays them on the app. Now the parking availability prediction model is re-trained every 15 minutes, improving the performance of the predictions. The development of sensor level prediction for parking lots, rather than using zone-level predictions, also improved accuracy. PNNL moved the prediction server from a cloud-based system to a dedicated workstation to cater to the increased resource demand of the prediction service. The sensors continue to stream real time and predicted parking occupancy information for the test area in Seattle. PNNL made the Open Park parking app source code and base read-me files publicly available at https://github.com/pnnl/parking.

Achievement #2 – Conducted an experiment to understand and quantify the impact of the use of the parking app on delivery drivers' behaviors and performance in the study area

The research team designed an experiment to test the impact of using the parking app on commercial vehicle drivers' efficiency. Drivers were recruited for the experiment, and each was given a delivery van and a list of three manifests to complete. Each manifest contained 15 randomly generated delivery addresses, all in the 10-block Seattle study area, and each driver was assigned at least one manifest with the parking app and one without the app. Less experienced drivers were also given an extra manifest containing only 5 addresses to familiarize themselves with the study area and the task. For each route performed, a researcher rode along with the driver and collected GPS traces and time stamps. Data was then processed to estimate the following performance metrics: cruising for parking time, parking dwell time, number of deliveries performed per stop, number of stops per tour, and total vehicle miles traveled. The final dataset obtained contained 33 routes. The team observed a total of 560 deliveries, performed in 142 vehicle trips. Analysis of the experimental data is ongoing.

Key Finding – During the experiment, the drivers changed their parking behaviors from choosing the shortest path between delivery destinations to targeting specific open commercial vehicle load zones when using the app. A preliminary analysis of the data showed that the mean time spent cruising for parking decreased by 10% when the parking app was used.

Achievement #3 – Integrated parking occupancy and cruising information into scheduling and routing

To illustrate and isolate the effect of available parking information on urban deliveries, the team developed an algorithmic framework. This framework showed the effect of parking information on routes generated for last mile deliveries. The approach is based on the suggestion that the delays caused by cruising for parking can be considered in vehicle routing to improve routes.

The algorithm consisted of five steps that illustrated the benefit of parking information:

- Step 1. Set a benchmark through the generation of delivery routes using a solver for a Vehicle Routing Problem (VRP) based on commercially available travel times between addresses within an urban delivery network.
- Step 2. Predicted the true travel time of a commercial vehicle including cruising for parking in the same urban area, using GPS data from a representative carrier.
- Step 3. Updated the routes generated in Step 1 with the true travel times generated in Step 2 to simulate actual route times during delivery.
- Step 4. Regenerated routes with the same VRP solver as in Step 1, but with the updated travel times that consider cruising for parking from Step 2.
- Step 5. Compared the results from Steps 3 and 4 to evaluate the effect of parking information.

The team evaluated the algorithm using one year's worth of carrier-provided GPS data from the Seattle area.

Key Finding – Preliminary results showed a 5% decrease in total tour time when using the app to include parking information in vehicle routing.

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 - Tested the effect of parcel lockers on delivery efficiency (dwell time and time spent in building)

The team developed an experimental design to estimate the effect of the use of parcel lockers on delivery vehicle dwell time and time a delivery driver spends inside a building. The team collected data for two periods (before and after the installation of lockers) from two comparable buildings (one with a locker and one without a locker), and built regression models, controlling for vehicle type, peak delivery hours, volume and other factors known to influence delivery times.

Key Finding – The regression models showed that installing the locker caused a 40-60% drop in time spent inside the building and a 33% drop in commercial vehicle dwell time at the curb. The results showed that the locker significantly reduced the time delivery drivers spent inside the building moving from floor to floor and door to door to drop off packages. Dwell time was not influenced to the same degree, possibly due to drivers spending the additional time on other activities, including staging packages or delivering to other nearby buildings.

Achievement #5 – Studied usage behavior of locker users and assessed performance of lockers from users' perspective

The project team developed and administered an online survey of residents regarding the locker installed in a residential building, nine months after the locker was installed and started operating. About 60% of the locker users responded to the survey. This high response rate reflects an overall satisfaction with the locker performance.

Key Finding – Users reported high levels of satisfaction about the locker performance and positive attitudes toward the locker as an urban delivery solution:

- 92% of users reported they are satisfied or very satisfied with the lockers
- 20% reduction in lost or stolen packages
- 6,369 total packages delivered in first 6 months of locker use

Achievement #6 - Developed a simulation to model the delivery process and identify optimal locker configuration to maximize public benefit

The goal was to build a tool that could allow building managers and city planners to choose the combination of boxes and overall size for a new locker that would minimize congestion, using only a few parameters. The locker provider, Parcel Pending, collected data automatically, and used it as inputs to the simulation. The inputs included the average time between deliveries, average number of packages per delivery, packages left from the previous day, and the size distribution of packages.

Achievement #7 – Conducted community outreach efforts to increase locker usage at the two non-residential sites

Since reduced commercial tenant activity remains a considerable constraint to activating users at the two non-residential locker locations (a commercial building and a public parking lot), the project team sought to improve locker usage rates at those sites. Several community outreach efforts were made to increase usage rates, including post card mailings, displaying flyers in common spaces of nearby buildings, and posting to neighborhood social media accounts. The team also developed an online community survey to understand the awareness and impressions of the public locker located in a parking lot.

Key Finding – 96% of respondents were aware of the public parcel locker and 70% reported being "likely" or "very likely" to use it. Survey feedback included praise for the convenience during the pandemic and concerns about the security of packages, and desire to store refrigerated items in the lockers. Following the community survey, the team saw an 18% increase in people registered for the locker.

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, and increase underutilized private loading bay occupancy in the afternoon peak times, in the pilot test area

Achievement #8 – Better Understood Private Loading Bay Management Practices

The project team sought to address the lack of municipal understanding of private loading bay management practices and priorities through reviewing the literature and conducting interviews with private loading bay managers. Using an inventory map of private loading bays in downtown Seattle generated by previous Urban Freight Lab work, and Google Street view to determine building ownership and preliminary contact information, the team identified 16 candidate buildings and contacted the owners for interviews. The purpose of this effort was to understand the state of planning and operations of private loading bays in an urban environment.

Key Finding – Private loading bay managers have little motivation to encourage higher utilization of their loading bays, and are not experiencing consistent internal challenges with a lack of loading bay capacity. Loading bay managers noted that most delivery vehicles used the curb, particularly for smaller packages and vehicles.

Achievement #9 – Quantified on-street and off-street parking capacity for commercial vehicles

The project team designed and conducted a survey to quantify the curb loading capacity relative to the private loading bay capacity.

Key Finding – The greater downtown region of Seattle has approximately equal capacity in on-street and off-street commercial parking.

Achievement #10 – Developed algorithm to quantify alley usage

The project team developed an algorithm that takes data from the sensors located in alleys in the study area as input and outputs vehicle counts. The team used the algorithm in a single alley to quantify alley usage.

Conclusions

This project has produced the following outcomes:

1. **Empirical evidence of the benefits of lockers to reduce dwell time and time in building** - The implementation of the parcel locker allowed delivery drivers to increase productivity: 40-60% reduction in time spent in the building and 33% reduction in vehicle dwell time at the curb.
2. **The viability of a real-time parking information and prediction app.** Preliminary results show use of this tool can reduce route time by approximately 5% - The tool collected parking occupancy and cruising information and integrated it into scheduling and routing predictions. The prediction model optimally routed vehicles to minimize both total driving and cruising time, resulting in a 5% reduction in route time.
3. **Understanding the management of off-street loading bays and the capacity of this network -** Utilization of off-street loading bays remained low despite its capacity being approximately equal to on-street commercial parking. Low motivation to incentivize use of off-street loading bays and reports that most delivery vehicles continue to use on-street (curb) parking were key influential factors in understanding the management of this network.

The project team has demonstrated the feasibility of the project's approaches, and established and measured the urban goods movement system. Future work should develop commercially viable solutions based on these findings, and further develop real-time, integrated management of the urban goods system. Doing so will provide carriers, customers, and communities with shared benefits.

Key Publications

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

Dalla Chiara, G., Krutein, F.K., Ranjbari, A., Goodchild, A. "Commercial Vehicle Driver Behaviors and Decision Making: Lessons Learned from Urban Ridealongs", *Transportation Research Record* 2675, issue: 9, (2021): 608-619.

Dalla Chiara, G., Donnelly, G., Gunes, S., Goodchild, A. *How Cargo Cycle Drivers Use the Urban Transport Infrastructure.* Transportation Review Board Annual Meeting (2022).

Donnelly, G., Goodchild, A. *Comparison of Off-street and Curbside Commercial Parking Capacity in Seattle's Central Business District.* Transportation Review Board Annual Meeting (2022).

Ranjbari, A., Diehl, C., Dalla Chiara, G., Goodchild, A. *Can Parcel Lockers Reduce Delivery Times?* Transportation Review Board Annual Meeting (2022).

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- Lacuna
- General Motors
- PepsiCo
- REEF Technologies
- Seattle Department of Transportation
- Sound Transit

I.6 Drones, Delivery Robots, Driverless Cars, and Intelligent Curbs for Increasing Energy Productivity of First/Last Mile Goods Movement (Carnegie Mellon University)

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Project 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 (See Figure I.6-1) and sizes, carrying a range of payloads through various campaigns and altitudes. The team recorded testing environment conditions of wind speed, temperature, and other factors, and on-board sensors recorded voltage and current, GPS location, speed, wind speed, and drone movement characteristics for each flight. This enabled the team to estimate the energy used for each flight at a high resolution.

Figure I.6-1. 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.6-2). 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.6-2. Automated ground delivery robot used for testing (Photo: CMU Team)

In Fiscal Year 2021, 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

In FY2020, 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.6-3. The team analyzed three distinct regimes of flight operations: takeoff, cruising, and landing. 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.

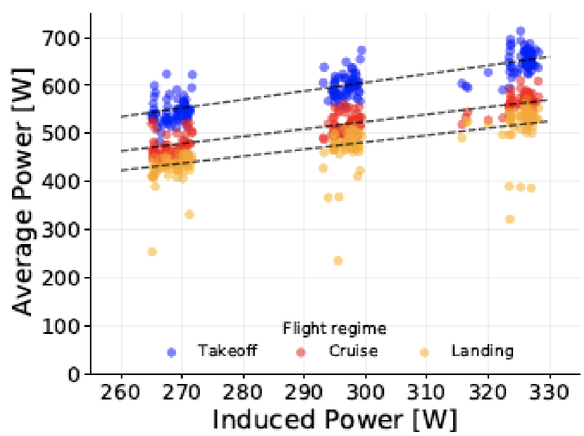

Figure I.6-3. Machine learning model developed to separate flight regimes and assess energy use

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.6-4 shows a model of cumulative energy consumption of a package delivery drone as a function of distance.

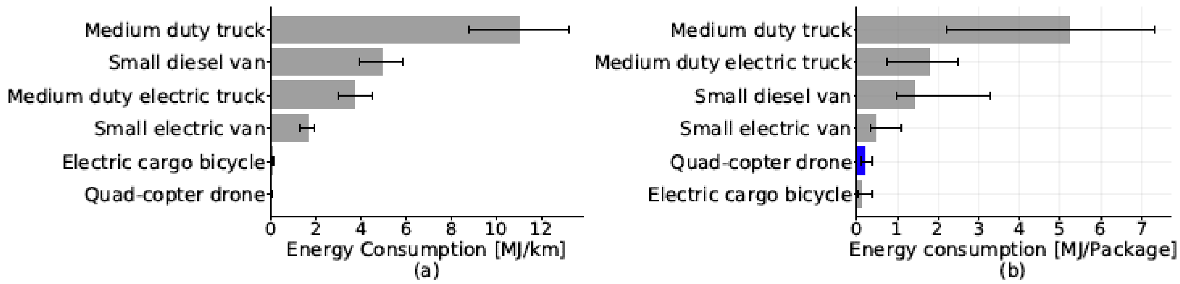

Figure I.6-4. Model of cumulative energy consumption of a package delivery drone as a function of distance.

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 (CFD) 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 a UAV to solve the inverse problem of predicting the inlet conditions as the UAV traverses the flow field, as shown in Figure I.6-5. These results have implications for route planning and energy productivity of delivery.

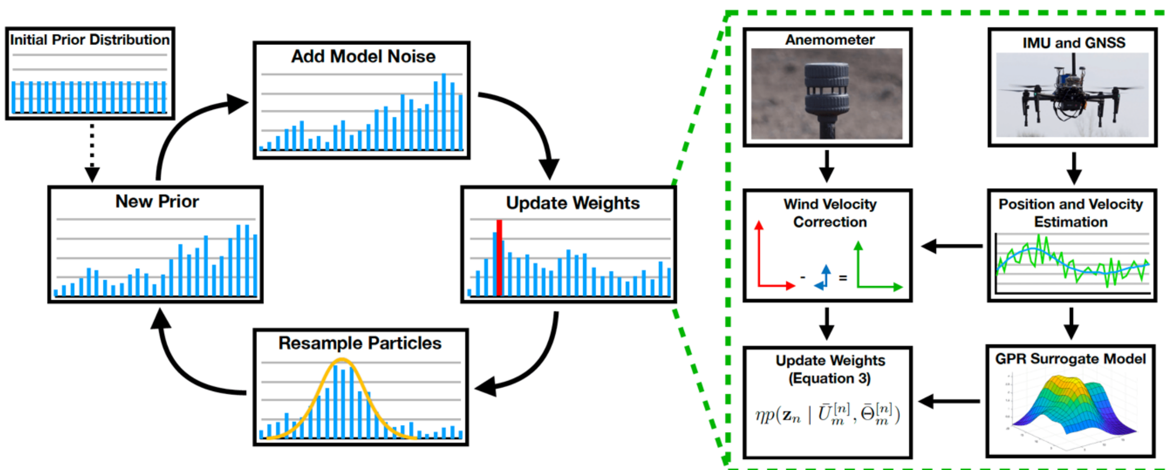

Figure I.6-5. Methodology using on-board drone wind energy measurements to estimate urban wind fields for path planning

In FY 2021, the team published a dataset of drone energy use in an open data repository, published a data paper in *Nature Scientific Data,* published a modeling paper in the *IEEE International Conference on Robotics and Automation (ICRA)*, and submitted an energy analysis paper to *Patterns*. The team also disseminated the results to stakeholders at several conferences and University invited lectures in 2021, including the Transportation Research Board of the National Academies Annual Meeting, the INFORMS Annual Meeting, the IEEE Robotics and Automation Society, the Kent Lecture Series at the University of Illinois Urbana-Champaign, the School for Environment and Sustainability at the University of Michigan, the Payne Institute for Public Policy at the Colorado School of Mines.

Additional planned field tests in FY2021 have been limited due to COVID-19 restrictions. One of the research tasks proposed additional tests, but the team was able to conduct a larger than expected number of tests before

COVID-19 and has sufficient data. The team will continue to evaluate the potential for additional field tests going forward. The team filed a patent based on this project's research in 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 2021, Carnegie Mellon University filed an amendment to this patent in the U.S. Patent Office's 3600 Technology Unit, U.S. Patent Application No. 16/505,995.

Conclusions

In FY 2021, 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 and data paper in *Nature Scientific Data*. The team is continuing simulations 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 this year; one publication is under review, and the team is finalizing several more research publications for submittal to peer-reviewed journals.

The energy consumption of small quadcopter drones is comparable to the most energy efficient modes of last-mile delivery when the total mass of delivery is not the main feature considered. For example, in delivery situations involving small and light items with high added value, such as small electronics and medicines, drones might become a competitive tool to reduce transportation emissions in large urban centers. In these scenarios, we found that drones can reduce the energy consumption by 96% and 60% per package delivered by replacing diesel trucks and electric vans, respectively. We also found that the delivery intensity, i.e., the number of packages delivered per km, and the fuel carbon intensity are the main factors contributing to the drone's energy and environmental performances.

Key Publications

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. (2021). In-flight positional and energy use data set of a DJI Matrice 100 quadcopter for small package delivery. *Scientific Data*, (1), 1-8. https://doi.org/10.1038/s41597-021-00930-x.

Choudhry, A., Moon, B., Patrikar, J., Samaras, C., Scherer, S. (2021). CVaR-based Flight Energy Risk Assessment for Multirotor UAVs using a Deep Energy Model. *2021 IEEE International Conference on Robotics and Automation (ICRA)*. 262-268. https://doi.org/10.1109/ICRA48506.2021.9561658.

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Burns, A.J., Michalek, J.J., Samaras, C. (2021). Smart curb space – Optimal Freight Vehicle Parking Assignment to Increase Energy Productivity. *INFORMS Annual Conference 2021.* October 26, 2021, Anaheim, CA

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)*. https://doi.org/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.

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[2] Gebeloff, Robert and Karl Russell, How the Growth of E-Commerce Is Shifting Retail Jobs. The New York Times. July 6, 2017.

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I.7 Integrating Microtransit with Public Transit for Coordinated Multi-Modal Movement of People (Ford Motor Company)

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

Project Introduction

The growing presence of on-demand transportation services provides a unique opportunity to influence the urban mobility status quo, shifting from personally owned and operated vehicles to the Mobility as a Service (MaaS) paradigm. To be successful, microtransit (i.e., on-demand shuttles) service providers will need to be able to offer services that are seamlessly integrated with public transit and do so with a high degree of efficiency to make the service operationally 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. A comprehensive field experiment that shuttle riders to and from major transit stations near Seattle, Washington in collaboration with King County Metro.

4. A quantification and assessment 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, but 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 the Seattle area. These models will test the algorithm against a range of fleet operations alternatives to help our transit agency partner plan for the pilot, 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 a real-word pilot program, using dynamic microtransit software from The Routing Company and in collaboration with King County Metro, in the Seattle metropolitan area, and a second city yet to be identified. 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.

Project modifications

All project milestones related to pilot launch were achieved working together with Seattle and Minneapolis as city partners, including deployment of a behavioral survey and planning microtransit services using the Cornell algorithm in a simulation environment. In early 2021, Ford encountered unexpected and insurmountable errors in implementation of the algorithm with the original software supplier and began working with a new software supplier, The Routing Company. Due to this change, Minneapolis Metro Transit, withdrew from the project as they preferred to continue working with the original supplier. Ford and TRC worked together to identify a second city partner, focusing on Columbus, Ohio, based on strong interest from a transit agency there, but ultimately the agency was not be able to join the project due to budget constraints, other local priorities, and the risk of low ridership during the COVID-19 pandemic.

In our experience working with transit agencies in Minneapolis and Columbus, we found they needed 3-6 months to come to a decision about joining this project. Although the federal funding and research support made the project an attractive opportunity, they had to consider overall microtransit plans and needs, identify a potential pilot which fit the grant criteria and timeframe, identify financial resources to match the DOE funding to support a full year pilot, and secure internal and external political support. In both cases, the complexity of local needs and stakeholders, as well as COVID-19 impacts, made it difficult for these agencies to participate in the research.

Results

We report results from: simulations conducted for King County Metro, the behavioral model used to calibrate the simulations and inform service planning, and the initial weeks of the pilot program deployed in King County.

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. Simulation efforts began in 2020 with final iterations concluding in 2021. While the preliminary simulation environments had focused on basic service and operations design, including an initial synthetic population, we evolved the simulations to demonstrate more advanced capabilities, simulating, for example, demand and operations for a wheelchair accessible service. Table I.7.1 shows our final list of baseline constraints from which we designed numerous simulation scenarios. Note that “detour time” describes the additional in-vehicle minutes added to a ride to pick up additional passengers. For example, if a rider took microtransit to the grocery store, a 10-minute drive, but the microtransit operator deviated a block to pick up a second rider who was also going to the grocery store, the total detour time would be two minutes.

Table I.7.1. Baseline Constraint Defaults, Final Simulations

Constraint	Default Setting Value	Related KPIs	KPI Calculation or Observation
Maximum Wait Time First Mile Origin	20 min	Avg Wait Time First Mile Origin/Home (mins)	Sum ([pick-up time] - [request time])/ Total trips
		Maximum Wait Time First Mile Origin/Home	Maximum value observed
Maximum Detour Time[1]	20 min	Avg Detour Time (mins)	Sum ([in-vehicle travel time] - [taxi travel time]) / Total trips
		Max Detour Time (mins)	Maximum value observed
Minimum Wait Time First Mile Transfer	0 min	Avg Wait Time First Mile Transfer - Microtransit to Fixed Route (mins)	Sum ([FR arrival time] - [microtransit arrival time]) / Total trips
Maximum Wait Time Last Mile Transfer	10 min	Avg Wait Time Last Mile Transfer – Fixed Route to Microtransit (mins)	Sum ([microtransit arrival time] - [FR arrival time]) / Total trips

1. Note that “detour time” describes the additional in-vehicle time to pick up additional passengers.

One of the key simulation features that we developed was the ability to match a rider request for microtransit with a particular fixed-route bus or train, testing the General Transit Feed Specification - Realtime (GTFS-RT) connectivity algorithm. Specifically, we were testing how far in advance a customer would need to book a trip to successfully make her connecting service. Figure I.7-1 shows that the more advance notice a rider gave when requesting a transit connection, the more people the microtransit operations could serve.

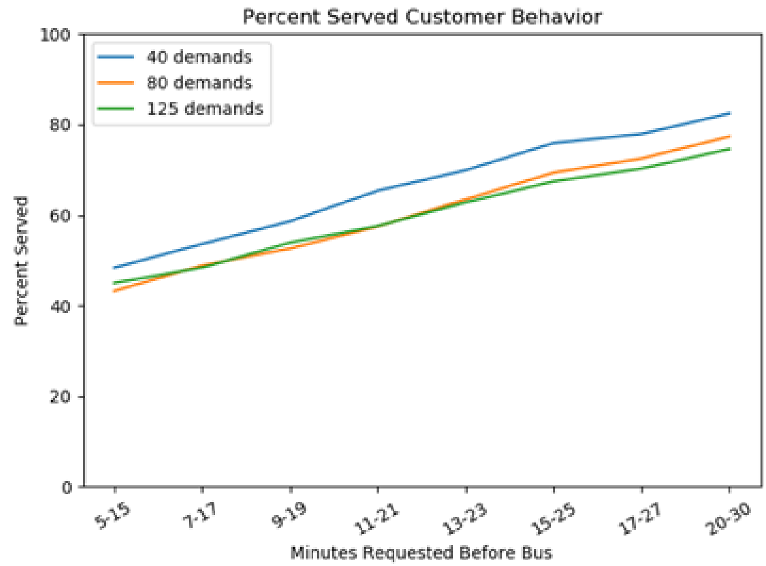

Figure I.7-1. The simulations showed that the more notice customers provided when requesting the first-mile/last-mile service, the more customers could be served overall.

The simulations produced several important findings that helped King County Metro plan the service and set customer expectations. One key finding was that requiring first mile trips to reach the station in time for a particular fixed route service may require customer education regarding the ideal timing for a request. Another finding came from the total number of hubs needed to provide adequate connectivity to the service area. Because Kent Station is in the south-central portion of the service area, King County Metro had asked Cornell and Ford to simulate service with a second transit hub added in the north, providing customers a choice of two hubs to connect with. Simulations showed that adding the second transit hub reduced average time spent in vehicles but increased average wait time for customers waiting to be picked up at both hubs. Based on these simulations, King County Metro decided this was an acceptable trade-off and added the second transit hub to the service design. Finally, the simulations impacted policy around service quality. For example, reducing the "max wait time at home" constraint reduced average waiting by up to a minute (from 6.8 minutes down to 5.7) and provided marginal efficiency gains for those served; however, 3%-5% more customers were rejected and not served.

Behavioral Model

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. The survey revealed the somewhat unexpected finding that the pandemic did not significantly impact interest in microtransit; service design factors such as convenience and affordability continued to direct a survey participant's interest in microtransit, over and above public health concerns.

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).Figure I.7-2, for example, shows that the median willingness to pay for prompt arrival ranged between $.76 to $1.47, in general showing variance by income level. 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. In early 2021, these results were used to calibrate the simulation modeling to guide algorithm development.

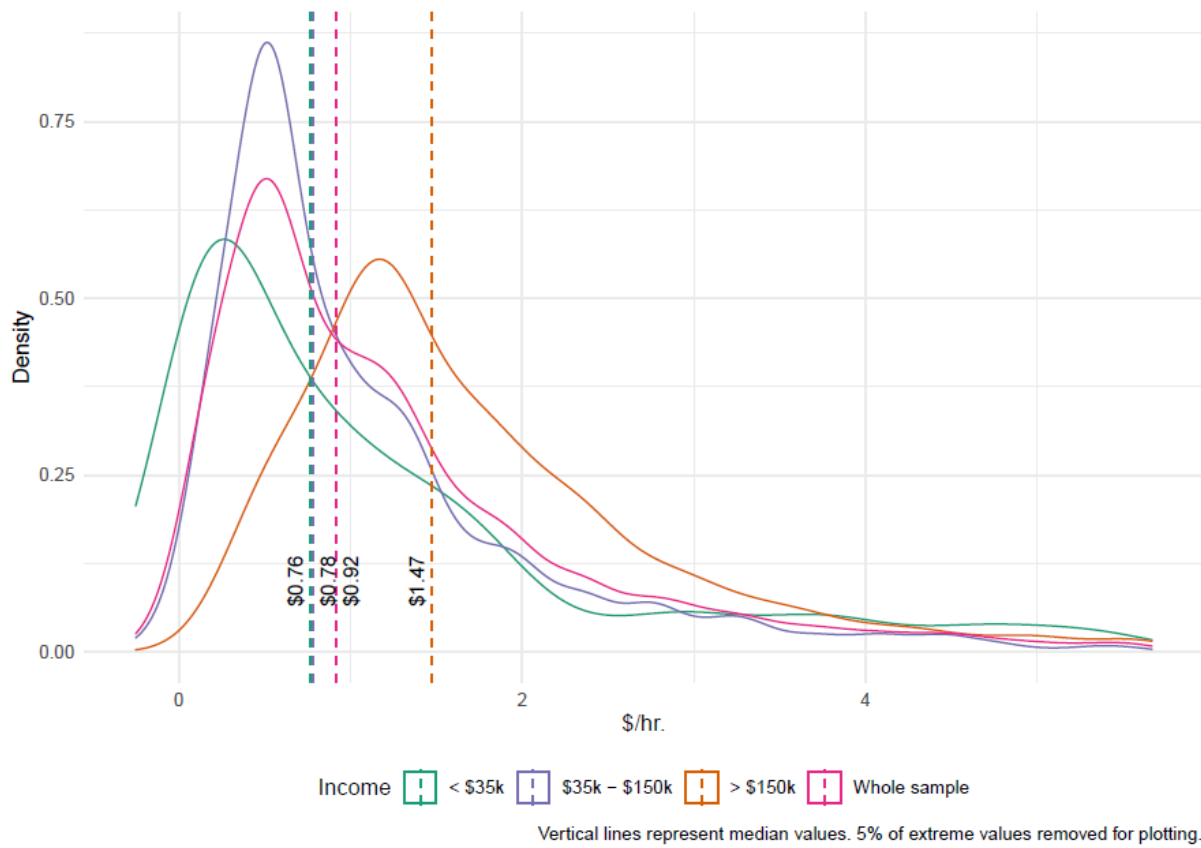

Figure I.7-2. Willingness to pay for prompt arrival

Ride Pingo to Transit, King County Metro

In mid-September 2021, the first pilot program launched in the City of Kent, a community twenty miles south of Seattle. The microtransit app powering the service, called Ride Pingo to Transit, uses the global optimization algorithm developed under the cooperative agreement to connect with the GTFS-RT feeds of both King County Metro and Sounder Transit. The app shows prospective riders upcoming routes connecting with one of two transit hubs in the service area: Kent Station, which has Metro local and Rapid bus and Sounder commuter train services, and Kent Valley, a hub near a large Amazon fulfillment center with local Metro bus service. Using the Ride Pingo app, riders can use a feature called "Transit Connect" to select the fixed route service they wish to connect with, and the algorithm will ensure riders get to the hub about 5-8 minutes before the bus or train arrives, just enough time to proof against missed connections while minimizing wait times at the stop. Some riders are even using the microtransit service to travel from one transit hub to the other. During the early weeks of the pilot, a driver shortage forced operations cutbacks, with only 3 of 5 vans able to operation. This supply limitation has in turn depressed demand. Nevertheless, ridership continued to grow each week as word of the service spread. Figure I.7-3 shows ridership trends for the first month of service. Metro preferred to hold off on a major marketing push until the service could be fully staffed, out of concern that riders would have a disappointing first experience if their ride was declined or they had to wait too long.

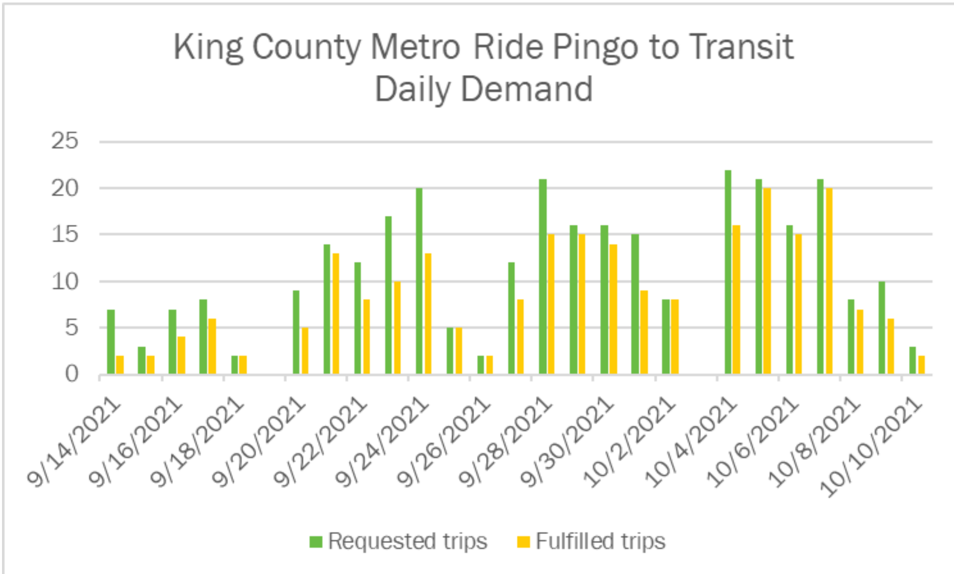

Figure I.7-3. Daily fulfilled demand for the King County Metro microtransit pilot program

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I.8 Understanding and Improving Energy Efficiency of Regional Mobility Systems Leveraging System Level Data (Carnegie Mellon University)

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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 three regional networks: Southwestern Pennsylvania region, Philadelphia region, and Columbus, Ohio region, modeling 1.2 million, 2.5 million and 1.4 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. A sophisticated model and algorithm is proposed, validated and tested to ensure the network simulation can approximate real-world system-level multi-source data, in all the three regional networks.

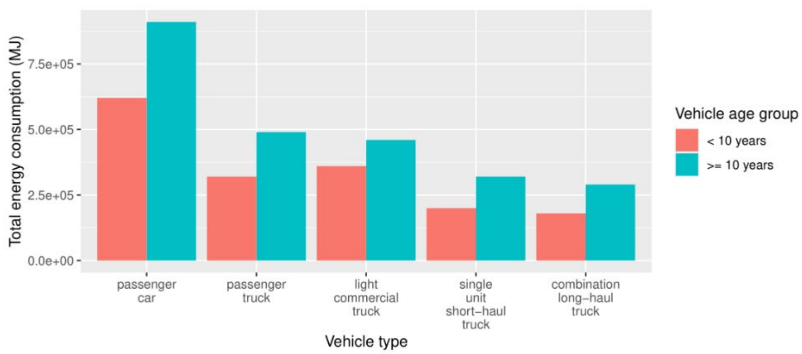
2) Mitigating computational complexity in a large-scale network through developing a machine-learning based algorithm to improve computational efficiency, and developing parallel computing techniques for multi-core central processing units (CPUs) or Graphics Processing Units (GPUs). As a result, the large-scale network simulation calibration process is able to approach all those observations within 24 hours, and one shot of the network simulation can be completed in 20-25 minutes on a regular personal computer. We will continue to improve the accuracy and efficiency by deploying this model in DOE high performance computing (HPC) framework in the next budget period.

In addition, based on the high-granular vehicle traces data output from the simulation model, we 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, Columbus and Philadelphia regional networks.

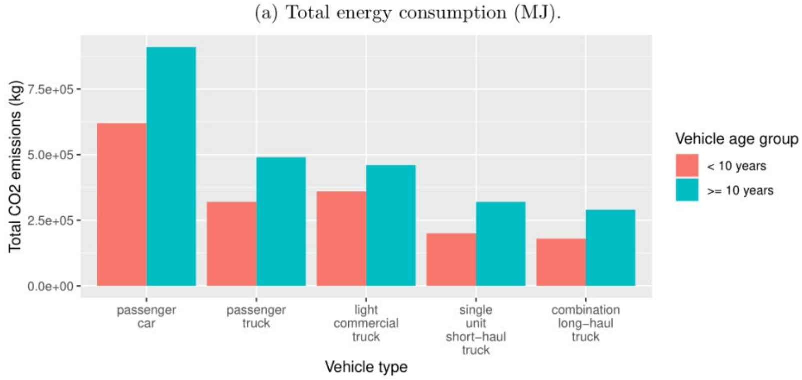
We categorized vehicles into ten groups: passenger car, passenger truck, light commercial truck, single unit short-haul truck, combination long-haul truck, electric car, and electric truck, as well as by two age groups: 0 to 10 years and more than 10 years old. As a result of the data-driven simulation 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.8-1. 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.

We set up scenarios of six vehicle electrification policies as follows, and perform the network simulation respectively for both the Pittsburgh and Philadelphia regions.

- All trucks above 10 years old are replaced with electric vehicles
- 50% of trucks above 10 years old are replaced with electric vehicles
- All passenger cars above 10 years old are replaced with electric vehicles
- 50% of passenger cars above 10 years old are replaced with electric vehicles
- 50% of all groups above 10 years old are replaced with electric vehicles
- 50% of all groups are replaced with electric vehicles.



(a) Total energy consumption (MJ).



(b) Total CO_2 emissions (kg)

Figure I.8-1. Total energy consumption and CO2 emissions for each vehicle class in Pittsburgh region

From the results, we found that replacing older vehicles with electric vehicles would bring substantial societal benefits for the region, reducing energy use by up to 32% and greenhouse gas emissions by 34%. We plan to study more scenarios on demand, infrastructure improvement, and parking policies in the next budget period. 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, making it independent of 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 networks framework in any other regions.

Currently we are preparing the initial alpha release of the software platform (under Rust) and once it is released the development will be fully transferred to the repository https://github.com/pengjiz/macposts. Another software platform is prepared under C++ and Python, and has been released to the repository http://mac-posts.com/

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

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Start Date: November 30, 2018 End Date: December 31, 2021
Project Funding: $1,035,831 DOE share: $828,663 Non-DOE share: $207,168

Project Introduction

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

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

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

Objectives

The project level goals are:

1. Quantify the costs of problems using novel mobility metrics applied to validated microscopic simulations of the traffic in FtC
2. Use vehicle identification data and emissions and fuel economy (FE) modeling of high-impact vehicles (buses and class 8 trucks), along with optimization of both traffic management systems and connected vehicle energy management, to improve the mobility and energy of the FtC transportation system, as measured using the proposed mobility metrics, and
3. Transmit these findings to other municipalities including CCoD and beyond.

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

Approach

The goal of this project was to utilize individual vehicle and systems-level transportation big data to develop real-world implementable techniques for energy efficiency. We collected a real-world dataset in FtC, Colorado using technology that is currently available. This dataset was used to (1) create individual vehicle prediction models and emissions models using cutting-edge artificial intelligence (AI) techniques, (2) create traffic prediction models, (3) create boundary condition constraints for optimal trajectory derivation, and (4) develop a Mobility Energy Productivity (MEP) model for Fort Collins, Colorado which did not previously exist. Each of these techniques is novel but the most interesting results occurred from the intersection of all techniques. It was found that when optimal vehicle control is combined with optimal traffic light control, significant energy efficiency improvements that do not compromise travel time are unlocked. This result is apparent in the MEP comparison.

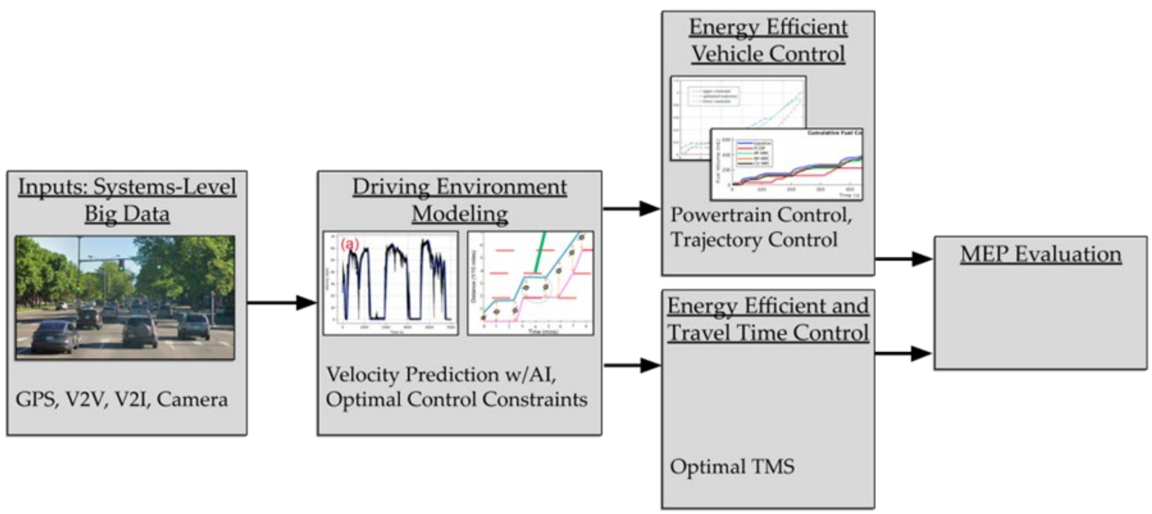

Figure I.9-1. This project uses real-world transportation big datasets to develop implementable energy efficiency control technology for conventional, hybrid electric, and electric vehicles

Results

1.. Optimal Energy Management Strategy (EMS) Enabled from Systems-Level Big Data

Systems-level data provides energy efficiency improvements at the individual vehicle level through a Predictive Optimal Energy Management Strategy (POEMS). To evaluate this process, we have collected a real-world dataset, used the dataset to predict velocity with cutting-edge artificial intelligence (AI), and derived the optimal control strategy using optimal control theory. The result is an insight into the energy efficiency improvements that can currently be obtained when systems-level data is put to use.

1.1. Real World Data Collection

As a foundational piece of the broader analysis of Optimal EMS enabled by transportation system data, the team used a representative dataset of transportation system data which would be available to a hypothetical Intelligent Connected Vehicle (ICV). See Figure I.9-1. The team conducted a literature review and produced a broad categorization for ICV data along with an analysis of information flow through an ICV system. Having defined the generic dataset, the team collected a representative dataset in Fort Collins, Colorado, consisting of a repeated cycle driven for 20 laps over 3 days and between 2 drivers. The processed version of this dataset is available to the research community at https://gitlab.com/airabino/opendata. Details of this work are presented in the first 2020 conference paper [1].

1.2. Velocity Prediction

This study expands on previous findings that deep neural networks employing Long Short-Term Memory (LSTM) provide low error velocity prediction. A test vehicle equipped with sensors measured ego vehicle position and velocity, ADAS-derived near-neighbor relative position and velocity, and infrastructure-derived transit time and signal phase and timing to generate a synchronous dataset. The team used different groupings of data gathered in Fort Collins, Colorado to create an LSTM deep neural network. The team assessed the outcomes using MAE, and compared the Predictions from different groups. The tea, also investigated the effect of the various input dataset groups on forward velocity prediction windows of 10, 15, 20, and 30 seconds. An increase in the prediction horizon resulted in an increase in the inaccuracy. The results reveal that a fully inclusive dataset in 10-second velocity prediction windows has the lowest Mean Absolute Error (MAE) of future velocity prediction. The most influential parameters for prediction accuracy were found to be GPS data, current vehicle velocity data, and vehicle-to-infrastructure data. Furthermore, the team demonstrated the real-time implementation of the LSTM neural network used for velocity prediction. Details of this work are presented in the second 2020 conference paper [2].

1.3. Control Evaluation

To observe fuel economy realization, the team used a real-world highway drive cycle in the high-fidelity, controls-oriented 2017 Toyota Prius Prime model operating in charge-sustaining mode. The team proposed (1) perfect full drive cycle prediction with dynamic programming, (2) 10 second prediction horizon model predictive control (MPC), and (3) 10 second constant velocity prediction as important metrics for comparison to no velocity prediction control. The first optimal EMS requires a complete drive cycle prediction ahead of time, but the other two techniques just require a limited horizon velocity prediction. To derive optimal engine torque and speed, these different velocity predictions are fed into an optimal EMS derivation method. The constant velocity prediction algorithm outperformed the baseline control approach, but underperformed the MPC method, as per our findings. The team further shows that the MPC method generated fuel economy improvement results that were extremely close to the full drive cycle prediction case while employing a 10 second prediction window. As perception systems improve, MPC may be able to be implemented in real vehicles. Furthermore, the findings of constant velocity prediction are strong enough that optimization should be incorporated in vehicle controls using an MPC framework. Details of this work are presented in our third 2020 conference paper [3].

1.4. Velocity Prediction + Control Evaluation

Having collected a representative ICV dataset, studied methods for high-fidelity velocity prediction, and studied optimal EMS methods as full cycle and real-time controls, the group conducted an analysis of the effectiveness of the velocity prediction enabled optimal EMS system as a whole for increasing the FE of HEVs. This study addresses a recognized gap in the research with respect to the performance of predictive optimal EMS with actual data-based velocity predictions. Based on previous research by the group and others, the team implemented a predictive optimal EMS system composed of the best candidate approaches for its subsystems based on the real-world data collected by the group. This study found that, utilizing a deep LSTM ANN, high fidelity velocity prediction was possible in the 10-20 second time horizon window, while infrastructure data allowed for slight increases in fidelity in the same window as compared to that data which is available to non-connected vehicles. Ultimately, a 10-15% FE improvement over baseline was seen for velocity prediction enabled optimal EMS with real world data and real predictions. Details of this work are presented in our 2021 journal paper [4].

2. Emissions Modeling Enabled from Systems-Level Data

This study investigated several deep neural network methods for light-duty diesel vehicle (LDDV) emission and fuel consumption prediction. Deep recurrent neural networks (RNN), deep convolutional neural networks (CNN), deep feed-forward neural networks (FFNN), and deep long short-term memory networks (LSTM) are among the five methods that have been developed. The team also developed a multivariable linear regression (MLR) approach to allow for a more thorough evaluation of machine learning-derived methods, and used a portable emission measuring system, which consisted of four experiments conducted on a set route by the same driver using an LDDV in Fort Collins, Colorado in spring 2018. In addition, the team conducted one experiment on a random path to test the models' performance, developed several input classes of dataset variables, and conducted sensitivity analysis to determine the best combination. The results show that when given datasets with more variables (EOV and IOV), the deep neural network's performance improves consistently. The most favorable criteria designated as IOV for emission prediction are determined to be manifold absolute pressure (MAP), engine speed, and fuel usage. For all neural network methods, the same pattern is found for fuel usage as more variables are added. All of the models were simulated after selecting the best-fitting emission and fuel consumption classes. MOVES is also used to run a simulation for emission prediction. When compared to other neural network models, the result indicated that deep neural networks have a high level of accuracy. In particular, LSTM outperformed all other models in terms of predicting emissions and fuel consumption. For more accurate emissions and fuel consumption estimates, we advocate utilizing LSTM and other history-sensitive deep RNNs that can account for both delayed and recurrent impacts. If developed for a vehicle and integrated into the vehicle controller, this model could be useful for real-time vehicle/engine controls optimization, resulting in real-time fuel consumption and emissions reductions. Details of this work are presented in our first 2021 conference paper [5].

3. Autonomous Optimal Eco-Driving

Eco-Driving is a critical technology for improving automotive transportation efficiency. It is achieved by modifying the driving trajectory over a particular route to minimize required propulsion energy. Eco-Driving can be approached as an optimal control problem subject to driving constraints such as traffic lights and positions of other vehicles. In this paper we demonstrate the connection between Eco-Driving and best interpolation in the strip, which is a problem in approximation theory and optimal control. By exploiting this connection, we are able to generate optimal Eco-Driving trajectories that can be driven with an autonomous system and evaluate them using conventional, hybrid-electric, and fully electric vehicle models from FASTSim software. Our results quantify the energy efficiency improvements that can be achieved with the proposed approach. Details of this work are presented in our second 2021 conference paper [6].

4. Optimal EMS + TMS w/MEP Evaluation

Transportation vehicle and network system efficiency can be defined in two ways: 1) reduction of travel times across all the vehicles in the system, and 2) reduction in total energy consumed by all the vehicles in the system. The mechanisms to realize these efficiencies are treated as independent (i.e., vehicle and network domains) and, when combined, they have not been adequately studied to date. This research aims to integrate previously developed and published research on Predictive Optimal Energy Management Strategies (POEMS) and Intelligent Traffic Systems (ITS), to address the need for quantifying improvement in system efficiency resulting from simultaneous vehicle and network optimization. POEMS and ITS are partially independent methods which do not require each other to function but whose individual effectiveness may be affected by the presence of the other. In order to evaluate the system level efficiency improvements, the Mobility Energy Productivity (MEP) metric is used. MEP specifically measures the connectedness of a system while accounting for time and energy externalities of modes that provide mobility in a given location. A SUMO model is developed to reflect real traffic patterns in Fort Collins, Colorado and data is collected by a probe SUMO vehicle which is validated against data collected on a real vehicle driving the same routes through the city. Individual vehicle and system level efficiencies are calculated using SUMO outputs for scenarios which integrate POEMS and ITS independently as well as jointly. Results from application of POEMS and ITS show improvement in energy consumption and travel times respectively when compared to the respective baseline scenarios. Our conclusion is that there are promising synergistic benefits to travel time and energy efficiency when POEMS and ITS are combined. Details of this work are presented in our upcoming 2022 conference paper [7].

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

1. Rabinowitz, Aaron I., Tushar Gaikwad, Samantha White, Thomas Bradley, and Zachary Asher. 2020. "Synchronous and Open, Real World, Vehicle, ADAS, and Infrastructure Data Streams for Automotive Machine Learning Algorithms Research." SAE Technical Paper.

2. Gaikwad, Tushar, Aaron Rabinowitz, Farhang Motallebiaraghi, Thomas Bradley, Zachary Asher, Alvis Fong, and Rick Meyer. 2020. "Vehicle Velocity Prediction Using Artificial Neural Network and Effect of Real World Signals on Prediction Window." In SAE Technical Paper Series.

3. Patil, A. A., F. Motallebiaraghi, R. Meyer, and Z. D. Asher. 2020. "Comparison of Optimal Energy Management Strategies Using Dynamic Programming, Model Predictive Control, and Constant Velocity Prediction." In SAE Technical Paper.

4. Rabinowitz, Aaron, Farhang Motallebi Araghi, Tushar Gaikwad, Zachary D. Asher, and Thomas H. Bradley. 2021. "Development and Evaluation of Velocity Predictive Optimal Energy Management Strategies in Intelligent and Connected Hybrid Electric Vehicles." Energies 14 (18): 571

5. Motallebiaraghi, Farhang, Aaron Rabinowitz, Shantanu Jathar, Alvis Fong, Zachary Asher, and Thomas Bradley. 2021. "High-Fidelity Modeling of Light-Duty Vehicle Emission and Fuel Economy Using Deep Neural Networks." SAE Technical Paper.

6. Mahmoud, Yara Hazem, Nicholas E. Brown, Farhang Motallebiaraghi, Melinda Koelling, Richard Meyer, Zachary D. Asher, Assen Dontchev, and Ilya Kolmanovsky. 2021. "Autonomous Eco-Driving with Traffic Light and Lead Vehicle Constraints: An Application of Best Constrained Interpolation." IFAC-PapersOnLine 54 (10): 45–50.

7. Motallebiaraghi, Yao, Rabinowitz, Hoehne, Garikapati, Holden, Wood, Chen, Asher, Bradley. (In Review). "Mobility Energy Productivity Evaluation of Prediction-based Vehicle Powertrain Control Combined with Optimal Traffic Management". SAE Technical Paper.

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I.10 Advancing Platooning with Advanced Driver-Assistance Systems Control Integration and Assessment (Cummins, Inc.)

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Start Date: October 1, 2018 End Date: December 31, 2021
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 for platooning has shown significant fuel economy improvements under test track ideal driving conditions. There is limited test data available to assess the performance of platooning under real-world driving conditions, however. In this project, truck platooning with CACC is tested under real-world driving scenarios with two and three truck configurations, and the fuel economy impact and technology barriers with potential solutions are identified through test data analysis.

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

Three truck platooning fuel economy tests

In 2020, the project team completed the 2-truck platooning tests under real-word driving scenarios and reported the results in the 2020 Annual Progress Report. In 2021, the project team completed the platooning tests under real-world driving scenario with a 3-truck configuration. 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.10-1 [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. This is the same route used for the 2-truck on-road tests in 2020 and was selected through collaboration with the National Renewable Energy Laboratory to be representative in terms of road grade variations comparable to the national road grade data of U.S. highways. Between the 2-truck on-road tests in 2020 and the 3-truck on-road tests in 2021, there were three changes in the route, however: (1) the red portion was a construction zone in 2020 for 2-truck tests, but not for this year’s 3-truck tests; (2) the 3-truck platoon did not engage on I-265 (in the green portion) due to platoon formation complexity and high traffic volume; and (3) there were construction zones in the high-grade section during this year’s 3-truck platoon tests.

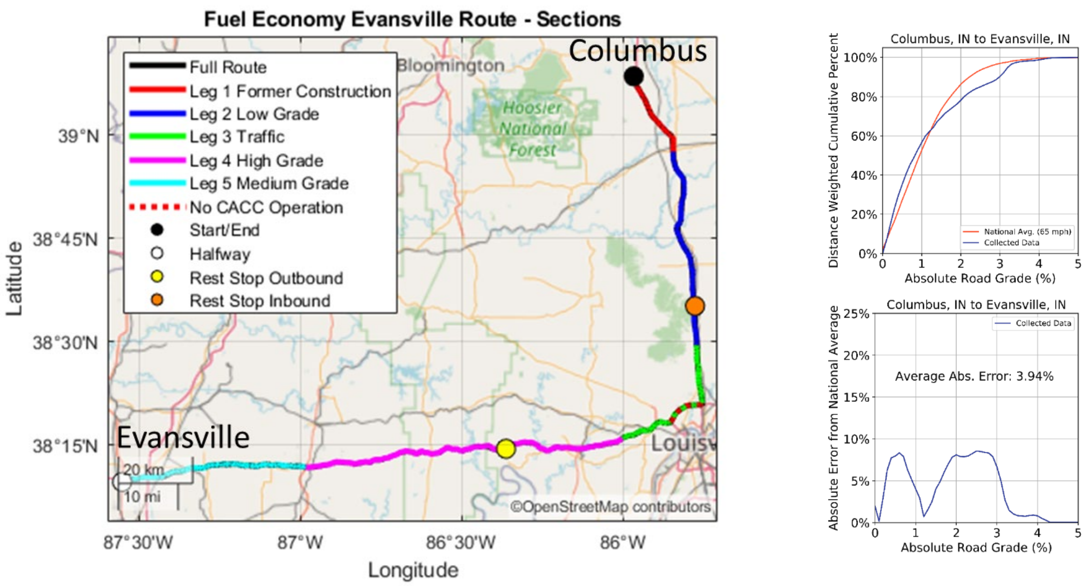


Figure I.10-1. Selected Route for Fuel Economy Tests in Indiana

Test Procedures

The team conducted four different test phases, as listed below:

1. Steady state (SS) CACC 0.6s (3-Truck 2021): 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. On road CACC 0.6s with ADEPT (3-Truck 2021): CACC test at 0.6 Sec headway time gap on Indiana route with lead truck in cruise with ADEPT eco-driving features enabled (baseline: cruise at 64 mph or at speed limit if below 65 mph). ADEPT is a suite of fuel economy eco-driving features available on engine software by Cummins [2].
3. On road CACC 0.6s with ADEPT (2-Truck 2020): CACC test at 0.6 Sec headway time gap on Indiana route with lead truck in cruise with ADEPT eco-driving features enabled (baseline: cruise at 64 mph or at speed limit if below 65 mph).
4. On road CACC 0.6s without ADEPT (2-Truck 2020): CACC test at 0.6 Sec headway time gap on Indiana route with lead truck in cruise with ADEPT eco-driving features disabled (baseline: cruise at 64 mph or at speed limit if below 65 mph).

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

Test Vehicles

The project team used four trucks for the 3-truck test phases. As shown in Table I.10.1, all four trucks are the same except for the tires. Lead, Middle and Trail trucks have Michelin tires with telemetry.

Table I.10.1. Vehicle Specification

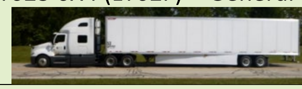
	Control Truck	Lead/Middle/Trail Trucks
Truck Model	INTERNATIONAL 2020 LT625 6X4 (LT62F) – General Freight Long Haul Sleeper 	
GVW	68000 lb	
Engine	Cummins X15 Efficiency Series, EPA 2017, 430HP @ 1800 RPM, 1450/1650 lb-ft	
Transmission	Eaton Endurant 12-Speed Fully Automated Manual Overdrive	
Rear Axle Ratio	2.79	
Steer Tire	Bridgestone R283A ECOPIA 295/75R22.5 100psi	Michelin X Line Energy 275/80R22.5 100psi
Drive Tire	Bridgestone M710 ECOPIA 295/75R22.5 100psi	Michelin XDA Energy 275/80R22.5 100psi
Trailer Tire	Bridgestone R283A ECOPIA 295/75R22.5 100psi	Michelin X Line Energy 275/80R22.5 100psi
Trailer Model	2016 Hyundai 53' Van	2020 Great Dane 53' Van

Figure I.10-2 details the naming convention (truck labels) for two and three truck platoon configurations. 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.

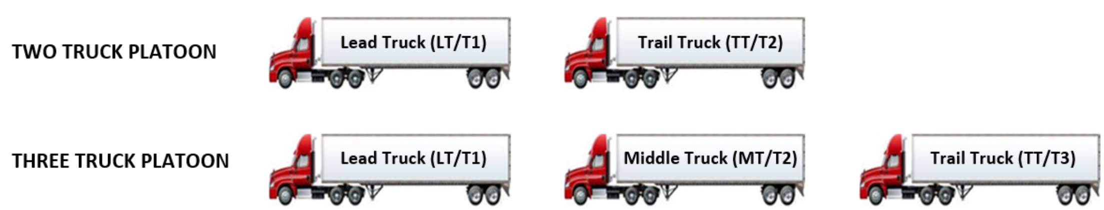
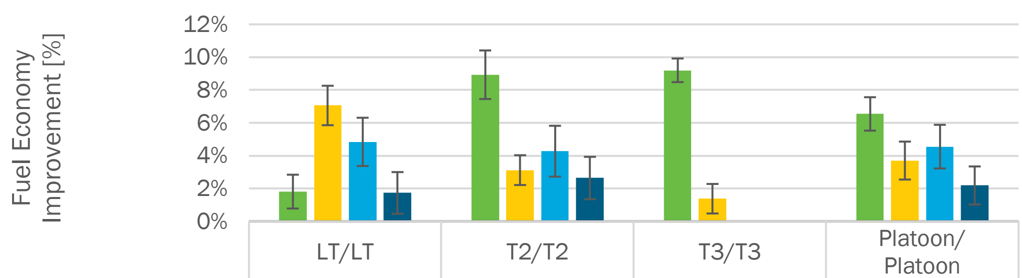


Figure I.10-2. Truck Configuration and Label Disambiguation

Fuel Economy Test Results

The comparison of the fuel economy test results is summarized in Figure I.10-3.



	LT/LT	T2/T2	T3/T3	Platoon/ Platoon
3 Truck SS vs BL (Test Track)	1.81%	8.93%	9.20%	6.54%
3 Truck ADEPT vs BL	7.06%	3.12%	1.38%	3.70%
2 Truck ADEPT vs BL (2020)	4.84%	4.27%		4.55%
2 Truck No ADEPT vs BL (2020)	1.73%	2.64%		2.18%

Figure I.10-3. Fuel economy results, compared to the baseline (BL: Baseline; LT: Lead Truck in the First Position of Platooning, T2: Truck Following LT in the Second Position of Platooning; T3: Third Truck in 3-Truck Platooning Configuration. Note that for 2-Truck platooning configuration, there is no T3)

A few observations to highlight are:

- Combined on-road platoon results show improvement for the entire platoon in all configurations; however, the improvement seen in steady-state track tests was not achieved in on-road tests.
- There is a clear improvement between baseline and CACC for LT and T2. However, for T3 in the 3-Truck configuration, the improvement is smaller than the ones for LT and T2.
- LT improvement in 3-truck and 2-truck tests is attributed to the impact of eco-driving ADEPT features including predictive cruise control and neutral coating and Platooning effects combined.

The fuel economy test results of 3-Truck and 2-Truck platoons are divided into sections per the route description in Figure I.10-1 and the results are presented in Figure I.10-4 to further assess the impact of road grade variations.

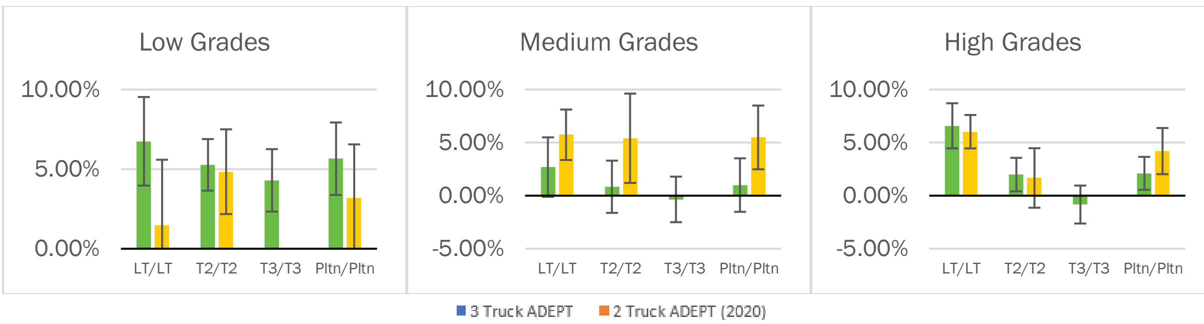


Figure I.10-4. Fuel Economy Results - Sections

- All sections show an improvement for platoons, but with mixed results for the individual trucks.
- Platooning with high grade variation shows significant reduction in fuel saving compared to operation under low grade conditions. In all these sections, traffic was relatively low. (See 2020 Annual Progress Report for the impact of traffic in 2-Truck platooning).

Technology barriers and issues

- Safety concerns
  - There are many places where platoons cannot form or be maintained due to safety concerns, such as dense traffic, construction areas, or road junctions (e.g., on-ramps). Between 20% and 30% of the route was "non-platoonable" each day.
- Traffic
  - In places with on-ramps and off-ramps especially, vehicles frequently had no choice except to merge between the trucks in the platoon, thereby disconnecting the platoon. Much effort to reengage is sometimes needed, especially in dense traffic, reducing benefits of platooning in those conditions.
- Wasted energy
  - The project team found that a significant amount of energy was wasted through excessive braking and motoring events in an effort to maintain the desired distance gap under high grade or high traffic portions of the route, thus lowering fuel economy improvements. Reducing wasted energy or recovering energy will improve fuel economy.

- Grade variations
    - High variations in grade prevent the platoon from remaining at the ideal time gap, in large part due to characteristics of the selected platoon controller. A combination of delayed (reactive) acceleration uphill, low truck acceleration capability (due to engine torque limits), and aggressive distance tracking (due to safety requirements) lead to wasted energy (e.g., the trucks will unintentionally separate going uphill and then purposefully accelerate down the hill to return to the proper gap). In addition, the reduced drag will cause the trailing vehicles to require more engine braking (wasted energy) to prevent over-speeding. These phenomena are reduced when the lead vehicle has ADEPT eco-driving features enabled, but more could be done to efficiently use energy as a platoon.
- Driver behavior
    - Lead Truck (LT) driver behavior, in conjunction with platoon navigation through traffic, was a significant factor in the 3-truck test. It caused lower average speeds and increased transient activity. It is clear that the LT driver has significant influence on the outcome of the platoon, especially if the driver does not use automated systems like cruise control consistently and frequently.
- Differences in Gross Vehicle Weight (GVW)/heterogenous configurations
    - Different weights, powertrains, and vehicle specifications will complicate platooning control. For example, heavier/slower vehicles may lead a platoon at an unreasonably slow speed, or, the slower vehicles may lose a platoon as they cannot retain the required average speed.
- Tire condition
    - Differences in stopping distance occur in situations where tire conditions vary among the trucks in the platoon. Weather conditions will further complicate this effect, making it challenging to safely platoon during non-ideal conditions.
- Changes in Vehicle to Vehicle (V2V) technologies
    - Advances in communication technologies have prompted a shift from decades-old DSRC (dedicated short-range communication) protocols toward C-V2X (cellular vehicle-to-everything). However, the infrastructure to support C-V2X is not yet widespread enough for high-volume implementation, and standards for these technologies continue to be developed.

Importance of tire connectivity

In 2021, through collaboration with Michelin North America, the project team studied the impact of steer tire (in the front axle position) and drive tire (in the drive axle position) constructions on the stopping distance performance of loaded and unloaded tractor-trailer Class 8 trucks running on dry asphalt road pavements. A first set of analytical tire tests that characterized tires individually indicated that the braking tire performance on dry asphalt is dependent on the tire construction. To quantify the effect on the vehicle braking performance, the project team conducted a second set of tests to measure the stopping distance of two groupings of steer and drive tires representing the extremes of these tires' individual braking performance on dry asphalt pavements. For these tests, these two steer and drive tire parings were mounted separately on a tractor pulling a semi-trailer fitted with common trailer tires. The tests indicated that the stopping distance between the two tire sets can vary by as much as 4.7% when the trailer is fully loaded and as much as 1.2% when the trailer is empty. The test data in 2020 show that this difference in stopping distance can increase to more than 20% under wet conditions.

The individual tire characterization with respect to braking performance was used to create tire models. The tire models were then coupled with vehicle simulation models to predict the stopping distances on dry pavements. The simulations predicted the correct tire set ranking, although the amplitude was higher than that obtained through vehicle tests. A subsequent slip histogram analysis showed that this discrepancy was probably due to a model versus actual vehicle difference in how the anti-lock brake system is tuned with the tire peak friction coefficient.

This project has shown that information in real time about the tire adherence capabilities can increase the fuel savings of vehicles running under platooning configurations. This improvement is because the tire characteristics have a considerable effect on the vehicle braking performance. Specifically, this work has shown that differences in tires can cause the stopping distance of a Class 8 vehicle to vary by as much as ~5% on a dry road and as much as ~20% on a wet road. In fact, these variations on wet surfaces placed the tire construction and wear state ahead of other variables such as the vehicle load. Furthermore, tests also showed that on dry asphalt pavements, differences in tire construction can lead to variations in vehicle stopping distance as high as 5%. Additional tests indicated that the variations noted were due to differences in the friction capabilities on wet and dry pavements provided by tires of different constructions.

To capitalize on these findings, the project team developed tire models to determine in real time the friction coefficient generated between the tire and the road as a function of the tire construction, road pavement and vehicle usage conditions. The project team then used these friction coefficients in vehicle models to predict the optimum platooning distance between Class 8 vehicles running different duty cycles. The simulations indicated that knowing the tire friction capabilities in real time allows the platooning distance to be further optimized by advanced predictive and optimal platooning control, thus increasing the vehicle fuel savings. For the trail platooning vehicle, these gains are predicted to be between 2% for low traffic and low road grade conditions and 5% for duty cycles that include road grade variations.

Advanced platooning solutions: connected and cooperative eco driving

Platoons consisting of automated convoys of heavy-duty trucks are designed to maintain close gaps between trucks to exploit drafting benefits and improve fuel economy, and have traditionally been handled with classically-designed connected and adaptive cruise control (CACC). Classical methods that enforce a gap can reduce energy use in steady-state uninterrupted operation. During transients induced by traffic or road grade, however, maintaining a desired gap may require application of brakes, thus wasting energy, or may lead to platoon disengagement when the trail truck falls behind.

The Clemson University (CU) partners addressed the above challenges of classical CACC by devising optimization-based control algorithms that are predictive in nature rather than reactive. These methods provide the capability to optimize the balance between gap tracking and powertrain efficient operation to minimize energy use [3]. The team focused on devising variants of a Model Predictive Controller (MPC) that optimized the longitudinal motion and lane decisions of each truck over a receding horizon and showed considerable improvement in fuel economy compared to traditional methods in high fidelity simulations. The benefits were higher when V2V connectivity allowed communication of future intentions by the preceding trucks to the following trucks. In heterogenous platoons, road tests showed that in hilly roads and during gear shifts, the platoon may still split due to a truck falling behind. To address this experimentally observed issue, CU introduced a considerate MPC variant that enables the leading trucks to accommodate those behind them by slowing down for them when necessary. The project team demonstrated the performance of the considerate strategy in a real-world driving scenario against a similar non-considerate control strategy. Overall, the team found that the considerate strategy significantly improved harmonization between the platooned trucks and prevented platoon disengagement.

While a constant target speed for the platoon is energy efficient on relatively flat roads, in hilly scenarios where maintaining a constant speed requires brake actuation, a variable target speed is more energy efficient.

Test data showed that for truck platooning in situations with high grade variation, when the Cummins ADEPT eco-driving features were integrated on the LT, significant fuel savings resulted.

An important analytical contribution by the team is the successful formulation of target speed optimization over the remaining route to the destination as a Linear Program that is solved an order of magnitude faster than previously proposed methods in the literature. Therefore, the proposed method has considerable energy saving potential for commercial implementation, not only in platooning but also in long-haul trucking [4].

The team also identified opportunities for energy savings by more systematic and optimized lane change decisions. The team proposed an optimal lane change algorithm, tailored for the complex geometry of a class-8 tractor-trailer, and successfully simulated realistic scenarios in dense traffic microsimulations. The proposed algorithm allows a single truck or a truck convoy to safely initiate and complete a lane change or take-over maneuver with energy efficiency consideration at its core [5].

Conclusions

The project team tested 3-truck platooning with CACC under real-world driving conditions, and the results are analyzed in this phase of the project. 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. The team conducted on-highway testing on a route in Indiana representing operation of long-haul class 8 trucks in the U.S, including low, medium and high-grade segments. The team compared data from the 3-truck platoon tests to previous 2-truck platoon test data, and while both 2-truck and 3-truck results indicated fuel economy benefit with platooning, the improvement was not as high in the 3-truck platoon as for the 2-truck platoon. The team identified several barriers that can contribute to the reduced fuel economy benefit with the 3-truck platoon, as well as challenges with platooning in any configuration. The team identified a few solutions to potentially address some of the issues with CACC for truck platooning.

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I.11 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, 2022
Project Funding: $1,885,514 DOE share: $942,757 Non-DOE share: $942,757

Project Introduction

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

Objectives

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

Approach

The project plan was developed to create a commercial EV charging solution that could be deployed on existing streetlighting infrastructure. The team identified eight essential 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 and Duke Energy.

Figure I.11-1 shows how these tasks create an overall product-development roadmap. The team initially developed a prototype using innovative technology. In parallel, the team also worked to understand community needs for curbside EV charging in the Carolinas, and the technical challenges associated with technology deployment. These learnings led to a field-testing phase. The team is currently synthesizing the information obtained throughout the project to develop a final product. Product development in this case involves much more than technology development and market understanding. Curbside deployment involves construction in the public right of way, which causes many potential complications.

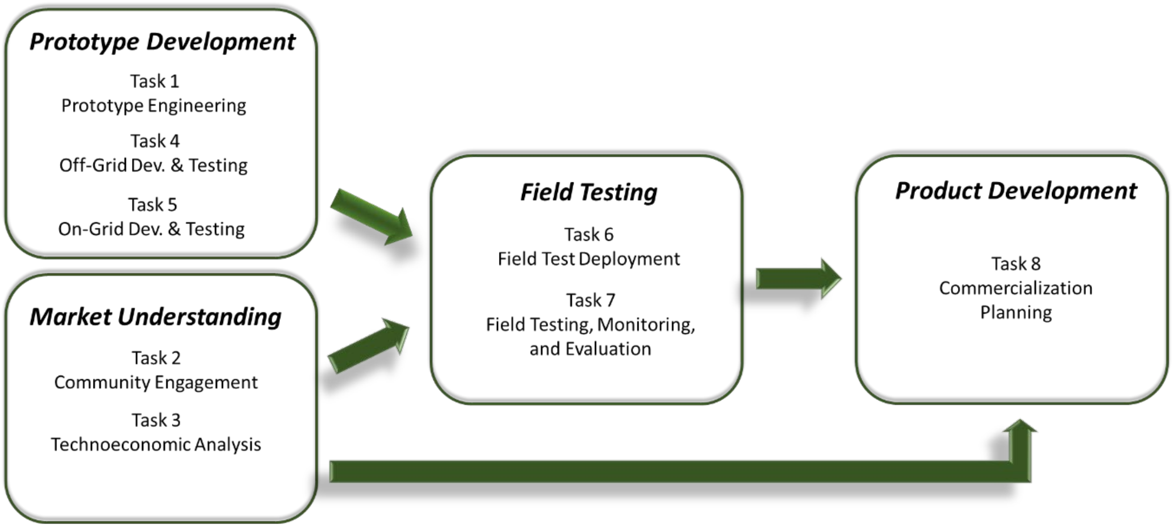

Figure I.11-1. Prototype charging station deployed on the campus of UNC Charlotte

Results

The first two budget periods focused on the two leftmost boxes shown in Figure I.11-1. In January 2021, the team transitioned to the field-testing tasks shown in the middle of that image, and launched the first two prototypes 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. Figure I.11-2 shows a customer using one of the on-campus stations.

Figure I.11-2. Prototype charging station deployed on the campus of UNC Charlotte

Figure I.11-3. Evolution of the charging station. Left: Initial prototype mounted on an overhead distribution pole at a test facility. Right: First commercial prototype.

Budget Period 3 focused heavily on the development of a commercial product. This work leveraged the learnings obtained throughout the previous budget periods. Figure I.11-3 show how the prototype system has evolved throughout this process. The image on the left shows the initial prototype installed on an overhead distribution pole at a test facility maintained by the project's utility partner. Power is fed from the overhead distribution circuit and first runs through the electric meter before entering the EV charging unit. The image on the right shows how the system evolved during Budget Period 3. This unit has been designed to be deployed at several curbside locations throughout the Carolinas. The system, which is called polevolt^{TM}, is designed to be deployed on any streetlight or overhead distribution pole. Power cables routed from overhead circuits enter the unit through the side connected to the pole. The unit shown in this image has a touch screen with a user tutorial. The charging cable is placed on a reel that allows the cable to retract into the unit. LEDs inset along the edge of the system indicate the system status.

Product development required the team to understand the challenges associated with deploying Level 2 charging stations on existing curbside utility infrastructure. The team discovered three primary sets of challenges, as follows:

Regulatory Barriers

The first is a complicated set of regulatory barriers. There are many utility poles located throughout urban environments, and these poles can be used to support power distribution circuits, outdoor lighting circuits, and telecommunications cables and equipment. The number of parties using a pole can create significant regulatory barriers in North Carolina and many other states. Installing a charging station, or any equipment for that matter, on a pole requires approval from all parties using the pole. Regulations in North Carolina only allowed the project team to deploy on poles used solely by Duke Energy's Outdoor Lighting Division. Use of other poles is possible but requires appropriate regulatory approval.

Utility Infrastructure

The second set of challenges encountered during the project relates to the technical specifics of utility infrastructure. The team installed equipment on existing lighting circuits, which generates several specific questions that must be answered when deploying equipment. First, one must determine if the lighting circuit has a voltage compatible with Level 2 EV chargers. These systems require either 208V or 240V. Some areas only have 120V or 277V circuits, and these cannot be used. Second, one must determine if the circuit has enough capacity to support the load from the EV charger. Utilities can determine this by evaluating the wire gauge and expected loading information from their databases. Third, one must determine if the intended pole is located too far from a transformer. If so, the unit can violate voltage requirements.

Public Right-of-Way Issues

The final set of challenges encountered during the project relates to installing charging infrastructure in the public right-of-way. This creates numerous challenges, including (1) concerns about accessibility for handicapped citizens; (2) worries over the potential for improperly stored cables to end up in the sidewalk or street where they can become hazardous; (3) questions over payment; (4) concerns about vandalism; and (5) debate over how a broader deployment strategy should be developed. The project team has documented these challenges throughout the project, and they have come from a deliberate stakeholder engagement process. Issues raised during this process affected the implementation of the system. For example, the team included a cable reel inside the unit because of concerns about cable management that emerged from stakeholder discussions.

Product development goes beyond the creation of the actual EV charging station and its associated management software. Given the involvement of a major utility, the team also explored questions around programs that can be offered by regulated utilities to address equity. Many of the vehicle owners without access to dedicated off-street parking live in low-to-moderate income urban neighborhoods. The polevolt™ system provides an opportunity to install chargers in these neighborhoods, which are much less likely to feature prominently for commercial charging providers.

Conclusions

This project has achieved two major outcomes. First, the team has developed a technology that can be easily installed on existing streetlight infrastructure. This technology has been demonstrated and is being commercialized. Second, the team has documented the primary challenges associated with using utility poles to provide a platform for EV charging. These learnings can benefit utilities and municipalities throughout the country.

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Acknowledgements

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I.12 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: December 31,2022
Project Funding (FY18): $3,000,000 DOE share: $1,500,000 Non-DOE share: $1,500,000

Project Introduction

Electric vehicles (EVs) are projected to take a significant share of new car sales in the very near future. While EVs were only 2.0% of the nationwide market in 2018 [1], EV sales could be as high as 32% of total light-duty vehicle sales by 2030 and could reach 45% by 2035 [2]. With the proliferation of EVs from traditional manufacturers comes a growing need for charging infrastructure. EV charging primarily occurs at three locations: at home, at work, and other (e.g., destinations). The U.S. Department of Energy indicates that 80% of EV charging is done at home [3], making access to home charging critical to achieving widespread EV adoption.

While residential charging at single family homes has developed rapidly, there are barriers to providing charging at multi-unit dwelling (MUDs). There has been limited deployment of curbside residential charging stations adjacent to apartments and condominiums. MUDs make up approximately 34% of the nation's housing inventory in major metropolitan areas [4]; however, less than 5% of home-based charging occurs at MUDs [5]. Some of the primary barriers that have limited widespread deployment of EV charging at MUDs and curbside residential locations include:

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

Objectives

The project objective 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 installing and operating EV charging at MUDs, as well as sample agreements and policies. The project will also evaluate and implement innovative, cost-effective, and flexibly expandable charging technology and software solutions that enhance the residential MUD and curbside EV charging systems market. The project results and the *Toolkit* will be broadly disseminated to ensure a meaningful, and lasting market impact, including increased MUD property and curbside charging infrastructure deployment and EV adoption by MUD residents and people without dedicated parking.

Approach

Each year of the three-year project is structured around activities that develop the required knowledge to create a comprehensive *MUD and Curbside Residential Charging Toolkit.* The *Toolkit* will allow MUD owners/managers to select the best solutions for their properties to overcome the identified barriers to deploying EV charging infrastructure.

Year one activities were 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 evaluated technical barriers by conducting stakeholder interviews and by analyzing EV charging infrastructure usage data from various MUD sites across the nation. This illuminated current charging/demand patterns, identified improvement opportunities, and served as the baseline dataset. The team also used historical and project-developed survey data results to identify non-technical/soft barriers to MUD charging infrastructure deployment. The project identified currently available tools and resources (e.g., fact sheets, webinars, articles, and a website) and evaluated how well they helped MUD owners/managers overcome the identified barriers. Where gaps existed, the project team developed tools and resources that provide a clear approach for tenants to work with MUD owners/managers to deploy EV charging infrastructure.

In the recently completed year two, the project team demonstrated seven innovative EV charging technologies in real-world MUD and curbside residential charging sites. The team collected and analyzed operational and business case data to quantify the innovations’ performance. The findings are being used with other inputs 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.

In year three, 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.

Year three, the final year of the project, will focus on refining the *MUD and Curbside Residential Charging Toolkit* and disseminating project learnings. The *Toolkit* is designed to be an online website with dedicated user roadmaps for each of the different stakeholder groups such as MUD residents, building owners/managers, and Homeowner Associations. The *Toolkit* will feature resources and tools to provide educational information for the users and help them identify possible barriers in their MUD through a self-evaluation survey. The survey’s results will then be used in the technology recommendations tool to search for technologies that could address the barriers identified. Beyond this key feature, the *Toolkit* also features MUD charging roadmaps and best practices of EV charging program design to assist users in preparing for their respective endeavors.

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 the number stakeholders reached and issue a final survey to project stakeholders to evaluate the impact of tools and resources created through the project. The project team will also disseminate project learnings through conferences, webinars, and journal publications such as the Electric Vehicle Symposium and the Roadmap Conference.

Results

The project team documented the innovative charging solutions and how each operates in real-world conditions to highlight how each overcomes one or more barriers identified at MUD properties.

The seven companies and their innovative charging infrastructure technologies included in the VCI-MUD project demonstrations are briefly described below:

- The **Cyber Switching EV Master Controller** uses multiplexing and/or rotational charging to manage up to four charging stations on a single electrical circuit. This approach is suitable for long-duration charging such as overnight MUD charging. This maximizes the use of existing electric infrastructure and delays the need for costly infrastructure upgrades. The EV Master Controller also minimizes electrical load, demand charges, and costs.
- **OpConnect**'s network software manages charging, grid integration, and is highly scalable. The system's control algorithm optimizes charging across a network of charging stations (small to large) and dynamically manages the load across the group to minimize electrical load, demand charges, and costs while meeting the EV charging needs. This maximizes the use of existing electric infrastructure and delays the need for costly infrastructure upgrades. The OpConnect system also minimizes electrical load, demand charges, and costs.
- **PowerFlex**'s Adaptive Load Management system's network software algorithms optimize power consumption across small to very large networks of charging stations, managing the load from all charging stations to maintain a safe power output within the transformer's capacity. The PowerFlex system provides grid integration, is highly scalable, and can accommodate from a small number to a very large number of charging stations. This maximizes the use of existing electric infrastructure and delays the need for costly infrastructure upgrades. The system also minimizes electrical load, demand charges, and costs.
- **Electric Vehicle Institute** provides turnkey charging station installation, ownership, and management of AC Level 2 charging stations and direct current fast chargers (DCFC). Charging sites include a wide range of locations, including MUD-adjacent sites (within a short walk). This offsite installation approach can be used when on-premises installations are not approved. The demonstration locations in the VCI-MUD project are nearby where multiple MUDs are co-located to maximize usage. The charging stations are also used by other mixed-use users during the day to increase utilization.
- **FreeWire Technologies Mobi EV Charger** is a mobile battery-powered AC Level 2 charging station. The Mobi is self-propelled to allow users to move the Mobi to where EVs are parked. The Mobi can charge two vehicles concurrently at 6.6 kWh each. The Mobi requires a single AC Level 2 charging station so it can be charged in one location and serve EVs across a wide area (e.g., parking garage). The Mobi could be used to evaluate EV charging needs, charging station placement, and provide a bridge as the charging station network grows. It could also be used as a permanent solution.
- **Liberty Plugins HYDRA-R** system uses multiplexing and/or rotational charging to manage up to 10 charging stations on an electrical circuit. This solution maximizes charging, minimizes power requirements, manages utilization and load, and can delay the need for infrastructure upgrades.
- **EVmatch**'s system uses software that extends the functionality of non-networked charging stations in shared use situations to provide scheduling, reservations, overstay notifications, adjacent session user communication, billing, data collection (baseline and in-use), as well as analytics to minimize/avoid increasing the facility's demand charges during peak load periods.

During the COVID-19 pandemic, MUD properties and the technology providers were primarily focused on maintaining their existing operations. Technology demonstrations at new sites took much longer to establish than anticipated. There were delays in establishing data sharing agreements and then in gathering the data for a baseline at the Project's various sites. As a result, the project used data from an existing site at four of the technology providers (OpConnect, Liberty Plugins, and Electric Vehicle Institute). Some of these installations had been operational for several years and had data from thousands of charging sessions to share. Three of the sites and individual technologies solutions were put into service during the project period (Cyber Switching, EVmatch, and PowerFlex). As a result of COVID's remote work and stay at home orders, like other drivers, EV drivers' vehicle and charging station usage were much lower than the typical pre-COVID usage. Acknowledging this, the project team accepted DOE's offer and extended the period for collecting data and user experience feedback by three months, to capture additional usage data, including usage more like pre-COVID conditions. Even with the extension, two technology demonstration sites did not reach 100 charge sessions.

The project team developed a 5-10 page Case Study for each technology/host site demonstration that included a summary of: 1) the property description, 2) the technology solution, 3) the charge session data analysis results, and 4) a business case analysis comparing the capital and operational costs of the innovative technology to the estimated costs under typical baseline installation options (i.e., high-cost/feature networked charging stations, low-cost/feature networked charging stations, and non-networked charging stations). The planned MUD Property Manager interviews and MUD resident web surveys intended to be implemented in June 2021 were delayed and will be implemented in March 2022. The results of these interviews and surveys will be added to the Case Studies and *Toolkit* to provide important candid feedback on the real-world perceived operation, costs, and use.

The project supported each of the innovative charging technology providers' understanding and experience with MUD properties' needs. This experience has helped the technology providers refine their product/service offerings for MUDs and expand their technology into the challenging and cost-sensitive MUD property market.

The project team grouped the key functionalities of the Vehicle Charging Innovation – Multi-Unit Dwelling (VCI-MUD) innovative technologies into five categories:

1. **Community charging station management** – OpConnect, EVmatch, Liberty Plugins HYDRA-R, and PowerFlex

2. **Power management system** – OpConnect, PowerFlex, and Liberty Plugins HYDRA-R

3. **Electric circuit multiplexer** – Cyber Switching Master Controller, EV Master Controller, and Liberty Plugins HYDRA-R

4. **Mobile charging** – FreeWire Technologies Mobi

5. **Off-site owned/operated charging stations** – Electric Vehicle Institute

The project team developed fact sheets for each of the five (5) innovative technology categories. (See example fact sheet in Figure I.12-1). The fact sheets contain the EV charging barriers, a technology overview, ways to address the barriers, and an example of a technology or technologies that can address these project barriers. These fact sheets will be available for users of the online Toolkit and distributed to partners via the Project Advisory Committee, Clean Cities Coordination meetings, and outreach done in Budget Period 3.

VCI-MUD

Multi-Unit Dwelling (MUD) Electric Vehicle (EV) Charging Technology Solutions:

Shared Electric Circuit/Rotational Charging

MUD BARRIERS TO INSTALLING EV CHARGING

Parking Limitation: Limited number of parking spaces can be allocated for shared EV charging

Parking Operation: MUD Property Managers need ways to: 1) maximize shared EV charging usage to minimize the number of shared parking spots and/or 2) share power among a group of charging stations at assigned parking spots that minimizes disruption to parking spot logistics.

Electrical Infrastructure Cost: Conventional solutions require a dedicated circuit/ power for each charging station. Properties without sufficient electrical capacity will require costly electrical infrastructure upgrades.

Charging Station Cost: MUD property managers want to use cost-effective charging stations that provide the required functionality

Operating Cost: Establishing a business case for MUD properties to offer EV charging to residents is challenging. MUD Property Managers want lower charging network provider fees, strategies to reduce power cost, and be able to bill for usage.

HOW SHARED ELECTRIC CIRCUIT/ROTATIONAL CHARGING CAN ADDRESS EV CHARGING BARRIERS

Parking Limitation: Allows for more cost-effectively installing charging ports at more parking spaces to reduce/eliminate the number of shared parking/charging spaces. Can be used in dedicated or shared parking situations.

Parking Operation: Power is shared among a group of charging stations. So when charging session is completed drivers do not need to move their vehicle right away (or ever for dedicated parking situations).

Electrical Infrastructure Cost: Maximizes usage of available electrical capacity before infrastructure upgrades are needed

Charging Station Cost: Compatible with any low-cost non-networked EV charging station manufacturer/model or an electric outlet for properties that require residents provide their own charging station/cordset

Operating Cost: ow monthly subscription fees. If MUD property opts to charge station usage fees, MUD property receives revenue (net after electric and charging network provider fees).

Example VCI-MUD Project Innovative Technologies Demonstrations:

Cyber Switching EV Master Controller and Liberty Plugins HYDRA-R

Without a Charge Controller

With a Charge Controller

Source: Cyber Switching

TECHNOLOGY OVERVIEW

Cost-effective circuit sharing management system controls low-cost non-networked charging stations. Power management to maximize circuit utilization by only charging connected vehicles that need a charge. Reduces electrical infrastructure requirements. Compatible with any non-networked EV charging station manufacturer/model. Shares the power from one electric circuit between multiple (up to 10) charging ports. Positive user experiences in long-dwell parking situations (overnight parking at home). Systems' web-based interface for MUD Property Manager interface and usage data access. Some systems have mobile app interface for users to initiate/manage charging sessions.

CYBER SWITCHING®

LIBERTY ACCESS TECHNOLOGIES
A Division of Liberty Plugins, Inc.

For more information, visit: VCI-MUD.org

Center for Sustainable Energy

energetics Clean Energy Consulting

FORTH

Clean Cities
U.S. Department of Energy

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December 2021

Figure I.12-1. Example Technology Fact Sheet One-Pager

Conclusions

The project has assembled a large and diverse dataset that deepens our understanding of MUD and curbside residential charging. The qualitative data has confirmed many of the barriers to 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

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Innovative Charging Infrastructure Technology Pilot Demonstration Plan (June 2020)

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I.13 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. Without easy access to charging, however, 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) built out a demand-driven model of potential siting locations. In 2021, the project research team from MST transferred to Penn State University (PSU) and continued researching demand and site selection considerations. The National Renewable Energy Laboratory (NREL) modeled 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 developed a site selection evaluation checklist. Community listening sessions revealed 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. 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 2022.

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 submitted the policy framework to the City; created site visit checklists and evaluated proposed locations; and created a community outreach plan and messaging documents. Each of these topics is discussed in detail below.

Siting

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 Programs 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.

MEC and other project partners drafted site selection criteria that will be used in the go/no go decisions. A site selection committee, comprised of project team members, was 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 team held the first site selection committee meeting. Committee members determined that the first step in the process should be review by the City's Streetlights and Parking Programs. 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 a few additional sites in floodplains due to flood hazards and the likelihood of being flagged during the National Environmental Policy Act (NEPA) review process, causing delays. Site visits were delayed due to the COVID-19 pandemic but took place throughout 2021. Project subrecipients 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 conducted limited community outreach, by notifying neighborhood groups of our plans and training site visitors on interacting with residents.

While initially 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. During the 2021 site visits, the project engineer selected streetlight poles for EVSE installation that would require the least costly upgrades. The project engineer eliminated more areas due to lack of suitable and cost-reasonable streetlight poles that could serve POIs or multifamily residents. See Figure I.13-1 for a visual of the streetlights selected by the project engineer for further review and approval, overlaid on the 6 different city council districts.

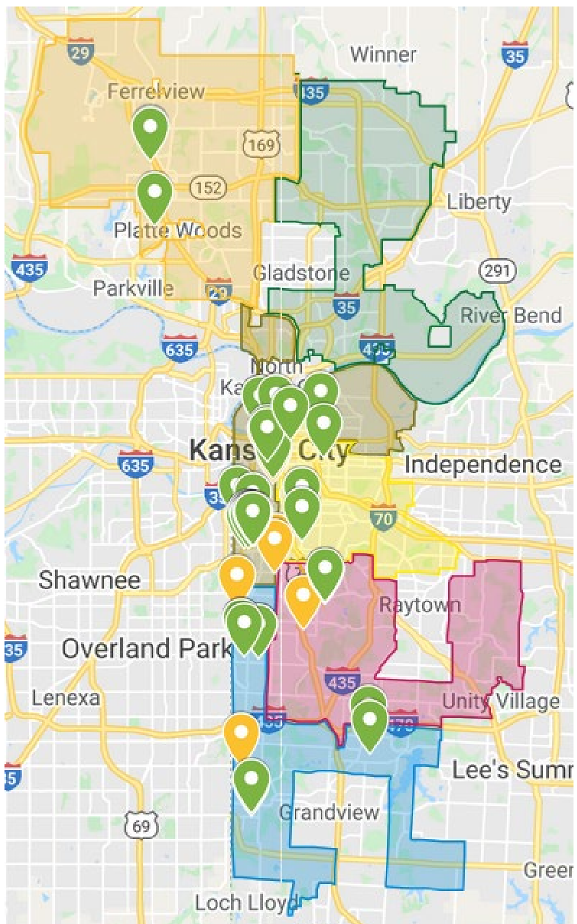

Figure I.13-1. Go/Maybe EVSE sites. MEC

MEC and project subrecipients conducted individual in-person site visits to document conditions and verify information and data collected from virtual site visits. This step captured invaluable information such as new points of interest, new infrastructure, additional community feedback, and other important information. A few additional site visits may be necessary based on community feedback on the proposed sites. All of the data for each site has been captured in the site evaluation spreadsheet, including area demographics, land development, pole type, voltage, cost, community feedback, NEPA factors, and other data. The team also collected relevant data for the permitting process, parking review, and other city review and approval processes in the spreadsheet.

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. MEC plans to analyze reasons for non-selection and incorporate this information into the final report.

Engagement

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 drafted messaging for community outreach and engaged local organizations to assist with building out a stakeholder matrix of participants. Due to the ongoing COVID-19 pandemic, plans for community outreach were delayed. MEC, NREL, and EV Noire conducted two online community listening sessions in summer 2021, results of which will be incorporated into final site selection.

MEC began outreach to community organizations in early 2021 to inform them of the project and plans for site visits, and finalized updates to the project webpage. Interested organizations can learn more about the project by visiting the project website, signing up for newsletters, participating in a listening session, or commenting on the project.

MEC delivered one targeted project presentation per request for an interested neighborhood association in early 2021. Feedback from residents was generally positive, but some attendees expressed concerns about parking. Residents voiced support for the proposed sites in their neighborhoods and agreed that sites should be located along the identified points-of-interest.

MEC, EVNoire, and NREL contracted with two local community organizations that represent the communities served by the project to support project outreach and engagement efforts. These two local partners assisted with prospecting and inviting other local organizations, disseminating project information, and providing feedback on content and outreach plans. Community partners also reviewed project information and documents for relevance to their community members. MEC and community partners conducted extensive outreach and invited community organizations, particularly those that represent traditionally underrepresented groups. Participants were incentivized to attend with gift cards.

Around a dozen individuals in total participated in the sessions, mostly from our targeted invitations. Diverse neighborhoods across the city were represented, and disadvantaged neighborhoods in the east side had a very strong showing in comparison to other areas of the city. No community members voiced opposition to the project, although there were calls for more equitable distribution across the city, especially in disadvantaged areas. There were also calls for more EV education, especially in disadvantaged areas with fewer EVs, where people may not be as knowledgeable or aware of EVs.

Throughout the rest of the year, MEC, EVNoire, and NREL worked on synthesizing the feedback from participants and incorporating it into site selection, city policy recommendations, and other relevant project activities, and presented it in a final report. Based on community feedback, MEC will consider additional sites if they are feasible and in accordance with our approved Statement of Project Objectives.

Engineering

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 needs, which will be determined by final site selection.

City Policy

The project team met as part of the City's EV green group 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. The primary objective of the City Policy Feasibility document is to assess the current environment for EV charging in Kansas City, Missouri, explore ways to implement policy that supports those efforts, and proactively prepare for the growing market of EV users in the Kansas City metropolitan area. This report gave an overview based on current and national trends in the market of why EV implementation is vital for the future of the Kansas City community. The subcommittee gave MEC permission to share the draft with the rest of the project partners and MEC began to solicit input from them on the document. The City's EV green group considered this input as they finalized their specific recommendations. This task was delayed due to reduced staff capacity at the City caused by turnover and the COVID-19 pandemic. In 2021, MEC worked with City staff to update and revise the policy draft and submitted a final draft to the Kansas City, Missouri Office of Environmental Quality.

From discussions with City staff, MEC identified several ordinances that could positively or negatively impact the project. The city has an ordinance to prohibit the parking of internal combustion engine (ICE) vehicles at EV parking spaces. MEC plans to conduct more research into how this ordinance is enforced by the city. Additionally, the City has an ordinance that requires the approval of adjacent property owners and tenants when parking in front of their property is restricted. Due to the restriction on ICE vehicles at EV parking spaces, it appears this project will now similarly require property owner and tenant approval. MEC also plans to incorporate adjacent property owners and tenants into the community outreach plan prior to final site selection. MEC plans to continue regular meetings with the City Parking Program to ensure the project meets City requirements for community outreach and permitting. MEC also identified several sites near city-owned parks. As a result, these sites will need to undergo review and approval by the City's Parks and Recreation Department. MEC met with Parks and Recreation to present the project and requested review in late 2021. Review and approval are anticipated from both the Parks and Recreation Department and the Parking Program in early 2022, prior to permitting and installation.

Barriers

A new challenge with the equipment ownership plan has presented itself. The Missouri Public Service Commission (PSC), in the interest of preventing monopolies, has limited the number of charging stations Evergy is allowed to own. MEC has contacted the PSC regarding this matter and hopes to resolve the issue through a waiver from the PSC. Due to ownership uncertainties and delays in the appeal process, the EVSE installations have been suspended until a strategy can be developed.

Evergy filed an appeal with the PSC in early 2021 and MEC submitted a letter of support for this filing. MEC and Evergy strategized alternate paths forward so that the project activities can continue in the meantime. MEC and Evergy considered 3 alternatives: 1) for MEC to own the chargers and later transfer ownership to Evergy or another party; 2) for MEC to own the chargers and lease them to Evergy; and 3) for Evergy to decommission some of their current chargers and replace them with the chargers under this project.

In 2021, MEC staff presented a draft plan to the MEC Board of Directors for their consideration of option 1. The BOD expressed concerns with plans for MEC to own the chargers, due to the need for restructuring the organization and purchasing additional insurance. Insurance provision for EVSE is a major barrier for small and mid-size organizations; since actuarial tables have not been generated and this type of installation has not been incorporated into regular business practice, coverage is considered high risk and is cost prohibitive. Other project partners expressed similar concerns and will not consider ownership. Due to the ongoing PSC review of Evergy's charging station network, Evergy declined to consider option 3 any further at this time.

MEC is continuing to explore ownership options until we receive a decision from the PSC. Installations will be delayed until a viable ownership strategy can be established, likely early 2022. MEC and Evergy met with the Office of Public Counsel (OPC) to present the project and answer questions. Throughout 2021, MEC continued to provide relevant information to the PSC, Evergy, and OPC as requested to aid in decision-making.

Lessons Learned

- Real world data does not always match data collected on a computer. It is a best practice for project partners to visit proposed installation sites in person to verify site conditions and capture new information. Some of the information gathered from in-person observations included additional community input, parking difficulty, and newly installed infrastructure.
- Using utility poles instead of streetlights may provide more cost-efficient installations as they tend to have more capacity and require fewer upgrades; however, adequate street lighting is a key safety factor for vehicle drivers according to community feedback.
- State and local policies and decision-makers may be unprepared for pilot projects of this nature, due to technological innovation, ownership considerations, right-of-way impacts, and community impacts. As such, project delays may occur as regulations and guidelines need to be updated by government agencies to allow the project to proceed. It is imperative that project leaders communicate with these entities early and often to navigate regulations, permits, approval processes, and other hurdles.
- While a data-driven approach to site selection is generally advised, real world limiting factors should have a greater impact on decision-making than theory or models. While a model may identify a proposed site as ideal, if it is not feasible or is opposed by the community or project partners, it cannot proceed.
- Some areas of the city are more suitable than others for streetlight charging, primarily due to availability of streetlights, curbside parking, multifamily housing, points-of-interest, traffic safety, and other factors. Since the existing conditions on which streetlight EVSE depend are distributed inequitably, proposed sites based on existing conditions and trends will also not be distributed equitably.

Conclusions

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

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

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Start Date: Oct 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 LaGuardia and John F. Kennedy 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.14-1. Framework of the METS-R platform. More details of our approach are summarized as follows:

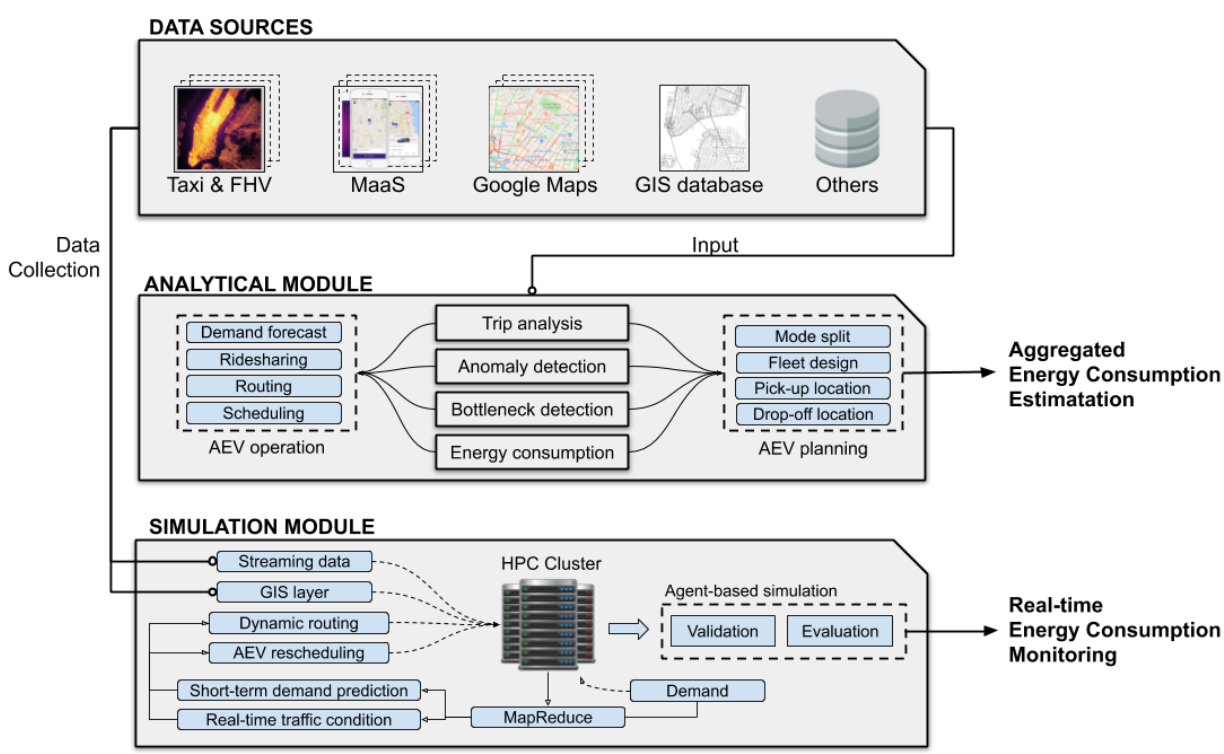

Figure I.14-1. Framework of the METS-R platform

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 [0]. 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 reduces the computational cost.

Results

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 team had focused on designing and extending the planning and operation algorithms, in addition to developing the high-performance simulation platform. During the third year of the project, the team achieved three milestones.

1. The project team extended and revised the high-performance agent-based simulation developed in the second project year. First, the team integrated two advanced operational algorithms including the hub-based ridesharing for AEV taxis and the demand-adaptive transit scheduling for AEV buses into the simulation. The team developed these algorithms and validated them by small-scale numerical experiments. Second, the project team reimplemented the server side of the HPC module in Python to facilitate the integration of the operational algorithms and provide useful application programming interfaces (APIs) for future extension. Third, the team also revised the visualization tool by adding more metrics, including the accumulated flow and energy consumption on each link and the heatmap of vehicle distribution. See Figure I.14-2. A demo for this tool can be found at https://engineering.purdue.edu/HSEES/METSRVis/.

2. The project fulfilled the scenario design for the METS-R system evaluation. The team adopted a two-step unsupervised method to reduce the human bias. First, a Gaussian mixture model was applied to segregate the daily demand patterns (the vectors of hourly travel demand from/to each transportation hub) into normal and abnormal cases. Then the normal cases were further divided into three clusters using K-means algorithm. The number of clusters was selected based on the highest silhouette score. Figure I.14-3 shows the distribution of weekdays and the level of demand in different scenarios. Based on the distribution of weekdays, the first and second scenario are referred to as the normal weekend

usage with low demand and high demand respectively, and the third scenario is the normal weekday usage.

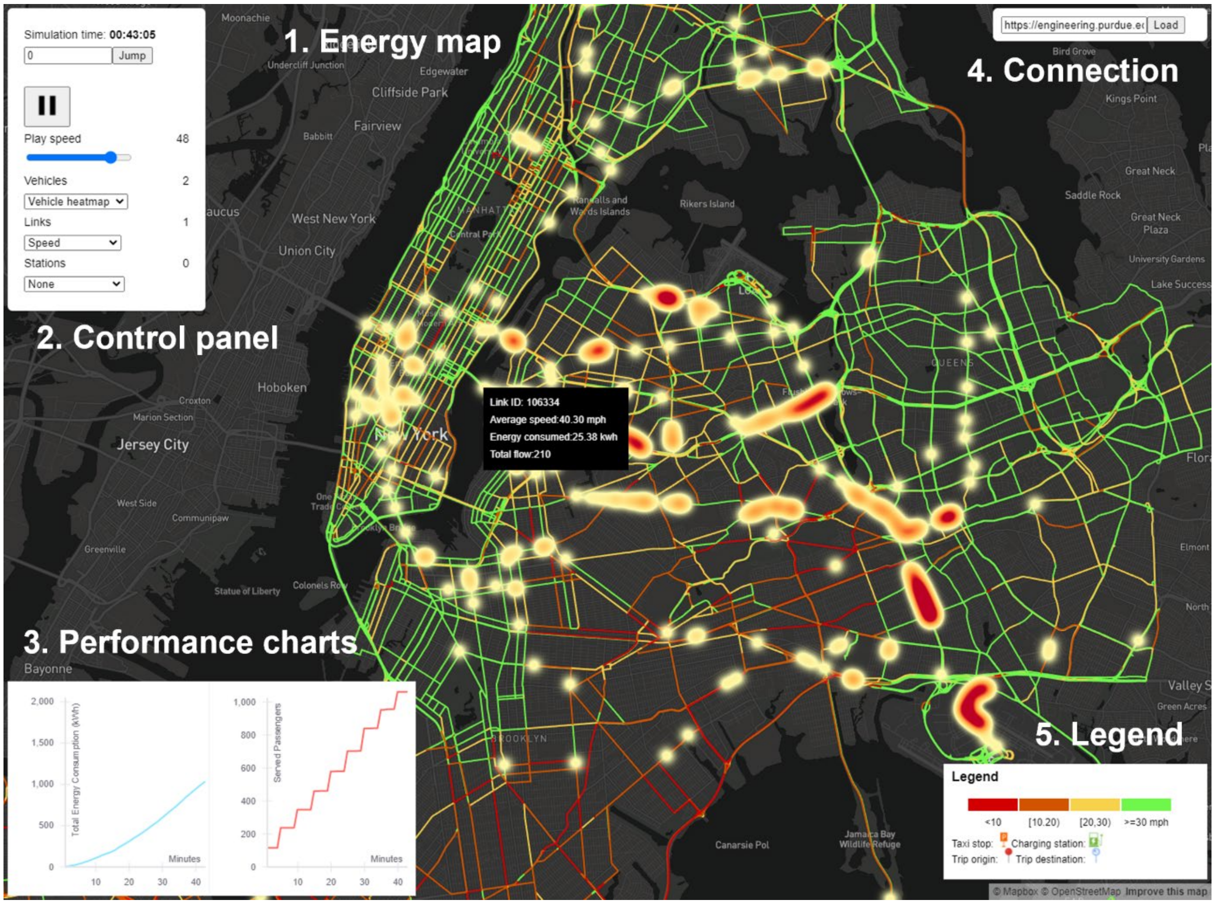

Figure I.14-2. Visualization of the simulation result

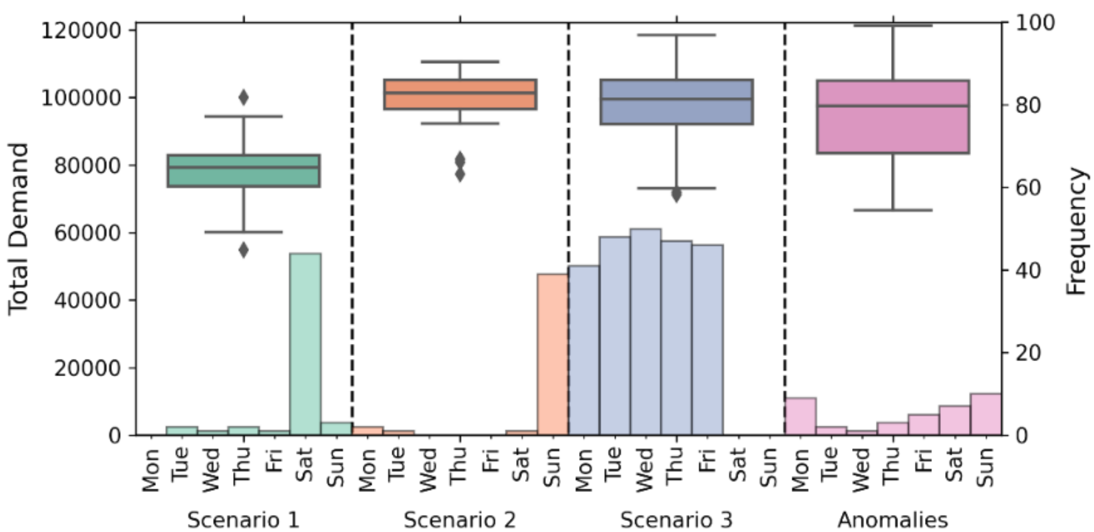

Figure I.14-3. Distribution of weekdays and daily travel demand in different scenarios

3. The team conducted the numerical experiments to evaluate the METS-R system. Based on the preliminary experiments, the team proposed to evaluate the METS-R system based on ten metrics that cover the perspectives of infrastructure planning, service operation, and environmental cost. The team evaluated each strategy using a subset of metrics, as shown in Figure I.14-4. Figure I.14-5 shows an example of such comparison for evaluating the ridesharing algorithm under the low vehicle supply case with 3500 EV taxis. It can be observed that the system with the ridesharing algorithm consistently outperforms the no ridesharing one.

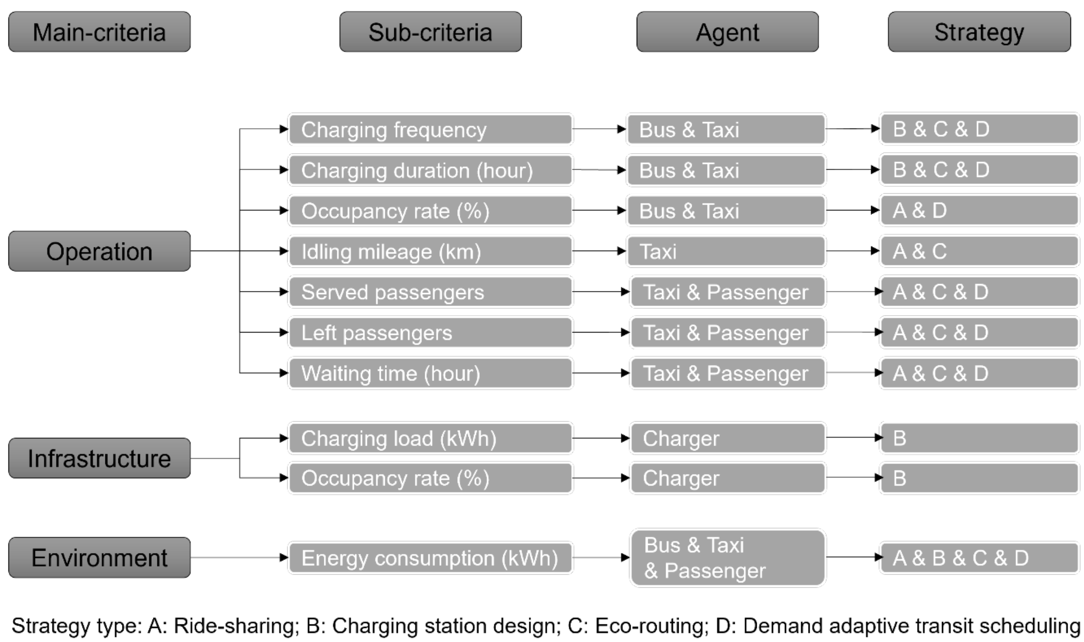

Figure I.14-4. Metrics for evaluating the performance of the METS-R system

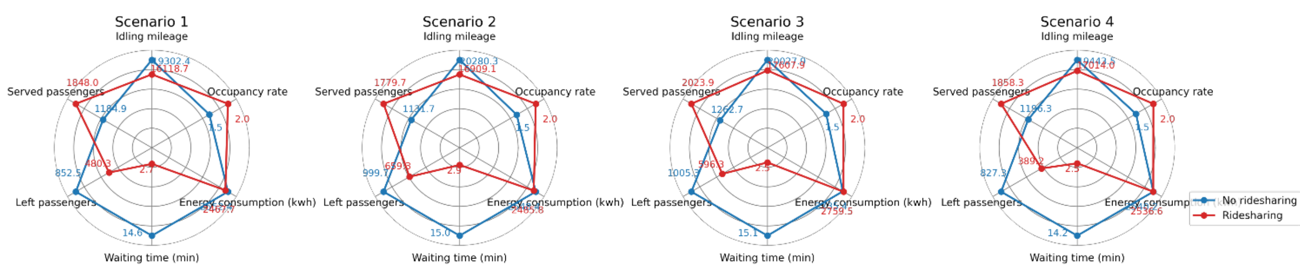

Figure I.14-5. Results for evaluating the ridesharing algorithm

Conclusions

In this project, the team developed METS-R, an operational planning platform for designing the next generation mobility solution with AEV, to substantially save energy for serving passengers at transportation hubs. The platform consists of a data analytic module to fuel novel planning and operational algorithms, and a high-fidelity simulation module to validate the system performance. The METS-R simulator is equipped with the HPC module to improve the efficiency of performing expensive operational algorithms, i.e., eco-routing, ridesharing, and demand-adaptive transit scheduling. As a result, we can simulate at least 3,000 EVs and 17 transit routes for one day in two hours. The project team conducted extensive numerical experiments with four (three typical, and one abnormal) demand scenarios. The results suggest that adding the proposed planning and operational algorithms can save 20%-60% of energy consumption in the transportation system without comprising the passenger service requirements and system efficiency.

Key Publications

Lei, Z., Xue, J., Chen, X., Saumya, C., Qian, X., He, M., Sobolevsky S., & Ukkusuri, S. V. (2021, September). ADDS-EVS: An agent-based deployment decision-support system for electric vehicle services. In 2021 IEEE International Intelligent Transportation Systems Conference (ITSC) (pp. 1658-1663). IEEE.

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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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I.15 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 1,041 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 has completed several tasks which have led to the successful completion of a series of milestones in the second year of the project. Milestones from year two include:

1. Data Collection: Data collection complete and meets requirements for analysis
2. Data Cleaning and Analysis: Conduct Project Advisory Committee (PAC) meeting to obtain feedback on data cleaning and analysis efforts
3. Repair Code Decoder: Complete preliminary and maintenance repair code decoder

4. Data Transfer: Complete transfer of data to DOE.

The Go/No Go milestone for the second year of the project was to complete a transfer of data to DOE.

Data Collection

Clean Fuels Ohio continued to partner with five DOE Clean Cities Coalitions, via sub-contract agreements with Virginia Clean Cities, Wisconsin Clean Cities, Dallas-Fort Worth Clean Cities, Oklahoma Clean Cities, and Tulsa Clean Cities whereby each partner identified and secured key NGV fleet stakeholders in their regions. Clean Fuels Ohio also continued to partner with a newly added Clean Cities coalition, Clean Communities of Western New York (CCWNY), via sub-contract agreement, along with Clean Communities of Central New York and Empire Clean Cities, as subcontractors to CCWNY, to identify additional NGV fleet data partners. Clean Fuels Ohio continued to facilitate conversations with various partners including the National Renewable Energy Laboratory (NREL), NGVAmerica, Cummins, natural gas fuel providers, North American Council for Freight Efficiency (NACFE), Hexagon Agility Systems, South Coast Air Quality Management District, National Association of Fleet Administrators (NAFA), Argonne National Laboratory, Energetics, and more, to identify additional key NGV freight and goods movement fleets.

As detailed below, the project team has secured fleet partnership agreements involving 1,616 vehicles to date and continues to work to secure agreements involving 2,453 potential additional vehicles. This will round out the dataset with a potential total of 4,069 vehicles and a diversity of freight and goods movement fleets across the country. See Table I.15.1.

Table I.15.1. NGV UP-TIME: Fleet Partner Engagement

Fleet Name	Data Agreement Status	# of Vehicles
Fleet A	**Signed**	1,188
Fleet B	**Signed**	172
Fleet C	**Signed**	118
Fleet D	**Signed**	85
Fleet E	**Signed**	53
Fleet F	In Progress	185
Fleet G	In Progress	500
Fleet H	In Progress	700
Fleet I	In Progress	38
Fleet J	In Progress	150
Fleet K	In Progress	378
Fleet L	In Progress	200
Fleet M	In Progress	320
Total Secured:	**1,616 Vehicles**	
Total In-Progress:	**2,453 Vehicles**	
Total Potential:	**4,069 Vehicles**	

To further clarify the amount of NGV and diesel maintenance cost data collected to date, 1,445 vehicles with maintenance cost data out of the 1,616 total vehicles secured via agreements are currently in the Energetics database. 171 vehicles with maintenance data are in the process of being uploaded into the combined, cleaned database. Clean Fuels Ohio plans to secure agreements from potential fleet data partners encompassing ~2,500 additional vehicles with maintenance data.

Clean Fuels Ohio and Energetics worked with committed fleet partners to explain the data collection process and review and confirm the fleet partner's maintenance job coding system, or Vehicle Maintenance Reporting Standards (VMRS) system, and other high-level fleet-specific operations information (i.e., type of maintenance labor, adherence to factory service, common natural gas truck failures, warranty, etc.). Energetics supported committed fleet data partners with the data gathering process by providing instructions for dataset upload and submission to a secure Energetics SharePoint portal with unique user-specific logins, to ensure satisfactory data collection required for analysis. Clean Fuels Ohio and Energetics anticipate continuing fleet vehicle maintenance data collection throughout the rest of Budget Period 2 and completing this milestone in the early phases of Budget Period 3.

Energetics has progressed with data collection efforts from committed fleet data partners and continues to use its Microsoft Azure cloud computing platform for data storage, manipulation, and analysis, for initial data quality review and gap assessment. Clean Fuels Ohio plans to collect additional vehicle profile, operations, fueling, and maintenance data to develop a comprehensive, consistent, diverse dataset throughout the rest of the project data collection period.

Data Cleaning and Analysis

After collecting each fleet partners' dataset, Energetics reviewed each fleet's data for consistency, completeness, and erroneous or outlier data, to resolve issues and create a complete fleet dataset for the project's database. Energetics also plans to remove any personally identifiable information (PII) and business sensitive information and replace it with project-defined values in the final consistent dataset. As part of quality control procedures, Energetics will also contact data partners, if needed, with questions about data, to ensure each fleet's dataset is complete and valid.

Clean Fuels Ohio continued to engage with its diverse PAC to obtain feedback on data collection, cleaning, and analysis efforts. Clean Fuels Ohio convened the PAC in June 2021 and presented initial vehicle and maintenance data analysis metrics. Based on PAC feedback on these vehicle metrics, the project team received input to include additional vehicle profile descriptions such as vehicle make and engine type. Clean Fuels Ohio plans to present additional data cleaning and analysis efforts at the final PAC meetings in 2021 Q4, to receive final feedback and input, and successfully complete this milestone in 2022 Q1.

The visualizations in the following figures display a preliminary and initial vehicle maintenance data analysis of natural gas and diesel trucks in a freight and goods movement day cab/regional transport application. It is important to note that the graphics in this report are preliminary and only represent data from the first 866 vehicles that the project team received from fleet data partners. The project is now at a point where it has received data for 579 additional vehicles since these graphics were developed, totaling 1,445, as cited in the previous section.

Figure I.15-1 displays the five vehicle makes, with a majority of the trucks being Volvo due to one of the fleets being quite large and using exclusively this make.

Figure I.15-2 displays the distribution of vehicle model years for both diesel and natural gas, with a majority being 2015 model year and after trucks which the project is focusing on. Figure I.15-3 displays the distribution of diesel engine sizes with a majority being 11L diesel trucks. All natural gas trucks in the database so far are 12L sized engines and are the newest or latest generation Cummins engines.

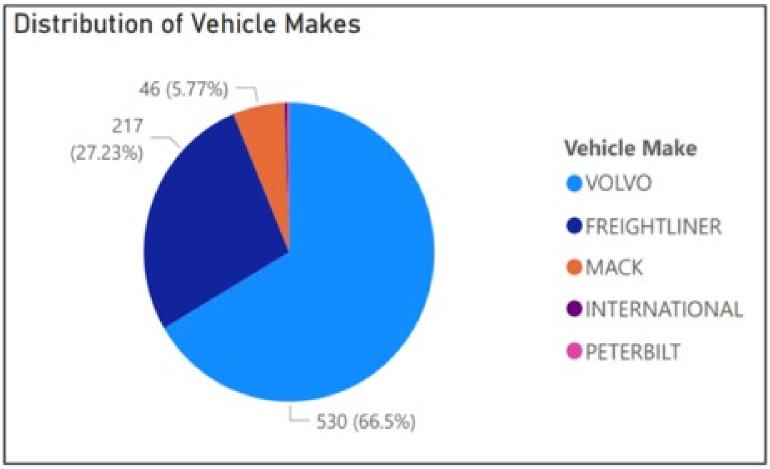

Figure I.15-1. NGV UP-TIME: Distribution of Vehicle Makes

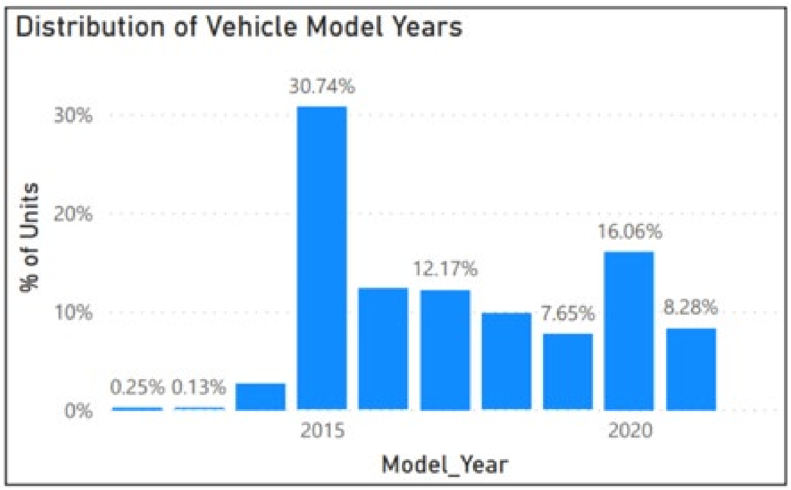

Figure I. 15-2. NGV UP-TIME: Distribution of Vehicle Model Years

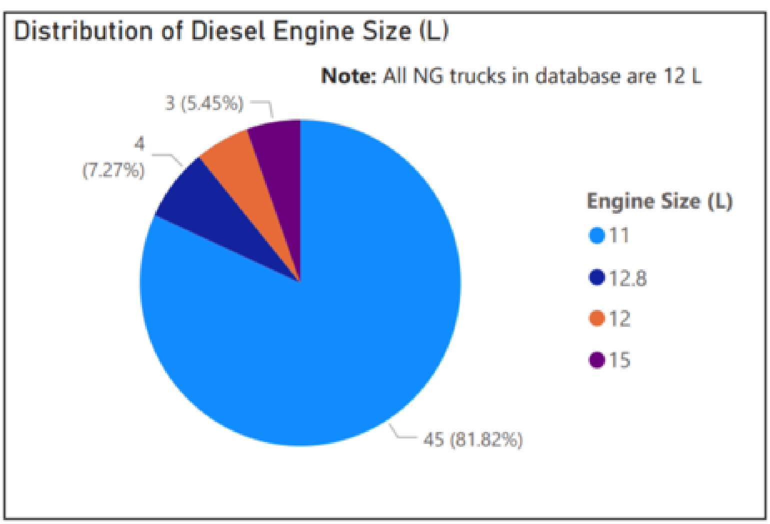

Figure I. 15-3. NGV UP-TIME: Distribution of Diesel Engine Size

Figure I.15-4 displays the number of vehicles by fuel type. A majority of vehicles in the database so far are natural gas trucks because the database is still missing diesel vehicle data from a large key fleet partner.

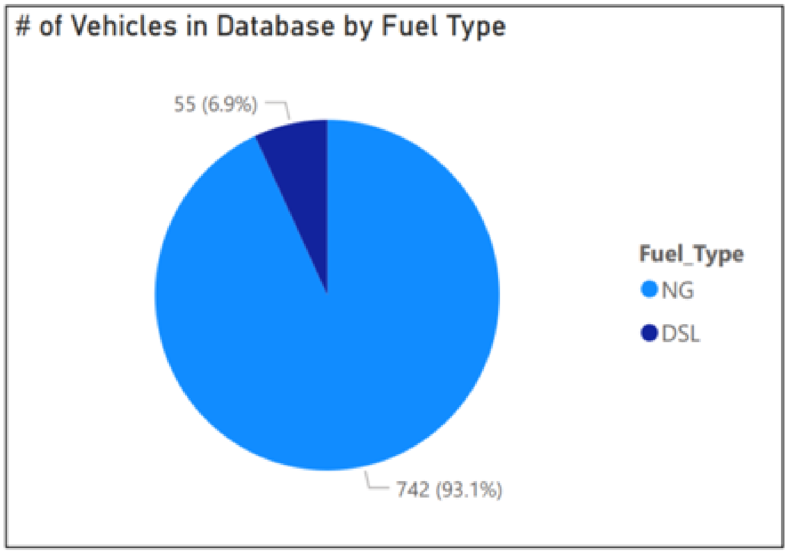

Figure I. 15-4. NGV UP-TIME: Number of Vehicles in Database by Fuel Type

The graphic in Figure I.15-5 displays initial metrics on maintenance data showing maximum recorded mileage based on model year of the truck. The dark blue bars (diesel vehicles) show the highest mileage vehicles from Model Years 2014-2016 and the light blue bars (NGVs) show the high mileage being before and after 2020.

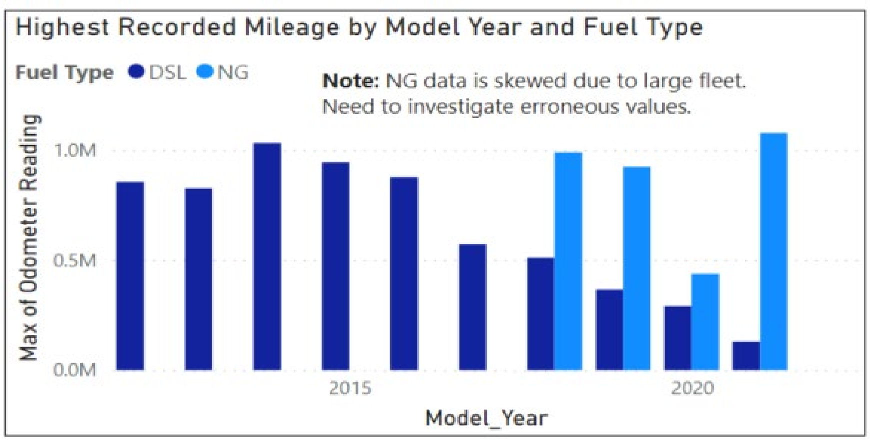

Figure I.15-5. NGV UP-TIME: Highest Recorded Mileage by Model Year and Fuel Type

The graphic in Figure I.15-6 displays the number of average repair orders per vehicle by fuel type with NGVs having a slightly higher amount with around 160, compared to the diesel vehicles with around 140. Overall, the data analysis visualizations represent a preliminary analysis on vehicle and maintenance data for 866 primarily NGVs. The project anticipates constructing less skewed and more realistic outputs of data analysis and visualization as the study continues to recruit additional fleet data partners.

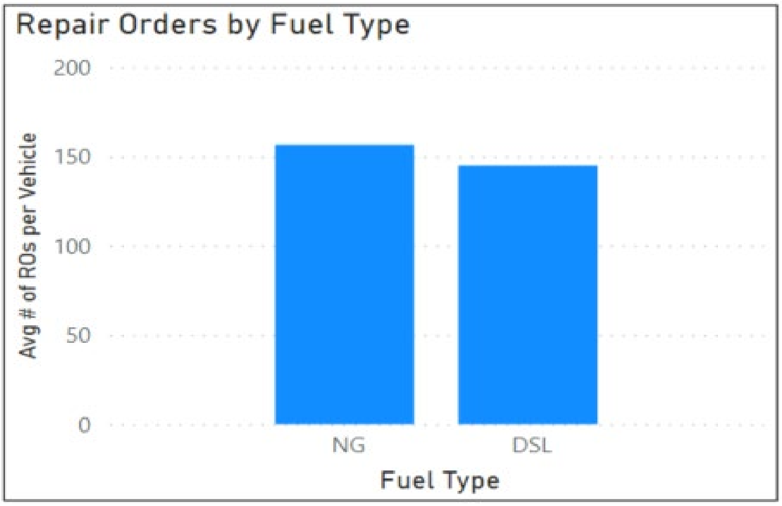

Figure I. 15-6. NGV UP-TIME: Repair Orders by Fuel Type

Repair Code Decoder

Overall, the project team has made good progress in developing the repair code decoder. The following figures represent Energetics' initial attempt to decode VMRS codes based on number and percentage of repair orders for NGV trucks (Figure I.15-7) and diesel trucks (Figure I.15-8).

Fuel_Type	VMRS System Code	VMRS System Description	# of Repair Orders
NG	045	POWER PLANT	23.23%
NG	002	CAB & SHEET METAL	15.44%
NG	044	FUEL SYSTEM	14.20%
NG	053	EXPENDABLE ITEMS	13.78%
NG	034	LIGHTING SYSTEM	13.06%
NG	013	BRAKES	11.50%
NG	501		11.27%
NG	017	TIRES, TUBES, LINERS & VALVES	10.66%
NG	042	COOLING SYSTEM	8.41%
NG	033	IGNITION SYSTEM	8.36%
NG	001	AIR CONDITIONING, HEATING & VENTILATING SYSTEM	4.83%
NG	509		4.77%

Figure I. 15-7. NGV UP-TIME: VMRS System Codes and Descriptions for Natural Gas Vehicle

The project team was only able to go as far as the system codes and plans to develop repair and assembly codes as the project continues and adds more vehicle maintenance data. Regarding pure system codes for natural gas trucks, the project saw the highest percentage of relevant repair orders related to power plant, cab & sheet metal, fuel system, expendable items, and lighting system. Energetics has decoded the system code from data collected to date and plans to finalize developing the decoder with component and assembly data from the remaining VMRS codes of potential fleet data partners. For diesel trucks, the project saw the highest used repair order codes related to cab and sheet metal (including everything from windshield wipers to body work), lighting systems, and tires, tubes, liners, and valves.

Fuel_Type	VMRS System Code	VMRS System Description	# of Repair Orders
DSL	002	CAB & SHEET METAL	22.98%
DSL	034	LIGHTING SYSTEM	20.19%
DSL	017	TIRES, TUBES, LINERS & VALVES	14.48%
DSL	013	BRAKES	13.44%
DSL	045	POWER PLANT	13.31%
DSL	032	CRANKING SYSTEM	7.11%
DSL	043	EXHAUST SYSTEM	6.53%
DSL	044	FUEL SYSTEM	5.68%
DSL	003	INSTRUMENTS, GAUGES, WARNING & SHUTDOWN DEVICES, & METERS	4.69%
DSL	023	CLUTCH SYSTEM	4.64%
DSL	063	SATELLITE COMMUNICATIONS	4.23%

Figure I.15-8. NGV UP-TIME: VMRS System Codes and Descriptions for Diesel Vehicles

Clean Fuels Ohio and Energetics anticipate the remainder of the repair code decoder development process to be straightforward once all fleet vehicle maintenance data and VMRS codes are gathered into the database. The project team plans to finalize the repair code decoder throughout the rest of Budget Period 2 and in the early phases of Budget Period 3 to meet the successful completion of this milestone, as indicated in the project timeline.

Data Transfer

Clean Fuels Ohio and Energetics conducted initial communications with NREL and the Livewire Team to meet the milestone of completing a data transfer to DOE in Years 2 and 3. The project team will continue working with NREL to develop processes to transfer and incorporate anonymized fleet datasets into potential destinations such as the Transportation Secure Data Center, Fleet DNA, and/or LiveWire, to improve future data analyses. Clean Fuels Ohio and Energetics plan to transfer all available up-to-date and anonymized natural gas and diesel truck fleet maintenance cost data to NREL by the end of the project This process will give DOE and national laboratories access to extensive tools and resources to further analyze this data and will enable fleet managers and other key decisionmakers to evaluate the benefits and drawbacks of natural gas and diesel vehicles.

Conclusions

Clean Fuels Ohio and the project team are largely proceeding as planned with project set up and deliverables for Budget Year 2. The global COVID-19 pandemic remains the biggest development impacting the project to date, affecting the team’s ability to collect data from NGV UPTIME partners that are freight and goods movement fleets. The majority of the project’s fleet partners have been impacted by COVID-19. These impacts break down into two broad categories:

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

Initial responses from potential fleet data partners have been that they remain interested and committed to the project, but that mission critical tasks will take priority over any new projects at this time. Due to the uncertainty in the length of time these challenges will persist, we are anticipating a continued slowdown in securing additional agreements and data submissions from fleet partners.

The project's scope of work in the Statement of Project Objectives states that the project will include data from at least 1,041 total vehicles accumulated across at least 383 vehicle months. The project team has collected maintenance cost data for 1,145 vehicles and is seeking ~2,500 additional vehicles with maintenance data. Clean Fuels Ohio plans to secure agreements from potential fleet data partners that are actively engaging with the project team. Clean Fuels Ohio believes that a project extension would allow the team to significantly expand on the current vehicle quantity and to greatly impact this maintenance cost study.

I.16 Smart CNG Station Deployment (Gas Technology Institute)

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Start Date: October 1, 2019 End Date: December 31, 2023
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 its maximum capacity. Natural gas vehicle (NGV) fuel systems are typically oversized in response to this systematic underfilling. By increasing utilization of the vehicle's available fuel capacity, the vehicle fuel storage volume can be reduced, which can lower fuel system cost by as much as 20-25%. 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 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 of 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 that 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, which 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 was structured to include a CNG dispenser manufacturer and a company that fuels NGVs for commercial customers. Kraus Global and Clean Energy joined the team at the proposal stage to fill these roles. 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. During the past 12 months, Kraus Global chose to withdraw from the program due to changes in company ownership and concerns about ownership of the technology. GTI is currently communicating with potential replacements. 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 plans to expand on that data by collecting at least a year of filling and operations data on multiple vehicle platforms. 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, and other relevant data. The plan calls for demonstrations to 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 mix 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 on 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. (DOE extended the first budget period by a year, due to Kraus Global's withdrawal from the project, and delays related to field deployment of the sensors.) 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. The dispenser manufacturer 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 will be tested in the field.

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. 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 has been extended due to delays caused by the COVID pandemic so that it will occur over 48 months.

Results

After evaluating two different DAS using parts from HEM and Campbell Scientific in the first year of the project, Ozinga technicians installed the HEM DAS on a cement truck for initial testing. The Pelican Case that holds the DAS and the location where it was mounted in the cab of the truck are shown in Figure I.16-1Figure I.16-1. It sends data for storage and review over the cellular interface as designed. GTI collected and reviewed the data to confirm acceptable system operation. After confirming acceptable operation, GTI built the additional DAS.

Figure I.16-1. HEM DAS Components mounted in Pelican case and Pelican case inside Ozinga Brothers cement truck

All the HEM DAS for Ozinga were delivered and are being installed on trucks of several different vintages that have different engines and fuel systems (either from Agility or Momentum) with CAN Bus arrangements that vary widely. GTI is currently debugging the hardware and the installations because some systems were initially connected to the wrong CAN Bus. GTI has also resolved more minor issues related to phone charging and location problems. The phones that are used to communicate data need to be kept away from sun and heat to avoid overheating. The trucks are located at multiple sites in the greater Chicago area, including Mokena (Ozinga Main Office location), Chinatown (near downtown Chicago), Des Plaines (close to GTI's main office), Montgomery (Illinois), and Gary (Indiana).

Four additional HEM DAS intended for Clean Energy have been purchased and GTI is finalizing their construction. These will be used to lab-test the smart dispenser components. All the CAN Bus data, including the pressure and temperatures, 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. GTI will collect and analyze the data to measure and evaluate system performance. Data also needs to be transferred from the vehicle to the fill station during filling of the CNG tanks and from the data logger to a cell phone in the cab so that the tanks' fill status can be communicated, and the remaining range can be calculated for the driver. [This is the subject of a parallel DOE-funded project.] Wi-Fi will be used for real-time data transfer and cellular service will be used for data transfer to the Cloud. During this period, we calculated the volume of data that will be collected and selected a cost-effective way to collect and store that data.

GTI has also completed the smart dispenser module that will interface with the vehicle data acquisition systems. The dispenser logic and filling algorithm are being programmed onto an ESP32 microcontroller. This device will use vehicle and dispenser data in real time to accurately select which smart vehicle is connected and then control the dispenser using GTI's smart filling algorithm. The ESP32 microprocessor has both Wi-Fi and Bluetooth capabilities and is the same processor used in the HEM equipment. An example of the ESP32 is pictured in Figure I.16-2. The ESP32 is being designed to identify and scan vehicles close to the CNG dispenser so that the vehicle pressure and temperature can be recorded in a table of nearby vehicles. If a vehicle then connects to the dispenser, the measured tank pressure will be matched to the list of vehicles to determine if any of them might have connected. If there is a match a secure connection is established for the duration of the fill. If the ESP32 does not identify a smart vehicle, then the dispenser will fill the vehicle using a normal fueling protocol. GTI has developed a connection flow chart for the ESP32 and vehicle and is now programming that logic onto the ESP32. The advantage of the ESP32 is that it can theoretically be installed on any dispenser, new or existing, turning it into a smart dispenser that is capable of interfacing with vehicles that have HEM streamers or similar data transmission devices.

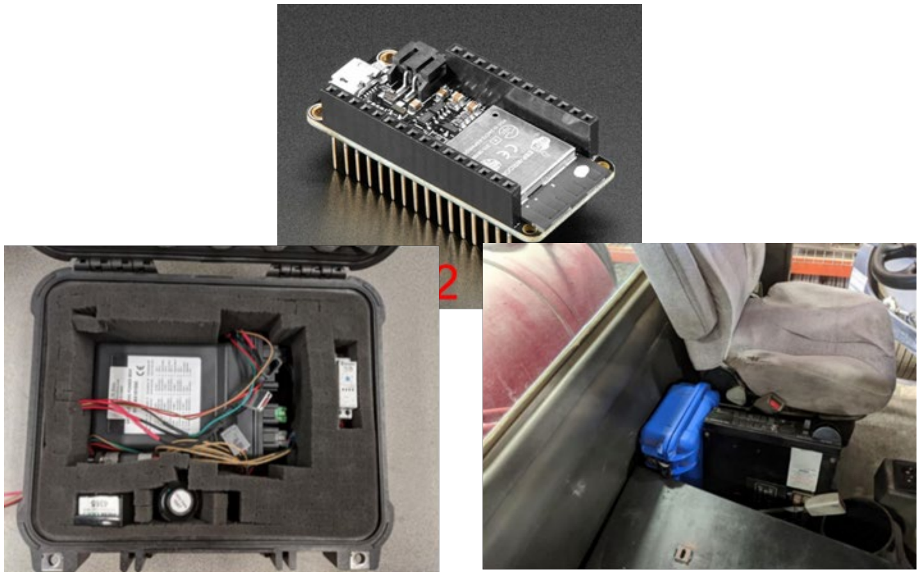

Figure I.16-2. An example of the ESP32 microprocess being developed for installation inside a dispenser

GTI surveyed multiple dispenser manufacturers and they all use a Modbus communication protocol onboard the dispenser. Therefore, GTI decided to program the ESP32 with a Modbus protocol that will allow the dispenser, as the Modbus master, to scan the ESP32 frequently to get updates about the filling status of the connected vehicle. To summarize, the ESP32 will identify the connected vehicles, calculate how full they are using GTI's filling algorithm, and then provide the dispenser with that information using Modbus so that the dispenser can deliver a full fill. This strategy requires less input from the dispenser manufacturers as they can treat the ESP32 like any other Modbus connected device. This makes it possible for the GTI smart dispenser system to work with any commercial dispenser using a Modbus communications protocol.

The ESP32 was bench tested as shown in Figure I.16-3. The CAN shields each represent a vehicle connected to the HEM streamers being used for Wi-Fi communications. The ESP32 connects to the streamers to read data from the vehicles, analyzes the data, and then provides the analyzed data to the PC that is set up as a Modbus master. Data transfer from the vehicles to the dispenser has been successfully demonstrated. One of the last steps was connecting to multiple vehicles and selecting the correct connected vehicle. This last task had some final bugs that caused the Wi-Fi connection to time out when repeatedly reconnecting. GTI resolved these bugs and tested the ESP32 overnight using eight streamers that the ESP32 connected to thousands of times to prove the code was stable. With this test the system appears to be functional and is ready for lab testing. Although GTI continues to work on and test the smart dispenser components, a commercial dispenser will eventually be needed to test the performance of the system. GTI has had very promising discussions with three companies that could take Kraus' place on the team and provide GTI with the dispensers and technical support necessary to fully integrate GTI's microprocessor into the commercial dispenser. Alternatively, GTI could purchase a dispenser and modify the control code in house.

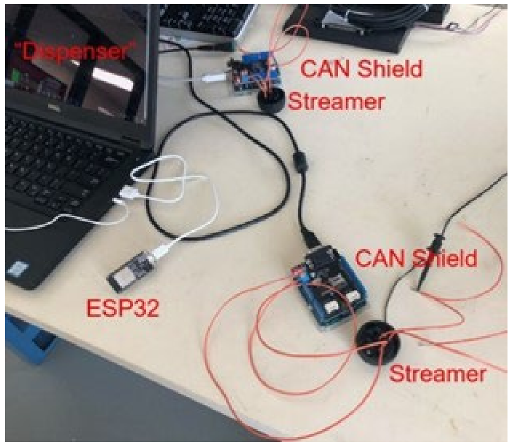

Figure I.16-3. The smart dispenser test bench is shown with HEM streamers sending data to a smart dispenser

GTI modified an existing test cell to enable the prototype ESP32 to be tested during controlled CNG fills. GTI is connecting two similar CNG tanks to the onsite CNG storage and is connecting a HEM DAS to each tank. The tanks will be filled using varying speeds, starting conditions, etc., to ensure the ESP32 logic is working properly and that it always identifies the correct smart vehicle to fill. Testing has started.

Preliminary Data Analysis

GTI collected limited baseline data from two Ozinga trucks, #1416 and #1825. Data and conclusions are preliminary and are expected to change once data across the entire 6-truck Ozinga fleet is collected and analyzed, including vehicles stationed in urban, suburban and rural areas. Initial data from the two trucks are shown in Figure I.16-4 and Figure I.16-5. Truck #1416 is stationed in Chinatown and serves customers in the downtown area as well as suburbs close to Chicago. The second truck, #1825, operates in Mokena, a suburban area 40 miles southwest of Chicago. Figure I.16-4 displays the distance traveled by the two trucks during their shifts, with the bars representing the probability density function (PDF) of trips ending in a given bin (with a bin-width of 10km each) while the continuous trace represents the cumulative distribution function (CDF) on the right. Operating close to the Chicago downtown area is associated with heavier traffic and reduced average speeds, whereas the operation in more rural areas allows for higher average speeds. This translates into truck #1825 covering more than twice the distance compared to truck #1416, with median (CDF=0.5) distances of ~140km and ~55km per day, respectively. The maximum distance driven for truck #1416 was found to be about 120km while truck #1825 drove up to 260km. This shows the influence of different duty cycles on fuel consumption.

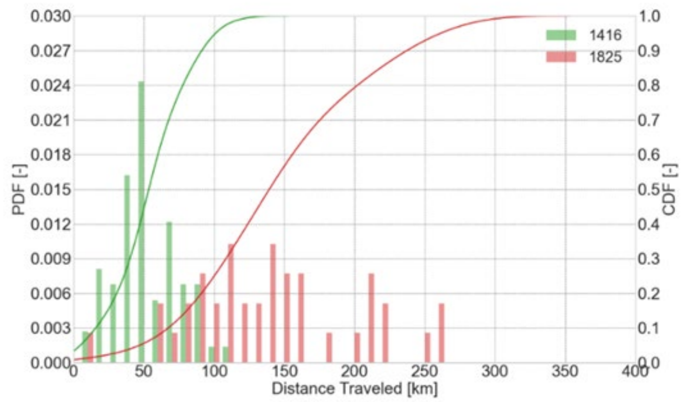

Figure I.16-4. Probability density function (PDF) and Cumulative density function (CDF) across distance traveled for truck #1416 (Chinatown) and #1825 (Mokena).

Operating a truck at higher speeds leads to higher fuel consumption and this trend is demonstrated in Figure I.16-5. The fact that the median fuel consumption for truck #1825 is only about 50% more compared to truck #1416 (~113kg versus ~75kg), even though it travels more than twice the distance each day (on average), illustrates that low powertrain efficiencies are associated with low average speeds due to the higher fraction of stop-and-go traffic close to the Chicago downtown area. The initial data demonstrate that truck fuel economy varies widely based on factors such as the truck's weight, route, driving conditions, and driver.

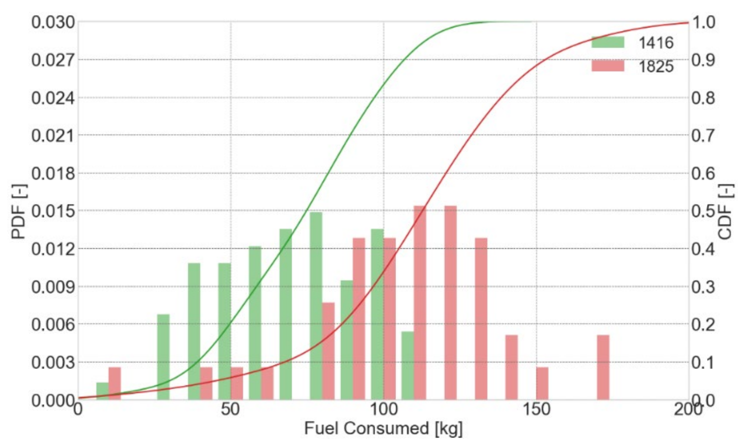

Figure I.16-5. Probability density function (PDF) and Cumulative density function (CDF) across fuel consumed for truck #1416 (Chinatown) and truck #1825 (Mokena).

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. The team is evolving in response to changes in the commercial environment, but the initial data confirm the need for such a system and the simplicity and generality of GTI's approach make it attractive for new participants. 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.17 Next Generation NGV Driver Information System (Gas Technology Institute)

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Start Date: October 1, 2019 End Date: June 30, 2023
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 its 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's 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 capacity. 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 dependence 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. By increasing confidence in the fuel status of the vehicle, the 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 measurement of real-time conditions in the tank to accurately determine remaining fuel, and an accurate prediction of fuel temperature during vehicle operation to predict the amount of fuel that will remain stranded in the vehicle tank when the minimum operating pressure is reached. The gas in the tank cools as the pressure is decreased. This isentropic expansion cooling causes a further 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.

The heat transfer is a complex combination of several mechanisms which must be modeled to achieve the required accuracy. Previously developed modeling for hydrogen tanks, based on fundamental physics, is 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. 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 fuel-consumption-driven cooling.

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 using both 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 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

GTI built and tested two different Data Acquisition Systems (DAS). One system used parts from HEM Data that were designed for vehicle applications but have data-handling limitations. The other system used parts from Campbell Scientific Inc. (CSI) that are commonly used in industrial applications and have programming capabilities that provide data handling flexibility. After evaluating differences in cost, performance, communication format, and ease of programming in the first budget period, the GTI Project Manager decided to move forward with the HEM system because it was functioning properly and there were still data filtering and sampling issues with the CSI system. The HEM DAS collects CAN (Controller Area Network) bus data from the vehicle and added sensors, including pressures and temperatures, and transmits it over Wi-Fi and cellular networks. Ozinga Brothers technicians installed one HEM DAS on a concrete truck for initial testing. It sent data over the cellular interface for storage and review as designed. During this period, GTI calculated the volume of data that will be collected and selected a cost-effective way to collect and store it. A photograph of the HEM DAS mounted in a Pelican case for protection and the location of the Pelican case in the truck are shown in Figure I.17-1.

Figure I.17-1. HEM data acquisition system in Pelican case (left) and mounted in truck (right)

Data is transferred from the vehicle to the Cloud. GTI then collects and analyzes the data to measure and evaluate system performance. Data is also transferred from the data logger to a tablet, phone, or other device in the cab so that the tanks' fill status can be communicated and the remaining range calculated for the driver. ANL is addressing this function. GTI purchased 21 4G system data loggers from IOSix. After the 4G systems were received and tested there were problems with slow data transfer. GTI switched to a new Cloud platform and downloaded new software for the loggers. GTI's technical team members then assembled multiple systems in their Pelican cases and installed them in a variety of trucks owned by Ozinga.

GTI is developing a software tool for automated conversion and analysis of the large volumes of data expected from the fleet of dataloggers. In the meantime, the group at ANL has begun analyzing the data received from the first truck in detail. Installation of the data acquisition systems in Ozinga vehicles has progressed so that our focus now is on troubleshooting installation/communication issues and establishing data processing procedures. Eighteen data acquisition systems were delivered to Ozinga and 14 have been installed to date. Twelve of the systems are for this project and six are for the parallel DOE-funded Smart Station project. That project is developing a methodology for assuring full filling of CNG tanks during refueling.

GTI is installing systems on Ozinga trucks of several different vintages. They have different engines and fuel systems (either from Agility or Momentum) with CAN bus arrangements that vary widely. The newer trucks (2018 and later) have multiple CAN systems and identifying the location of the correct data is often difficult and time consuming, sometimes based on trial and error. The data management group at GTI is building a new process for collecting and storing the truck data that will help alleviate these issues by making the data easier to organize and view. That system is still under development. While the data management tool is being developed, the phones Argonne installed on the trucks have been retrieving data from Ozinga trucks #1416 and #1825 for several weeks. Argonne has been analyzing that data, which is discussed below.

Preliminary Data Analysis

This analysis is based on limited data from two trucks, #1416 and #1825. Conclusions are preliminary and are expected to change once data across the entire 12-truck fleet is collected and analyzed, including vehicles stationed in urban, suburban and rural areas. Initial data from the two trucks is shown in Figure I.17-2 and Figure I.17-3. Truck #1416 is stationed in Chinatown and serves customers in the downtown area and suburbs close to Chicago. The second truck, #1825, operates in Mokena, a suburban area 40 miles southwest of Chicago. Figure I.17-2 displays the distance traveled by the two trucks during their shifts, with the bars representing the density of trips (i.e., percentage of the total number) ending in a given bin (indicating the distance travelled - with a bin-width of 10km each) while the continuous trace represents the cumulative distribution function (CDF) on the right. Operating close to the Chicago downtown area is associated with heavier traffic and reduced average speeds, whereas the operation in more rural areas allows for higher average speeds. This translates into truck 1825 covering more than twice the distance compared to truck 1416, with median (CDF=0.5) distances of ~140km and ~55km per day, respectively. The maximum distance driven for truck 1416 was around 120km while 1825 drove up to 260km.

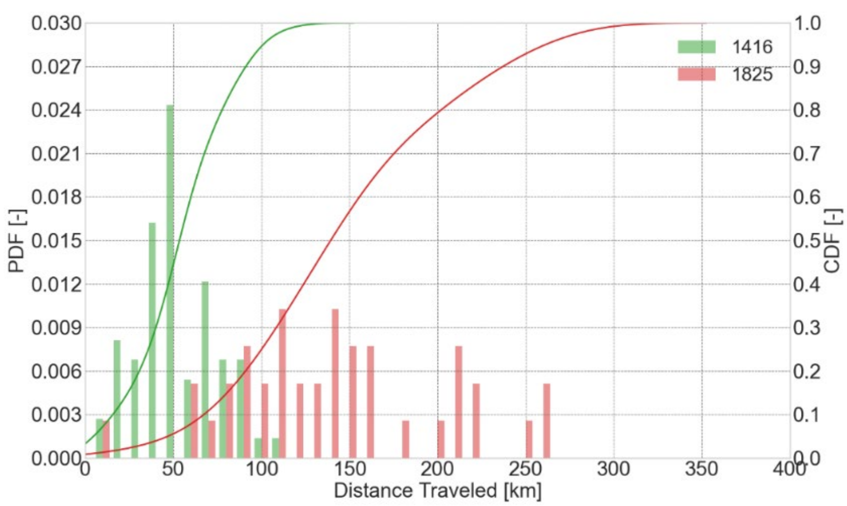

Figure I.17-2. Probability density function (PDF) and Cumulative density function (CDF) across distance traveled for truck 1416 (Chinatown) and 1825 (Mokena)

Operating a truck at higher speeds leads to higher fuel consumption and this trend is demonstrated in Figure I.17-3. The fact that the median fuel consumption for truck 1825 is only about 50% more compared to truck 1416 (~113kg versus ~75kg), even though it travels more than twice the distance each day (on average), illustrates that low powertrain efficiencies are associated with low average speeds due to the higher fraction of stop-and-go traffic close to the Chicago downtown area.

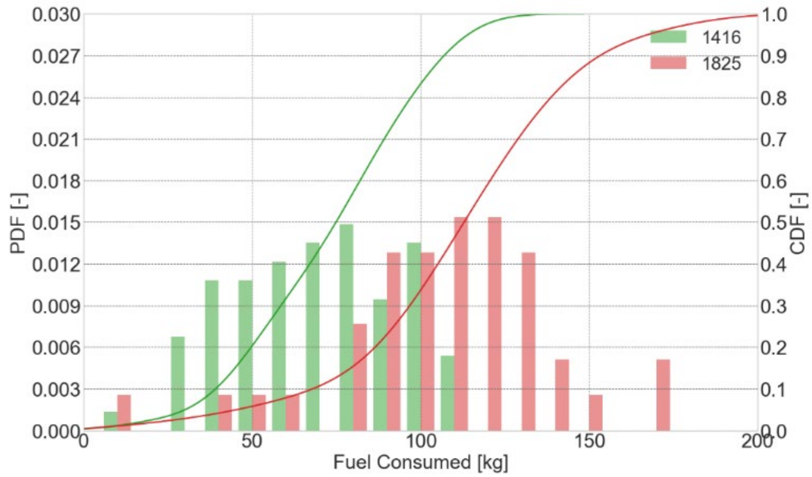

Figure I.17-3. Probability density function (PDF) and Cumulative density function (CDF) across fuel consumed for truck 1416 (Chinatown) and truck 1825 (Mokena)

The following plots focus specifically on truck 1416. For this analysis, GTI analyzed a dataset of 91 operating days, with Figure I.17-4 showing the accumulated fuel consumption for a given day between March and September 2021. The distinct black dashed line illustrates the average fuel consumption across all 91 samples with a slope of 9.45 kg per hour. The average operating time is around 8 hours, which translates into an average fuel consumption of around 75 kg per day. However, the graph also shows that the same 75 kg of fuel can provide as little as 6 hours of operation or as much as 10 hours of operation depending on the duty cycle. Viewed differently, 8 hours of operation can consume as little as about 55 kg or as much as about 90 kg of fuel. This demonstrates that truck fuel economy varies widely; this variation can be attributed to factors such as the truck's weight, route, driving conditions, and driver.

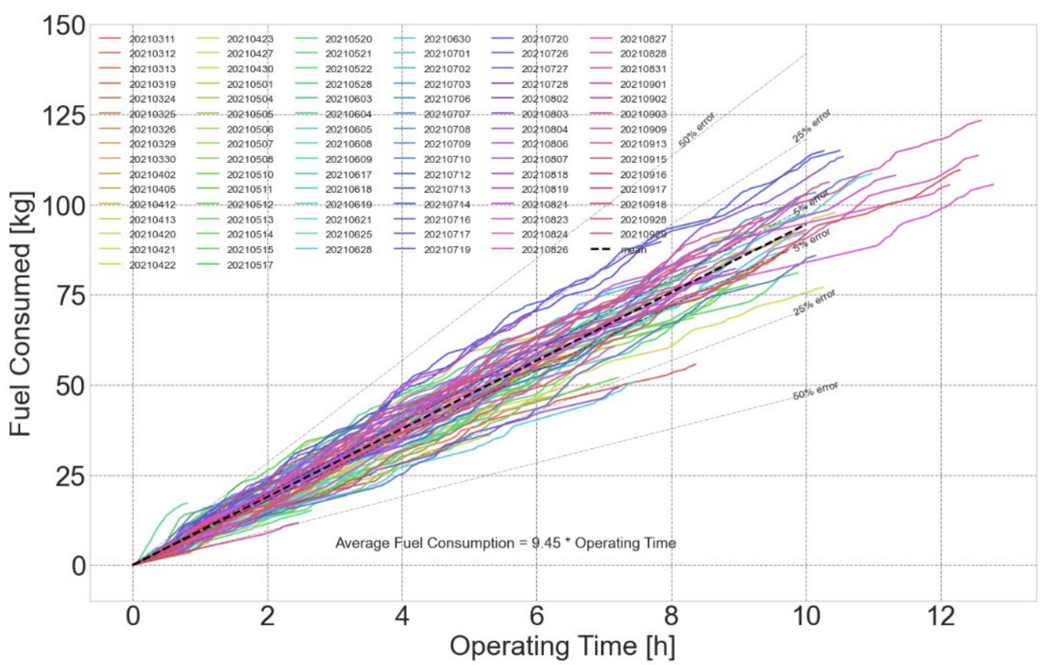

Figure I.17-4. Fuel consumed versus operating time across 91 operating days for truck #1416

Figure I.17-5 shows the variation in distance traveled for a given fuel amount consumed. Focusing on 75 kg, which is close to the median fuel amount consumed across a single day, shows the shortest distance traveled was around 32 km while the longest distance traveled was around 104 km, a spread of 72 km. This illustrates the difficulty in predicting the miles-to-empty for a given tank level while remaining within the imposed error bound of 5% or 25 miles/40 km (whichever is greater) at any given time during vehicle operation. Knowledge of planned destinations for a given day may be necessary for success. Additional data collection and analysis will be performed to identify opportunities to further narrow down the observed error bounds.

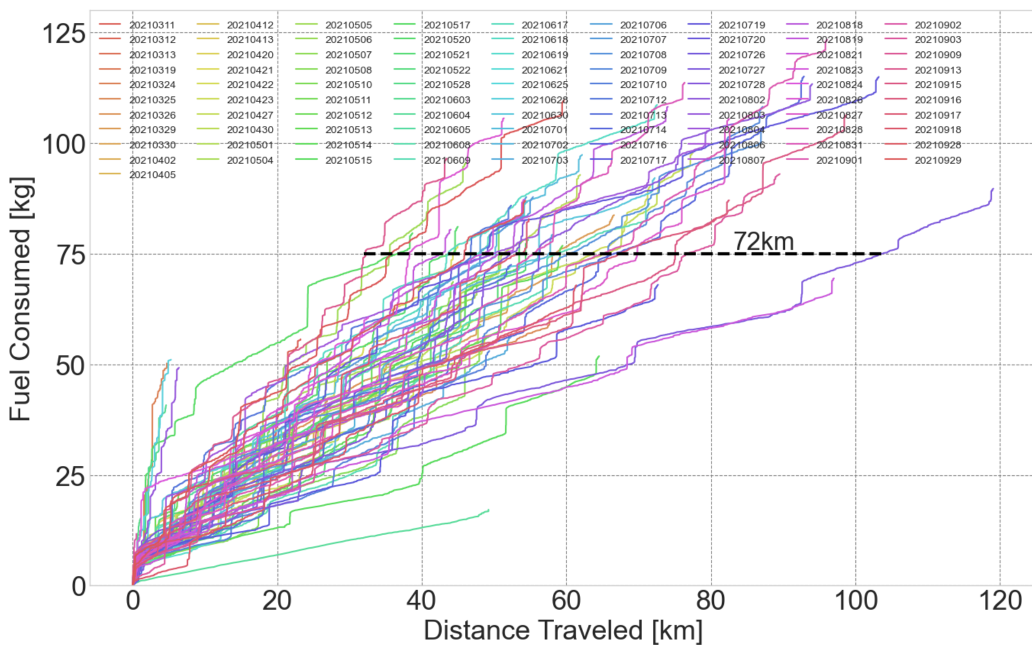

Figure I.17-5. Fuel consumed versus distance traveled across 91 operating days for truck #1416

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. GTI and ANL developed and installed the models and data acquisition systems during this budget period. Testing has begun on a subset of the twelve trucks to determine whether a simple, cost-effective system can provide NGV drivers with the information they need to overcome range anxiety. This will provide NGV designers with the confidence they need to stop oversizing their fuel storage systems.

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 and John Walton of the Chicago Area Clean Cities Coalition (CACC).

I.18 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
- Savannah River National Laboratory
- Southeast Alliance for Clean Energy (SACE)
- Sync Energy AI
- 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 that can be employed in storm, disaster, or petroleum fuel disruption recovery, 2) alternative fuel resources for such fleets, 3) means by which AFVs 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 AFV 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 network.
- 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 GIS technology. The inventories at minimum are thought to be:

- Alternative fuel infrastructure, including electric, natural gas, propane, 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, propane and other 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, propane, 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 databases 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, propane, 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

Year 1: Organization

Task 1.1 Infrastructure Disruption Research and Task 1.2 Inventory Creation

During Year 1 completion of research and compilation of the inventories necessary for the project’s planning phase were completed.

The project team organized a GIS Working Group, the first of five working groups, during Year 1 that continues to meet bi-weekly to support Year 2 analysis and planning. Each Subtask Leader has worked closely with the GIS Working Group to ensure the inventory, and GIS modeling meets their needs for creating the final plan.

The GIS model will be part of the final plan and will be able to simulate thirty mile and fifty-mile buffer maps for electric vehicle supply equipment (including charging infrastructure) and hurricane evacuation routes, historical road closures during severe weather events, current travel patterns and additional infrastructure requirements and costs. We anticipate completing a draft version of the model by mid-November 2021 and review by the Plan Formation Core Team in early December 2021.

Year 2: Planning

Task 2.1 – Assessment

Subtask 2.1.1-Disruption

The Subtask 2.1.1 working group has aggregated the Year 1 inventory data from utility companies, state agencies, and nonprofit organizations in North and South Carolina to augment the contents of North Carolina's and South Carolina's emergency preparedness plans by identifying:

- AFV fleets employed in storm, disaster, or petroleum fuel disruption recovery.
- Alternative fuel resources for those fleets, including fueling stations and adequate fuel supplies.
- Means by which AFVs can better serve in recovery actions.
- Communication of this information to increase its use by the state emergency organizations.

The Subtask 2.1.1 working group endeavored to determine what the utilities considered to be "disruption", i.e., the physical effects interfering with normal operation and infrastructure recovery. The working group submitted a draft narrative on disruption to the Subtask 2.2.2 Plan Formation working group.

Subtask 2.1.2-Coverage

The Subtask 2.1.2 working group studied data provided by the Southern Alliance for Clean Energy, Duke Energy, North Carolina's Electric Cooperatives, North Carolina Department of Transportation, the North Carolina Department of Environmental Quality, and the South Carolina Department of Regulatory Affairs-Energy Office to determine the number of charging stations needed to adequately provide coverage during a storm or other infrastructure disruption evacuation. Examples from Florida and Houston hurricane evacuation indicate that insufficient EV charging can lead to congestion caused by stalled/abandoned EVs that disrupt evacuation Different scenarios during significant storms were evaluated to fully define appropriate evacuation and infrastructure disruption response coverage. The Subtask 2.1.2 working group developed strategic alternatives to expand fast charging stations in areas along evacuation routes and considered strategies to increase resilience in local communities impacted during a storm and infrastructure disruption. The Subtask 2.1.2 working group output includes a draft "coverage" narrative for the plan, continued input on finalizing GIS maps of Direct Current Fast Charging infrastructure locations and radius from other stations as this will support a major plan recommendation.

Task 2.2 – Plan Creation

Subtask 2.2.1 – Opportunity Prioritization and Solutions

The Subtask 2.2.1 working group reviewed and identified the following "best practices" for plan inclusion:

- Evacuation Routes: case studies from Florida and West Coast wildfires.
- Technology: continued fueling stations operation during infrastructure disruption.
- Energy storage, renewables and generators to provide alternative fuel and power.

- First responder vehicles: current use, projected future use, infrastructure support of future use; and Zero Emission Vehicle use as energy storage/back-up power during infrastructure disruption.

The Subtask 2.2.1 working group surveyed national and global best practices for resilience and recovery practices. It evaluated reliable alternative fuel vehicle operation and fuel diversity availability with identified infrastructure disruption and recovery needs, considering access during adverse, system-disrupted conditions, state of the art technologies and diversity of supply by geography and type.

The Subtask 2.2.1 working group has submitted its final draft narrative for Plan inclusion.

Subtask 2.2.2 - Plan Formation

The Subtask 2.2.2 working group is aggregating material from all other project working groups and creating the draft Carolina Alternative Fuel Infrastructure for Storm Resilience Plan.

Conclusions

The project partners have adjusted to virtual operation and meetings during the Pandemic and have the project on schedule to produce the objectives and plans described in the project's Statement of Project Objectives. Project partners and various state agencies and non-governmental organizations appreciate the value of the plan. 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 AFV 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 21 of the project's 36 months and dedication to producing the project's Year 2 objectives on time.

I.19 Statewide Alternative Fuel Resiliency Workplan (Florida Office of Energy)

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Start Date: October 1, 2019 End Date: December 31, 2023
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. To accurately assess the current status within the state, the project team held virtual workshops. This afforded the opportunity to collect and analyze data on alternative fuel practices and protocols that currently exist in Florida. Upwards of sixty 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 attended the workshops.

The workshops resulted in the development and disbursement of a survey that sought to document practices that are critical for fleet managers in preparing for emergency response to natural disasters, to synthesize findings about capabilities and limitations of vehicle performance to withstand hurricanes, standing water, and flooding. Results from the survey will be analyzed and incorporated into the final Plan.

Data Gathering

There were delays in some of the data gathering efforts due to the COVID pandemic, as most site visits were not allowable during most of the year for protection of staff. Site visits were able to be scheduled for December of 2021 and beyond. The project team performed the following reviews during FY2020-2021:

- Executed a site survey visit on a newly constructed residential buildings complex (~130 rental units) equipped with backup generator -- Shell Harbor, Retirement Living, Brevard County, FL. The site is supplied with natural gas (metered underground pipe service) by the local gas utilities. Contrary to the initial verbal communications with the management, the survey discovered that the emergency generator utilizes diesel as fuel for emergency backup power generation.
- Updated status of alternative fuel corridors and stations in Florida.
- Evaluated alternative fuel vendors.
- Made efforts to initiate a query on a database administered by the Florida Agency for Health Care Administration – with the goal to identify sites that utilize alternative fuels for emergency backup generators, but legal and confidentiality issues arose.
- Continued surveying fleets regarding their resilience practices and experience with standing water.
- Reviewed 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.
- Held discussions with a manufacturer of solar charging stations (EVArc) for information on stand-alone grid independent product/battery storage choices.

Results

The project team developed the following products and completed the following efforts in FY2020-2021:

- UCF/FSEC developed a brochure for informing stakeholders about hurricane resiliency, entitled “Resilient Florida Buildings: Alternative Fuel Options for Maintaining Power During Outages.”
- UCF/FSEC produced informational video “Resilient Florida Buildings: Alternative Fuel Options for Maintaining Power During Outages.”
- TBCCC/USF created a database of AFV Vendors in the state to engage.
- TBCCC/USF developed and distributed a survey to stakeholders that evaluates current resilience practices of Florida fleets. The project team has not identified any fleets encountering standing water thus far.
- TBCCC/USF collected data on AFV fleets in the Tampa Bay region, including garage locations and fuel stations, as well as critical infrastructure geodata. The team conducted site visits at a CNG facility operated by Waste Pro and propane stations operated by Seminole County Public Schools. Additional site visits have been scheduled for the end of 2021.

- TBCCC worked with the Southeast Florida Clean Cities Coalition to identify alternative fuel fleets in South Florida and schedule site visits. The visits to Broward County Transit and City Furniture occurred in August 2021.
- UCF/FSEC drafted the script for the "Emergency and Resiliency Power: Natural Gas Fueled Generator" video. The video will be taped in FY2021-2022.
- 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.
- NREL completed a preliminary draft of "NHTSA Alternative Fuel Utilization, Infrastructure, and Growth Projections".
- NREL developed draft geospatial analysis that evaluated projections and infrastructure needs by county.

FDACS placed a public access Level 2 EV Charger at the FDACS office building in Tallahassee and has established a partnership with Florida Department of Management Services to identify additional state-owned site hosts for chargers to be placed.

Web-based Electric Vehicle Supply Equipment (EVSE) Tool

The USF team continued reviewing relevant existing EVSE tools, identifying challenges and gaps in the existing tools, and working on designing its own web-based EVSE tool. The team finished developing the prototype web tool and is now testing it. Included is the EV evacuation planning algorithm/model providing for efficient EV charging and routing that was developed by the team.

Conclusions

None at this time.

Acknowledgements

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I.20 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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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 (Míorides) 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 clients 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 of the carsharing service.

Approach

The pilot project will integrate a volunteer ridesharing program (Míorides) 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). Míorides will reward Míocar members with free personal Míocar carsharing use when they volunteer to drive people who need transportation in Míocar vehicles.

Míorides 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 Míorides.

Participating agencies that are seeking to fill a segment of their current transportation service to their clients will identify riders in need of transportation.

The DOE funds and ongoing Míocar operations will support the start-up of the Míorides 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, the project team will evaluate the pilot over a one-and-a-half-year period using integrated survey data and observed user data provided by Mobility Development and Volunteer Transportation Center, for each of the service’s volunteer drivers and riders. 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 to reduce GHG emissions.

Results

Following the year one decision to move forward with launching the Míorides pilot, year two focused on pilot implementation. This involved volunteer driver recruiting efforts, development of a pilot marketing plan, completion of pilot component field tests including the ridesharing software (SNAP), and ongoing coordination with project partners.

The pilot encountered significant barriers to implementation, however, as a result of COVID-19. This included reduced travel demand due to COVID-19 related shutdowns, difficulties recruiting volunteer drivers due to health and safety concerns, and limited opportunities to promote the pilot at in-person events and meetings. Additionally, General Motors issued a recall of the Chevy Bolt in July 2021 due to battery fire risk, which removed 17 of the 27 vehicles in the Míocar fleet from operation.

Though these challenges led to delays in testing the pilot, Míorides recruited active volunteer drivers, and project partners expect the service to become active by November 2021. The project team expects the service to provide rides to locations such as community events and meetings, food and shopping-related destinations, and medical appointments. The project team is preparing to administer surveys to these riders by the end of year two to capture their perspectives on the Míorides service and how it is affecting their transportation experience.

The project team ramped up its marketing efforts during the third quarter of year two, and several agencies have expressed interest in working with Míorides to provide rides during the coming year. This includes agencies such as Tulare County Green Line Call Center and Kings Area Rural Transit, which are seeking ways to provide residents with transportation options to fill existing transit gaps; and Friends Outside, which is an organization that provides families with transportation solutions for long-distance prison visitation. Additionally, the project team has been communicating with the Central Valley EJ Network, which works to provide its clients with transportation access to health care appointments. The project team continues to engage with its affordable housing partners including UPHoldings, Self-Help Enterprises, and Winnco, and has received significant interest in the service from affordable housing residents. Overall, the project team conducted 10 marketing events, 5 presentations to local agencies, and more than 50 one-on-one in-person and telephone discussions with these and other agencies and individuals, promoting or responding to inquiries about Míocar or Míorides. Additionally, the project team developed a research presentation highlighting the pilot, and presented it at the virtual Transportation Research Conference to Advance Transportation Equity on September 10, 2021.

The project team has modified its project management plan to account for the above challenges and is prepared to complete pilot ramp-up and continue evaluation data collection moving into year three of the project.

Conclusions

Based on experiences during year two of the pilot project, the project team concludes that existing pilot projections are achievable by the end of year four. This includes pilot growth from to a service that includes 20 volunteer drivers, serves 130 active riders, makes 2,080 trip legs, and provides 52,000 passenger miles on average per quarter. The project team has determined that to meet these projections, upcoming efforts must emphasize effective driver recruitment efforts, ensuring proper health and safety protocols to account for continued COVID-19 impacts, and maintaining and improving community partnerships to increase pilot awareness and integration within participating communities.

As Míorides had not yet provided rides as of the end of this reporting period and the pilot evaluation is still in progress, the project team is not yet able to develop conclusions related to the performance of the pilot. However, conclusions from the Míocar pilot have provided insight into driver behaviors and needs, and the evaluation of the Míorides pilot will allow for refinement of these findings into conclusions and actionable recommendations. For example, data collected for the Míocar pilot evaluation suggest that individuals with lower household incomes, larger household populations, and fewer personal vehicles than household adults are more likely to use the service more frequently. Additionally, many Míocar members live several miles from an EV carsharing hub and currently need to take public transit or use personal vehicles to access Míocar. Data collected from Míorides clients will allow for comparisons to these trends within Míocar to assess similarities and differences between the driver and rider populations. These and other findings will be further assessed during the Míorides pilot and evaluation, with data collection beginning shortly after the service becomes operational near the end of 2021.

Acknowledgements

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

I.21 The Clean Rural Shared Electric Mobility Project (Forth)

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Start Date: October 1, 2019 End Date: June 30, 2023
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

At the end of 2020, DOE granted the CRuSE Project a 6-month extension for its first Budget Period, through June 30, 2021. Budget Period 2 began on July 1, 2021. As such, the major tasks to be completed in 2021 were divided into two categories to reflect the time spent across two Budget Periods:

A. Project Initiation and Launch
   1. Complete Charging Station Installations
   2. Plan Outreach and Promotion + Public Launch
   3. Begin Data Collection

B. Project Refinement
   1. Implement Spanish-Language Upgrades to Reservation Platform
   2. Begin Data Analysis
   3. Refine Outreach and Promotion Strategies.

Progress made toward these major tasks was as follows:

Complete Charging Station Installations

Four of the five charging stations have been installed as of August 2021. Three of these were installed in advance of the public launch described below and the fourth was completed soon thereafter, in August. The fifth charging station is scheduled to be installed in November 2021.

Plan Outreach and Promotion + Public Launch

The project team began planning for a public launch of the program in early 2021, with the goal of launching at three of the five sites in June 2021. By that time, three of the five charging stations would be installed to accompany the vehicles. Forth published a press release announcing the cars being available on June 9th which was followed by a ribbon-cutting event held on June 24th. In addition to the press release, the project team's local partners posted content on social media and digital communications channels to notify community members of the program's launch. In July 2021 Forth and local partner and transit provider, Columbia Area Transit, attended a local farmer's market to draw attention to the program and offer free test drives of the vehicle. At that event, the project team engaged 68 people and gave them discount codes to take their first ride.

Begin Data Collection

To accompany the public launch, Forth and Pacific Northwest National Laboratory worked with our technology partners to secure access to data that would be collected during vehicle reservations and charging sessions. Data tracking and collection began in June 2021.

Implement Spanish-Language Upgrades to Reservation Platform

The reservation platform, Envoy, underwent a launch of a new software application in late 2021 which will provide improved accessibility and user experience. In anticipation of this, Envoy has postponed the translation of its app until the rollout of the new app is complete. To provide as much accessibility as possible, the project team has ensured that all communications materials are provided in Spanish. In addition, Envoy offers customer service technicians that speak multiple languages. We can direct users that might be having technological difficulties with the app or the reservation process overall to these technicians.

Begin Data Analysis

The main goals of the data analytics efforts related to the CRuSE project are to understand the patterns around car-sharing and user behavior, analyze the economics of the program and quantify the emissions reduction. With the launch of the program in the summer of 2021 and subsequent setup of the data infrastructure, we have begun the data analytics efforts spanning June 2021 – October 2021. The following provides some of the initial analytics related to two different datasets, namely, the charging data (source: OpConnect) and the car booking data (source: Envoy) provided by Pacific Northwest National Laboratory.

- <u>Analytics environment and Data pre-processing</u>: The charging data from OpConnect is available for export as CSV files, one per charging station. These are combined into a single CSV file with appropriate codes for the stations. The booking data is available from Envoy's PowerBI platform where data can be exported as Excel files. All the data is analyzed using a Python workflow that makes use of pandas, numpy and seaborn packages, for data ingestion, analyses, and visualization, respectively. The full dataset comprises 37 bookings and 206 charging sessions. Since there was extensive testing before the launch, a number of the bookings and charging sessions were of small duration. Hence, those datapoints were filtered out of the subsequent analyses. This left us with 19 bookings and 185 charging sessions.

- Pattern Analysis with booking and charging data: Figure I.21-1 shows the distribution of the number of bookings by weekday (left) and by the hour of the day (right). Earlier in the week appears to be more popular as do the afternoon times.

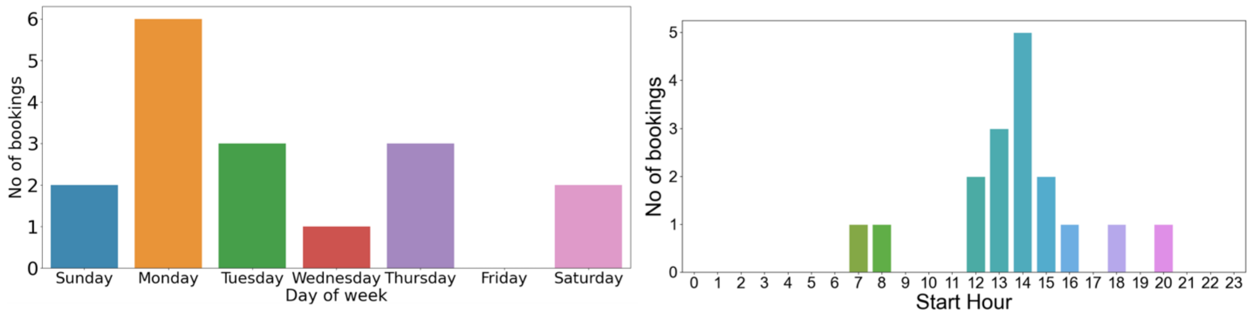

Figure I.21-1. Distributions of the bookings by the day of the week and hour of the day, Pacific Northwest National Laboratory

Pacific Northwest National Laboratory also analyzed the distributions of the charging data based on the length of the sessions and the energy utilization. This is depicted in Figure I.21-2. It can be deduced from the figures that there are a disproportionately higher number of short duration and correspondingly smaller energy usage charging sessions. We will be working with the charging station vendor, OpConnect, to check if this is due to the charging station behavior or if there are other potential explanations for the short charging session durations.

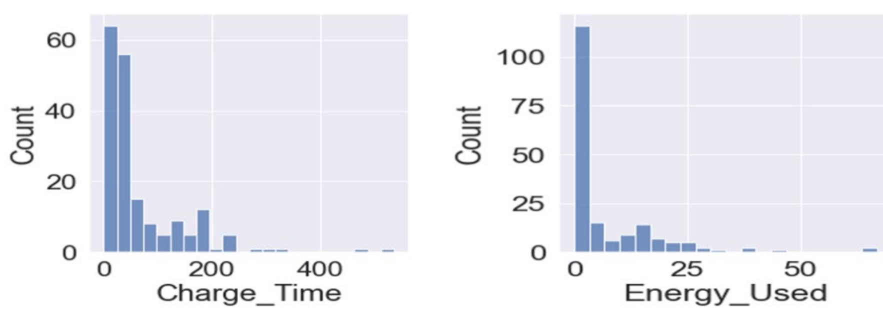

Figure I.21-2. Histograms of charging sessions in terms of charging duration (in minutes) shown on the left and energy consumed (in kWh) shown on the right, Pacific Northwest National Laboratory

- The panel of four figures in Figure I.21-3 shows the long-term weekly trends for the bookings in 2021, miles traveled, revenue, and the energy consumed in charging. The range shown is from the first week when charging stations were installed (week 17) through September 30, 2021 (week 39). While we observe dense groupings in the summer weeks the usage has been sparse after that, especially with the miles traveled and revenue generated. With more awareness campaigns and promotions being executed, we expect to see a higher usage in the coming months and the accrued data is expected to help us do more sophisticated analytics such as demand and revenue prediction.

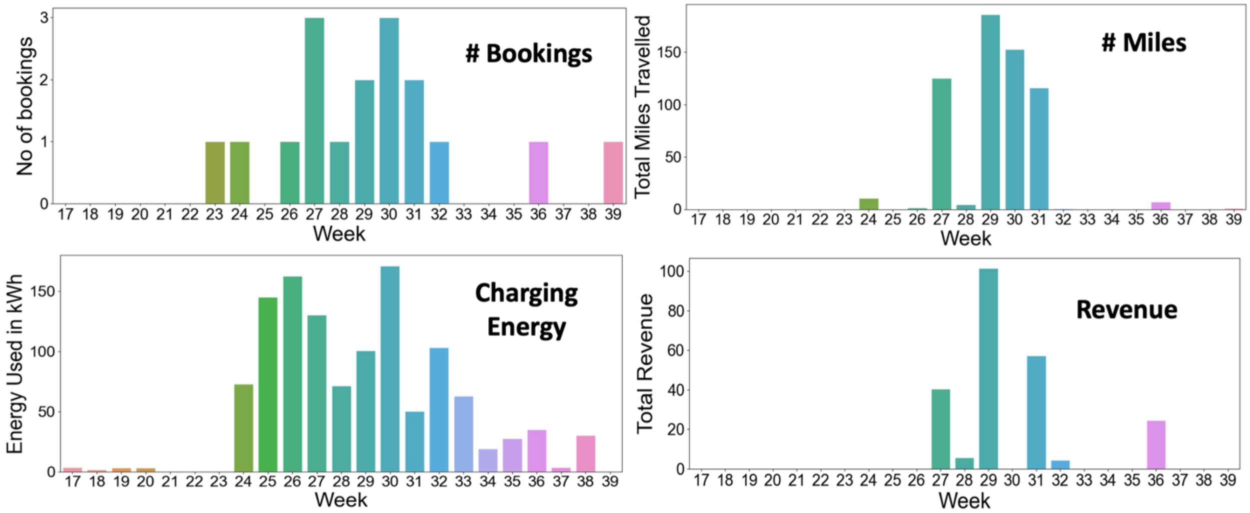

Figure I.21-3. Weekly aggregates over the number of bookings, number of miles, revenue and the charging energy consumed, Pacific Northwest National Laboratory

- <u>Greenhouse Gas (GHG) Emission Reduction</u>**:** While it is still very early to start quantifying the carbon savings of the program, we can make some estimates of the cumulative GHG savings thus far. Using the calculator available at fueleconomy.gov, we find that for Hood River, OR, compared to an average gasoline car, we save about 320 gm of GHG per mile driven, translating to a cumulative savings of roughly 0.2 metric tons of GHG for the months analyzed. We propose to extend this analysis to perform detailed calculations based on the charging data and the booking data available as part of the program.

Refine Outreach and Promotion Strategies

Based on early feedback received from users and project partners, we have created additional collateral to simplify the user experience and break down the process to participate. Additionally, utilization dropped off between August and September 2021 and the project team is exploring additional promotion strategies to reach new community members, including radio advertisements and local event newsletter spotlights. The team has also been connecting with businesses and organizations in the area that might be able to utilize the vehicles.

COVID-19 Impacts

The impacts of COVID-19 continue to be felt with this program. Response times and contract negotiations with partners have taken much longer than expected due to reduced organizational capacity and staff turnover across several project team organizations. For similar reasons, there have been delays in securing contractors to complete the installation of charging stations for this project. We are hopeful that these delays will decreasingly affect progress toward meeting project objectives and deliverables as we move into FY2022.

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 and DOE Technology Development Manager Michael Laughlin for the valuable insights and support

throughout 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 Laboratory
- Envoy Technologies
- American Honda
- OpConnect
- City of Hood River, OR
- Port of Hood River, OR
- Mid-Columbia Economic Development District
- Columbia Cascade Housing Corporation
- Columbia Area Transit
- Ride Connection.

I.22 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, 2023
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 (namely, a service taking riders of on-demand, advanced reservation or walk-up, 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 both long-distance rural trips and short-distance within-community 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 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 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 team is currently developing a software toolkit that implements the models and algorithms developed in this project to optimally match rider requests and shuttle/volunteer services, optimally route vehicles for pick-ups and drop-offs, and provide performance metrics of the mobility services in general. The software will provide portals for shuttle drivers, riders, system managers and volunteers, respectively. It is anticipated that the software will be tested in a pilot study in the Budget Period 3 for a period of three months in partnerships with the Greene County Transportation Program, Waynesburg University and 412 Food Rescue.

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 four focus groups on the Waynesburg University campus that consisted of over 100 faculty/staff/student representatives since 2020, despite the project delay imposed by the pandemic. The team conducted three versions of sample surveys to seek comments and feedback from those potential survey responders. The team then modified and improved the surveys, made an online survey portal, and submitted to the Institutional Review Board (IRB) for human subject research approval. The survey will be formally distributed and conducted by November 2021. It is anticipated that we will receive 400-500 samples from Waynesburg University and data analytics will be conducted and ready by December 2021. This would also be the opportunity to train a team of survey takers from Waynesburg University who will help conduct surveys for the general public in Spring 2022.

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. However, we had to halt this effort once the pandemic started. We plan to continue to interview and recruit volunteers starting in spring/summer 2022.

The team worked with Greene County Transportation Program to understand what data can be extracted from the current software used by Greene County, *Ecolane*. We have downloaded sample data and conducted some analysis to gauge its spatial and temporal coverage/resolution. In addition, we have processed the GIS map of Greene County with all road segments, and identified a number of points of interest for trips taken in 2019.

However, we are waiting for the surveys from the general public to extract additional points of interest. We had to halt this effort due to the impact of the pandemic. We plan to continue to conduct analytics for trip demand and points of interest in spring/summer 2022 (once the survey from the general public is completed).

The team developed an algorithm for simulating vehicle routing and demand matching for on-demand mobility service in general. The team also developed an algorithm to acquire time-varying travel time in the Southwestern Pennsylvania region and to simulate shuttle vehicle movement in the region. Based on dynamic simulation of general traffic, shuttle vehicles for mobility services, and rider requests, the team developed an algorithm to optimally assign an on-demand/walk-up rider request to a fleet of shuttle vehicles, based on status-quo and predicted rider requests. This simulation has not been calibrated using *Ecolane* and survey data from Greene County Transportation Program (because data are not fully collected as a result of the pandemic impact), but has been fully calibrated using trip data from a first/last-mile mobility service in Robinson Township, PA. A research paper on this model was recently published (Grahn et. al, 2021). The model is generally applicable in any area or region, and needs to be implemented for the overall Greene County – Allegheny County regional network in 2022.

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 the COVID-19 pandemic and the fact that the characteristics of trips made in rural counties vary substantially from a typical pre-pandemic day, the project has been extended for another 12 months at no cost. As of September 2021, most of the project tasks are on track for completion except a survey for the general public and the planning and establishment of a volunteer program, which will be completed within Budget Period 3 (FY 2022).

Conclusions

This research advances the technology and practices of mobility services in rural areas in the following aspects: a holistic rural transit mobility system addressing the citizens' needs, energy efficiency, a 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 the RAMP system can provide the first/last-mile connectivity or other flexible mobility services 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 and a critical mass of demand in several clusters 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 to identify system inefficiencies, and 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 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.

Key Publications

Grahn, Rick, Sean Qian, and Chris Hendrickson. "Improving the performance of first-and last-mile mobility services through transit coordination, real-time demand prediction, advanced reservations, and trip prioritization." *Transportation Research Part C: Emerging Technologies* 133 (2021): 103430.

I.23 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

TRC, Inc. is deploying an EV equipped with commercially available automated driving capabilities under a variety of rural seasonal and roadway conditions. 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 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

CFO completed the report, Rural Electrification in Ohio: Challenges and Opportunities, a survey of the issues specific to rural areas as they transition to electric vehicle fleets and work to deploy networks of Electric Vehicle Supply Equipment (EVSE). The report is intended to inform and educate rural and regional policymakers, and a Project Advisory Committee (PAC) Meeting in August 2021 convened stakeholders to review the semi-final draft and provide feedback. One finding that the report highlights is the evidence that people in rural areas in Appalachia pay a comparatively high cost for transportation as a percentage of their household income. This metric is called Transportation Energy Burden. See Figure I.23-1. As of late September 2021, plans were underway to further disseminate the documents via a wide variety of partner channels.

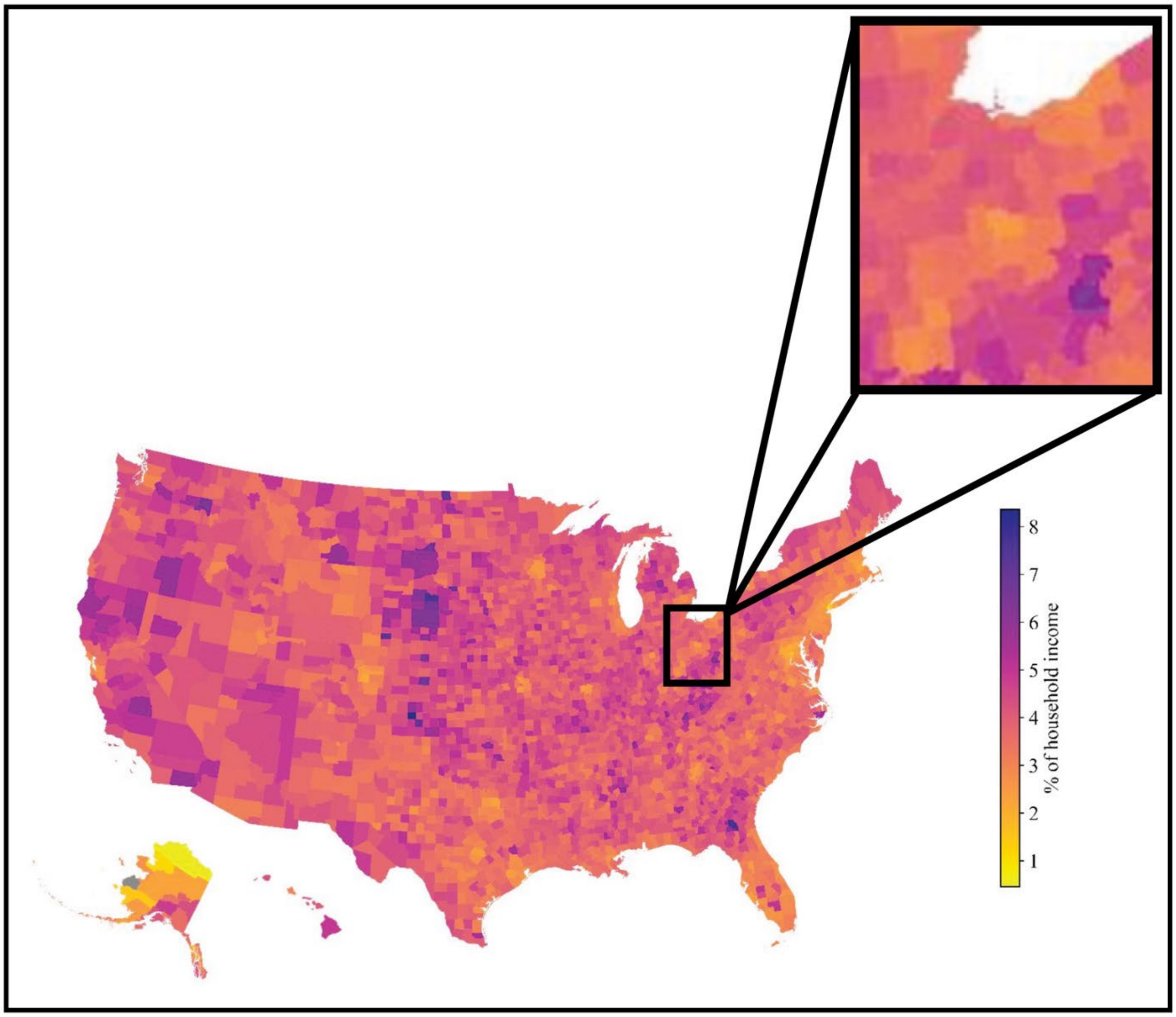

Figure I.23-1. (Figure 2 from the Rural Electrification Report, Map of transportation energy burden by county in the United States as a percentage of household income. Inset shows Ohio counties, with Athens County and surrounding Appalachian counties exhibiting the highest transportation energy burdens in the state. Source: Argonne National Laboratory.)

As a source of evolving data insights, the Ohio Department of Transportation's DriveOhio program has continued to contribute updated Ohio Bureau of Motor Vehicles data, outreach, and ongoing project performance management. DriveOhio opened the U.S. Route 33 Smart Mobility Corridor on September 15th, 2021 and the initiative is expected to provide R.O.A.D.M.A.P. with additional statewide automation and electrification insights.

HAPCAP concluded its first round of baseline data collection in the early months of 2021, building a performance dataset from its existing fleet of Athens Public Transit gasoline-powered shuttles. Following a procurement and selection process that reviewed five candidate models in the van and cutaway size classes, HAPCAP placed an order for an EV shuttle bus with a drivetrain supplied by Motiv Power Systems in April 2021. The shuttle will be built on the Ford E450 chassis. The production process has been delayed by ongoing supply chain bottlenecks affecting multiple suppliers and was still in early build status at the close of FY2021.

During the wait for the shuttle build, Rural Action and HAPCAP collaborated with an area high school, Federal Hocking Local, and arts nonprofit Passion Works to plan a collaborative design process for a themed vehicle wrap. Planning also took place for an additional Level 2 charging station to be sited at the transit depot, to provide overnight charging and as a supplement to the capabilities of the DC Fast Charge station installed in Budget Period 1.

TRC Inc. presented initial findings from controlled environment testing of a Tesla Model 3 at the Intelligent Transportation Systems Midwest Conference in November 2020. The team completed two on-road vehicle deployments in FY2021, the first in late fall of 2020 and the second in late summer 2021. Follow-up controlled environment testing took place in March 2021, with the Rural Action project team observing a portion of the testing on a visit to TRC's test facility March 16th, 2021. TRC spent the summer of 2021 performing analysis of data gathered from both the controlled environment testing and the two on-road deployments.

Rural Action hosted the virtual Appalachian Clean Transportation Forum, which took place November 16 and 17, 2020 and featured a recorded ride-and-drive event, demonstrations of electric taxicab services, and panel discussions on charging equipment and policy strategies, among other offerings. The Forum was also the setting for R.O.A.D.M.A.P.'s first Project Advisory Committee (PAC) meeting, which provided members with an overview of the project's task areas. Subsequent PAC meetings have focused on the Autonomous Vehicle Task and portions of the Individual Motorist and TSP Tasks.

Other outreach activities through the year have included a presentation for NREL's Rural Mobility Forum in June 2021; assistance with planning and executing partner Green Energy Ohio's 2021 Statewide EV Tour Week, which featured multiple stops in Athens, OH; production for CFO's Transportation Solutions Showcase, a digital resource library on electric and other alternative fuel vehicle options for fleets and individuals; and the Ohio Pawpaw Festival's Sustainability Village EV Showcase, which brought EV drivers together to share knowledge and insights on electric vehicle ownership experiences with festival attendees. Electric vehicles featured at this last event ranged from cars to electrified camper vans and e-bikes. See Figure I.23-2.

Figure I.23-2. EV owners chat with Ohio Pawpaw Festival attendees during the Electric Vehicle Showcase on September 18th, 2021. Source: Mryia and Todd Williams, Drive Electric Columbus.

The COVID-19 pandemic has continued to force creative solutions outside of the normal playbook of outreach activities. Both individual motorist ride-and-drive events and fleet outreach and education have been impacted. As an example, the Pawpaw Festival showcase was restricted to allowing people to sit briefly by themselves in car interiors rather than participating in lengthy test rides, and the Transportation Solutions Showcase is being designed as a contactless educational resource.

Conclusions

Most data collected so far in the second demonstration and deployment phase is in the process of being analyzed for insights. However, the Rural Electrification report contains findings that are ready for summary:

- Transportation Energy Burden is an important concept to help explain the urban-rural divide as it impacts electric vehicle adoption. This metric describes the proportion of a household's annual income that is spent on vehicle fuel costs, and is highest in the rural Midwest (Rural Electrification, p.5).
- Working with project partners and the ROADMAP Project Advisory Committee, the CFO team developed three recommendations for spurring EV adoption among rural individual motorists. The first is to provide financial incentives for EV purchases. The second is for local governments and non-governmental advocates to invest and engage in outreach programs that communicate the benefits of EVs and dispel fears about cost and limited range. The final recommendation is to support the research and development of EV pickup trucks, as trucks make up a significant fraction of current purchases in rural areas (p.8).
- Proper placement of EVSE in rural areas requires close coordination between utilities and rural electric cooperatives and is intimately linked with rural broadband availability, as most of today's charging stations are networked. 80% to 90% of households in low-density (<20 persons per square mile) areas of Appalachian Ohio lack broadband access (p. 9).
- EV adoption challenges for rural fleet operators include high initial costs and limited range and selection. These challenges are partially offset by improvements in ride quality and torque performance in hilly areas such as Appalachia (p. 15).
- The report recommends policy initiatives that catalyze emerging opportunities to onshore production of emerging automotive technologies. Ohio and the larger Midwest region have been historic strongholds of the vehicle supply chain, and recent shortages of semiconductors for auto manufacturing underscore the need for improved strategies in this realm (p.17).

Key Publications

Jones, Brandon and Nikolas Merten, Clean Fuels Ohio. 2021. Rural Electrification in Ohio: Challenges and Opportunities. https://ruralaction.org/our-work/sustainable-energy-solutions/clean-transportation/

Acknowledgements

The R.O.A.D.M.A.P. team wishes to thank NETL Technical Project Officer Erin Russell-Story and Contract Specialist Patrick Mayle for their continued support as the project moves through its demonstration and deployment phase.

I.24 Electric First/Last Mile On-demand Shuttle Service for Rural Communities in Central Texas (Lone Star Clean Fuels Alliance)

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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 timeliness and accountability and create the shared sense of purpose and commitment critical to success. Grant sub-recipients are Electric Cab of North America (eCab), Wheels & Water (W&W), and the National Renewable Energy Laboratory (NREL).

eCab is providing the vehicles and drivers and managing the service, interfacing with the Capital Area Rural Transportation System (CARTS) for operations and NREL and W&W to generate the appropriate robustness of data and analysis. W&W's expertise is in research, analysis and interpreting traffic and parking counts. and will be administering surveys and analyzing the data. W&W completed an institutional review board protocol approval process through NREL. The protocol was granted an "exempt" status for the data collection effort, which includes intercept surveys of existing and potential users of the eCab service in Bastrop, and semi-structured interviews of stakeholders in the Bastrop area.

NREL's contributions include analyzing 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 rural transit providing service to the City and County of Bastrop, within a much larger regional footprint. CARTS has services including a circulator route and a phone-in demand response country bus.

Additional local partners are the City of Bastrop, Visit Bastrop and the Bastrop Chamber of Commerce. These partners provide input on vehicle use opportunities and assist in promoting the vehicles and community outreach. MTM, Inc. produced a video highlighting Bastrop's use of the LSEV eCabs as a mobility alternative.

Initially, CARTS was scheduled to launch its CARTS NOW on demand response micro-transit service using their shuttle vans and a Via developed dispatch app during the summer of 2020, with eCab providing a similar service after-hours and weekends. However, plans were delayed and amended due to the pandemic. CARTS incorporated the eCabs into the CARTS NOW service with CARTS NOW badging and using the Via app and used them to "soft launch" in December 2020. CARTS added their shuttle vans in January 2021 with the official launch of their service. See Figure I.24-1. As Bastrop customer traffic gradually returned and the CARTS NOW program developed its ridership, the team chose September 27, 2021 to return to the original plan of eCab providing their service independent of CARTS NOW. See Figure I.24-2.

Figure I.24-1. "Wrapped" eCab operating as part of CARTS NOW service (photo: eCab)

Figure I.24-2. "Wrapped" eCab operating as Electric Cab (photo: eCab)

Results

Data is collected using vehicle telematics, as well as when the driver inputs information obtained visually and through conversation. Figure I.24-3 illustrates preliminary data on selected ridership categories.

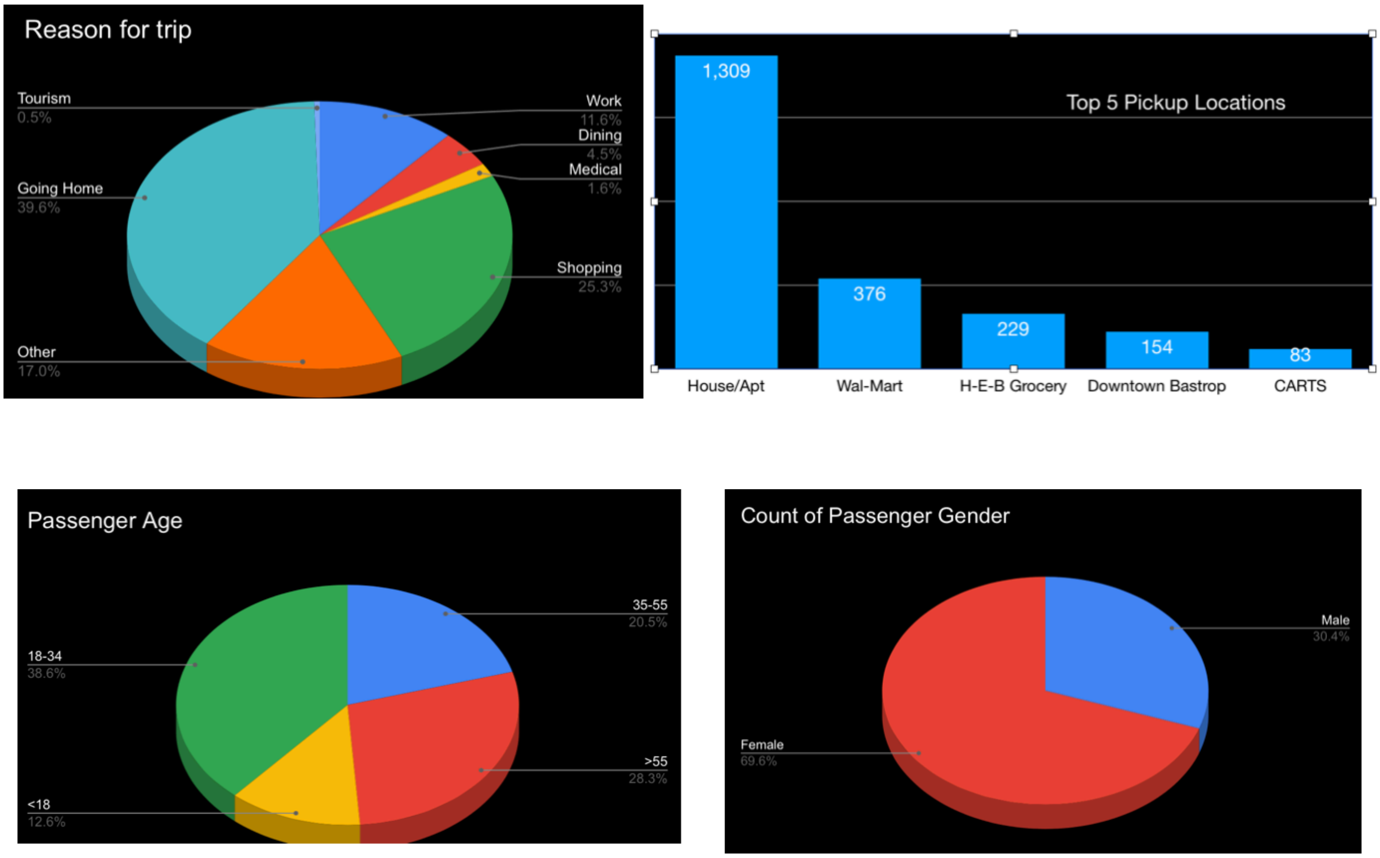

Figure I.24-3. Partial Ridership Results

The following results are key findings from the surveys collected at festivals and from passenger surveys to date. A total of 88 paper surveys were completed in person at the Summer in the City (SIC) event and 101 at the Patriotic Festival (PF) event. A total of 31 paper surveys have been completed by passengers riding in the eCabs. That survey is a shorter one that excludes questions found on the surveys that were included on the SIC and PF event surveys. All of the respondents to the passenger surveys, except two that were undecided, indicated the eCab service was somewhat or very important to them personally and/or to the community.

In the first version of the survey, administered at the SIC event, the questions regarding alternative mode that would have been taken and the influence of parking availability were only asked of those respondents who had already taken eCab. As a result, only 7 respondents from the SIC event had answered those questions. The survey was revised for the PF event to ask those two questions of everyone, regardless of whether they had already taken eCab. The following tables only show the PF and passenger survey results for those two questions.

Table I.24.1 presents the results of the question regarding how the respondent would reach the destination if eCab were not available. This information provides insight into the impact of eCab on accessibility in the community, energy efficiency, and air pollutant emissions. The top two responses from the passenger surveys to date (n=31) indicate that without eCab, the respondents would have just walked or would not have taken the trip. None of the respondents indicated they would have driven alone in a car for the trip. Based on the passenger surveys alone, the role of eCab is to provide an alternative to walking (which is an issue in the hot Texas weather) and to enable access to the destination (because the trip would not have been made).

For the PF event respondents, the top response to the question of how the respondent would reach the destination if eCab were not available was that they would drive alone. Those results indicate the potential of the eCab service to also offer energy-efficiency gains (and emissions reductions) as the service attracts those willing to use eCab to replace a drive alone trip.

Table I.24.1 Survey Responses: If eCab Were Not Available

	PF Event n=101		Passenger Surveys n=31	
If eCab was not available for the eCab trip(s) you took, how would you have reached your destination(s)? Check all that apply.	**# Selected**	**%**	**# Selected**	**%**
I would not have made the trip	5	5.0%	8	25.8%
Drive alone	46	45.5%	0	0.0%
Ride in a car with others	30	29.7%	4	12.9%
Walk	14	13.9%	14	45.2%
Bike	5	5.0%	1	3.2%
CARTS Bus	2	2.0%	5	16.1%
Motorcycle/ sit-down scooter	3	3.0%	0	0%
CARTS on-demand service	0	0%	0	0%
Other: Mom, Uber, taxi, borrow a car	3	3.0%	3	3.0%

Another question asked about the influence that parking availability at the destination had on whether to choose to take eCab. For those eCab riders that took the passenger survey, almost half indicated parking availability had no influence. In contrast, of those that took the survey at the PF event, the highest percentage of those responding indicated parking availability would have a strong influence on whether they would consider taking an eCab. See Table I.24.2.

Table I.24.2. Influence of Parking Ability

Response	PF Event n=101		Passenger Surveys n=31	
	# Selected	%	# Selected	%
Did not respond	43	42.6%	0	0%
Somewhat of an influence (one of several factors in decision to use eCab)	9	8.9%	3	9.7%
No influence (I choose eCab regardless)	7	6.9%	15	48.4%
Strong influence (primary reason, either because parking is limited or do not want to hassle with parking)	28	27.7%	4	12.9%
Not sure	15	14.9%	9	29.0%

Most survey respondents taking the passenger survey indicated they frequently encourage others to use the eCab service, they do not have concerns about their personal safety or comfort, and they believe that access to eCab for themselves and the community is somewhat or very important.

The goal is to continue collecting surveys to reach at least the minimum number needed to allow for statistical significance testing and development of population estimates. By setting the confidence interval at 95% and the margin of error (for the confidence interval) at 5% for a rounded-up population size of 10,000 (the City of Bastrop population is estimated at 9,516), a sample size of 370 Bastrop residents would provide 95% certainty that the Bastrop resident population response would be within 5 percentage points of the percentage of the sample response.

Conclusions

The goals of this project are to demonstrate the ability of a low-speed electric vehicle service in a rural community, to provide improved mobility and accessibility for residents, visitors, and workers, to improve energy efficiency of transportation options, and to reduce air pollutant emissions. To evaluate how the project is performing to meet those goals, the operations and research team collects data via drivers asking questions of passengers, surveys administered to passengers and participants in community events, interviews with businesses, and vehicle telematics. The benefit of pursuing a community-based, in-person surveying and interview effort is that it simultaneously serves as a way to inform the community about the service.

Improving mobility and accessibility

Despite a pandemic, a transition from CARTS to independent operation (which required a different hailing app), and a change in operating days (to include weekends) and hours (from daytime to evening) in September 2021, eCab's cumulative ridership continues to increase and the number of rides on a weekly basis is starting to match the numbers pre-transition, even though the new operating hours for now are fifteen fewer per week. The ridership and survey data indicate eCabs provide a useful service to the community, evidenced by eCab continuing to attract ridership after the September transition. Some passengers indicated via survey they would not have made the trip without eCab, thus improving mobility, and most survey respondents indicated the eCab service is important to the community. Highlights of ridership data include the significant finding that almost 70% of the riders are female (suggesting eCab is considered a safe transportation mode), that 40% of the riders are in the 18 to 34-year range (indicating that the service is appealing to a wide range of ages) and that the most popular destination (~40%) is home, which gives an indication of the use of eCab by residents of the City of Bastrop within the eCab service area.

Energy efficiency and air pollutant emissions

The vehicle telematics data (e.g., mileage) will be analyzed to determine how use of the eCabs to provide the trips compares with trips taken by other modes in a proportion informed by the survey responses. According to the passenger surveys, 45.2% would have walked, 25.8% would not have made the trip, 16.1% would have taken a CARTS bus, and 12.9% would ride in a car with others. From an energy efficiency and air pollutant emissions standpoint, the replacement of a walking trip with eCab would be less energy efficient and result indirectly in more emissions (assuming non-renewable sources of electric energy were used for charging the electric vehicles; otherwise, zero emissions). However, this highlights the need to consider the value of a person's time and comfort as components of improving accessibility. If walking takes a long time and/or occurs in uncomfortable weather (e.g., very hot, rainy, or very cold), then the use of an alternative that is quicker and more comfortable than walking and more energy-efficient and lower emissions than other transport modes (e.g., cars or buses) can be considered a net gain when considering the three goals of accessibility, energy efficiency, and air emissions. The research team will continue to monitor the impact in that regard. For respondents that indicated they would not make the trip without eCab, rather than make a value judgment on whether the trip should be made or prevented (i.e., demand management), again, the eCab trip should be seen as a gain in accessibility in the community.

Data will continue to be collected from the vehicles, from drivers as they question passengers, with on-vehicle passenger surveys, and from surveys and interviews of those in the community. The data will then be used to develop a range of quantitative estimates of accessibility, energy, and air emissions.

Acknowledgements

Lone Star Clean Fuels Alliance would like to acknowledge: Dave Marsh, Rachid Breir and Dana Platt of CARTS for coordination, integration and marketing; Katie Kam, Wheels & Water LLC., for surveying and analysis; Chris Nielsen for eCab operation and collecting ridership data; Stanley Young and Andrew Duvall of NREL for insight, guidance and analysis; the Bastrop Chamber of Commerce; the City of Bastrop and Visit Bastrop; and MTM, Inc. for general support and marketing of the eCab service.

I.25 East Zion National Park Electric Vehicle Shuttle System Plan (Utah Clean Cities Coalition)

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Project Funding (FY21): $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 Zion National Park (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. Of unique importance to note, the shuttles must be able to pass side-by-side through the historic narrow Mt. Carmel Tunnel in Zion National Park. This tunnel is open to free flowing traffic less than 15 minutes a day due to oversized vehicles, buses and RVs.

Approach

The project will reach the objectives by completing 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 included collection of input from stakeholders, identification of key transportation strategies, mapping the shuttle system and issuing a Request for Proposals (RFP) to potential EV and EVSE vendors.

EVSE and Shuttle Stop Development with the East Zion Initiative

The second budget period included selection of vendors, purchase and installation of infrastructure, and development of shuttle stops. The East Zion Initiative has been a dynamic collaboration with the EVZion Steering Committee members. Utah Clean Cities (UCC) created the brochure, presentation slides and other collateral for social media, and the EVZion project team continually curates it. The EVZion shuttle demonstration is an integral part of the East Zion Initiative and integral to the park experience and new visitor center.

The third and final budget period includes purchase, acquisition, and deployment of the second shuttle, the completion of a technology pilot study and creation of a National Park EV Development Smart Mobility Concept Plan- MOVE- Mobility Outdoors Visitor Experience. This allows the project to possibly be replicated and scaled to meet the needs of national parks, monuments, state parks and other areas servicing large visitor populations in rural, gateway communities.

Achievement of overall project data gathering and success of the electric shuttle is dependent upon the data analysis led by the National Renewable Energy Laboratory (NREL) a national laboratory funded under a separate DOE award. UCC will coordinate and collaboratively conduct data gathering and logistical routing 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, vehicle deployment evaluations, driver performance and logistical analysis.

Results

Through 2019 to the present, the project team assembled a Steering Committee and has engaged collectively and in smaller work groups on a regular basis with virtual meetings/calls, and met on-site on several occasions during the COVID outbreak (when appropriate, following CDC guidelines). The Steering Committee is integral to project success, and all the members are actively engaged in developing, deploying, evaluating, and using EVSE charging infrastructure. Additionally, the Steering Committee oversaw all tasks accomplished throughout the first and second year, as outlined below.

The Steering Committee members are shown in Table I.25.1. Further, the key community members that are following the project are shown in Table I.25.2, Community Partners.

Table I.25.1. Steering Committee Members

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

Table I.25.2. Community Partners

Organization	Category
Drive Clean Colorado - Clean Cities Coalition	Clean Cities Coalition
Northern Colorado Clean Cities	Clean Cities Coalition
Treasure Valley Clean Cities Coalition/ Supported By YTCC	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, Capitol City	Municipality
Springdale, Gateway to Zion	Municipality
Five County Association of Governments	Government
Bureau of Land Management	Government
Department of Administrative Services - Governor	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 UCC team then sent the data to NREL to be analyzed. Based on the data, the team defined the shuttle parameters and specifications. The UCC team reviewed the full report and recommendations, released the RFP, Request for Proposal, at the end of December 2020, and selected the vendor in February 2021. The contract was awarded to Davey Coach with an EV and Logistics upfit by Lightning out of Colorado. Delivery of the first EV Shuttle is expected by late October 2021 to the gateway community of Kanab, Utah. A ribbon cutting is planned in connection with a Governor’s Outdoor Summit on October 28th, 2021.

EVSE at Kanab

The project team coordinated with Kane County to finalize the Environmental Questionnaire and procure the EVSE infrastructure for Kanab in 2020. The EVSE installment and running operations met all milestones. This was the first scheduled installation of EVSE in the project; additional infrastructure will follow near the new East Zion visitor center at Applecross Junction and at the gateway town of Springdale, located at Zion National Park West side.

Conclusions

During the second year of the EVZion project, the project partners successfully continued working with key members of the Steering Committee and deeply engaging with federal, state and local Utah leadership. UCC, Zion Forever and the EVZion Steering Committee hosted several large and smaller press events. In 2021, UCC was notably involved with hosting the new Governor of Utah, Spencer Cox at the new visitor center site; touring the area with the Governor’s Office of Energy Development team; and ribbon cutting the new EVSE. The first EVZion Shuttle will be unveiled at the Governor’s Outdoor Energy Summit in October 2021. UCC was also honored to be a working partner and invited guest of the planned non-profit event to be held in October by Zion Forever, which curates the visitor experience of the East Zion Initiative and Zion National Park.

Additionally, UCC has worked with various Utah and regional stakeholders to develop onsite infrastructure for the East Zion Initiative. The continued work with the Governor's Energy office, public officials, and private industry along with key leadership from the gateway, rural town of Kanab, Utah, has delved into a new clean energy feasibility study of a new water waste treatment plant for the growing city.

This treatment plant would be designed as a state-of-the-art methane capture project, producing electricity, methane and, ideally, hydrogen to use in virtual pipelines and in fuel cell storage, and producing onsite electricity. This project could also pair with a newer feedstock to Utah, Biochar, which is using invasive tree species as feedstock and offloading the byproduct of hydrogen to be effectively used in a "virtual pipeline". The hydrogen could potentially operate the next all-electric fuel-cell shuttle model in the EVZion Pilot demonstration in 2022.

Acknowledgements

The Utah Clean Cities team would like to recognize the efforts of Daniel Nardozzi, the project's NETL Project Manager, Utah Clean Cities Board of Trustees, and our EVZion Partners.

I.26 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. MEC has more than 20 years of experience working with alternative fuel 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 and 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 quantitative 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 region.

Objectives

The objectives of this project are to demonstrate the feasibility of electrification for freight yard and terminal tractor 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, Penn State University, 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 put into service by the pilot fleets is manufactured by Orange EV. Based in the Kansas City metro, in Riverside, MO, 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 in container handling operations. The pilot fleets are described below:

- Lazer Spot is the leading provider of yard management in North America, working at 400+ sites in the USA and Canada for manufacturers and retailers. Lazer Spot, which recently acquired Firefly Transportation, deployed two trucks in the Chicago metropolitan area. One of their deployments is Orange EV's all new T-Series Tandem pure-electric terminal truck.
- Johnson County Wastewater Department deployed 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, deployed their truck at a client site in Wyandotte County, KS, which is also located in the Kansas City metropolitan area.
- Orange EV also took possession of a demonstration truck that is available for use by interested fleets across the U.S. at no cost except for a shipping fee of up to $500.

Approach

In addition to telematics and data collection, the project team is holding quarterly roundtables during the three-year duration of the project, allowing the pilot 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 develop relationships across the region, with the goal of demonstrating the feasibility of battery-powered terminal trucks.

Year two of the project is focused on community outreach. Pilot fleets worked with MEC and Orange EV to host at least one community workshop. Presenters shared the benefits of electrification and other alternative fuels in freight applications, and the pilot fleets revealed their experiences and best practices with fleet electrification. Successful workshops with follow-up surveys and meetings will 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 that will allow 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

In 2020 MEC onboarded the project partners and the pilot fleets deployed four trucks, in addition to the deployment of the Orange EV demonstration vehicle.

In 2021 MEC focused on data collection and community outreach. In 2022 Penn State University will analyze qualitative and quantitative data collected from the below activities.

- During the quarterly roundtables, the pilot fleets discussed several topics. During one meeting, the fleets shared their experiences and best practices operating the vehicles in cold weather.
- MEC distributed quarterly surveys to the pilot fleets. The surveys focused on the following topics: pre-deployment, charging infrastructure, telematics, and vehicle operation & maintenance.
- As of September 2021, eighteen fleets across the U.S. had utilized the demonstration vehicle. MEC continues to work with Orange EV to ensure the demonstration fleet surveys are completed and to connect the users to additional resources when requested.

Upcoming Activities

On October 19, 2021, MEC will host a virtual community workshop, *Electrifying Terminal Trucks: Best practices and lessons learned from deployments in the Kansas City region and beyond*. After a brief presentation, the pilot fleets, Orange EV, the project researcher from Penn State University, and Kansas City's electric utility will share their real-world experiences with zero-emission freight handling in a roundtable format. Expected attendees include Clean Cities Coordinators, fleets, energy justice advocates, nonprofit organizations, and more. Post-workshop, MEC will connect attendees with additional resources and facilitate a meeting with the roundtable participants to document what went well and what they would change for future events.

In addition to the above, MEC will work with Blue Symphony, a local marketing agency, to create a short video highlighting the project. The goal of the video is to demonstrate real-world operations of electric terminal tractors in various fleets' unique work settings while sharing the practical and human benefits of heavy-duty vehicle electrification. Blue Symphony will film at each deployment site and work with MEC to edit the video. MEC will work with the pilot fleets to promote the video in 2022. See Figure I.26-1.

Figure I.26-1. Blue Symphony, a Kansas City-based marketing agency, interviews a vehicle operator at Johnson County's wastewater treatment facility.

Conclusions

Data collection continued in 2021 for the project. Analysis will take place in 2022. No conclusions to date.

Key Publications

Video: Driving the Future with Electric Terminal Trucks.

Acknowledgements

Report content and project leadership have been primarily provided by Emily Wolfe, Sr. Program Coordinator & Policy Analyst at Metropolitan Energy Center.

I.27 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 complement 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 (QVM), Upper Cumberland Human Resource Agency (UCHRA) as the primary public transit provider in the 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 electric vehicle (PHEV) 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 diverse user communities within the UC region. The project team will establish an EV charging station network to support these EV operations.
- Data Tracking and Collection: The project will strongly focus on collecting comprehensive data (e.g., technical data, pre-demonstration and post-demonstration survey/interview data) from the proposed EVs, charging infrastructure, and the served communities.
- Data Analysis: The key questions to be addressed for 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? In addition, the team will develop an EV 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. In addition, the project team will create public education opportunities for the rural communities in the UC region via reoccurring public events.

Results

During the second year of the project (FY 2021), the project team has had the following accomplishments:

As of September 30, 2021, the project partner, Seven States Power Corporation, has identified all 9 public charging station hosts and successfully installed eight Level-2 dual-port charging stations (three in FY 2020 and five in FY 2021) and one DCFC station (in FY 2020) in the UC region, as shown in Figure I.27-1. The DCFC station is only the second DCFC station in the entire UC region, while the eight Level-2 dual-port charging stations are the first charging stations installed in eight small rural towns in the UC region (Smithville, Sparta, Carthage, Livingston, Spencer, Lafayette, Byrdstown, and Jamestown). The established public charging stations are critical in the rural EV ecosystem and have served broad EV communities (visitors and local residents). The DCFC station in this project has been frequently utilized by the EV communities. As of September 30, 2021, the established charging station network has supported 364 EV charging events (325 charging events recorded from October 1, 2020 to September 30, 2021). The total energy supplied from the public EV charging stations to EVs is 5,769 kWh. The public EV charging stations have contributed to saving 724 gallons of gasoline fuels. In addition, they have reduced greenhouse gas emissions by 3,719 kg in total.

In the first year (FY 2020), the project team introduced three compact EVs in the project for demonstration, including one 2019 Nissan Leaf SL Plus (with a 62-kWh battery pack and a 215-mile EV range), one 2020 Nissan Leaf SV Plus (with a 62-kWh battery and an EV range of up to 225 miles), and one Nissan Leaf SV (with a 40-kWh battery and a 149-mile EV range). In the second year (FY 2021), TTU also acquired a PHEV F250 pickup truck equipped with a hybrid conversion kit (featured with 15-kWh usable battery pack and a post-transmission motor) from XL Fleet. All four PEVs are equipped with on-board diagnostics data loggers for data collection. The PHEV pickup truck is equipped with an additional data acquisition system and battery State of Charge (SOC) display system to inform the users. The photos of the three Nissan Leaf EVs and the PHEV pickup truck are shown in Figure I.27-2 and Figure I.27-3, respectively.

Figure I.27.1. Eight level-2 Dual-port and one DCFC Charging Stations Installed in the Rural UC Region

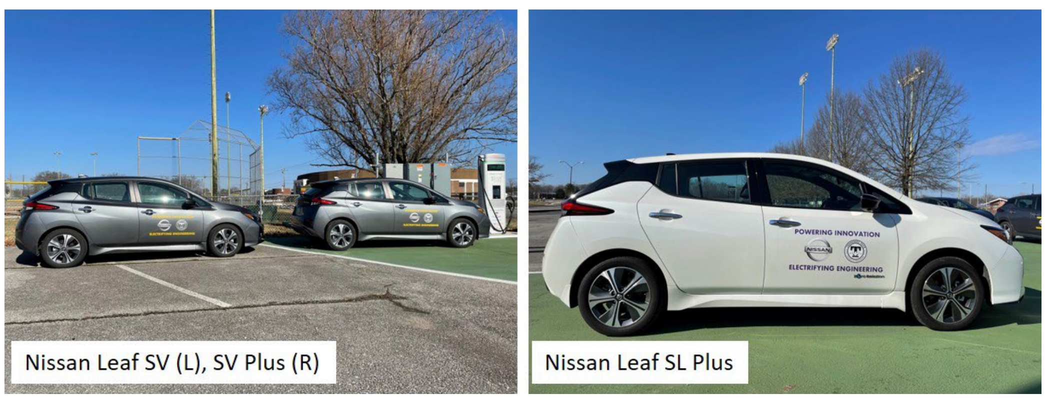

Figure I.27.2. Photos of three Nissan Leaf EVs

(a) PHEV Pickup Truck (b) SOC Display and Data Acquisition System

Figure I.27.3. Photos of the PHEV Pickup Truck (left) and SOC Display and Acquisition System (right)

The local rural transit agency, UCHRA, will deploy one battery-electric E-450 shuttle bus to serve the rural residents without personal vehicles. UCHRA ordered the all-electric shuttle bus through Creative Bus Sales, Inc. The conventional gasoline-powered shuttle bus is currently in the manufacturing process and is expected to be delivered to Phoenix Motorcars for electrification by mid-November 2021. The global chip shortage has caused some delay in the conventional bus manufacturing process. The electric shuttle bus is expected to be delivered to the transit agency for service in Q1 of 2022.

The project team created a signature two-week EV test drive program for the rural communities in the Upper Cumberland region to test drive the project EVs. It has been in effect since August 10, 2020. The recruitment information has been exposed to 11 of 14 counties in the Upper Cumberland region. A majority of them are rural areas with limited or no EV exposure. As of September 30, 2021, the project team has achieved the following accomplishments:

1) **530** rural residents from the 11 counties in the UC region have been exposed to and have attempted to sign up for the EV test drive opportunity.

2) **330** residents have provided complete contact information to allow the project team to follow up with them and provide additional application materials.

3) **100** participants have been approved for the two-week EV demonstration.

4) The project EVs have been demonstrated to **71** approved participants (7 in FY 2020 and 64 in FY 2021) with each participant driving an EV for two weeks as daily commute vehicles (occasionally for intercity trips) to learn EV operation, EV charging, benefits, issues, and learn the best practice.

5) The recruitment and demonstration efforts have reached diverse communities including rural communities, low-income communities, women, elderly and minority groups. The EV demonstration has reached 8 Counties: Putnam, DeKalb, Jackson, White, Cumberland, Macon, Smith, and White in the Upper Cumberland region. The EV fleet has accumulated 40,967 miles in the Upper Cumberland region through the EV test drive program.

A large set of data has been collected on the project vehicles (Nissan Leaf SV, SV Plus, SL Plus, and plug-in hybrid pickup truck), including:

1) **62** sets of Nissan Leaf EV data (including charging data, second-by-second vehicle-level data, battery data, electric motor data, and others) from test drives of the participants with each dataset covering two-week operation window.

2) **74** sets of pre-demonstration survey data, 55 sets of post-demonstration survey data, and 40 sets of post-demonstration interview data.

3) **9** sets of plug-in hybrid pickup truck data from a 2-week EV demonstration (including charging data, second-by-second vehicle-level data such as fuel consumption rate and vehicle speed, battery levels at the start and end of a trip, and others).

4) A large set of plug-in pickup truck data and baseline pickup truck from internal testing in local routes and on airport runway in closed environment.

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

1) Plug-in hybrid pickup trucks are of strong interest in the rural Upper Cumberland region. According to the survey results, about 51% of the 220 participants are interested in a test drive of a PHEV pickup truck, while the remaining 49% of the participants are interested in passenger EVs like Nissan Leafs. More specifically, 42% of them are interested in EVs with a 215-mile range and 7% of them are interested in Nissan Leaf EVs with a 149-mile EV range.

2) Through the EV demonstration to 71 rural residents in diverse applications, the current EVs technologies have proven to be feasible solutions to meet the transportation needs for rural communities from an EV range perspective. More specifically, for rural communities with shorter daily commutes (60 miles or less), EVs with an approximately 150-mile EV range can meet the needs. Rural residents are more comfortable with EVs that can provide 215-mile EV ranges or longer, however. For rural communities with long daily commutes (80 miles or longer), EVs that can provide 215-mile EV ranges or longer are necessary to comfortably enable long-distance trips.

3) Through the EV demonstration to 71 rural residents in diverse rural applications, it was found that lack of public EV infrastructure has limited impacts on EV operation when rural residents have access to a 110-volt outlet, or a 220-volt outlet (such as an electric dryer outlet) for EV charging at home or at the workplace. A majority of rural residents in the EV test drive program did not report any operational issues due to EV charging. Public EV infrastructure has the largest impact on EV operation where EV users have no access to a 110-volt or 220-volt outlet for EV charging at home or at the workplace (e.g., multifamily home residents). In the demonstration, the participants living in multifamily homes relied on public DCFC stations for charging their EVs. An alternative solution is to install Level 2 charging stations at the multifamily homes. These are currently nonexistent in many multifamily homes in rural areas. Lack of EV infrastructure along the main corridors (particularly DCFC stations) also has negative impacts on EV deployment for inter-city travels, due to range anxiety, even when it is technically feasible to complete the trips with or without charging events.

4) A two-week EV test drive program is a very effective approach to help rural communities gain EV experiences, comprehensively understand EV operation (including driving and charging), benefits and limitations of EVs, and improve their perceptions of EVs. More specifically, 70% of participants have a very positive perception of EVs and 28% of them have a somewhat positive perception regarding the EVs they experienced in the test drive program. From the survey data, the project team found that participation in the EV test-drive program had very significant impacts on the participants' decision making in EV adoption. About 88-90% of the participants are more likely to adopt EVs as their next vehicles and more likely to purchase and lease EVs than before. The participants in the EV test program can help accelerate EV adoption, as 90% of the participants are likely to recommend EVs to others. The project team also found that the EV test drive program can improve the participants' awareness of EV charging stations.

5) The project team observed from the survey data that the top three compelling reasons for rural residents to purchase or lease EVs are low fuel cost, positive environmental impact, and low maintenance cost, respectively. The team observed from the survey data that the top three compelling reasons for rural residents not to purchase or lease EVs are short driving range, limited charging stations, and high purchase cost, respectively.

6) In the comparisons of EV and gasoline-powered vehicles, survey results show that the rural participants favor EVs in the cost of operation, overall value, overall quality, driving enjoyment, and performance/handling. In participants' opinions, EVs and conventional vehicles have comparable appearance. Conventional vehicles outperform EVs in the areas of purchase cost and driving range.

7) The feedback from the participants in the EV test drive program demonstrates that the project team has done an excellent job in making the test drive program informative, enjoyable, and helpful to the

participants. A majority of the participants feel this test drive program made good use of their time to learn more about EVs.

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

1) Four EV "Ride-and-Drive/Show-and-Tell" events during National Drive Electric Week, Drive Electric Earth Day, and annual Genetic Excellence Angus Bull Sale event (October 1, 2020 – September 30, 2021). The key numbers of the EV outreach events are summarized in

2) Table I.27.1.

Table I.27.1. Key Numbers of EV Outreach Events (October 1, 2020 – September 30, 2021).

Event and Location	Event Date	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
EV Ride-and-Drive Event, Crossville, TN	October 3, 2020	80	80	9	18
Genetic Excellence Angus Bull Sale, Cookeville, TN	January 2, 2021	24	24	2	0
EV Ride-and-Drive Event, Cookeville, TN	April 17, 2021	120	120	14	20
EV Ride-and-Drive Event, Knoxville, TN	Sep. 25, 2021	100	40	100	0

3) The project team hosted two webinars on March 31, 2021 and April 21, 2021, respectively, to prepare rural communities for EV adoption. The first webinar, which focused on utility and EV charging stations, attracted 219 registrations and 138 attendees. The second webinar, which focused on light-duty passenger EVs, attracted 46 attendees. Three major Original Equipment Manufacturers, including Nissan North America, General Motors, and VW, all participated in this webinar to introduce their vehicle electrification plans and products. In addition, four participants from the test drive programs were invited to share their EV experiences from rural transportation perspectives. Overall, the participants very positive experiences with the attendees. The recording of the two webinars can be found on the project website [1].

4) TTU and ETCF have collaborated to establish a sustainable EV chapter with the different stakeholders in the rural UC. The PI attended the 2021 DOE Vehicle Technologies Office Annual Merit Review and presented the latest updates of the project to the reviewers on June 24, 2021 and has received positive comments from the reviewers. The PI also participated in other EV outreach events such as the Tennessee Valley Authority's EV Think Tank, and Drive Electric Tennessee's Town Hall event, to promote EV adoption in rural areas and share project updates. Furthermore, the PI also assisted the local rural transit agency with a grant application to adopt EVs for their microtransit service.

Conclusions

Through the demonstration of a small PEV fleet in the proof-of-concept rural EV testbed in the UC region, the project team found that there is strong interest from the rural communities in the UC region in adopting EVs. The successful EV demonstrations to more than 71 participants through the EV test drive program and comprehensive data analysis prove that, despite limited public EV infrastructure in rural areas, EVs are feasible solutions to meet the transportation needs of most rural communities, although the preferred EV range may vary based on the residents' daily commute distances. In addition, data analysis results reveal that the main barriers to EV adoption in rural areas are short driving range, limited charging stations, and high purchase cost. Furthermore, the two-week EV test drive program was found to be a very effective approach to help rural communities gain EV experience, comprehensively understand EV operation (including driving and charging), benefits and limitations of EV, and improve their perceptions of EVs.

Key Publications

K. Yang and P. Chen, "Optimization of Charging Schedule for Battery Electric Vehicles Using DC Fast Charging Stations," in the 2021 Modeling, Estimation, and Control Conference (MECC 2021), pp. 418-423, 2021.

H. Shen, Z. Wang, K. Yang, L. Maxavier, P. Chen, and J. Wang, "Comparison of Different Variable Combinations for Electric Vehicle Power Prediction Using Kernel Adaptive Filter," in the 2021 Modeling, Estimation, and Control Conference (MECC 2021), pp. 858-863, 2021.

M. Lamantia, Z. Su, and P. Chen, "Remaining Driving Range Estimation Framework for Electric Vehicles in Platooning Applications." in 2021 IEEE American Control Conference, pp. 423-428, 2021.

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[1] https://driveelectrictn.org/fleetsandprojects/#Projects

Acknowledgements

The project team is grateful to DOE NETL Project Manager Trevelyn Hall for valuable feedback and guidance that helps improve this project. The project team is also grateful to NETL Contract Specialist Shane Buchanan for his time and efforts on 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.28 Heavy Duty EV Demonstrations for Freight & Mobility Solutions (Clean Fuels Ohio)

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Project Funding: $1,559,011 DOE share: $779,011 Non-DOE share: $780,000

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, the replacement 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 second year of the project:

- Identified and compiled data gaps and design improvement needs
- Made MD and HD telematics improvements
- Compiled EV deployment data; and
- Began data development for MD-HD EV analysis model.

The Go/No Go decision point for the second year of the project is to create EV analysis models.

Clean Fuels Ohio worked with project partner Sawatch Labs to develop an initial list of data points and specific targeted areas of interest to inform the MD-HD EV data analysis on the Sawatch ezEV telematics analysis platform. Clean Fuels Ohio continued to work with Sawatch Labs to add MD and HD EVs to their data analysis platform and perform the data analysis, visualization, and key reporting functions. Clean Fuels Ohio engaged with the three OEMs and three fleet demonstration partners to request signed letters of commitment providing a specific amount of data based on number of vehicles and number of data months.

Clean Fuels Ohio worked with Sawatch Labs to develop a comprehensive "Data Collection and Analysis Plan" covering key topics including data diversity, data partner recruiting, data parameters and other collected information, data collection process, data storage methodology and security, and data analysis. Sawatch Labs began to collect OEM and fleet data from the project partners and will collect additional data throughout the remainder of 2021, to identify data gaps and design improvement needs.

Clean Fuels Ohio engaged with the three OEM partners in the project (SEA Electric, Orange EV, and Lightning eMotors) to collect financial and operational performance data from vehicles deployed to date. After receiving signed letters of commitment from the OEMs and facilitating several conversations on available data and best ways of transferring/collecting data, Clean Fuels Ohio received vehicle summary scorecards from Orange EV and is in the process of receiving data from SEA Electric via Geotab telematics data API requests. Clean Fuels Ohio is navigating pathways to partner with other MD and HD EV OEMs to collect additional vehicle operational & financial performance data to vet the Sawatch MD-HD EV analysis tool.

Clean Fuels Ohio has facilitated communication between Sawatch Labs and several EV OEMs throughout 2021 and they have provided relevant Geotab PIDs for their EV integration. To the extent the PIDs are available in the Geotab DataStream, Sawatch Labs is prepared to surface them in their data layer and analytics visualizations.

Sawatch Labs' development of the MD-HD EV analysis modeling tool depended on three key functions, including characterizing duty cycles and vehicle roles, vehicle loads and loading characteristics of duty cycles, and accessory usage.

Economics & Environment | Parking & Charging | Assumptions

Estimated Operational Metrics in a 2022 Sea-Electric Hino 195

These metrics estimate what the usage numbers would be if the miles driven by your 2013 ISUZU NPR/NPR-HD had been driven in a 2022 Sea-Electric Hino 195.

VMT	GHG Reduction	Operational Cost Difference*	TCO* (Lifetime)	TCO** (%)	Average Daily Idling Hours
5,470	97%	▼ More than -$42,000	▼ More than -$42,000	▼ -28%	3.0

* Total Cost of Ownership (TCO) Change and Operational Savings reflect the financial savings over the lifetime of the vehicle.

** TCO Change takes into account the purchase price of the recommended vehicle, Operational Savings does not.

Figure I.28-1. Real-world sample output of the Sawatch ezEV platform/tool for a MD vehicle (SEA Electric Hino 195) from a non-disclosed fleet.

Figure I.28-1 shows a high-level output of the Sawatch ezEV platform/tool, that was originally built for sedans/light-duty vehicles and is now being extended to cover MD-HD vehicles. The output graphic of the tool with the specific SEA Electric Hino 195 inputted displays a low VMT for what would be expected in a good fit; however, the idling was such that it drove a good TCO. The SEA Electric compared favorably to a comparable new ICE vehicle in cost. The GHG reduction points out this was a very clean electricity mix, but it is atypical of their results from other EV trucks. The confidence score was driven by the amount of operational data (at least 90 days) Sawatch received from the fleet partner, but this score shows less than half of that. Overall, this vehicle displays a very good fit in the medium-duty class that overcomes the TCO challenge of electric trucks.

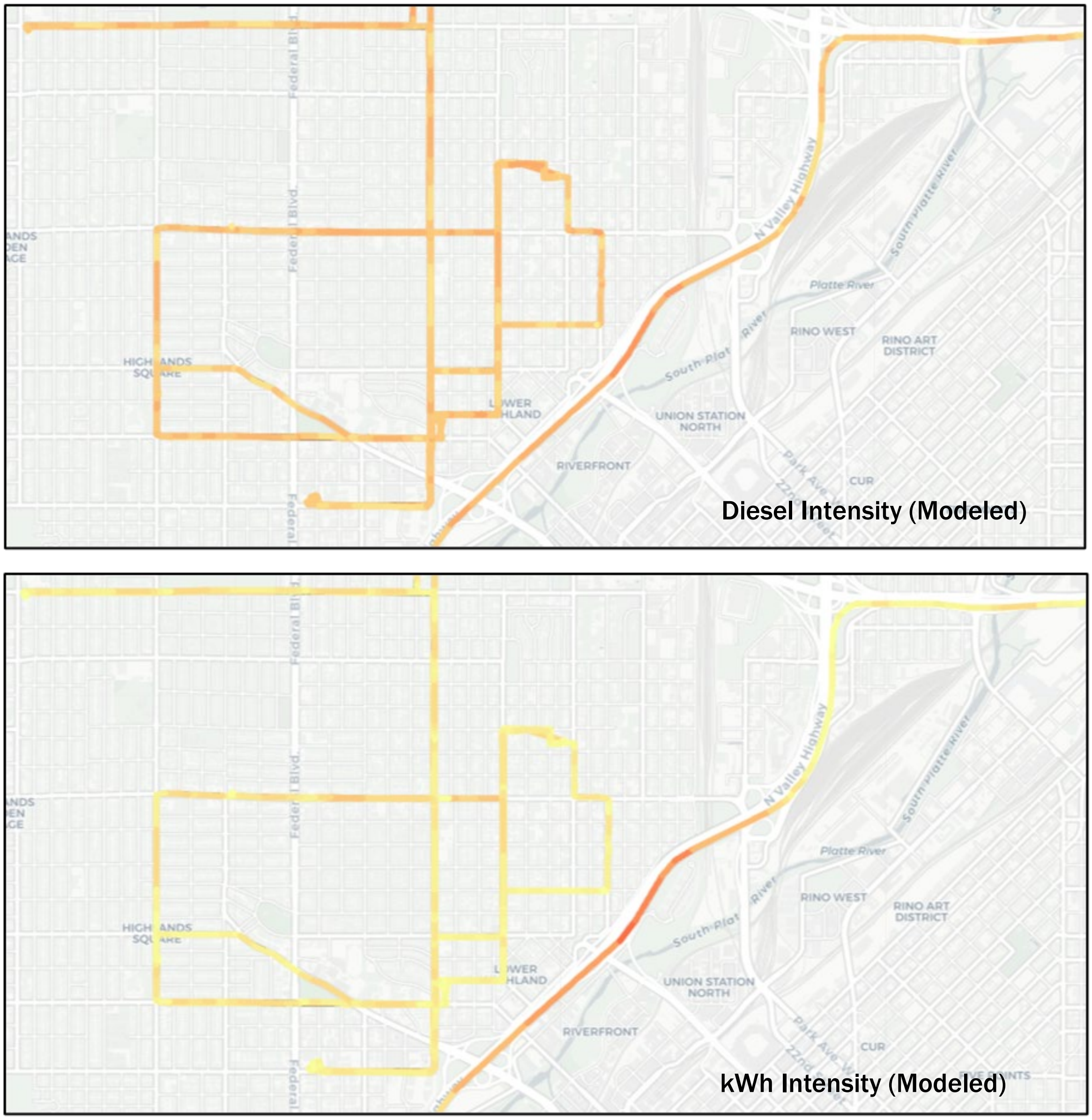

Figure I.28-2. Output of the Sawatch medium-duty EV tool via a side-by-side map of fuel intensity between a diesel and EV truck from a real world non-disclosed fleet.

To showcase the granularity of how Sawatch tries to analyze electric truck operational and cost data, Figure I.28-2 displays an energy model comparing a diesel truck in terms of its operation and the intensity of the same duty cycle with an electric truck. The red displays a higher intensity in efficiency of the transmission while the orange displays a lower intensity. Comparing the red and orange lines between the diesel intensity and electric intensity in a stop-and-go application, Sawatch observed that the colors are flipped between the two models. As a diesel truck travels the highway (the straight path on the left portion of the path), the diesel truck comes into its own. As the diesel truck travels through the neighborhoods and turning streets, there are higher volumes of red in the vehicle path indicating a higher intensity where constant acceleration and deceleration is a problem. Functionally, Sawatch looked at the difference in efficiency of the transmission, and since an EV truck does not have a transmission and benefits from regenerative braking as well, it was able to deliver instantaneously whereas the diesel truck displays inefficiencies in a low speed, stop-and-go application.

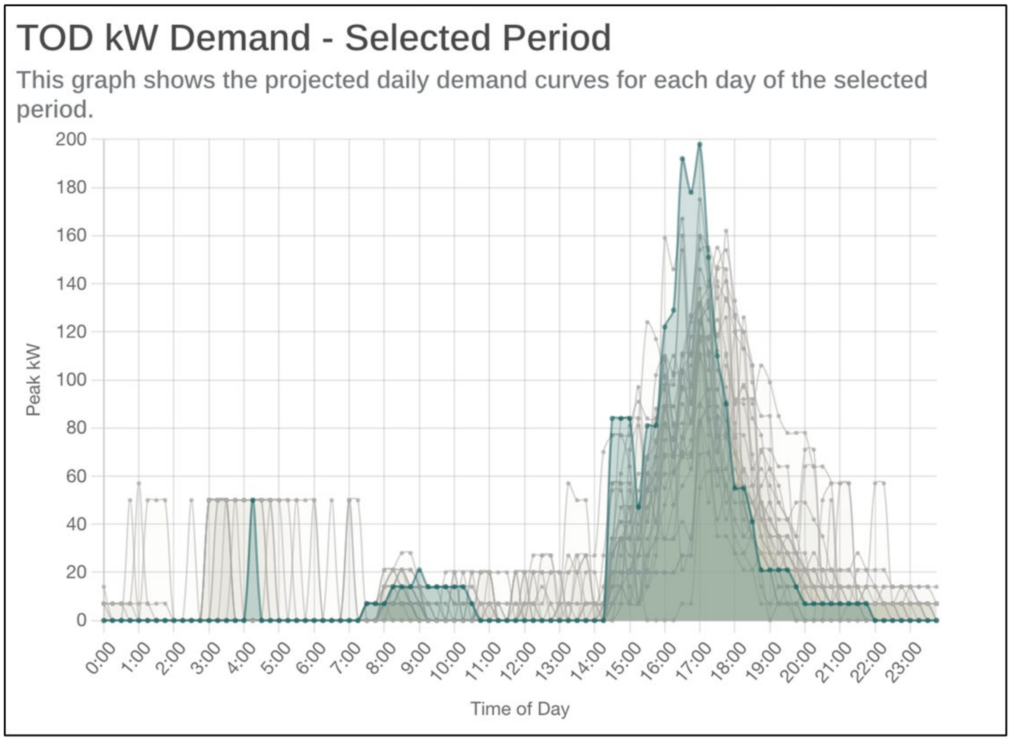

Figure I.28-3. Modeling of facility electrical draw that identifies scale and timing of peak draws as well as need for peak mitigation via smart charging equipment.

Figure I.28-3 shows facility draw modeling by identifying scale and timing of peak draws which ultimately identifies the need for peak mitigation via smart charging equipment. Furthermore, extending into the impact of electrifying medium and heavy-duty vehicles and looking at fleets in congregation, Sawatch Labs has developed an additional tool that not only looks at the suitability but the impact on facilities which addresses a significant part of this space. In general, fleet managers haven't had to think about peak demand, demand charges, and the difference between on peak and off-peak electricity rates which are all core components with a huge impact on the ROI of an electrifying fleet. Peak demands are not cheap and are extremely complicated so Sawatch built this tool to forecast facility draw modeling for medium and heavy-duty electric vehicles and see what the impact would be on facilities for a fleet that has electrified 10%, 20%, or 100% of their fleet and ultimately what that impact is on the grid. Sawatch has also worked and discussed with utilities about how they are addressing vehicle to grid impacts which ultimately contributes to the success of the electrification of these types of vehicles.

Clean Fuels Ohio is working with Sawatch Labs to add three vehicle applications to Sawatch ezEV telematics analysis platform (Class 8 Orange EV, Class 6 FreightLiner M2, and Class 4 Ford Transit Van). Sawatch Labs has created and continues to develop the beta version of their MD-HD EV data analysis to model EV telematics data from project OEM partners and other relevant OEMs.

The following vehicles have been added to the Sawatch Labs ezEV analytics platform as of Q3 2021:

- 2022 Sea-Electric Hino 195
- 2021 Peterbilt 220EV 200 Mile BEV
- 2021 Peterbilt 220EV 100 Mile BEV

- 2021 Ford Transit E350
- 2022 Volvo VNR BEV Tractor
- 2022 Freightliner eM2.

Conclusions

Clean Fuels Ohio and the project team are largely proceeding as planned with project set up and deliverables. 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. The global supply chain disruption has caused delays in receiving the vehicles and equipment. These impacts largely affect the project fleets that are deploying the vehicles. Otherwise, our other project partners are able to move forward, as they are essential services and experiencing continued business during the pandemic.

I.29 Electric Vehicle Widescale Analysis for Tomorrow's Transportation Solutions (Energetics, a Division of Akimeka, LLC)

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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, a Division of Akimeka, LLC, 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 Coalition, Kansas City Regional Clean Cities, Drive Clean Colorado, Empire Clean Cities, Columbia-Willamette Clean Cities, Palmetto Clean Fuels Coalition, 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. 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 PEVs and EVSE being used today?
    - Is PEV 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

Energetics is conducting ongoing EVSE and PEV data collection, management, and anonymization. The team has implemented quality control techniques on the data and added error flags to data that is suspicious. Non-PII datasets are provided to the National Laboratories quarterly via LiveWire, a DOE data platform that can restrict access to certain recipients (only the National Laboratories are permitted to access the preliminary quarterly datasets; public access will be allowed for the final fully anonymized dataset).

The EV WATTS Team continues to engage potential data partners to discuss project participation. At the end of September 2021, EV WATTS had secured data sharing agreements from 65 entities and consent for participation from 58 individuals. The initial estimated quantity of data from these data partners was approximately 26,000 EVSE and 1,100 PEVs. The actual quantity of data collected varies based on the active EVSE and PEVs; the actual number of PEVs is a little less because of pending telematics device installations while the actual number of EVSE ports is higher because entities continue to install or include more over time.

Energetics published an online interactive dashboard summarizing the EVSE data collected and continues to update the dashboard quarterly. Figures I.29-1 through I.29-6 are screenshots from the dashboard that showcase the content of the EVSE database at the end of September 2021 as well as the analysis and results that come from this large nationwide collection of real-world station operations.

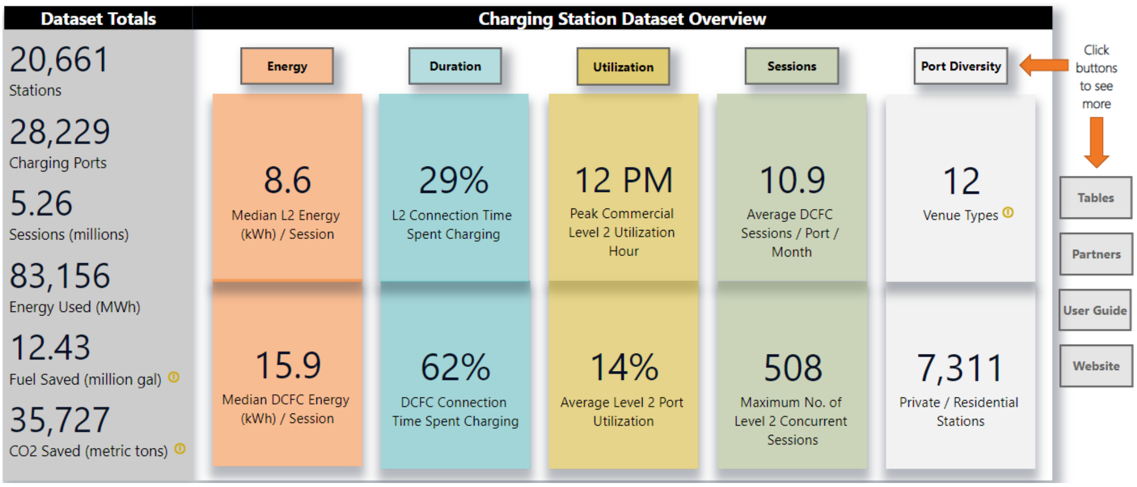

Figure I.29.1. EV WATTS EVSE Database Dashboard – Summary

Figure I.29.2. EV WATTS EVSE Database Dashboard – Port Diversity

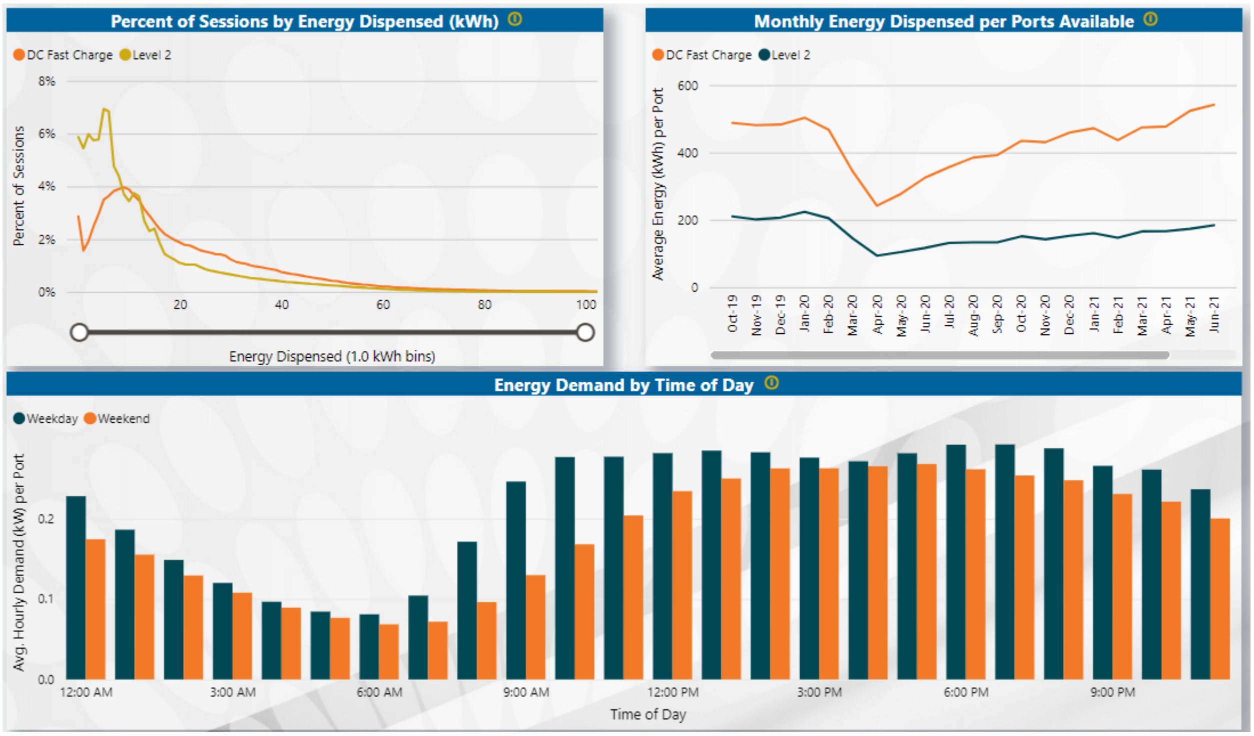

Figure I.29.3. EV WATTS EVSE Database Dashboard – Energy Analysis Results

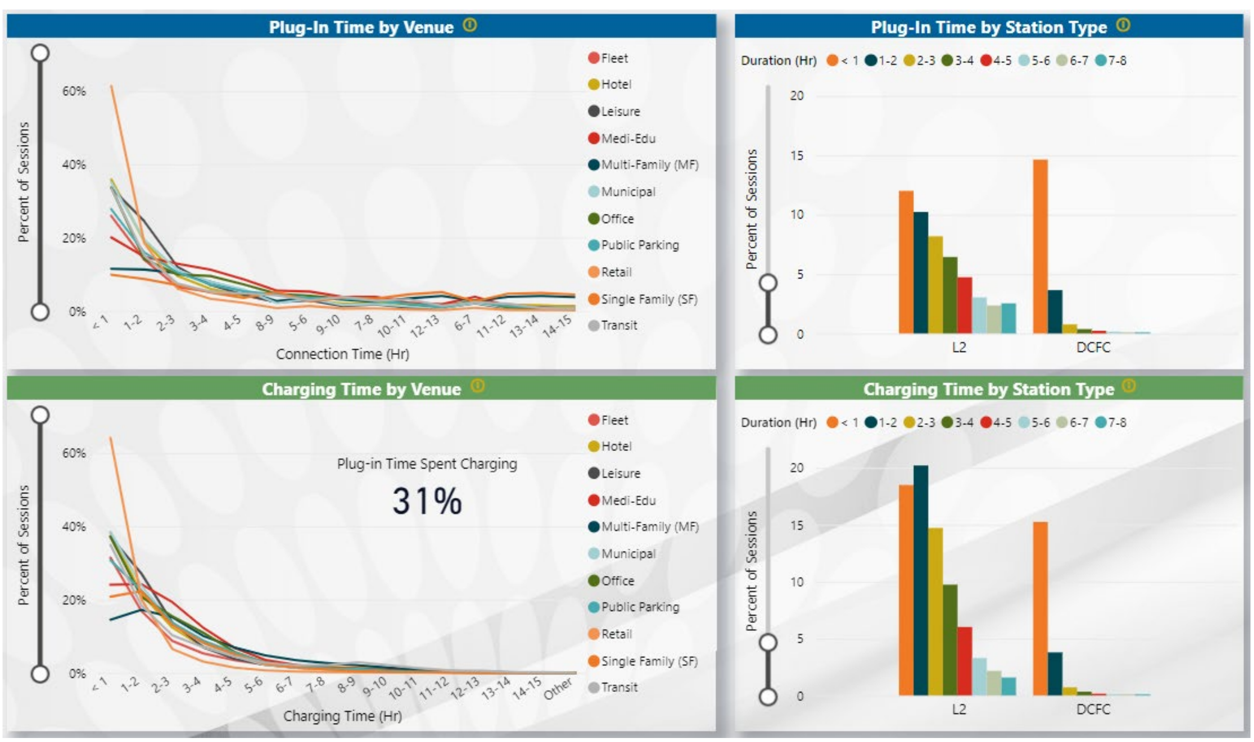

Figure I.29.4. EV WATTS EVSE Database Dashboard – Session Duration Analysis Results

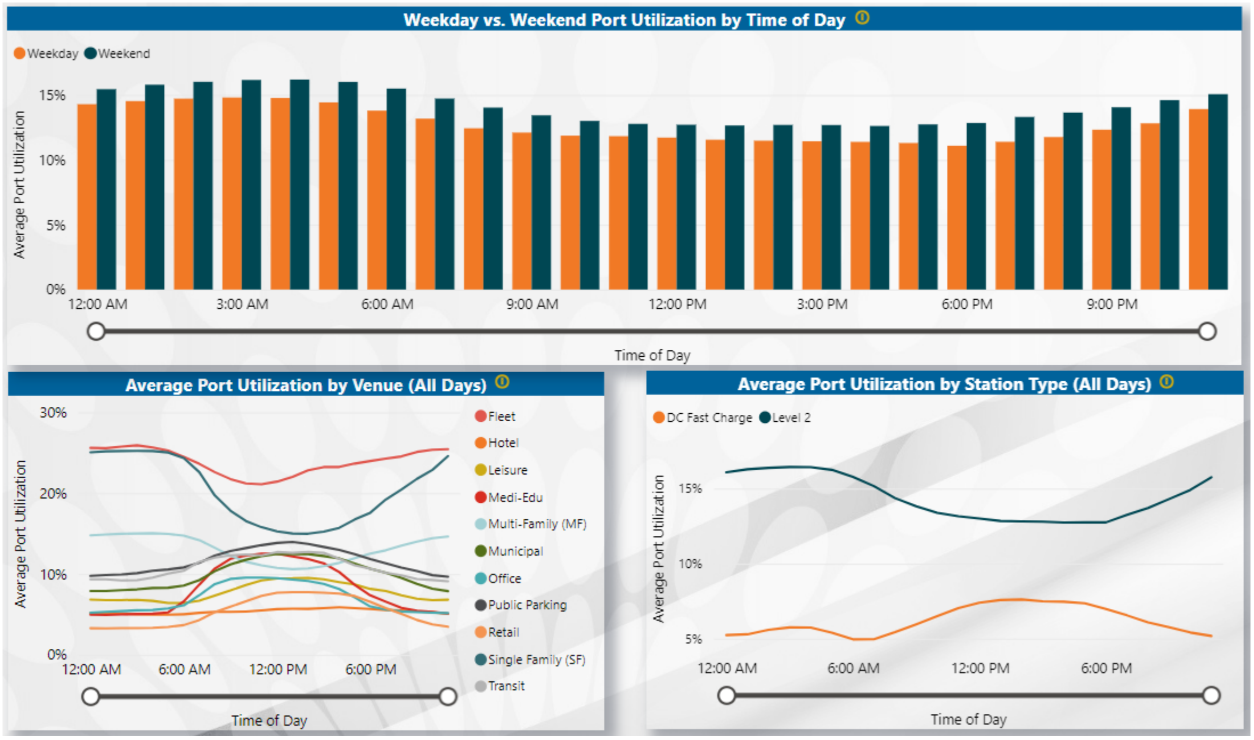

Figure I.29.5. EV WATTS EVSE Database Dashboard – Utilization Analysis Results

Figure I.29.6. EV WATTS EVSE Database Dashboard – Session Analysis Results

Conclusions

The collected data and subsequent analyses on that data have revealed valuable insights on how PEVs and EVSE are being used. The EVSE dataset, which is more complete, has shown the following interesting results. Further analyses by Energetics and the DOE National Laboratories continues to provide additional insights.

- The impact on public charging due to COVID-19 was significant and recovery continues to vary across different venues. Residential charging, which likely only decreased because fewer miles were being driven by PEVs and not because people weren't at these locations, has almost returned to pre-pandemic levels. Leisure destination charging locations are seeing more activity than pre-pandemic but charging at office locations is still much lower than it was.
- Chargers at single family homes, multi-family homes, and fleets show a distinct u-shaped daily curve because of less daytime charging, whereas most public locations have n-shaped daily curves.
- PEVs are remaining plugged into chargers more than three times longer on average than they are drawing power to charge their batteries.
- It is rare to have a station occupied more than 50% of the time (due to different driving patterns between day and night as well as week and weekends). Average utilization is 5-8% for fast chargers and 12-17% for Level 2 chargers.

Other project-level observations and challenges that may be lessons learned for other similar projects currently or in the future are also mentioned below.

- COVID-19 has impacted the team's ability to engage data partners. The data partners have not prioritized EV WATTS participation because of more pressing challenges and limited staff availability. The remote work environment has limited in-person conferences and meetings where we could have better connected with prospective data partners. Some organizations have also delayed plans to install charging stations or acquire PEVs due to budget constraints.
- Data confidentiality and protection are significant concerns from data sharing partners, as they want to ensure their information is not used maliciously, or in a way that could negatively impact them. There is also an increasing recognition that data has value, and many entities are looking for something in return for their participation (not necessarily financial compensation, although some are looking for that, but ideally something that helps them improve their operations. While our analyses and reports provide them some insights, we can't provide in-depth consultations to each participant).

Key Publications

Project materials and an interactive dashboard summarizing the charging station data are available on the project website: www.evwatts.com

I.30 Medium and Heavy-Duty Electric Vehicle Deployment – Data Collection (CALSTART)

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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.

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) 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, 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.30.1. 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		
VIN Number		

Charging Data

Where made available by the fleet, 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 any available 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 as available from sites selected for inclusion in this project. See Table I.30.1.

Maintenance Data

The maintenance data will include all electric vehicle-related maintenance information available from fleets, 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

The projects identified for data collection are grouped into the following three categories:

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

During this second year, the project team moved from Phase 1 into Phase 2 of the project. The data facet of the project focused on growing and finalizing vehicle commitments for the data pipeline, working with fleets to receive data from their vehicles, establishing a standard processing workflow for data, uploading datasets, and beginning the high-level analysis process on publicly available data. The project team cleaned and uploaded data from all thirty-seven (37) Category A vehicles, comprising eight Category A project fleets; thirty (30) Category B vehicles, comprising six Category B fleets with agreements; and twenty-one (21) Category C vehicles, comprising one Group C manufacturer partner with an agreement. The project team signed agreements with several identified Group B and new Category C projects, and uploaded several new Category B and C datasets. Tables I.30.2 through I.30.5 show, by vehicle group, the number of vehicles that are confirmed by signed data sharing agreements, and notes their data collection status. The first set of data from Category A projects was uploaded at the end of 2020, and encompasses a total of thirty-seven (37) vehicles. In support of the project's outreach component, the team has begun discussions with the Clean Cities Coalition partners to develop a structure and schedule for webinar events, with educational webinars anticipated to be deployed around Q1-Q2 2022.

Table I.30.2. Status of Vehicles within Category A

	Confirmed Vehicles			Pending Vehicles
	Vehicles with Agreements	Completed Vehicles	Active Vehicles	Not Started
HD	25	25	-	-
MD		-	-	-
LD	12	12	-	-
Off Road		-	-	-
Category A Total	37	37	-	-

Table I.30.3. Status of Vehicles within Category B

	Confirmed Vehicles			Pending Vehicles
	Vehicles with Agreements	Completed Vehicles	Active Vehicles	Not Started
HD	83	15	68	88
MD	54	10	44	3
Off Road	13	5	8	0
School	4	0	4	51
Category B Total	154	30	124	142

Table I.30.4. Status of Vehicles within Category C

	Confirmed Vehicles			Pending Vehicles
	Vehicles with Agreements	Completed Vehicles	Active Vehicles	Not Started
HD	6	0	6	5
MD	0	0	0	0
Off Road	35	21	14	2
School	58	0	58	0
Category C Total	99	21	78	7

Table I.30.5. Summary Counts of Vehicles within all Categories

	Confirmed Vehicles			Pending Vehicles
	Vehicles with Agreements	Completed Vehicles	Active Vehicles	Not Started
HD	114	40	74	88
MD	54	10	44	3
LD	12	12	0	0
Off Road	48	26	22	2
School	62	0	62	51
Total	290	88	202	144

Conclusions

This project seeks to collect, aggregate, clean, analyze, and publish data from medium- and heavy-duty vehicle deployments across the United States. As of writing, in its second year of implementation, the project has uploaded a total of eighty-eight (88) vehicle datasets across all MD and HD vehicle categories through the end of 2021.

Over the course of the project, we have encountered several implementation challenges. Fleet communications have proven to be more difficult than anticipated, particularly in the dynamic environment of the COVID-19 pandemic. Furthermore, fleets that are otherwise willing to share data have been slow to sign up due to requirements of needing executed data sharing agreements in order for a fleet to participate. The project team will often need to address concerns with data sharing flagged by a fleet's legal department, which makes recruitment, in some cases, a long and tedious process. This is a more prevalent issue when working with commercial fleets versus public fleets. This has caused delays in the data collection process, as our data sharing agreement sets provisions for the limitations of the data's use and the responsibilities of both the data supplier and CALSTART as the receiving organization and data custodian.

Datasets also exhibit a wide array of variations in quality and comprehensiveness due to the diverse nature of data sources – including different vehicle types, manufacturers, and data platforms. While the datasets uploaded to LiveWire aim to create a unified national dataset which follows a consistent framework, raw datasets often vary in their level of aggregation, frequency and consistency of metric reporting, metrics reported, data quality, and units reported. As a result, data processing usually requires an individualized approach for each fleet, leading to longer processing times.

We have also encountered issues with fleets requesting dataloggers, with delays occurring during a secondary contractual process which requires fleets to sign a telematics agreement in addition to a general data sharing agreement. Some fleets monitor their vehicles via proprietary dataloggers pre-installed by OEMs on vehicles, requiring the involvement of an additional party to authorize sharing data and adding another layer of complexity to the agreement with those fleets.

We continue to work toward developing agreements with projects and fleets around the United States, focusing on creating a diverse and representative national dataset of MD and HD BEV deployments.

Next steps for the project involve adding and uploading data from new fleets in order to expand the dataset's geographic diversify; building up data analysis efforts to generate reports on fleet metrics, vehicle types, and geographies; working with our Clean Cities Coalitions to develop and implement webinars; and further developing and finalizing our data dashboard design.

Key Publications

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 National 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.31 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, 2023
Project Funding: $1,668,349 DOE share: $670,000 Non-DOE share: $998,349

Project Introduction

Figure I.31-1. Mid-Atlantic Electric School Bus Experience Project Logo. Logo courtesy of the Mid-Atlantic Electric School Bus Experience Project.

The Mid-Atlantic Electric School Bus Experience Project (MEEP) is working with school bus manufacturers, Clean Cities coalitions and other partners to provide electric school buses for free short-term and 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. See Figure I.31-1.

These demonstrations and deployments 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 (VA DEQ), Maryland Department of the Environment (MDE), New Jersey Department of Environmental Protection (NJDEP), and regional electric utilities (Dominion Energy, BGE, PEPCO and Exelon).

Objectives

The objective of MEEP 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.

MEEP provides a user level introduction to electric school bus technology in the region; provides a wide range of stakeholders with needed information about electric school buses; allows school districts to gain experience with electric school buses from multiple manufacturers for an extended period of time; evaluates vehicle performance (including comparison to baseline conventional fuel buses); troubleshoots issues that arise; and provides 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, at the start of this project, had 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 short-term and 6 to 8-week demonstrations in the multi-state project region.

In the first year of the project, 2020, the project team conducted kickoff activities and came together to prepare for and initiate the experience placements. This included 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.

With an approved no-cost extension for the first project period, the first budget year of the project was extended into 2021. In this second year of the project, the project team identified participating school districts, recorded and published training, held outreach events, and coordinated short-term demonstrations. During this period, the project team placed significant emphasis on virtual events and trainings and supported the 105 vehicles deployed by project partners in during 2021. Throughout this project, the project team has been addressing major hurdles of design, specification, infrastructure, education, and operations.

The MEEP project team has been supporting 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 are also eligible to receive a free Level 2 charging station for charging the bus during the demonstration project, and for use by the school after the project. This project is presenting “on the ground” use studies and success stories for local, state, and national deployment of electric school bus technologies. This is critical to providing confidence for future decision-making that fully considers the cleaner electric school bus option.

It is still early in the project, with two thirds of the project remaining. These efforts will continue into the next phase of the project and include long-term demonstrations 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.

Results

The MEEP project is underway, and experiencing some market specific challenges related to the ongoing logistics issues, and the state of electric school bus manufacturing and deployment. Demonstration challenges such as bus driver shortages and gathering limitations related to the COVID-19 pandemic curbed school districts' ability to accept demonstrations; however, many districts have expressed interest in accepting demonstrations once they have regained the capacity to properly support and utilize them.

Limited availability of demonstration vehicles has also impacted the project's ability to complete long-term demonstrations. Many manufacturers only have a few demonstration buses, most often built according to California or New York specifications, that are shared by their dealers and shipped or driven around the country for demonstrations. With recent funding opportunities, the few demonstration buses that are on the road have been in high demand and short supply. Additionally, these funding opportunities have resulted in an influx of electric school bus orders to Original Equipment Manufacturers (OEMs), creating a backlog. Since OEMs make their money by selling vehicles, they have given customer orders for bus purchases priority over the production of new demonstration vehicles.

Manufacturing and deployment delays have also been exacerbated by the supply chain difficulties that have arisen since the start of the COVID-19 pandemic. Other barriers to completing long-term demonstrations include state requirements that demonstration buses must meet the specifications for the particular state and must be insured by the school district, if the vehicle is to be operated for more than a test drive. Due to these limitations, the project has focused on supporting short-term demonstrations with available dealer and OEM buses as the project awaits the availably of buses for the originally planned 6 to 8-week demonstrations.

Some of the challenges the project has been facing have arisen from positive developments in electric school bus adoption. Since the MEEP initiation, partners including the VA DEQ, MDE, and Dominion Energy have initiated other electric school bus programs and deployments throughout the region. This has been a real positive for MEEP (given there were no electric school buses operating in the region when the project began) and opens up additional opportunities for participation, exposure, and data collection. Clean Cities Coordinators and VEIC team members have conducted outreach to schools and have received several requests and applications from each state/region to participate. Of these partner programs this year, the project in collaboration with MDE deployed an electric school bus in Frederick County, MD, which will serve as cost-share for MEEP. As we await news regarding the availability of buses for long-term demonstrations, the project team has continued to engage school districts with virtual educational events and shorter-term demonstrations.

In Virginia, awardees of the first round of the VA DEQ Clean School Bus Program were announced in August 2021. Awardees in Culpeper, Fairfax, and Loudon, Virginia had all been participants in demonstrations through MEEP prior to applying for the VA DEQ program, suggesting that these demonstrations had a positive impact on the districts' purchasing decisions. Fairfax now has the largest electric school bus fleet in the state with 18 buses. Procurements for the first round of VA DEQ Clean School Bus Program are underway. The second round of funding has been announced for the fall. Three buses from the VA DEQ Clean School Bus Program deployment were set to be committed as cost-share at the beginning of this project, but since deployments were delayed, this portion of the cost share was also delayed.

As of September 2021, the 50 buses from Dominion Energy Electric School Bus deployments have been delivered. Dominion Energy also pledged additional infrastructural support for the recipients of both rounds of the VA DEQ Clean School Bus Program that are in Dominion's service territory. Appalachian Power has also awarded funds for 9 electric school buses and their charging infrastructure in southwest and central Virginia, with enough funding for one more school bus as we approach the end of 2021. The first of these buses was scheduled to be delivered to Washington County in November 2021. Washington County was one of the school districts that attended a MEEP demonstration event during the spring of 2021.

A major deployment in the project area that has been making headlines since it was announced in early 2021 is the Montgomery County, Maryland electric school bus deployment, in conjunction with Highland Electric and Thomas Built buses. This project is taking place in collaboration with project partner, MDE. This contract is the largest single procurement of electric school buses in North America, starting with 326 buses over the next 5 years. The first bus is scheduled for delivery in December, 2021. Twenty-four additional buses will be deployed in early 2022, with 61 following in fall of 2022. Approximately 120 buses will be delivered each of the following years until all 326 have been deployed. While commitments like this have shifted the gaze of manufacturers to deployments rather than demonstrations, it has done wonders for electric school bus outreach and education. Deployments like that happening in Montgomery County, Maryland show that electric school buses at scale is a viable option about which the public is excited. See Figure I.31-2.

Figure I.31-2. Electric school bus chargers in the ground at the Bethesda, MD school bus depot where the first of the Montgomery County electric school buses will be deployed. Photo courtesy of Highland Electric.

Activities this period

- Project bi-weekly calls are underway.
- Published 14 blog posts.
- Recorded and currently editing driver training videos.
- Updated project recruitment fliers and project request for proposals to reflect the shift to short-term demonstrations.
- Conducted an inventory of interest in school districts in the region.
- Engaged school bus and additional manufacturers (Blue Bird, IC, Thomas, Micro Bird, and Motiv).
- Engaged a financing company (Highland Electric Fleets.)
- Held 21 short-term demonstrations across the project region.
- Hosted 6 virtual events and workshops.
- Project members have been invited to speak about the project at 7 conferences and events.
- Deployed project electric school bus in Frederick County, MD.

Conclusions

After the delays the project experienced in 2020, 2021 has presented multiple opportunities to bring short-term electric school bus demonstrations to school districts in the project area. While many manufacturers and dealers have shifted their priorities to support electric school bus deployments, this has not meant that demonstrations have been halted. Rather, the project team has shifted to support short-term demonstrations when demo buses are available, and has further focused on supporting deployed buses in the project region.

As MEEP progresses, the project team will continue to work with manufacturers and dealers to secure buses for long-term demonstrations. The MEEP project team will also work with school districts with existing electric school buses as sources of operational data and potential short-term demonstrations.

Key Publications

Electric School Bus Projects – Planning for Charging Stations at Your Facilities
Electric School Bus Projects – Charging Stations
Electric School Bus Projects – Buses and Routes
Short-Term Placement Application
Project Flier for Short-Term Demonstrations
Electric School Bus and Infrastructure Guidebook (in collaboration with the Kentucky Clean Fuels Coalition)

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. We would also like to acknowledge all of the manufacturers, dealers, and school districts that have shown interest in this project and have done work to support these demonstrations.

I.32 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.32-1.
- Support electric vehicle (EV) access into high visitation areas throughout rural America.
- Offer regional transportation solutions to gateway communities through public/private partnerships.

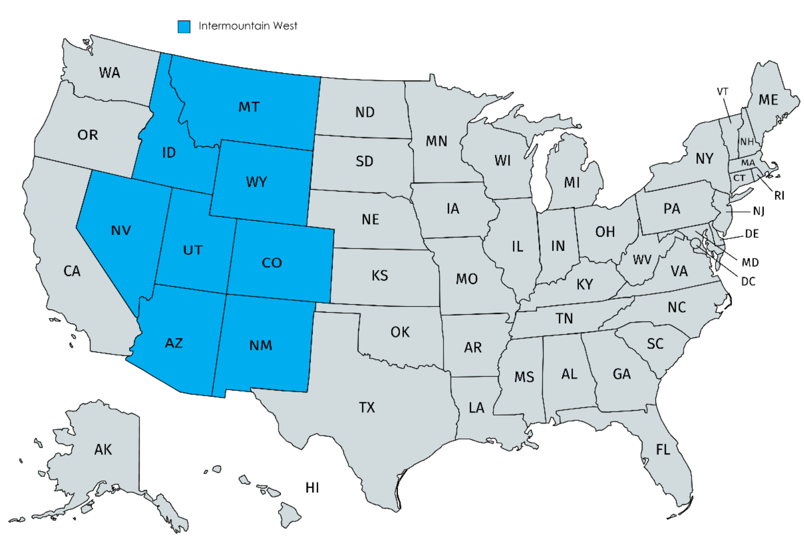

Figure I.32-1. Intermountain West

Objectives

The goal 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.

Conduct Needs Assessment, Aggregate Tools, and Develop Strategy

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, recreation 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.

Deploy Infrastructure, Develop Public and Private Partnerships, and Expand Corridors

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 markets; 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 2, the project team continued with monthly and quarterly meetings with the assigned CORWest Advisory Committee, as shown in Table I.32.1, and engaged them through virtual meetings/calls, and 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 second year, as outlined below.

Table I.32.1. 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
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

During the first budget period, the project team accomplished the first part of the Needs Assessment, dissemination of the questionnaire of EV 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 gateway communities – 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 including gathering data from state departments of motor vehicles.

Final version of the Electric Vehicle Charging Needs Assessment Report can be found here

Demand Charge Assessment

UCC and NASEO worked with external stakeholders to review and refine the forthcoming report on demand charges. In April, NASEO reached out to four external organizations to provide a review of the report, to ensure our assumptions and methodology checked out: the Electric Edison Institute, the Regulatory Assistance Project, MJ Bradley and Associates, and the National Association of Regulatory Utility Commissioners. Additionally, NASEO reached out to each electric service provider included as a case study within the report. NV Energy and Tucson Electric Power provided comments that were then incorporated into our report.

After incorporating comments from external reviewers, NASEO examined and reconfirmed the public information pertaining to the rates in the report to ensure data was current. The report was forwarded to DOE for final review and approval. The Demand Charge Assessment was scheduled to be completed in October of 2021.

NASEO provided the final draft to UCC. All the CORWest Advisory Committee members, WIBE, and NASEO reviewed this completed report. This report has been published on the Utah Clean Cities website, NASEO's website, and shared with stakeholders. The purpose of this report is to "review the research methodology and key findings from the questionnaire, EV registration data collection, and mapping exercise; provide a summary of trends and typical issues being faced in the region; and offer recommendations for ways the CORWest project partners – state agencies and Clean Cities Coalitions – may address high-priority needs and support EV deployment and DCFC investment in the region" (Demand Charge Assessment Report).

Webinars/Education

As outlined in the project plan, the CORWest partners worked to facilitate two CORWest webinars in the second year:

- FreeWire Webinar with Denver Metro: UCC, in partnership with Drive Clean Colorado, held an interactive discussion on July 14, 2021, with leaders from Utah, Nevada, and Colorado to learn more about infrastructure development along key corridors in our region, with special guests from Freewire to talk about their mobile charging products.

- Demand Charge Assessment Review Webinar: UCC, in partnership with NASEO, plans to host an overview webinar to review and share highlighted details of the Demand Charge Assessment findings, with NASEO leading a webinar to report preliminary findings.

Branding

UCC and NASEO launched the CORWest Signage and Branding Working group to identify needs, challenges, and opportunities for placing EV signage along major roadways and corridors in the Intermountain West and will explore options for developing and using an Intermountain West EV corridor "brand." The working group is composed of CORWest Advisory Committee members (REV West state agencies and Clean Cities Coalitions). The working group met first in March 2021 and decided through a brainstorm session to move forward with brand development, with the support of a professional consulting firm, to be determined next quarter.

During the CORWest branding workshops, held in partnership with NASEO and branding support, Kristy Grayson with Dixie State University, the project team held four successful workshops that resulted in an understanding and direction of branding needs for the CORWest program. Each branding workshop brought together CORWest state teams and leads from interested Office of Tourisms within the selected states.

The project team also (softly) launched the CORWest website during the second half of 2021, with a full public launch scheduled for 2022. UCC is currently working on final touches with each of the CORWest partners to update individual state content details and setting planning efforts for website content upkeep.

Additional

UCC was given the opportunity to share our work here and regionally due to interest generated by DOE's Vehicle Technologies Office (VTO), and USDOT's policy director, Rob Hymen, requested a meeting with UCC. USDOT chose the CORWest team over more than a dozen projects across the nation for this discussion. This project has grown in breadth and depth since inception and the interest was very positive from the USDOT. The USDOT asked for a second meeting where we reviewed several of our projects, our work in general with the Clean Cities program and highlighted the work at NREL and the AFDC; the AFDC presented on some of the key tools for the USDOT. Currently we are slated to meet again and possibly host an onsite, Utah-based field trip.

UCC also participated in two major roadmaps that included EV-centric commitments:

- Western Governors Association: Electric Vehicle Roadmap Initiative
    - UCC was a major contributor to the Utah EV Roadmap and supported those efforts as a subrecipient on another DOE VTO contract, Drive Electric USA, as the prime contractor on CORWest. UCC has steadily delved into the world of hydrogen and renewables and continues to participate in several forums both locally and with Argonne Laboratory. UCC has met with several key stakeholders with the emerging transportation systems in southwestern Utah and has been involved with a major branding effort for the southwestern part of the state.
- ONE UTAH Roadmap
    - Utah DOT has relied consistently on UCC's current and past work on electrification efforts. UCC has helped lay the foundation and proposed projects for the entire state in the ONE UTAH Roadmap. It has been officially released to the public, and will be assessed, reviewed, and refreshed as needed in 250 days, and reconstituted at the end of 500 days (mid-May 2022). The One Utah Roadmap will also share accomplishments of the current Utah Governor's administration.
    - UCC continues to collaborate on a high level with the Utah DOT to complete this legislatively mandated EV Roadmap to increase EVSE throughout the state. There is a specific focus on rural and gateway communities, as much of Utah's landscape is rural and will need to be built out with EVSE to complete Federal Highway Administration Alternative Fuel Corridors. The Utah Department of Environmental Quality has placed EVSE throughout the state with VW settlement monies and will continue to administer the final funding monies through its Workplace Electric Vehicle Charging Funding Assistance Program.

Conclusions

During the second year of the CORWest project, the project partners successfully developed the core branding image and goals for CORWest, (soft) launched the CORWest website, and published two assessments, as required in the project plan. UCC finalized the Needs Assessment and Demand Charge Assessment and hosted two webinars. Year 3 project goals include continued engagement with stakeholders, finalizing the ultimate toolkit, and hosting various awareness events related to CORWest and EV Corridors.

Acknowledgements

The team would like to recognize the efforts of Daniel Nardozzi, the project's National Energy Technology Laboratory manager.

I.33 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)] and by major parking providers (universities, airports, hotels, corporate campuses). 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, also known as electric vehicle supply equipment (EVSE), including Level 2 and DC Fast Chargers (DCFC), for use by any licensed drivers.

In the second year of the project, project partners continued the planning for and deployment of EVs and EVSE at three locations; maintained and refined a mobile EV reservation platform; began marketing EV mobility hubs to relevant user audiences; and began drafting the Replication Playbook draft.

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. 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 continued to work with Columbus Yellow Cab to deploy EVs and utilize EVSE at the three project locations:

- Southside Mobility Hub: Leveraging funding and incentives available through the utility (AEP) and the Smart Columbus program, Yellow Cab has fully installed Level II charging and two (2) DCFC charging stations at their Camaro Drive location. This location is fully operational and currently providing the main charging facility for the 20 Tesla Model 3 vehicles operational in Yellow Cab's fleet. This location is currently operational for existing Yellow Cab drivers; the public facing access will be launched in late 2021 and early 2022.

- Short North Mobility Hub: Since paperwork/agreements with the City of Columbus were finalized last quarter, Columbus Yellow Cab has been receiving assistance from the city with programmatic and strategic elements of the launch. However, the supplier of EVSE equipment for the Short North mobility hub made the project team aware that extensive supply chain delays are resulting in disruptions for the equipment needed, with a 20 to 30-week delayed delivery lead-time (the worst-case scenario). Clean Fuels Ohio has still progressed with key tasks to date in Budget Period 2, including completing designs for the mobility hubs, selecting EVSE equipment/vendors, engaging utilities to provide power live at sites, and obtaining necessary agreements and permits.

- Eastside Mobility Hub: Columbus Yellow Cab officially finalized its purchase of a lot in the Milo Grogan/Linden community of Columbus (specifically at the intersection of Essex and Cleveland Avenue) during Q2 of the budget period. The installation will be delayed, however, due to necessary changes to rezone the lot from residential to commercial, and following brownfield construction requirements. The Eastside Mobility Hub is still in active plans to move forward but, at the moment, not in a high state of readiness to be completed and deployed by the end of Budget Period 2.

As an alternative to deploying additional mobility hub(s) to meet the project's deliverables, Columbus Yellow Cab has been engaging with the Columbus Metropolitan Library System to offer and construct mobility hubs at three specific library branches (Linden, Hilltop, and Parsons). These library branches offer built-in electrical infrastructure via the library buildings, amenities for visitors and drivers, good lighting, and a safe place for community members. These three library branches are located in underserved and disadvantaged neighborhoods that have been historically redlined. The selection of these three locations would place EVSE ports where there are currently none available. Clean Fuels Ohio and the project team are moving forward with these three library branch mobility hub deployments.

The agreement between Columbus Yellow Cab and the Columbus Metropolitan Library system will ensure that the same number of parking spots is available for the EVSE ports as in the original plans. HTNB has developed initial site schematics for potential charging locations at these three library branches.

Clean Fuels Ohio has continued to work with Columbus Yellow Cab on the launch of the EV reservation platform to the public. Columbus Yellow Cab already owns an existing app-based vehicle reservation platform that is live for its 300 + taxi drivers and allows them to reserve and use vehicles. Once the mobility hubs have been deployed, the mobile reservation platform will allow for reserving/using EVs at the mobility hub locations, as well. Its launch will showcase a unified, neutral app-based vehicle reservation platform for multiple shared vehicles use cases. Columbus Yellow Cab continued to work with charging station and network provider, Greenlots, to configure plans for integrating the Greenlots platform with the existing Columbus Yellow Cab reservation app. See Figure I.33-1.

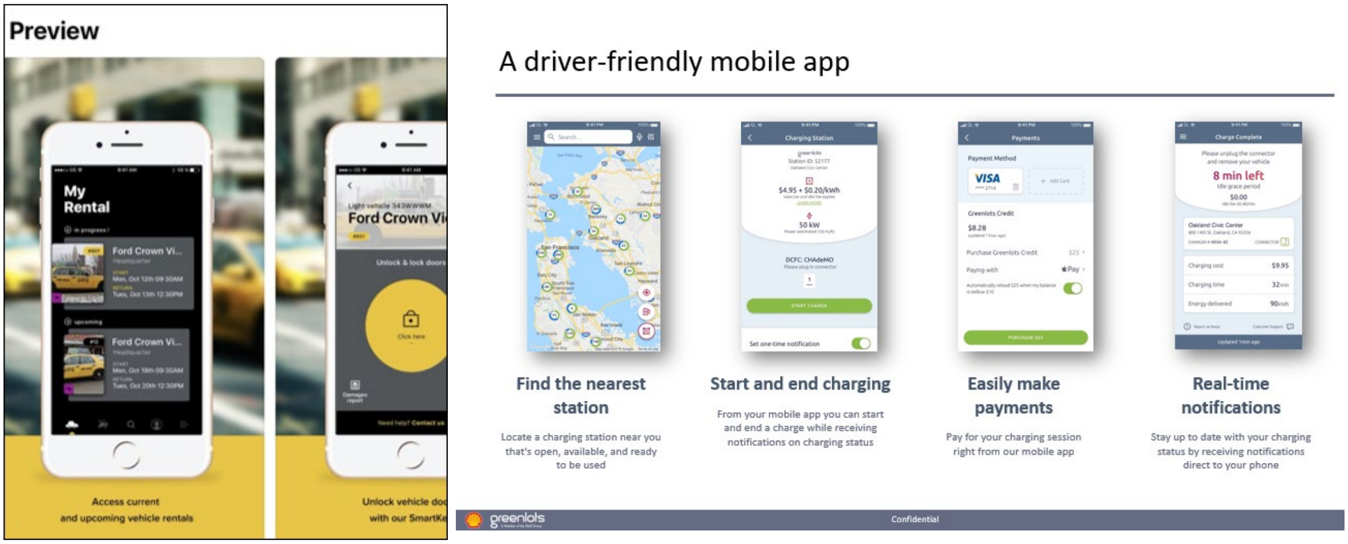

Figure I.33-1. Driver-friendly mobile app

This will allow any user to have access to Columbus Yellow Cab's decentralized network of EVs for any use case, including taxi drivers, TNC drivers (Uber, Lyft, etc.), drivers working for on-demand delivery services (Amazon, etc.), and drivers utilizing Columbus Yellow Cab EVs in a car-sharing service capacity for personal or domestic purposes. This will eliminate barriers for users and maximize EV usage and return on investment. Clean Fuels Ohio and Columbus Yellow Cab will address maintaining and refining of the mobile EV reservation platform once it is launched and receives feedback from users.

Clean Fuels Ohio continued to work and engage with Columbus Yellow Cab on developing and executing a Marketing and Community Engagement Plan for the EV mobility hubs, to educate Columbus region residents about EV mobility hub availability, access, and utilization. The project team will work through multifaceted communications channels, PAC members, and various community associations to educate relevant users and residents about the availability of EV mobility hubs, as well as how to register, reserve, and operate EVs and EVSE. See the EV Mobility Hubs Marketing and Community Engagement Plan listed under the Publications section below to see more details of the plan.

Clean Fuels Ohio is monitoring and tracking all data and resources from project partners that will be integrated in the project Replication Playbook. Clean Fuels Ohio received a write-up/summary from project partner, Mobikit, that outlines how the geospatial planning tool can be used to plan for mobility hubs in other regions/cities. It includes lessons learned, best practices, reflections on what could have been done better and built upon, and challenges/opportunities. Clean Fuels Ohio will seek Replication Playbook write-ups from partners Columbus Yellow Cab and HNTB during the remainder of 2021. Clean Fuels Ohio plans to finalize the Replication Playbook and resources by the end of 2021.

Conclusions

Mobility hub deployment challenges, including COVID-19-related supply chain disruptions and staffing shortages, have delayed the project. The milestone to finalize the deployment of the Short North mobility hub has yet to be completed as a result of the EVSE hardware delivery delay. Because of these delays, Clean Fuels Ohio requested a no-cost time extension in September 2021 to extend project year 2 by six (6) months. Challenges around rezoning for the final Eastside Mobility Hub location have resulted in the proposal of a new series of sites to complete project deliverables.

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 2 timelines and milestones.

Key Publications

Columbus Yellow Cab EV Mobility Hubs Marketing & Community Engagement Plan

I.34 Integrated Fuel Cell Electric Powertrain Demonstration (Cummins Inc.)

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Start Date: October 1, 2020 End Date: December 31, 2023
Project Funding: $7,208,624 DOE share: $3,443,063 Non-DOE share: $3,765,561

Project Introduction

Heavy-duty fuel cell electric vehicles are not new to the truck and bus market. Fuel cell and hydrogen technologies have not gained widespread market adoption, however, and have even been supplanted by battery electric technology in some heavy-duty vehicle markets. While the cost of batteries, the most expensive component in battery electric vehicles, continues to go down thanks to increasing order size and growth in passenger electric vehicle sales, fuel cell electric vehicles have not experienced the same growth, and as a result the same fall in prices, over the last 10 years. Heavy-duty fuel cell electric vehicles still face technological and market challenges that need to be overcome to advance the adoption and commercialization of hydrogen technologies. In particular, the integration and packaging of the different components of a fuel cell electric powertrain is complex and remains costly. In addition, hydrogen fuel prices and the cost of fuel cell stacks and hydrogen fuel storage solutions remain high, and there is a need to increase hydrogen storage energy density. Cummins proposes to design, build, test, and demonstrate a fuel cell electric powertrain for heavy-duty trucks and buses that can help to reduce costs and advance the commercialization of hydrogen vehicles. In addition to meeting the goal of the solicitation's area of interest, the proposed fuel cell powertrain technology offers the following benefits: 1) Vertically-integrated powertrain, 2) Modular and scalable, 3) Highly integrated and manufacturable, 4) Increased driving range, 5) Increased fuel economy, 6) Rapid refueling, 7) One to one replacement of conventional vehicles, and 8) Reduced Total Cost of Ownership.

Objectives

The objective of the project is to develop and demonstrate a modular and scalable integrated fuel cell electric powertrain for use in heavy-duty trucks and buses capable of the metrics shown in Table I.34.1.

Table I.34.1. Project Target Metrics

Parameter	Measure
Range (Component Level)	≥ 300 miles
Fuel Economy (Component Level)	≥8 miles per kg H_2 (truck) / ≥10 miles per kg H_2 (bus)
Fueling Time	≤10 minutes
Vehicle Availability	≥90%
Component Commonality	≥75% between bus and truck version of powertrain
Vehicle Upfront Cost	$800,000 (bus) / $600,000 (truck) for 1,000 annual sales
Maintenance Cost	$0.40 per mile
Fuel Cost	$5 - $6 per kg H_2 at high volumes

Approach

Cummins Inc. is the project lead and will provide overall project management, task coordination, and administrative functions for the project. Cummins will also manage all the technical tasks, working with GILLIG and Navistar to design the integrated fuel cell electric powertrain; building, commissioning and testing the prototype fuel cell vehicles; providing service and support during the field demonstration at SARTA and Werner Enterprises; assisting CALSTART with the data collection and analysis; developing the product development and manufacturing plan; and working with CALSTART, Clean Fuels Ohio and Long Beach Clean Cities on project outreach and the technology commercialization pathway. SoCalGas and South Coast Air Quality Management District will provide cost share to the project, participate in regular project meetings and reviews, and provide feedback to the Project Team on policies and legislation driving the hydrogen economy and the commercialization of fuel cell and hydrogen technologies.

Results

This project has experienced several administrative delays that have prevented the completion of any technical tasks. Most notably, a large contingent of Cummins' engineers were unable to work on the project until July 2021 due to pending foreign national access requests. In addition, Cummins has experienced delays in contracting with Navistar and GILLIG. Lastly, Cummins' fuel cell technology has significantly evolved compared to the technology originally proposed in early 2020 and this has opened the opportunity to revise the project schedule to bring in this new and improved technology into this project.

Conclusions

Although delayed, Cummins remains committed to the success of this project and is working with DOE staff to amend the contract in order to accommodate its latest fuel cell technology.

I.35 Field Demonstration of a Near-Zero, Tier 5 Compliant, Natural Gas Hybrid Line-Haul Locomotive (Gas Technology Institute)

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Start Date: October 1, 2020 End Date: December 31, 2023
Project Funding: $5,199,733 DOE share: $2,599,733 Non-DOE share: $2,600,000

Project Introduction

DOE has an objective to increase utilization of alternative fuels in the railroad industry, but it is greatly hampered by a lack of engine technology development from traditional locomotive manufacturers who have historically emphasized incremental change. Prior attempts to demonstrate alternative fuels in rail service from the original equipment manufacturers failed to gain industry acceptance because they achieved only Environmental Protection Agency (EPA) Tier 3 emissions and had relatively low natural gas substitution rates that did not substantially reduce operating expenses. In this project Gas Technology Institute (GTI), in collaboration with OptiFuel Systems, LLC and other partners, will conduct a field demonstration of a 4,300 hp, Tier 5-compliant, Hybrid Line-Haul Locomotive that can operate on compressed or renewable natural gas (CNG/RNG) with near-zero emissions.

Table I.35.1 shows a comparison of current locomotive emissions standards and the goals of this project. Of the 39,000 total locomotives operating for Class I, II, and III railroads in the U.S., only 3,000 meet Tier 3 emissions standards and less than 1,000 meet Tier 4. Class I railroads don't support a proposed Tier 5 emission rail standard because there is no reliable locomotive propulsion system that reduces both emissions and operating expenses. This program will integrate a suite of commercially available engine products to create a viable, safe, and reliable CNG hybrid system to power 4,300 hp locomotives with near-zero emissions, exceeding Tier 5 requirements while also reducing fuel costs and having a nominal maintenance impact.

Table I.35.1. Locomotive Emissions Requirements and Project Targets

Locomotive Equipment	Fuel Type	NOx (g/bhp-hr)	PM (g/bhp-hr)
US Class I Line-Haul Fleet	100% Diesel	8.5	0.21
Tier 4 Standard	100% Diesel	1.30	0.03
CARB Proposed Tier 5	TBD	0.20	<0.01
OptiFuel (83% RNG), Near-Zero, 4,300 hp	CNG/Diesel Hybrid	0.05	<0.01

Currently, railroads are operating inefficient legacy diesel locomotives with emissions substantially higher than proposed Tier 5 requirements, that are costly to maintain. Reducing criteria pollutants is of critical importance because railyards tend to be in areas where underserved populations have some of the poorest air quality. GTI has a multi-engine approach that will increase fuel efficiency by 20% and, with the use of RNG, will reduce GHG emissions by 40%. The utilization of proven, commercially available equipment (i.e., engines, CNG storage, CNG refueling) and usage of domestic CNG and RNG has both emissions and cost advantages for the railroad industry.

Objectives

The project will develop and demonstrate a near-zero, Tier 5 compliant, 4,300 horsepower natural gas hybrid line-haul locomotive with 1,800 DGE (Diesel Gallon Equivalent) of on-board fuel storage. The locomotive will use multiple Cummins Westport ISX12N engines, developed previously, to meet the applicable Federal Railroad Administration (FRA), Department of Transportation (DOT), and EPA requirements, providing an affordable and viable pathway to near-term commercialization.

The objectives of this program are to:

- Demonstrate that commercially available and reliable components can be used to manufacture affordable Tier 5 and near-zero emissions line-haul-locomotives.
- Demonstrate the use of the new, on-road, 100% natural gas, near-zero Cummins Westport ISX12N engine in rail application.
- Demonstrate that multi-engine natural gas hybrid locomotives, including the utilization of regenerative braking, can increase overall system energy efficiency and reduce fuel consumption by 20% to 40%.
- Prove Class I, II, and III railroads can reduce their fuel cost, reduce criteria pollutants, and dramatically lower GHG emissions compared to diesel by using CNG and RNG.
- Collect data to validate durability and reliability while in rail freight service.

There are two concurrent challenges this program will overcome: 1) achieving near-zero emissions operation and 2) proving multi-engine line-haul service feasibility. Reliable technology must be demonstrated for regulators and railroads to mutually agree upon a viable pathway that meets their competing goals. Data gathered during the demonstration will be freely shared with public and private stakeholders to enhance the dialogue regarding the composition of the 39,000 freight locomotives currently operating in the US.

Approach

Since 1992, DOE's Vehicle Technologies Office has supported the development of multiple generations of Cummins Westport, Inc.'s natural gas engines for heavy-duty vehicles, resulting in a family of near-zero emission natural gas engines (B6.7N, L9N, ISX12N) in production for on-road use. These engines are proven, affordable, reliable, and have NOx emissions of 0.02 g/bhp-h and particulate matter (PM) of 0.01 g/bhp-h for on-road applications (i.e., in transient mode). This is 90% lower NOx emissions than the current EPA standard. In addition, in the steady state mode as a generator, the engines have EPA-certified NOx and PM emissions of 0.00g/bhp-h. In that mode, "zero emission" NOx and PM operation is possible for the rail, marine, and power generation markets. In October 2019, OptiFuel, with the support of Cummins Inc., secured EPA Rail Certification for the ISX12N as the first ever internal combustion engine to achieve 0.00g/bhp-hr NOx and PM certification. This is the engine that will be used as the basis for the locomotive powertrain.

In Budget Period 1, the project will begin by creating detailed system specifications for the locomotive. These specifications will be driven by applicable rules and standards from several governing bodies and validated by our TAG (Technical Advisory Group) consisting of personnel from Class I, II, and III railroads. They will also drive quantitative metrics to be used during systems validation and operational testing. Once the specifications have been completed and validated, engineering will begin on the locomotive design. Ordering of long-lead items will begin, as will planning and preparation for testing.

In Budget Period 2, OptiFuel will procure the base locomotive platform and continue procurement of other components (engines, generators, gas storage tanks, controls, etc.). The locomotive manufacturing will begin at Motive Power Resources in Minooka, IL. During this time, the team will use feedback from manufacturing to update the designs and identify process improvements to be incorporated into the final report.

In Budget Period 3, the project team will commence system validation and application testing. This will begin with testing the locomotive systems per the requirements developed in Budget Period 1 by team engineering and the TAG. Following that, the locomotive will be moved to the Association of American Railroads' (AAR) Transportation Technology Center, Inc. (TTCI) testing facility in Pueblo, CO. This testing will include:

- Dynamic and static vehicle testing.
- Three months of performance, endurance, and component reliability testing on a 50-mile, full-scale on-track testing that includes a high tonnage loop.

During the initial demonstration at the AAR's TTCI testing facility the locomotive will operate on the 50-mile test loop in real-world conditions. The operation at TTCI will allow the team to perform controlled testing and gather critical data on emissions, fuel consumption, specified performance metrics, dynamic and other safety characteristics, and reliability during revenue service simulations. Validating the performance and safety of the locomotive at the nation's premier railroad test site will provide results that can be shared with regulators and Class I, II, and III railroads across the country. After the TTCI testing, there will be three months of in-service field-testing in a practical application with Utah Railway. The demonstration will operate five days a week from Provo, UT to Ogden, UT, as shown in Figure I.3535-1. Additional operations could include trips over Soldier Summit and to Grand Junction to demonstrate a wide range of operating parameters and validating a pathway to commercialization.

Figure I.35-1. Utah Railway service map

Results

The project team held a kick-off meeting with DOE and GTI on October 28, 2020, where the approach and the Project Management Plan (PMP) were reviewed and confirmed. OptiFuel began design work even though a subcontract between GTI and OptiFuel was still in negotiation. This subcontract was executed later in the

Budget Period. GTI worked throughout the Budget Period to negotiate contracts with other participants on the team.

Although the team early on considered using four 400hp Cummins ISX12N natural gas engines and one diesel-fueled 2,700hp QSK60 engine, it was later proposed to use only 10 ISX12N engines because this would enable full operation on gas and lower emissions. It would also remove the need to store both diesel fuel and diesel emissions fluid (DEF) on board the locomotive. A preliminary concept is shown in Figure I.3535-2.

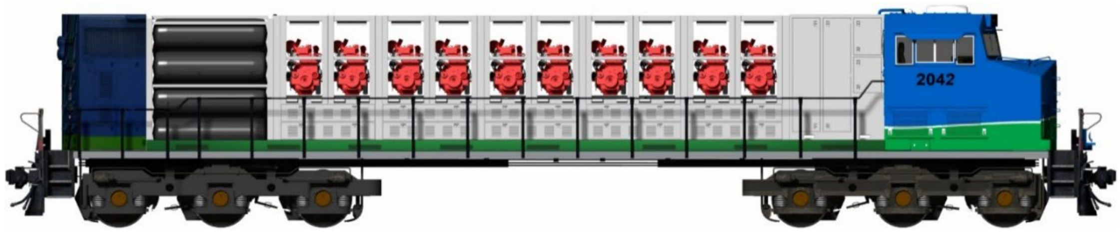

Figure I.35-2. CNG/RNG locomotive concept layout

OptiFuel started design work on a self-contained pod for each ISX12N engine that includes a generator, cooling system, energy storage (batteries), exhaust silencer, and controls, among other essential items. A concept drawing for the engine pod design is shown in Figure I.3535-3.

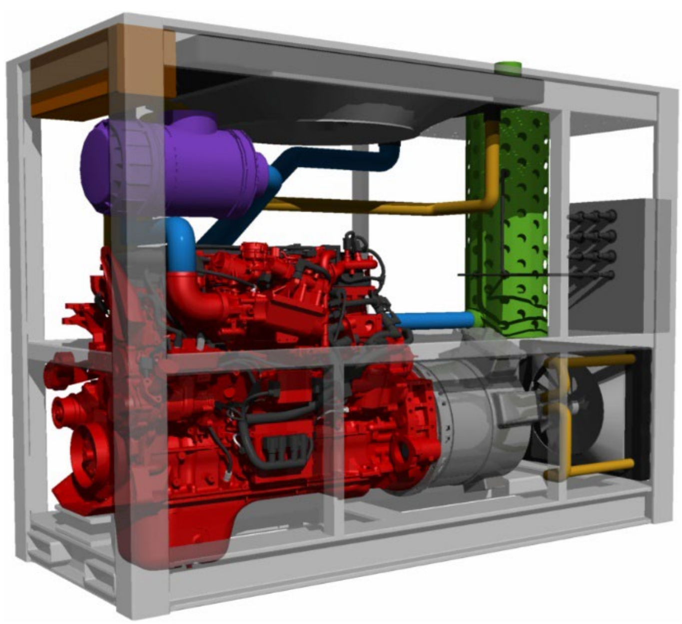

Figure I.35-3. ISX12N pod design concept

OptiFuel proposed to acquire a used SD70MAC locomotive from Progress Rail to serve as the base platform for the new engine concept and initiated procurement negotiations. In addition, OptiFuel initiated discussions with Utah Transit Authority (UTA) to host the demonstration testing, with Dominion Energy to provide the RNG, and with Lancer Energy to provide the refueling system. An EMD710 (3,000 kW) diesel engine will need to be replaced on the SD70MAC locomotive with the 10 CNG/RNG engines. This will require a new control system and control strategy for turning on and off the separate engines.

The team evaluated the tradeoffs of component attributes and system architecture. One of the considerations is adoption of the Nidec LSA 47.2 VS2 / 4P Synchronous Brushless Revolving Field Generator for the Alternator/Generator, rated at 300kW at 1,800rpm, 725VAC. This would enable implementation of BAE Systems' control system and power electronics that has been proven in numerous hybrid applications. The DC link would operate in the 650VDC to 800VDC range and could support the battery storage of 300kWh to 500kWh at 800V. The team evaluated the cost, lead times, performance and suppliers' capabilities to finalize the evaluation and make the decisions. One of the BAE architecture concepts is shown in Figure I.355-4. Later in the Budget Period the team chose to use a Medha control system due to a better fit for project schedule. The system design work is continuing but has been delayed because of staffing issues. OptiFuel is searching for additional staff in a talent pool consisting of engineers with locomotive experience from Wabtec (GE Transportation), BNSF Railway, Norfolk Southern, and Progress Rail.

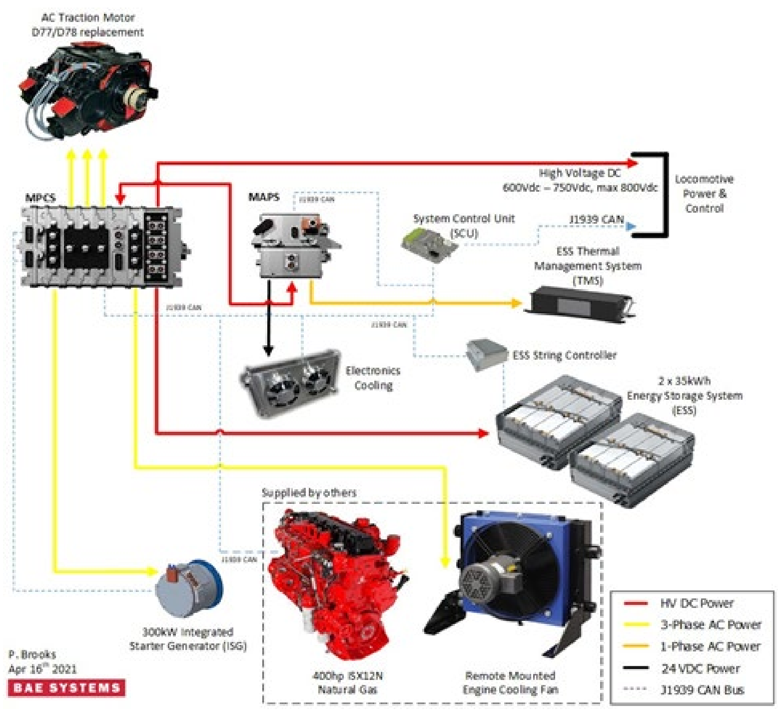

Figure I.35-4. Overall BAE system architecture with power electronics and battery storage

OptiFuel has continued working on logistics to acquire the locomotive platform and other potential sources beside Progress Rail have been identified. The EMD SD70MAC locomotive is 74 feet long and has two 3-axle trucks in a C-C configuration. It uses 6 three-phase AC traction motors (GM 1TB2630). The majority of SD70MAC models were produced with the 4,000 horsepower (3,000 kW) EMD 710 prime mover. An alternative option under consideration is the design of a new 80 ft. long platform using the SD70MAC trucks and traction motors. The alternative platform would incorporate 1,000 DGE of RNG storage in 26-inch, 5,000 psi cylinders inside and below the platform, allowing additional space on the top of the platform deck. This approach could provide additional protection of the RNG storage in case of accidents. The project team has initiated negotiations for acquisition of the locomotive platform. In the meantime, OptiFuel has continued working on the pod design to future-proof it for different Cummins engine ratings and a larger cooling system and alternator.

Conclusions

At the successful conclusion of this project, the team will have demonstrated that it is economically feasible to produce and implement CNG/RNG-powered locomotives in freight service. The project is using commercially available components to design and manufacture an affordable locomotive that makes use of the 100% natural gas Cummins Westport ISX12N engine. This project will quantify the reduction in emissions and increase in energy efficiency available to Class I, II, and III railroads by implementing multi-engine hybrid locomotives. The project is behind schedule, but the team expects progress to accelerate in Budget Period 2 and recover a significant portion of the schedule.

I.36 Delivering Clean Air in Denver: Propane Trucks and Infrastructure in Mail Delivery Application (Drive Clean Colorado)

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Start Date: October 1, 2020 End Date: December 31, 2023
Project Funding: $1,000,010 DOE share: $500,005 Non-DOE share: $500,005

Project Introduction

This project will purchase and deploy five propane-powered delivery trucks along with propane fueling infrastructure in the metro Denver area. The trucks will be Ford Class 7 (F-750) straight box trucks with Roush CleanTech ultra-low (.02 g/bhp-hr) NOx 7.3L V8 propane engines, which are new for model-year 2021, commercially available across the United States, and certified by the Environmental Protection Agency (EPA) and California Air Resources Board (CARB).

The demonstration fleet, Hi Pro Inc., is located in Commerce City, a close suburb of Denver. This fleet moves mail from the United States Postal Service (USPS) main hub to the individual post offices daily. Hi Pro, Inc. has a fleet of 35 vehicles in Colorado and will replace five diesel trucks with the trucks purchased as part of this project.

This project will partially fund and deploy five propane-powered delivery trucks along with propane fueling infrastructure in the metro Denver area.

Project Partners:

- Drive Clean Colorado (DCC)
- Hi Pro, Inc.
- AmeriGas
- National Renewable Energy Laboratory (NREL)
- Roush CleanTech
- Propane Education & Research Council (PERC).

Objectives

This proof-of-concept demonstration of alternative fuel vehicles (AFVs) in a selected vehicle fleet will lead to improved understanding of the costs, operational issues, emission reductions, and performance attributes associated with propane vehicles, and will inform technology adoption decisions for the USPS contractors market transformation from traditional to alternative fuel vehicles. By demonstrating the advantages of propane as a clean and cost-effective alternative to diesel and its viability in the test fleet, the project will share data, best practices, and lessons learned to catalyze other fleets nationwide to adopt propane trucks for mail delivery (and other applications). By reducing the risk of first adoption, the potential exists to transform the USPS mail delivery system into a low-carbon national fleet.

The project team will study the viability of propane as a long-term fuel option in the selected market and quantify the emission reductions in the delivery duty cycle. This project fills the gap for medium- and heavy-duty fleet vehicles that have had limited demonstration of alternative fuels, and which are less suited for electrification, due to the limited and expensive electric charging infrastructure and long-range needs of delivery service vehicles operating day and night.

Approach

Drive Clean Colorado (DCC) has formed a project committee that is currently meeting once every other month to provide updates on the status of truck delivery, infrastructure development, and data capture. This allows DCC to clearly communicate next steps, celebrate accomplishments, and address any unforeseen barriers to progress.

The fueling infrastructure site location (southside of Hi Pro, Inc.'s parking and service center in Commerce City, CO) has been surveyed and project partners have signed a fueling infrastructure agreement. The fueling infrastructure equipment has been built and will be installed on site in December of 2021.

Truck delivery date has been updated to February 2022. There is a high confidence in this estimated date due to increased accuracy of build dates from manufacturers in recent months.

The National Renewable Energy Laboratory (NREL) installed ten data loggers on ten Hi Pro, Inc. diesel fleet trucks in mid-January 2021, and they remained on trucks for four weeks to collect data. (Data collection period was January 17, 2021 through February 14, 2021). This data will be used as a baseline in the final case study deliverable.

Results

Truck Purchase Order & Delivery

Hi Pro, Inc. ordered trucks in partnership with Roush CleanTech in March 2021, with an expected delivery of February 2022. Delays in the auto manufacturing industry have affected the timing of truck delivery due to a global shortage of microchips; high demand has also led to prolonged build-times. See Figure I.36-1.

Fuel Infrastructure

Project partners AmeriGas and Hi Pro, Inc. have signed agreements for fuel purchase and installation of the propane Autogas fueling infrastructure, which Amerigas will install at Hi Pro, Inc.'s location in Commerce City, CO. Permitting is underway, and installation is set to be complete in line with delivery of propane trucks, projected to be February 2022. See Figure I.36.2.

Education and Outreach

DCC and PERC developed and disseminated a press release in April 2021. PERC has also used this project to inform other USPS contractors at their national association meeting of the possibilities of replacing their diesel class 6 & 7 straight truck fleets with cleaner, less expensive propane. DCC will conduct one webinar for key stakeholders to introduce the project and its goals in March 2022, upon delivery of trucks to Hi Pro, Inc. and integration of trucks into the working fleet. DCC announced the project to stakeholders in a monthly newsletter in May 2021, and published a project overview on the organizational website.

Figure I.36-1. USPS mail contractor McAbee Trucking, model Ford F-750. Photo credit: ROUSH CleanTech

Figure I.36-2. Propane Autogas refueling infrastructure by AmeriGas and Superior Energy Systems, similar to propane fueling infrastructure to be provided by AmeriGas at Hi Pro, Inc. site. Photo credit: Superior Energy Systems

Conclusions

As this project is still in the early implementation stages, conclusions are not yet identifiable.

Key Publications

Announcement in DCC newsletter: May 2021
Project overview on DCC website: Published
PERC press release published in LP Gas Magazine

Acknowledgements

We want to thank and acknowledge the Propane Education and Research Council (PERC) for their assistance with public relations & media support and for support in compiling this document.

I.37 Cold-Weather Operation, Observation and Learning Electric Vehicles: COOL EVs (American Lung Association)

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Start Date: October 1, 2020 End Date: December 31, 2023
Project Funding: $2,017,265 DOE share: $997,274 Non-DOE share: $1,019,991

Project Introduction

The Cold-Weather Operation, Observation and Learning with Electric Vehicles (COOL EVs) project supports the deployment of four battery electric vehicles (EVs) in four community fleets in the metropolitan area of Minneapolis/St. Paul and greater Minnesota. This project is strategically designed to overcome the challenges of cold weather operation, which is crucial to advance EV fleet applications. The four EVs included in this application are a rear loader refuse hauling truck, a box truck for supplies delivery, a medium duty passenger shuttle, and a school bus. The fleets will share some resources, including training, technology, and project management support.

Existing applications of heavy-duty EVs have shown that very cold weather can result in lower energy efficiency, lowering the overall available range. Minnesota has a continental-type climate and is subject to frequent outbreaks of continental polar air throughout the year, with occasional Arctic outbreaks, and intermittent periods of prolonged heat. The lack of widespread experience with EVs has presented challenges for fleet operators, as there are specific operating characteristics and fueling requirements associated with these deployments. The results of this demonstration will provide invaluable information to the medium- and heavy-duty EV industry about extreme weather performance, and how deployment and operational strategies for these vehicles can be optimized to overcome the challenges of extreme weather operation.

The identified solutions in this project are the result of years of work by project partners, and additional contributions, insights, and lessons from actual heavy-duty EV deployments. This project combines the experience and capabilities of four unique fleets, Minnesota's largest electricity provider, and two national 501(c)3 non-profits, including the Minnesota Clean Cities Coalition (MC3), to develop an alternative fuel proof-of-concept in four communities and fleets that will rapidly advance the sustained use of EVs in Minnesota.

Objectives

The objective of Cold-Weather Operation, Observation and Learning Electric Vehicles: COOL EVs is to demonstrate four unique EVs and electric vehicle supply equipment (EVSE) infrastructure in four community fleets in the metropolitan area of Minneapolis/St. Paul and greater Minnesota. The project will document and share knowledge across the value chain of medium- and heavy-duty EV deployments by providing insight into the impacts that cold weather operation can have on vehicle performance. There are currently no EVs in refuse hauling fleets in Minnesota. The battery electric school bus would be the first in its large district.

Project objectives include:

- Deploy the following EVs and EVSE: box truck to University of Minnesota, transport shuttle to Arrowhead Transit, 84-passenger school bus to Eastern Carver County Schools, rear loader refuse truck to Eureka Recycling.
- Prepare Performance Monitoring Report and conduct Community-based Outreach and Collaboration including first responder trainings, high voltage safety trainings, Key Performance Indicator (KPI) workshop, ride and drives, case studies, and promotional, training and outreach materials for tradeshows and presentations.
- Eliminate over 390,000 lbs. of greenhouse gas emissions and displace 17,024 gallons of diesel per year.

Approach

The COOL EVs initiative champions the efforts of fleets already committed to innovation and environmental benefits and will accelerate the growth of EV applications in these fleet types, as well as other fleet types that operate in cold-weather climates. The American Lung Association and MC3 rely on the enthusiasm of their fleet partners and project partners, Center for Transportation and the Environment (CTE) and Xcel Energy, to deploy and study these vehicles in different operating environments, evaluate the vehicles' ability to perform at the same level of operation as similar gasoline or diesel vehicles, and evaluate performance metrics and environmental benefits based on actual operation.

Through a comprehensive analysis of the vehicle performance data, best practices, policies, procedures, and scalability of each of these unique deployment applications, the project team will draw conclusions that will prove relevant for organizations of all types, sizes, and experience levels, which will increase the likelihood of successful EV deployments in the Twin Cities and throughout the state, and by fleet operators in other cold-weather climates. Each of the fleet operators on the project team has demonstrated successful proof-of-concept projects in the past sixteen years and is ready to invest in EVs.

The project team will complete four workshops to train fleet operators' staff and first responders on the safe and efficient operations and maintenance of the vehicles, and will complete three EV ride and drives to introduce fleet organization employees to light duty EVs. Project partners will attend a minimum of five conferences, trade shows and/or expos to promote the project. The American Lung Association anticipates capturing five million media impressions while executing the Training and Outreach Campaign. The campaign will target the general public, fleet decision makers, and first responders. All EVs will be certified by the U.S. Environmental Protection Agency (EPA) and/or the California Air Resources Board and meet applicable Federal Motor Vehicle Safety Standards for on road use.

Throughout the project, the COOL EVs team will document project successes and lessons learned to strategically identify best practices and effective vehicle deployment strategies for cold weather operation to deliver a comprehensive case study at the close of the project. To accomplish this objective, and ensure that the project can be replicated by other fleet operators across the U.S., the project team will focus on three major activities as follows:

- Deployment of EVs and Infrastructure.
- Comprehensive Community-based Outreach and Collaboration.
- Evaluation of Fleet Performance and Analysis of Seasonal Impacts.

Results

An electric 84 passenger Blue Bird School Bus for Eastern Carver School District arrived in August 2021 and has been active in the school district. The order included L2 EVSE equipment. Route optimization and planning is underway with CTE and the school district.

Eureka Recycling and project partners expect delivery of the electric waste hauler from Crane Carrier Co./Battle Motors by February 2022. Route optimization and planning is active with CTE and Eureka.

Allina Health Systems fleet backed out of the project at the end of June 2021 due to pandemic issues and staffing capability. The PI and partners developed a process to request a new fleet to fill the gap. The project team interviewed 12 fleets interested in participating in the project. Due to the interest and funding of partners, MC3 staff chose to include two fleets to replace the one original fleet. The new fleets are the University of Minnesota waste program and Arrowhead Transit in the northern rural region of Minnesota.

Conclusions

The COOL EVs project brings multiple unique and innovative fleets together, capitalizing on opportunities to consolidate training, performance monitoring, outreach and communication, and project management capabilities. These synergies will reduce costs and allow fleet operators in the community and eventually across the region to share lessons learned and best practices.

The COOL EVs initiative champions the efforts of fleets already committed to innovation and environmental benefits and will accelerate the growth of EV applications in these fleet types, as well as other fleet types that operate in cold-weather climates.

The COOL EVs project partners training and outreach initiative will address needed outreach, education, and coordination among key local and regional partners, and disseminate information regarding the use of EVs. The project team will provide training of first-responders, service technicians, mechanics, code officials, and managers to ensure safety while utilizing and responding to a variety of situations involving EVs.

Through a comprehensive analysis of the vehicle performance data, best practices, policies, procedures, and scalability of each of these unique deployment applications, the project team will draw conclusions that will prove relevant for organizations of all types, sizes, and experience levels, which will increase the likelihood of successful EV deployments in Minnesota and by fleet operators in other cold-weather climates.

I.38 St. Louis Vehicle Electrification Rides for Seniors (Forth)

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Project Funding: $1,032,392 DOE share: $500,000 Non-DOE share: $532,392

Project Introduction

St. Louis, Missouri, is a diverse Midwestern city that has encountered a half-century of economic downtown, with its population diminishing from 850,000 to 300,000 since 1950. Additionally, with no local or state incentives for electric vehicles (EVs), access to both EVs and charging infrastructure has been limited. Numbers show that Missouri has about 6,740 registered EVs, compared to Oregon, which has more than 36,000.

The overall goal of the St. Louis Vehicle Electrification Rides for Seniors (SiLVERS) project is to increase EV adoption and reduce transportation-related operating expenses for social service agencies in low-income communities. The project seeks to increase EV adoption by validating that EV fleets can save social service agencies money related to transportation operation costs while improving service delivery, providing access to electric vehicle supply equipment (EVSE) for employees and community members, and developing tools and best practices for use by community-based organizations (CBOs) and social service agencies nationwide, allowing them to replicate this approach.

The approach addresses multiple existing conditions that require improvements. First, the industry norm is that one private charger serves just one vehicle. Second, fleet vehicle chargers at workplaces are limited and often located behind a fence, so even where they are available, it is typically challenging for employees or community members to access them. Third, the overall EV adoption rate in St. Louis is very low. Fourth, CBOs in low-income neighborhoods are generally unaware of EVs, and do not have access to them or to their benefits.

SiLVERS provides EVs and associated infrastructure to two community centers, Northside Youth and Senior Service Center (NYSSC) and City Seniors Inc. (CSI), located in North and South St. Louis, respectively. These agencies provide non-emergency rides to elders and distribute food to homebound seniors.Additionally, this project seeks to expose the local community to the economic and environmental benefits of driving electric. The EVSE software platform will also enable community members to access the chargers when not in use by the CBO's fleet vehicles.

Showcasing a sustainable model for small CBOs to operate EVs as part of their fleets and host publicly-accessible EVSE is a use case that has not readily been explored as an opportunity to decrease transportation emissions and increase EV adoption.

Objectives

This modest pilot of five EVs and five chargers has the following objectives:

1) Measure if and how EV fleets can save CBOs and social service agencies money and improve service delivery.

2) Create a model for deploying EVSE that serves those fleets and can also serve employees and community members.

3) Showcase that pilots like this can accelerate regional EV adoption.

4) Create tools and best practices so this model can be replicated by CBOs and social service agencies nationwide.

These objectives aim to create the following outcomes:

1) Additional social service agencies adopt the model for their own fleets.

2) Improved skills and capacity of service agencies to manage their EV fleets; optimized charger usage; and reduced operating costs.

3) Increased EV adoption in the St. Louis market.

SiLVERS also has the following Performance Targets:

- Reduction in operations and maintenance costs of EVs compared to baseline of existing internal combustion engine (ICE) fleet vehicles.
- Increased use of EVs by the social service agencies (staff electing to use EVs over ICE vehicles in fleet).
- Increased number of employees who purchase EVs (assumed baseline of zero).
- Increased number of employees who use workplace charging (baseline of zero).
- Increased number of community members who use the new chargers (baseline of zero).
- Increased number of senior citizens transported in/rides delivered in EVs.
- Increased awareness and understanding of EVs by employees and community members (measured by pre- and post-project surveys).
- Creation of positive perceptions and experience with EVs by fleet managers and employees (measured through surveys).
- Increased adoption of EVs by other social service agencies in the St. Louis region and nationally.
- EVs included in future budgets for agencies participating in the project.

Approach

First, Forth assembled the project partners. As an equity-focused project, this included identifying two CBOs that provide services to elderly residents that require vehicles. Forth established a partnership with the St. Louis Area Agency on Aging (SLAAA) a governmental entity that provides funding to private CBOs to service the St. Louis elderly population. Forth selected Northside Youth and Senior Service Center and City Seniors, Inc. as the two participating CBOs, due to their geographic location (both CBOs service traditionally low-income areas, while the north of St. Louis has a larger population of residents of color). Forth and SLAAA found it important to have representation from both sides (North and South) of the city for this pilot phase. A third local nonprofit, North Newstead Association, was selected to help develop marketing materials and inform the community about the project.

Additionally, the team needed to select a charging network provider. A unique feature of SiLVERS is access, by employees and community members, to the chargers provided for the social service fleet vehicles. To increase use by multiple types of drivers, the chargers must be easily accessible both in terms of physical location and charging availability. ampUp's platform enables users to check availability of chargers, schedule time to charge, and pay seamlessly through an app. The ampUp network in the St. Louis metropolitan area is limited, as expected, due to low EV penetration within the region. As part of the project, ampUp will increase its marketing efforts in St. Louis to encourage more charger sharing and integrate more regional chargers on the ampUp network.

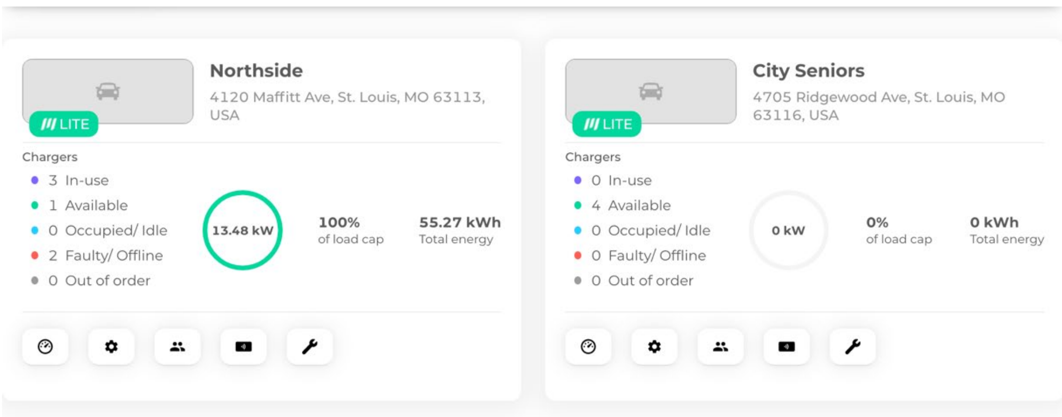

Figure I.38-1. Screen shot of the dashboard from the ampUp online interface for EVSE fleet management.

The ampUp technology solutions tailored for SiLVERS include:

1. *Fleet Manager web-based interface*. This provides both infrastructure and community management features (Figure I.38-1). ampUp Fleet Management software will optimize fleet charging times while creating an easy-to-use interface for fleet managers.

2. *Community management capabilities*. This allows the hosting service agencies to enable employees and neighborhood residents to charge during the times of day that chargers are not being used by the fleets. Agencies can set charging rules for other EV drivers, such as cost to charge and available times. ampUp collects usage and energy metrics at both the user and charger levels.

3. *Driver app*. Used by fleet drivers, employees and community drivers, this function provides automated notifications regarding charging start and end times, and charging reminders. Scheduling and payment integration allows each non-fleet driver to schedule and pay for charging using the app.

4. *Infrastructure management for hardware to software connections*. This connects the EV charger to ampUp's cloud through Open Charge Point Protocol (OCPP), allowing interoperability across software and hardware technologies. Because ampUp integrates with ten EV charging equipment or network companies, the platform is scalable and changeable if needed. EV telematics to ampUp's cloud will connect to the five EVs to capture data points.

5. *Vehicle level reporting*. Data requirements will be defined in the early phases of the project, but will likely include:

- Total energy use of chargers.
- Total greenhouse gas emissions avoided.
- Cost of energy to charge vehicles across program duration.
- Revenue from public charging.
- Charger utilization.
- Average battery capacity of fleet vehicles at beginning of the day.
- Average miles travelled per day.
- Cumulative miles travelled.

Forth initiated a Request for Proposals (RFP) process and selected a local electrician, Sachs Electric. Sachs was selected due to their qualified experience installing EVSE in the region. Ameren, the regional electric company, also was critical as there were necessary transformer upgrades for the charging stations. Additionally, Ameren provided a grant which covered a portion of the charging infrastructure and installation costs at the two sites.

Forth performed a fleet requirements identification and a transportation assessment. This task identified the most impactful fleets to electrify by evaluating the full ICE fleets of the selected agencies, to determine which vehicles should be replaced with EVs for the highest overall impact. In addition, baseline metrics for current vehicle selection will be captured. Forth selected Chevrolet Bolts to lease as the project vehicles, as they checked a majority of the requirements the partner CBOs had to complete their operations, which were primarily food delivery and personal rides given to seniors. The General Motors Foundation also provided $75,000 in matching funds to support the project.

Forth also provided a virtual training to CBO staff and volunteers on electric vehicles, how to charge, and the program as a whole, to prepare the organizations for participating in the program. This was recorded for future viewing of new staff and volunteers. The St. Louis Regional Clean Cities coalition (SLRCC) is also a partner in the project. They are responsible for disseminating project updates and findings to both regional entities and other Clean Cities coalitions across the U.S.

Throughout the first year of the grant, Forth has hosted quarterly meetings of all project partners (CBOs, City officials, charging providers, SLRCC, Ameren, and others) and monthly partner calls with CBO partners to maintain relationships, provide updates, and set deliverable timelines.

Results

Results to date include:

- Installed five charging stations (10 charging ports) at two CBO host sites. (3 stations at NYSSC and 2 at CS.).
- Leased and branded five electric vehicles (Chevrolet Bolts) and located them at CBO host-sites (3 vehicles at NYSSC and 2 at CSI).
- Held a ribbon-cutting event on September 30, 2021 with 40 attendees, to raise awareness and celebrate project launch. See Figure I.38-2.
- Provided a virtual training on vehicles, charging, and the program for 15 CBO staff and volunteers.

- SLRCC reported to us that they have shared project updates and raised EV awareness among 175 stakeholders via speaking to dealerships, the East-West Gateway Council of Governments' Air Quality Advisory Committee meetings, monthly regional calls, car club meetings, board members and local stakeholders.

Figure I.38-2. Photos from the SiLVERS ribbon-cutting event on September 30, 2021. Left: Northside Youth and Senior Service Center staff stand in front of the new program vehicle. Right: the group of project partners ready to cut the ribbon between the newly installed charging stations.

Conclusions

The project's activities had successes and unanticipated, usually COVID19-related, barriers. The delays of some of the chosen activities, in turn, impacted other chosen activities. For example, the delay in installation of the EV chargers consequently delayed the vehicle fleet training. As with many products in the U.S. supply chain, receipt of the EV chargers for the project was pushed back by several months. Once received, the supporting utility, Ameren, was delayed in connecting the charging stations to get them up and running. Ameren has been extremely short staffed due to effects of the COVID-19 pandemic. Additionally, delays in installing the charging stations resulted in delays to other deliverables, such hosting community workshops and information dissemination.

Overall, the program's greatest success is the collaboration with the various stakeholders, especially our community partners. The project team worked with North Newstead Association to create physical collateral (pamphlets, keychains, and flyers), to distribute information about the program. When the stations were finally installed, we had a fantastic ribbon cutting event with many local partners.

Now that the project's primary components are in place, Forth looks forward to implementation, which will include gathering data and measuring project impact, and disseminating project findings. Forth anticipates that rides and deliveries will begin in mid-November 2021.

Key Publications

Forth Blog: https://forthmobility.org/news/st-louis-silvers-launch-event

Acknowledgements

Forth would like to acknowledge the following current or previous project team members:

Daniel Nardozzi – Department of Energy, National Energy Technology Laboratory Project Manager

Erin Galiger - Former Forth Program Manager and SiLVERS Principal Investigator

Sabrina Cerquera - Former Forth Program Manager and SiLVERS Principal Investigator

Maurice Muia – City of St. Louis, MO

Scott Ogilvie – City of St. Louis, MO

Anneliese Stoever – City of St. Louis, MO

Shana Watson – Northside Youth and Senior Service Center, Inc.

Pamela Harris – North Newstead Association

Jennifer Bess – City Seniors, Inc.

Kevin Herdler – St. Louis Regional Clean Cities

Ken Patrick – Ameren

I.39 Pilot Heavy-Duty Electric Vehicle (EV) Demonstration for Municipal Solid Waste Collection (Municipality of Anchorage)

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Start Date: October 1, 2020 End Date: December 31, 2023
Project Funding (FY21): $567,826 DOE share: $16,395 Non-DOE share: $551,430

Project Introduction

In partnership with the U.S. Department of Energy, the Department of Solid Waste Services (SWS) for the Municipality of Anchorage is implementing a pilot demonstration of two heavy-duty electric refuse trucks and a medium-duty electric box truck. In addition, SWS will partner with the Alaska Energy Authority and eCamion, Inc. to install and test a direct current fast charging (DCFC) station that will slowly charge a battery during the day and charge both refuse trucks at night. This will mitigate costly demand charges ($20/kW).

Heavy-duty electric vehicles (EVs) are gaining recognition globally as an attractive alternative to their diesel-fueled counterparts. Fuel and maintenance savings can offset the higher upfront costs of heavy-duty EVs, making them cheaper than a diesel or natural gas vehicle over the life of a vehicle. This project will showcase the benefits of medium and heavy-duty EVs in fleets, particularly for the well-matched use case of municipal solid waste collection. Data and analysis produced as part of this project will provide a compelling case study in heavy-duty EV deployment that will encourage EV adoption across the state of Alaska and beyond.

Objectives

The objective of this project is to demonstrate an advanced technology fleet of five or fewer vehicles and supporting infrastructure in communities, fleets, or areas that have no or little experience with these technologies. Analyzing and sharing data from an arctic state will help other cold climates make decisions about EVs within their fleets. This project also addresses costly demand charges which are relevant to many fleets. Objectives include:

- Acquire and install equipment
    - Purchase two Peterbilt 520EV electric garbage trucks and a Peterbilt 220EV electric box truck.
    - Purchase and install electric vehicle supply equipment (EVSE) with battery backup; program for optimized charging times for both heavy-duty EVs.
    - Purchase and install a ChargePoint CPF50 station for the electric box truck.
    - Incorporate the medium duty electric box truck and heavy-duty EVs into daily use.
- Monitor pilot deployment and maintain equipment
    - Collect and analyze data from integrated software; produce quarterly analysis reports.

- o Provide project data to local and statewide fleet managers.
- o Compare performance to manufacturer claims and document in quarterly reports.
- o Offer private demonstrations, test drive opportunities, and reporting of lessons learned, best practices, and case studies to fleets in Anchorage and beyond.

Approach

After extensive research and discussions with heavy-duty EV manufacturers, Solid Waste Services committed to purchasing and deploying a Peterbilt 220e and two 520e's. The Peterbilt 520e is a product of a partnership between Peterbilt and Meritor, Inc, while Peterbilt partnered with Dana, Inc. to manufacture the 220e. All of SWS's current heavy-duty vehicles are manufactured by Peterbilt, and SWS technicians have extensive experience working on Peterbilt trucks.

SWS chose eCamion Inc. to provide a battery-based solution for the 520e's. The battery will slowly charge during low demand hours and then will be used to supplement the electrical grid when demand is high during business hours. The station will ensure the draw of electricity from the grid never exceeds a preset threshold, thus avoiding high demand charges.

In a partnership with the Alaska Center for Energy and Power (ACEP), SWS will investigate whether EVs are appropriate for heavy-duty fleet application for the Municipality of Anchorage and other cold climate communities. Deployment of these technologies will help address challenges faced by Alaska to widespread EV adoption and EVSE deployment. Additionally, this project will test the functionality and assess the value of a battery tied fast charging station.

The knowledge gained from the demonstration of medium and heavy-duty EVs as well as battery supported EVSE will benefit other fleet owners and EV stakeholders seeking to build out Alaska's EV charging corridor where distribution level infrastructure is limited. This knowledge can also be applied to other cold and/or sparsely populated regions.

Results

SWS took delivery of Peterbilt's first production electric vehicle in June 2021. SWS installed a Chargepoint CPF50 station in the warm storage facility at the current Central Transfer Station and charges the Peterbilt 220 overnight. A charge takes 7-9 hours based on the truck's daily duty-cycle.

SWS drivers have put the truck into operation. After initial trial periods, the 220e vehicle has had multiple operations issues and has been in and out of service for maintenance by the Peterbilt and Dana teams. For example, the drivers experienced a significant delay in gaining speed from a stop. It was eventually determined that the programming was set to try to mimic a diesel truck, and therefore start more slowly. Once the issue was identified, the programming was fixed. Charging the Peterbilt 220 with the ChargePoint CPF50 is going smoothly with no challenges.

The global COVID-19 pandemic, along with the accompanying border and factory closures, has made for long equipment lead times. The delivery of the first Peterbilt truck, the 220EV, was delayed 3 times, with the original delivery intended for early January 2021. Similar challenges are impacting the procurement of the additional trucks and charging station from eCamion, Inc. Peterbilt expects to deliver in early 2022.

One benefit to the delivery delays is alignment with the construction of SWS's new transfer station facility. The original intent was to install the eCamion DCFC station at the current transfer station, then move it over to the new transfer station across the street. Completing the installation at the new transfer station will save significant cost on electrical infrastructure upgrades, conduit runs, and the cost to move the station over to the new facility.

The vendor for our DCFC station, eCamion Inc., has continued to closely coordinate with the team building the new Central Transfer Station to ensure all requirements for installation are met. The necessary conduit and electrical infrastructure have been included in the design for our new warm storage facility to accommodate the DCFC station.

Photos: SWS saw great interest from community members at a public event in Anchorage in June and at the Anchorage EV Car Show in August. Residents were able to speak to EV owners and test drive EVs, as well as learn more about the Peterbilt 220e box truck. See Figures I.39-1 through I.39-3.

Figure I.39.1. SWS's Peterbilt 220e Box Truck at the Anchorage Electric Vehicle Car Show, August 2021. Photo credit: Tim Leach

Figure I.39-2. SWS's Peterbilt 220e Box Truck door at the Anchorage Electric Vehicle Car Show, August 2021. Photo credit: Tim Leach

Figure I.39-3. Peterbilt and Solid Waste Services showcased the new 220e Box Truck at a public event in Anchorage, June 2021. Photo credit: Peterbilt

Figure I.39-4 shows anticipated cost savings for the 520EV when compared to the 520 Diesel.

Note for use: modify yellow boxes, do not modify green boxes

520ev		520 Diesel	
Electric Assumptions		**Diesel Assumptions**	
Energy Rate ($/kWh):	$0.12	Diesel Cost (gal/$):	$2.85
Demand Rate ($/kW):	$22.40		
Working Days in a Month:	22	Working Days in a Month:	22
Monthly Maintenance Cost:	$333.33	Optional Monthly Maintenance Cost:	$1,000.00
Inputs		**Inputs**	
Charging Speed (kW):	25		
Battery Size (kWh):	308		
Daily Distance Driven (mi):	50	Daily Distance Driven (mi):	50
Efficiency (mi/kWh):	0.187	Efficiency (MPG):	1.75
Outputs		**Outputs**	
Time to Charge (hrs):	9.24		
Functional Electricity Rate ($/kWh):	$0.16		
Cost Per Mile ($/mi):	$0.86	Cost Per Mile ($/mi):	$1.63
Monthly Fuel Cost:	$946.40	Monthly Fuel Cost:	$1,791.43
Total Annual Cost (with Maintenance):	$15,356.80	Total Annual Cost (with Maintenance):	$33,497.14

Figure I.39-4. A snapshot of SWS's spreadsheet tool used to assess the potential cost savings provided by heavy-duty EVs

Conclusion

While portions of the pilot project are now delayed into 2022, SWS has been working diligently to incorporate the battery, charging stations, and EV trucks into the design of the new Central Transfer Station. This project has further encouraged SWS to go above and beyond in future-proofing the new site by laying conduit pathways to five bays from the eCamion battery, though only two will be operational with the battery per this project. SWS will also provide conduit pathways to seven warm storage bays from the electrical room. Even if SWS does not pursue more electric trucks right away, the facility will be EV-ready for decades to come.

While the Peterbilt 220e has come with its challenges, the SWS Equipment Tech Foreman observed that most issues appear to be human error in programming or installation rather than technical issues. SWS remains excited about installing the eCamion battery and incorporating the two Peterbilt 520e's into its fleet in 2022.

SWS will also focus on training the maintenance team in 2022 to better prepare them to work safely on the new vehicles.

I.40 Zero Emission Freight Future (Clean Fuels Ohio)

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Start Date: October 1, 2020 End Date: December 31, 2023
Project Funding: $1,736,859 DOE share: $868,325 Non-DOE share: $868,534

Project Introduction

Medium duty (MD) and heavy duty (HD) electric vehicles (EVs) are just beginning to see mass market introduction by the traditional commercial truck Original Equipment Manufacturers (OEMs), with a range of OEMs beginning to release EVs in the sizes and model types that are the workhorses of commercial fleets nationwide. While aftermarket conversions have been available for some time, fleets have been waiting for OEM models as a key tipping point in the MD and HD EV adoption curve. While these OEM models are newly becoming available, many fleet questions remain about the real world operational and economic viability of these MD and HD EVs. This project is designed to provide fleets the real world experienced need to answer these questions for themselves and disseminate this information from trusted fleet and Clean Cities peers. Clean Fuels Ohio is partnering with OEMs and electric vehicle supply equipment (EVSE) providers to operate three demonstration projects of MD and HD EVs with a goal of spurring Class 4-8 EV adoption in fleet applications nationwide.

Objectives

This project will prove the operational and financial effectiveness of MD and HD EVs in commercial fleets. Through diverse partnerships, the project will employ commercially available EVs, EVSE, facilities, and app-platforms to ensure technology deployment and showcase significant return on investment.

Approach

This project will prove the operational and financial effectiveness of MD and HD EVs in commercial fleets through activities in four major areas:

1) *MD and HD EV Pilots* in a diverse collection of fields and industries, with highly visible fleets in freight/goods movement: Bimbo Bakery, PITT OHIO, and the City of Columbus, Ohio Refuse Dept.

2) *Updated EV Operational & Economic Analysis Models*: Integration of MD HD EVs in Sawatch Labs EZ EV analysis platform with data input and detailed feedback from EV OEMs.

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

4) *Distribution of Replication Playbook to fleet stakeholders with similar vehicle operations* including sharing case studies and performing individualized analyses. 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 the following milestones in the first year of the project:

1) Held a kick-off meeting within 30 days.
2) Developed and finalized sub-awardee contracts.
3) Completed Project Advisory Committee (PAC) member communications distribution list.
4) Conducted PAC webinar/conference call to obtain feedback on project data gathering and analysis efforts.
5) Completed Initial EV and EVSE purchases.
6) Created detailed EV and EVSE specifications.
7) Demonstration EVs and EVSE operational.

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: collection of data and processes for analysis; outreach and communications collateral describing data gathering goals/data inputs requested from partners; development of a Non-Disclosure Agreement/Data Sharing Agreement template for partners providing data; and creation of a "value proposition" explainer collateral to inform partners of why participating in this project is a win-win for their organization and for the overall goal of increasing MD and HD EV adoption.

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. (Table I.40.1)

Table I.40.1. Zero Emission Freight Future: PAC Members

Organization	Point of Contact	Relevance
PITT OHIO	Taki Darakos	Pilot Fleet
Bimbo Bakery	Eric McCann	Pilot Fleet
City of Columbus	Kevin McSweeney	Pilot Fleet
Volvo	John Moore	OEM Tech Provider
Motiv Systems	Joe Gwin	OEM Tech Provider
Lion Electric	Orville Thomas	OEM Tech Provider
Sawatch Labs	Mary Till	Analysis Partner
Ohio Department of Transportation	Julia Brogan	State Expert/Dept. of Transportation
HNTB	Robert Evans	Engineering Expert

Organization	Point of Contact	Relevance
Black & Veatch	Quentin Cole	Engineering Expert
Columbus Partnership	Alex Slaymaker	Private Fleet Members
Electrification Coaltion	Matt Stephens-Rich	EVSE SME
Virginia Clean Cities	Alleyn Harned	Clean Cities Partner
Utah Clean Cities	Tammie Bostick	Clean Cities Partner
Wisconsin Clean Cities	Lorrie Lisek	Clean Cities Partner
Kansas City Regional Clean Cities	Kelly Gilbert	Clean Cities Partner

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) PITT OHIO (MD EV box truck)
2) Bimbo Bakery (MD EV step van)
3) City of Columbus (HD EV refuse truck).

Finally, Clean Fuels Ohio coordinated on the completion of purchase specifications for EV/EVSE with the three project partners, in conjunction with equipment suppliers and upfitters. Bimbo Bakery has received vehicle and EVSE spec sheets and finalized specifications with Motiv Power Systems as the conversion kit manufacturer, and Fontaine Modification as the vehicle upfitter. Bimbo Bakery has also selected Clipper Creek and OptConnect systems for the EVSE vendor, placed its purchase orders, and received electrical contract make-ready and installation quotes. PITT OHIO has decided to purchase a VRN Electric Truck from Volvo Trucks as well as a DC Fast Charging (DCFC) station from Gilbarco to be deployed and installed at their Parma, OH distribution center. PITT OHIO has placed purchase orders for both the Volvo VNR EV and the Gilbarco DCFC. Following a competitive bidding process, the City of Columbus received bids for its EV refuse vehicle purchase from two vendors and will make a final vendor selection in Q4 of 2021, pending approval from the Columbus City Council.

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 draw any significant conclusions at this point, and there is nothing considerable to report.

The global COVID-19 pandemic remains the biggest development impacting the project to date. The global supply chain disruption is causing delays in purchasing and receiving the vehicles; however, the project partners are still on track to deploy all three vehicles in budget year 2 of the project.

I.41 Demonstrating Electric Shuttles for the New Orleans Region (Tulane University)

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Project Funding: $1,566,510 DOE share: $737,555 Non-DOE share: $828,955

Project Introduction

Accelerating the adoption of electric vehicles (EVs) in our region will realize both immediate public health improvements in air quality and quality of life, and long-term reductions in greenhouse gas emissions. This project at Tulane University (Tulane), a private research university in New Orleans, Louisiana, seeks to address those problems. Tulane has long recognized the need to mitigate climate change by reducing greenhouse gas emissions. In 2008, Tulane joined the Presidents' Climate Leadership Commitment, a pledge to measure the impact of university operations on climate change and develop a strategy to reduce the university's carbon footprint. In 2015 Tulane adopted a climate action plan with the goal of realizing a 30% emission reduction by 2025 and achieving carbon neutrality by 2050. Switching to EVs is a key step in reaching carbon neutrality, as it moves fleet vehicles from fossil fuels to electricity that is increasingly sourced from clean and renewable sources.

The recent availability of the all-electric Grande West Vicinity LT-E electric shuttle bus gives the operators of fleets of medium-size shuttle buses an EV alternative. Tulane has operated diesel vehicles on shuttle routes between the university's Uptown, Downtown, Elmwood and University Square campuses, and to shopping and entertainment venues in and around the Greater New Orleans metropolitan area. This project replaces five diesel buses in the current fleet with all-electric Grande West Vicinity LT-E electric shuttle buses and develops an EV Charging Station area in a university-owned parking lot to serve the EV shuttles. This project aims to provide fleet operators in our region—particularly the many operators of medium-size transit vehicles—with a local example of the viability and value of all-electric vehicles, sharing locally-based information on EV infrastructure development and EV operation and maintenance costs.

Objectives

The objective of this project is to demonstrate an alternative fuel or advanced technology fleet of five or fewer vehicles and supporting infrastructure in an area that has no or little experience with these technologies. More specifically, this project will:

- Test, document and demonstrate the operational effectiveness of incorporating all-electric vehicles into a shuttle bus fleet in Southeast Louisiana.
- Pilot the development of a fleet charging infrastructure, to provide a model for utilities, fleet managers and contractors in our region.
- Develop a financial analysis of the lifetime costs of diesel and EV shuttle buses that includes a carbon price, to evaluate environmental impact.
- Share experience with fleet managers in our region, both at events and on-site workshops.
- Develop the experience needed to move the Tulane fleet to all or majority EVs.

Approach

The project is a collaboration of Tulane's Office of Sustainability and the Shuttles and Transportation Office (both of which are part of the university's Campus Services division) and the ByWater Institute, Tulane's interdisciplinary environmental research center, with assistance from Creative Bus Sales, the university's bus provider, our utility, Entergy, and the Southeast Louisiana Clean Fuels Partnership (SLCFP), our local Clean Cities coalition housed at the New Orleans Regional Planning Commission. The project will demonstrate all-electric shuttle buses operating on regular routes between Tulane campuses. The project will collect and analyze data to evaluate the cost, operational effectiveness, and air quality impacts of an all-electric shuttle bus fleet in the New Orleans region.

The project will be conducted in three phases:

1. *Procurement, Design and Infrastructure Upgrades* The project's first year has focused on procuring and preparing the EV shuttle buses and developing an EV Charging Station area on campus to serve them. Construction of the charging facility includes new electrical service from the local electric utility.
2. *Initial Deployment and Data Collection* After initial driver training and testing, the shuttle buses will begin deployment on regular university shuttle routes between campuses. Data collection will begin, including energy use, miles traveled, fuel economy, and preventive maintenance and repair costs. Tulane will share initial experience with EV charging infrastructure and shuttle operation through a case study and presentation at local events.
3. *Data Analysis and Outreach* The EV shuttle buses will continue to operate on regular shuttle routes. Data analysis will focus on carbon emission reductions and the financial case for switching from a diesel fleet to an electric fleet. It will include the costs of shuttle purchases, fuel, preventive maintenance, and repairs as in a traditional financial analysis, but will go a step further by quantifying the greenhouse gas emissions of each option and determining the monetary cost under a scenario where the university had to pay some type of carbon price. Lessons learned will be shared through a second case study, a Financial Analysis White Paper, and presentations to other fleet managers at on-campus workshops and Southeast Louisiana Clean Fuel Partnership events.

Results

EV Shuttle Bus Procurement

The Alliance Bus Group (now Creative Bus Sales), the university's bus provider, and Tulane identified the Grande West Vicinity LT-E electric shuttle bus as an appropriate EV replacement for the university's existing diesel shuttle buses. Its electric drive technology has been used in larger, higher capacity buses, but the Vicinity utilizes it in a smaller, 23 passenger transit application, making a proven electric vehicle technology available for fleets using medium duty vehicles. Tulane placed a purchase order with Alliance Bus Group in December 2020, with delivery of the vehicles expected in December 2021 or January 2022. The purchase of each bus included an ABB Terra 54 UL 50 kW DC fast charging station. Tulane's Creative Director Melinda Viles developed a graphic design highlighting the EV features; it will be printed and the buses wrapped when they arrive. (See Figure I.41-1)

Figure I.41.1. Tulane University EV shuttle bus elevation with bus wrap design

EV Infrastructure Development

During this past year, the Project Team developed an initial Site Plan Layout for the EV Charging Station area through regular Zoom meetings, multiple site visits and test fits, and then engaged a design team of electrical and civil engineers to develop and finalize construction documents. Tulane advertised the project for construction bids in June 2021, with the bids opened and the construction contract signed with Kevin Clark Electrical Services in August 2021. Hurricane Ida closed Tulane's Uptown campus from August 29-Sept 20, 2021. After a hold on minor construction projects is lifted, a construction kick-off meeting will be held, with construction estimated to begin in November 2021. The five charging stations have been delivered and are being held until the site is ready for their installation. EV infrastructure construction completion is anticipated by early January 2022.

The key steps in the EV Infrastructure design development were:

1. Initial Charging Station Plan Project Team members from Tulane Shuttles & Transportation and the Office of Sustainability developed an initial plan to locate all the charging stations in one area, with one charging station installed for each EV shuttle bus. This decision was reached after reviewing manufacturer information for the charging stations, the shuttles' schedule of use, and possible scenarios for charging in emergency situations with loss of power with Tulane's electrical supervisor. Project

Team member Scott Barrios of the Electric Mobility unit of KeyString Labs by Entergy obtained and helped the larger team understand the specifications for the ABB Terra 54 UL 50 kW DC fast charging station.

2. Electrical Service and Initial Site Plan Layout Staff from the Office of the University Architect joined the Project Team to review the parking lot where the diesel shuttles are currently parked to identify the specific site for the installation of the EV infrastructure. The Project Team met with Entergy's engineer and Tulane's electrical supervisor at the site to review current electrical service and possible locations for installation of a transformer and other electrical equipment to supply the charging stations. This review included the submission of an Electric Service Inquiry (a Customer Load Data Sheet) to the utility. The Project Team developed an initial plan for electrical service improvements and charging station area layout during this site visit.

3. Test Fits Project Team members from Tulane Shuttles & Transportation, the Office of Sustainability, and the Office of the University Architect held two test fits on the site to ensure that the buses would be able to easily turn into and exit the proposed spaces in the charging station area. (See Figure I.41-2) Conversations during the second test fit also included refinements of the plan (island size, location, illumination, height of curb/raising chargers for rain) and coordination of the entire parking lot with other needs (maintaining maximum spaces, Americans with Disabilities Act updates, maintenance, coordination with Athletics around the use of the lot, future EV charging needs, etc.). The University Architect also requested information on the turning radius of the new shuttles to confirm appropriateness of site layout.

Figure I.41.2. Tulane University staff use existing buses to test fit EV Charging Station area layout

4. Design Development by Electrical and Civil Engineering Engineers from Synergy, the selected engineering firm, walked through the schematic design on-site and explored the extent of design refinement needed for the project. Several substantial issues for discussion emerged during the review of the 50% Design Documents for the EV Charging Station area: stormwater height during intense rainfall events and the ideal height of the concrete pad for the chargers; whether additional charging stations or parking spots for other types of vehicles should be included in the design; and whether security cameras or additional lighting should be added to the design. After this conversation both insurance requirements and the location of the electrical systems within the chargers themselves were checked. Synergy ultimately included a 6" concrete pad in the design, placing the chargers about 1 foot above the surface of the parking lot.

Conclusions

An advantage of switching to EV shuttle buses is that the charging stations can be installed in parking areas currently used by fleets; however, planning should take into account other users, future uses of the site, and emergency conditions, in addition to electrical service. Having a liaison from our utility's in-house electrical mobility/beneficial electrification team on the Project Team has been invaluable, as he has provided key utility contacts and technical assistance, particularly with review of the charging stations. Although EV infrastructure is new to our region, it is well within the existing skill set of local design and construction professionals, who have applied their expertise to this project with enthusiasm.

Acknowledgements

Our Project Team includes Tulane staff members Brian Lowe, Jordan Stewart, and Laura Persich, and Scott Barrios of the Electric Mobility unit of KeyString Labs by Entergy. The Project Team has also included Jay Pittman, Eugene Hotard and Kevin Grubbs from Creative Bus Sales (formerly Alliance Bus Group) and Courtney Young from Southeast Louisiana Clean Fuels Partnership. In this phase Amanda Rivera, University Architect, Amber Beezley, Director of Feasibility, Planning and Programming, and Mark LeBlanc, Construction Project Manager, provided key assistance with the design and construction of the EV Charging Station area, and Melinda Viles, Creative Director, created the bus wrap design. Mark Bacques, Lead Sr. Engineering Associate, Entergy New Orleans, is handling the provision of electrical service. We wish to thank our DOE Project Manager Neil Kirschner for his helpful guidance and encouragement.

I.42 Advancing Climate and Innovation Goals of Memphis and Shelby County: Electrification of Key Fleet Vehicles to Capture Cost Savings and Climate Benefits (Shelby County Government)

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Start Date: October 1, 2020 End Date: December 31, 2023
Project Funding: $1,004,024 DOE share: $500,000 Non-DOE share: $504,024

Project Introduction

The Memphis Area Climate Action Plan, a strategic framework for reducing the area's carbon footprint, calls for a shift to low-carbon transportation modes and an overall greenhouse gas emissions reduction of 51% by 2035 [1]. The plan reports that on-road transportation produced 29% of Shelby County's greenhouse gas emissions in 2016, making on-road transportation the largest contributor of emissions. As emissions per person continue to rise in Shelby County, Shelby County Government can play a significant role in improving local air quality and reducing greenhouse gas emissions. This project, focused on local government fleet electrification, is an initial step towards accomplishing the goals of the plan. The project team consists of Leigh Huffman and Jared Darby from the Memphis & Shelby County Office of Sustainability and Resilience; and Darren Sanders, James Crook, and Charles Wood from the Shelby County Roads, Bridges, and Engineering Department (RBE).

Objectives

The objective of the project is to provide a small-scale pilot project for electric vehicle (EV) fleet adoption by Shelby County. The focus of this project is the installation of charging infrastructure, along with the acquisition of a limited number of EVs. Piloting a small number of EVs and installing charging infrastructure will help provide proof of concept for the future expansion of electric vehicles in the County fleet.

Approach

The project team will purchase five new electric vehicles – either original equipment manufacturer (OEM) factory-produced or conventional vehicles that are converted by OEM-authorized/warranted Qualified Vehicle Modifiers – that will be used by Shelby County's Roads, Bridges, and Engineering (RBE) Department. In addition, vehicle charging infrastructure will be installed in appropriate fleet parking areas to support these new vehicles, as well as future electric fleet vehicles. The project team will also ensure successful vehicle and charging equipment integration into fleet practices and duties by using a portion of requested funds to implement appropriate maintenance and operations training for key fleet services staff. Finally, the project team will analyze and evaluate vehicle performance and associated cost savings and greenhouse gas emissions reductions to better understand the impact and return on investment of this project.

Critical success factors include: efficient and effective project management; regular and productive communication among project partners; comprehensive research on the specific EVs and charging infrastructure to be purchased and installed that takes into consideration employee needs, fleet management processes, and effective use of data; and robust data analysis on the impact and effectiveness of the pilot project.

Results

During the first year the project team accomplished the following tasks:

- Generated a short list of applicable vehicles with pricing information.
- Chose appropriate vehicles to satisfy purchase requirements and demands.
- Worked with applicable manufacturers to identify infrastructure needs related to charging equipment.
- Worked with RBE to assess the most suitable sites for charging infrastructure on Shelby County property.

This project has experienced several delays over the course of the year. Staffing changes and delays in the rehire process necessitated pushing these tasks into the next budget period. An on-the-job injury caused one RBE staff member working on vehicle procurement to step away from his role entirely during recovery. Finally, the project team has encountered supply chain and manufacturing delays due to the COVID-19 pandemic, which has slowed the procurement of vehicles.

Conclusions

The first year of the project was a learning experience for all involved as the project team researched appropriate vehicles and charging infrastructure to meet the needs of RBE, while also providing a sufficient test case to determine cost effectiveness, fuel efficiency, and greenhouse gas emissions reductions. Staff is in the process of procuring the vehicles and charging infrastructure, and plans are moving forward for the design of the charging infrastructure locations as part of a larger renovation at the Shelby County Roads and Bridges Facility. Despite the delays and extensive internal procedural steps to purchase these vehicles, this project is underway with momentum and leadership support.

References

[1] Memphis-Shelby County Office of Sustainability and Resilience. "Memphis Area Climate Action Plan." Develop 901: Memphis and Shelby County Division of Planning and Development. Memphis and Shelby County Division of Planning Development, January 4, 2020. https://shelbycountytn.gov/DocumentCenter/View/37431/Memphis-Area-Climate-Action-Plan-2019-FINAL_4_JANUARY-2020.

Acknowledgements

The project team thanks Jonathan Overly of East Tennessee Clean Fuels Coalition for his invaluable assistance and guidance on this project. The team is also grateful for the work conducted by Dana Sjostrom and Vivian Ekstrom by applying for the grant and conducting initial research.

I.43 Medium-duty Electric Truck (eTruck): Pilot Electrified Fleets in Urban and Regional Applications

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Start Date: October 1, 2020 End Date: December 31, 2024
Project Funding: $2,000,153 DOE share: $1,000,000 Non-DOE share: $1,000,153

Project Introduction

The successes of trucking fleets rely on the capabilities of adapting to new technologies. Compared to conventional trucks, battery-electric trucks (eTrucks) have potential advantages in reducing fuel and maintenance costs as well as harmful and greenhouse gas emissions. The Medium-duty (MD) truck market is a likely candidate for a significant and near-term adoption of eTrucks in daily, return-to-base, urban and regional trucking applications of fewer than 100 miles per day. However, many trucking fleets have very limited or no exposure to the new eTruck technology. The lack of eTruck experience and the concerns about eTrucks including range limits, charging infrastructure availability, maintenance, and cost, are considered the main barriers for the broader adoption by trucking fleets of MD eTrucks. The wide range of urban and regional applications for MD trucking fleets necessitates MD eTruck demonstration data to facilitate eTruck adoptions.

The project is led by University of Texas at Austin with 14 team members. Smart Charge America leads the effort of charging station installation/removal in Texas, Lone Star Clean Fuels Alliance and Texas Trucking Association work on the outreach and trucking fleet recruitments in Texas. Tennessee Technological University leads the work in Tennessee. Seven States Power Corporation leads the effort of charging station installation/removal in Tennessee. East Tennessee Clean Fuels Coalition, Middle-West Tennessee Clean Fuels Coalition, and Tennessee Trucking Association work on the outreach and trucking fleet recruitments in Tennessee. The three eTrucks are provided by Lightning eMotors, SEA Electric, and Phoenix Motorcars. Oak Ridge National Laboratory and National Renewable Energy Laboratory will receive the data from the project.

Objectives

The objective of this project is to demonstrate a MD eTruck technology fleet of three eTruck vehicles and supporting infrastructure in fleets that have little or no experience with these technologies. The MD eTruck demonstration testbed is used to evaluate the performance of MD electric trucks in various applications by a diverse group of trucking fleets. The project may help potential fleets gain necessary eTruck knowledge and experience to make informed decisions about MD eTruck adoption. The project collects eTruck fleet operational and use data to analyze the challenges and needs associated with the use of MD eTrucks in fleets across a broad range of geographical locations.

Approach

To achieve the project objectives of promoting MD eTruck awareness in the trucking industry and facilitating the adoption of MD eTrucks in various trucking fleets for urban and regional applications, the planned approaches in this project include the following:

- Approach 1: MD eTruck demonstration and charging infrastructure development in various fleets to help fleets with limited or no eTruck experience make informed decisions on eTruck adoptions.
- Approach 2: Collect firsthand MD eTruck fleet operational data for daily return-to-base applications in Texas and Tennessee.
- Approach 3: Conduct data analysis and modeling to understand MD eTruck operations in various urban and regional fleet applications.
- Approach 4: Information sharing and outreach to promote eTruck public awareness and educate next-generation electric vehicle engineers.

Results

The main results accomplished in this year are summarized as follows.

1. UT Austin has purchased and prepared two eTrucks as shown in the figures below. One is a Class 4 eTruck made by Lightning eMotors and the second is a Class 5 eTruck made by SEA.

Figure I.43.1. Class 4 electric truck from Lightning eMotors

Figure I.43-2. Class 5 electric truck from SEA Electric

2. The Institutional Review Board application for eTruck demonstration has been approved for UT Austin. Recruitment materials have been prepared and fleet recruitment in Austin has begun. Lone Star Clean Fuels Alliance has reached out to fleets in Texas to encourage participation from public, private and government owned fleets with varying fleet sizes and daily mileage. Applications in Austin have been received.

3. Completed the data acquisition system setup for the Lightning eMotors truck.
4. Installed a Level-2 charger at UT Fleet for the Lightning eMotors Class 4 eTruck demonstration.
5. Tennessee Technological University has started preparing the IRB application and Phoenix Motorcars has started preparing for the eTruck.

Conclusions

The project has made initial progress including vehicle and paperwork preparations, fleet recruitment, and infrastructure installation towards achieving the objectives.

Acknowledgements

We acknowledge the collaboration and support from the project team members including University of Texas at Austin (UT-Austin), Tennessee Technological University (TTU), Lightning eMotors (Colorado), Phoenix Motorcars (California), SEA Electric (California), Smart Charge America (Texas), Seven States Power Corporation (Tennessee), Lone Star Clean Fuels Alliance (Texas), East Tennessee Clean Fuels Coalition (Tennessee), Middle-West Tennessee Clean Fuels Coalition (Tennessee), Texas Trucking Association (Texas), Tennessee Trucking Association (Tennessee), Oak Ridge National Laboratory (Tennessee), and National Renewable Energy Laboratory (Colorado).

I.44 WestSmartEV@Scale: Western Smart Plug-in Electric Vehicle Community Partnership (PacifiCorp)

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Start Date: October 1, 2020 End Date: December 31, 2023
Project Funding: $17,066,146 DOE share: $6,040,647 Non-DOE share: $8,061,287

Project Introduction

The *WestSmartEV@Scale* project is creating an enduring regional ecosystem across the Intermountain West to sustain accelerated growth in freight, business and consumer use of electric vehicles (EVs). The comprehensive and ambitious community partnership project includes more than 25 strategic partners spanning 7 states and will address regional challenges in five critical EV application focus areas: destination highways, underserved regions, urban mobility, freight and port electrification, and community and workplace charging.

Over the past four years, PacifiCorp and its partners have led innovative EV infrastructure and adoption initiatives in Utah as part of the DOE funded *WestSmartEV* project, EE0007997. The efforts catalyzed a 400% increase in EVs in Utah from 2,500 in 2016 to approximately 12,000 in 2020. The *WestSmartEV@Scale* project will leverage lessons learned and best practices from the tremendous success of the *WestSmartEV* project in Utah. It will inject new technology and innovation to facilitate successful expansion into a regional program covering portions of Washington, Oregon, Idaho, Wyoming, Nevada, and Arizona – covering all major corridors in and out of California. The expansion encompasses coastal, mountain, desert, farmland and forest regions with populations of over 20 million people living in communities that range from small rural and mid-size towns to large metropolitan areas. The project will cement synergy among the region's utilities, Clean Cities programs, local towns, cities, states, businesses, and consumers.

Objectives

The objective of the project is to identify pathways to accelerate use of EVs. The pathways will be evaluated by researchers through the analysis of EV infrastructure gaps, EV workforce development training, EV infrastructure deployment and data gathering, freight and port load, and grid evaluations. The impact of WestSmartEV@Scale is to further pull together and help bring to scale the multi-state regional activities. These areas have a common public interest in executing a strategic, directed, coordinated, phased deployment of EV and charging infrastructure programs that will break down barriers to, and accelerate, EV adoption. This project aims for unified, large-scale charging and vehicle data collection on all program activities, data analysis and processing, reporting, and public dissemination, which would not occur otherwise. Communities both large and small, urban and rural, will benefit from this project's generation of aggressive adoption activities and lessons learned.

Approach

The goals of the WestSmartEV@Scale project will be achieved through twelve synergistic, targeted and impactful subprojects that encompass the five critical EV application focus areas of: Destination Highways, Underserved Regions, Urban Mobility, Freight (Airport/Port), and Community/Workplace. The utility partners will work together with their local Clean Cities coalitions to implement the key aspects of the subprojects within their territory. The desired outcome of the WestSmartEV@Scale project is to create an enduring regional ecosystem across the Intermountain West to sustain accelerated growth in freight, business and consumer use of electric vehicles, as shown in Figure I.44-1.

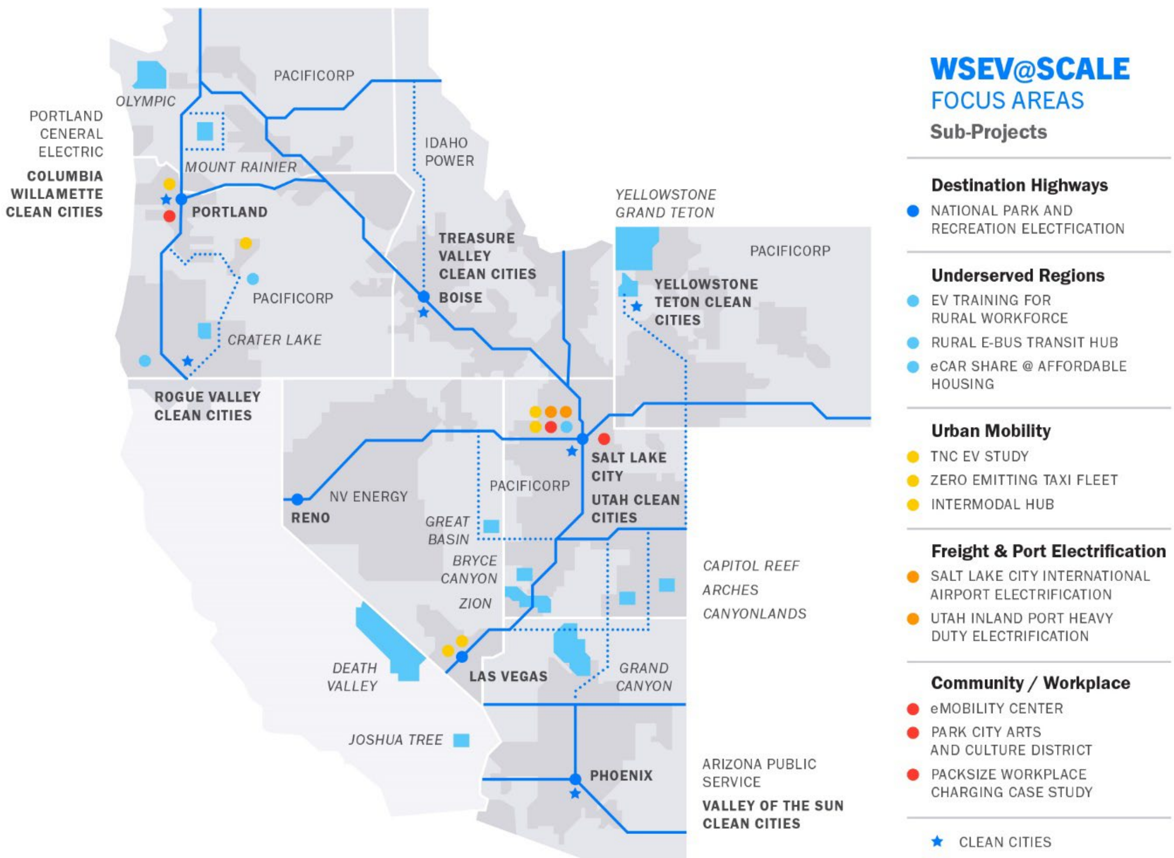

Figure I.44-1. WestSmartEV@Scale region, utility territories, and sub-project locations

The project will be administered in three annual phases:

Period 1: Modeling, Planning, and Design: The project team will conduct subproject level modeling, planning, and design.

Period 2: Implementation and Operation: For each subproject demonstration, the project team will conduct infrastructure and program implementation and operation, including data collection, partner and community engagement, and analysis and evaluation of real-world data for program performance and benefits.

Period 3: Outreach and Education: The project team will complete the evaluation of how to take programs and demonstrations to scale, supported by outreach and education across the region and broadly to the technical and public communities.

Descriptions of the subprojects are as follows:

Focus Area 1 - Destination Highways

- **National Park and Recreation Electrification:** Evaluate gaps in EV infrastructure to ensure access to National Parks and recreation areas in the region.

Focus Area 2 – Underserved Regions

- **EV Training for Rural Workforce:** Evaluate EV workforce development initiatives with communities.
- **Rural eBus Transit Hub:** Develop rural transit bus hub and study effectiveness of ebuses in rural communities.
- **eCar Share @ affordable housing:** Develop eCar Share program and evaluate expanding program to allow low-income residents to use the vehicles for ride hailing services.

Focus Area 3 – Urban Mobility

- **Intermodal Hub**: create a multi-megawatt, co-located, coordinated, and managed charging system at a multimodal transit center.
- **Transportation Network Company (TNC) EV Study**: Monitor driving and charging behavior of TNC EV drivers across multiple states.
- **Zero Emitting Taxi Fleet:** Evaluate the potential to effectively convert legacy taxi fleet to zero emitting vehicles.

Focus Area 4 – Port & Freight Electrification

- **Salt Lake City International Airport Electrification**: Evaluate various options for electrifying newly built airport, including the load and grid impacts.
- **Utah Inland Port Heavy Duty Electrification**: Evaluate potential to electrify newly created Inland Port using real world freight data and simulation testing.

Focus Area 5 – Community

- **eMobility:** demonstrate and study electric mobility options to alleviate transportation constraints in congested areas including multi-modal solutions.
- **Park City Arts and Culture District:** evaluate and demonstrate the effectiveness of an integrated location of ebuses, microtransit, and EV parking to provide solutions that reduce transportation sector emissions.
- **Workplace Charging:** Analyze workplace charging program and evaluate performance and technical requirements for smart charging at the workplace.

Results

Overall Project Results for fiscal year (FY) 2021:

- Participated on "An EV Future" panel hosted by DOE's Office of Electricity, Advanced Grid Research and Development Division, and discussed the goals and direction of the WestSmartEV@Scale project.
- Presented at Green Transportation Summit in Tacoma, WA highlighting WestSmartEV@Scale project.
- Team met with community leaders in Salt Lake City representing underserved communities discussing electrification efforts potentially benefiting their neighborhoods.
- Installed 5 direct current fast chargers (DCFC) and 508 Level II chargers throughout the project area.
- Presented to the National Park Service (NPS) and described WestSmartEV@Scale work on Task 1.

Focus Area 1 – Destination Highway Analysis: National Park and Recreation Electrification

- Stress-free electric travel to National Parks requires significant network expansion
- Initial WestSmartEV@Scale (WSEV) gaps analysis reveals the need for an additional approximately 105 DCFC stations for recreation travel routes that are uncovered with charging infrastructure. See Figure I.44-2.
- Next steps: EVI-RoadTrip charging simulation underway – results will provide greater clarity on volume of stations needed, number of ports, and more accurate travel trajectories.

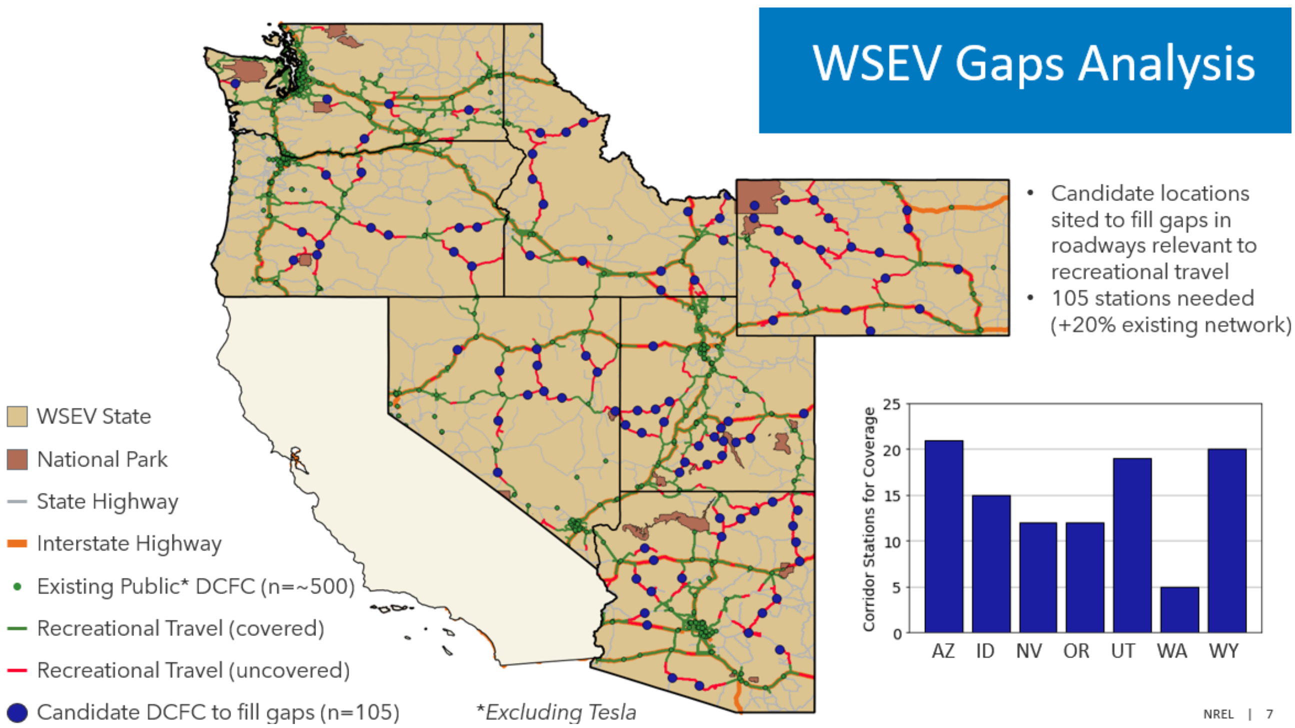

Figure I.44-2. Destination highway gap analysis

Focus Area 2 – Underserved Regions: eCar Share @ affordable housing

- Conducted research and identified three core design priorities for ecar share program:
    - Reliable & user-friendly **vehicle & technology:** select vehicles with sufficient battery range and software system that is easy to use for participants**.**
    - Effective & protective **partnerships & management** structures: ensure technology providers are engaged and insurance providers are informed on car share mechanics.
    - Powerful **onboarding & feedback** systems; ensure appropriate communication with participants both at the beginning of the program and throughout.
- Expected to launch program in early 2022

Focus Area 3 – Urban Mobility: Intermodal Hub

Utah State University developed load and grid models of the Utah Transit Authority's multi-modal central station that incorporates battery electric buses. The goal is to optimize energy usage and costs while maintaining quality of service. The models, based on reinforcement learning algorithms, maximize battery lifetime (preserving battery health) and controls charging of bus fleet and other metered services. See Figure I.44-3.

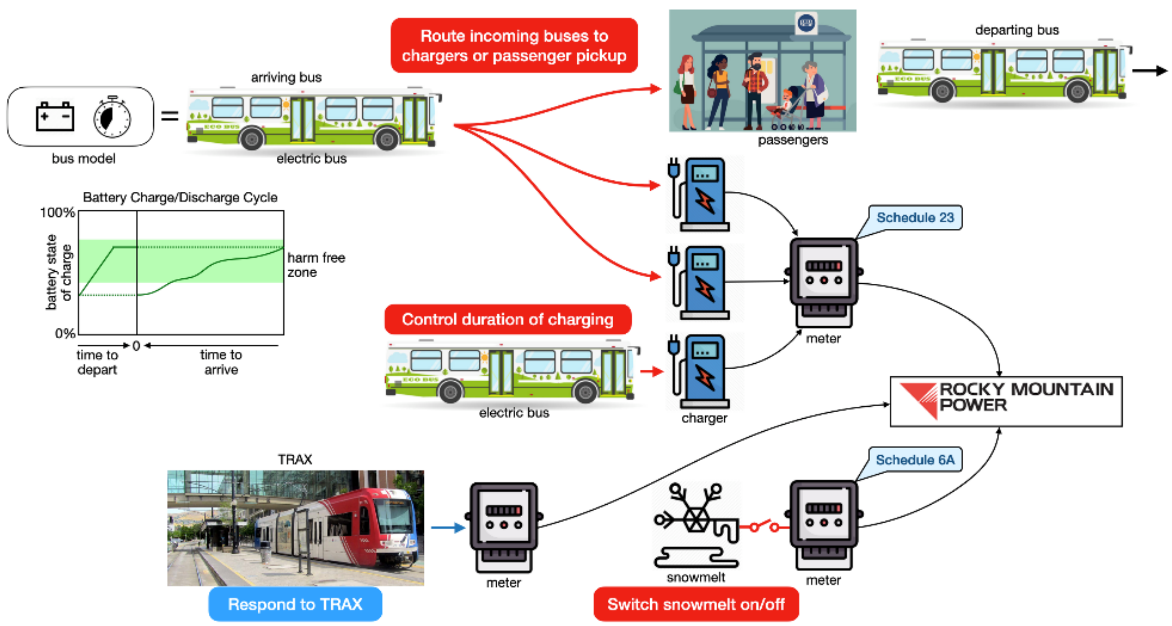

Figure I.44-3. Overview of battery electric bus charging

Focus Area 4 – Port and Freight Electrification: Utah Inland Port Heavy Duty Electrification

- The Utah Inland Port Authority (UIPA) is poised to facilitate a large throughput of freight and material goods. Operations inside the UIPA will negatively contribute to local air pollution (intra-port operations, and regional operations).
- Conducted surveys of companies within the Inland Port on their existing vehicle composition and interest in electrifying. Identified four businesses interested in participating in pilot project.
- Installed data loggers on existing vehicles. Loggers will provide observability into vehicle route trajectories (via GPS) and energy use.
- Data collected will be fed into NREL modeling to determine electrification feasibility and charging requirements.

Focus Area 5 – Community: Workplace Charging

The University of Utah conducted workplace charging site analysis at a commercial facility with 80 Level 2 chargers and 2 DCFC and found that workplace charging is bimodal (charging in the morning and after lunch) with significant potential for flexible loads. See Figure I.44-4.

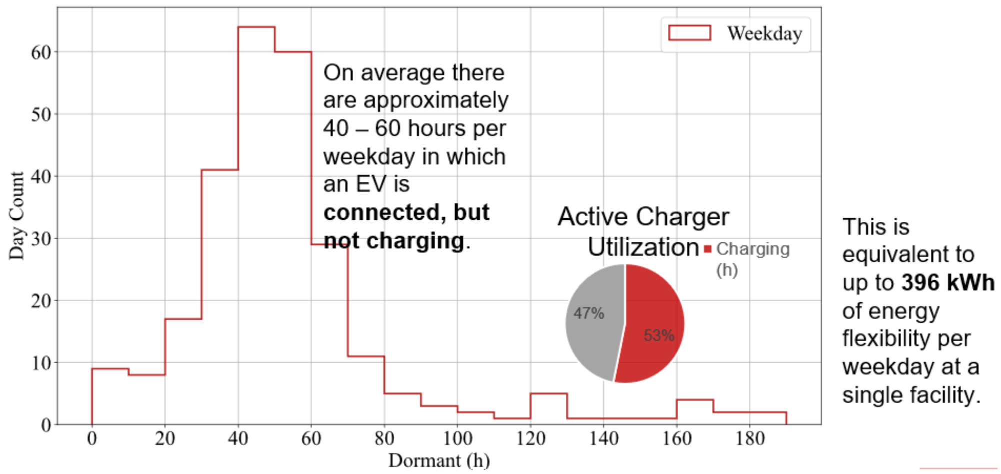

Figure I.44-4. Distribution of electric vehicle charging

The University of Utah developed an initial utility-managed flexible EV Charging framework. See Figure I.44-5.

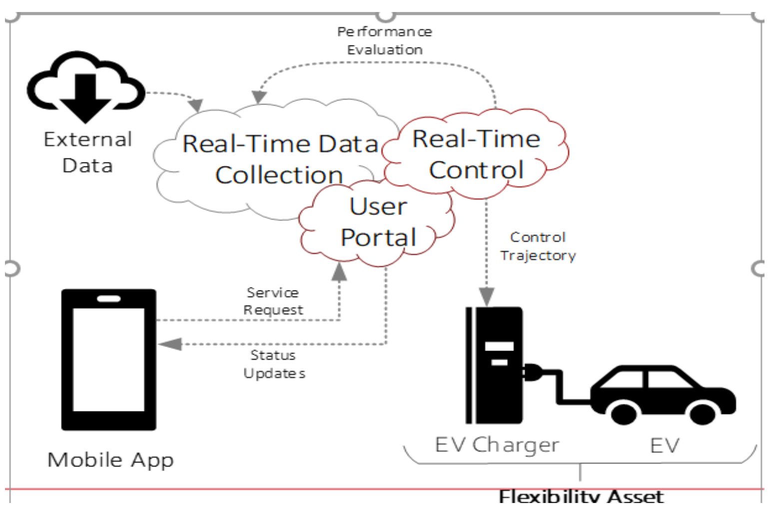

Figure I.44-5. Utility managed flexible EV charging framework

Conclusions

The project team continued to implement the key activities associated with the primary objective of the WestSmartEV@Scale project, which is to create an enduring regional ecosystem across the Intermountain West to sustain accelerated growth in freight, business and consumer use of electric vehicles. To date, the team has evaluated EV infrastructure gaps on roads leading to National Parks and recreation areas in the region. The team has also developed a reinforcement learning model to optimize energy use and reduce costs at a multi-modal urban transit facility. Lastly, the team has characterized the charging characteristics of workplace charging at a commercial facility and developed a utility managed flexible EV charging framework for smart charging.

I.45 Mid-Atlantic Electrification Partnership (Virginia Department of Energy)

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Start Date: October 1, 2020 End Date: December 31, 2023
Project Funding: $14,280,850 DOE share: $5,388,154 Non-DOE share: $8,892,696

Project Introduction

The purpose of this project is to support and foster a regional electric vehicle (EV) ecosystem in Virginia, the District of Columbia (DC), Maryland, and West Virginia, allowing all sizes of EV use for fleets, Transportation Network Companies, and consumers. This ecosystem project will connect the Capital Region's cities, employing multiple EV and infrastructure sub-projects, including multimodal hubs, such as airports, seaports, and logistics centers, while addressing educational, planning, and equity issues of populations near these hubs and within cities and towns. This project will support inter- and intra-city trips for commercial and government entities, consumers, ridesharing fleets serving social service centers, airports and other passenger destinations; schools; and trucks serving large distribution centers (ports), as well as EV charging for employees and visitors at these facilities. The project will develop an ecosystem of tools, education and teams, supporting educational events with frontline communities (those that experience "first and worst" the consequences of poor air quality), and piloting and strategically deploying light- medium- and heavy-duty EVs, while installing charging stations across the area.

Strategies to reduce the impact of air pollution are well-documented in research studies, e.g., clean air policies, and increasing access to and adoption of clean transportation options. Our work and research indicate that members of disadvantaged communities and frontline communities may not know about available opportunities or be aware of the correlation between vehicle emissions, air pollution, and public health impacts. Our effort will engage diverse community stakeholders in an authentic, culturally-relevant manner, acknowledging past injustices and identifying ways we can work collaboratively to address gaps in transportation and mobility as well as explore opportunities for economic and workforce development.

Objectives

The objective of this proposal is to enable a regional ecosystem in Virginia, the District of Columbia, Maryland and West Virginia allowing all sizes of electric vehicle (EV) use for fleets, Transportation Network Companies (TNCs) and consumers. This ecosystem project connects the Region's cities, employing multiple

EV and infrastructure sub-projects, and including multimodal hubs such as airports, seaports, mass transit hubs, and logistics centers, while addressing equity issues of populations near these hubs and within cities and towns.

This project supports inter- and intra-city trips for commercial and government entities, consumers, ridesharing fleets serving social service centers, airports and other passenger destinations, schools, and trucks serving large distribution centers (ports), as well as charging for employees and visitors at these facilities.

Approach

To accomplish these project objectives across the Mid-Atlantic Region, this project has implemented a three-year, strategically phased, directed, and coordinated implementation plan. The three annual phases are below:

Budget Period 1: Project Planning, Kick-Off and Analysis – Partners clarify existing, develop new, and create flexible pathways toward project commitments and milestones based on analysis derived from Argonne National Laboratory tools, and incorporate data collected.

Budget Period 2: Education, Analysis, Deployment, and Implementation - Partners reach out to stakeholders critical to achievement of project outcomes and milestones. Partners work with those critical stakeholders to implement project plans outlined in Budget Period 1.

Budget Period 3: Final Deployment, Analysis, Results, and Reporting - Partners will continue to finalize analyses conducted in earlier periods. Partners produce reports of results in various formats, and continue. Partners focus on continuing outreach in order to report results, share lessons learned with partners and others in the region, and explore possibilities for greater and continued impact.

Results

Commitment Review and Planning

The project team launched the Mid-Atlantic Electrification Partnership, solidified all commitments, and finalized and submitted outlines for achieving milestones.

Team Kick-Off Meeting

The team launched the project with a virtual kickoff meeting, and established a monthly meeting schedule via Zoom with all project partners. Subcommittee meetings on infrastructure, vehicle deployment and deployment site analysis were established and meet on a regular basis.

Educational Series Launch

Per local facility host rules and regulations, some ride and drive events have been converted to virtual events or static vehicle displays. Through these strategies, several meaningful outreach events have taken place, with a focus on diversity and inclusion.

Some examples include:

On April 22, 2021, project partners met virtually with the National Society of Black Engineers about electrification and infrastructure planning. On May 7, 2021, an online event about EVs and utilities took place at Morgan State University. The event was open to all students at Maryland Historically Black Colleges and Universities and was promoted by Morgan State's National Transportation Center. See Figure I.45-1.

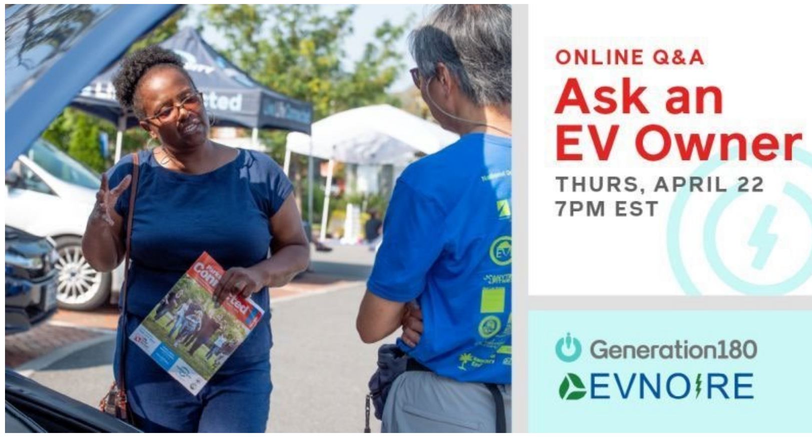

Figure I.45-1. EVNoire April 2021 webinar advertisement

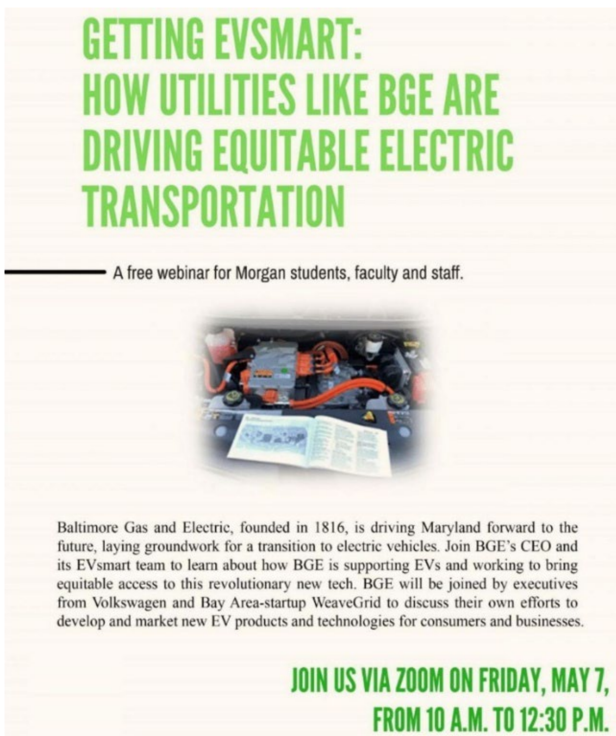

Figure I.45-2. EVNoire May 2021 webinar advertisement

On May 13, 2021, the project team hosted an interactive webinar featuring an EV infrastructure project partner. The partner discussed their charging technology and answered questions from citizens, businesses and governmental entities. See Figure I.45-2. In June 2021, the team held a series of in-person events in West Virginia, including outreach events in Valley Park and Charleston, as well as a dealership event in Hurricane.

The team held meetings with stakeholders at the state capitol and at West Virginia State University. The team met with International Brotherhood of Electrical Workers Local 466 in Charleston and held an in-person EV showcase event.

Successful outreach meetings took place with organizations in DC's two most underserved communities, Wards 7 and 8. Local organizations expressed interest in not only participating but leading the efforts.

The team created a public-facing project website with statistics and highlights at https://vacleancities.org/mid-atlantic-electrification-partnership/. See Figure I.45-3.

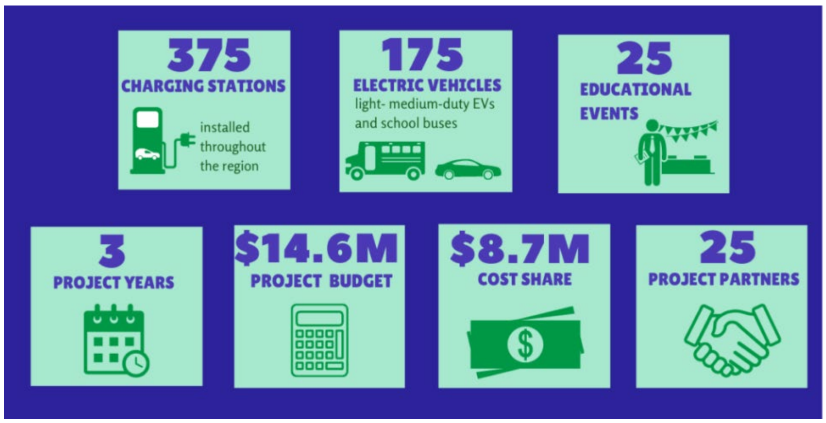

Figure I.45-3. Dashboard from project website

Site Analysis

Argonne National Laboratory's enhancement of the Energy Zones Mapping Tool (EZMT) mapping layers and suitability modeling have facilitated electric vehicle charging station planning. The EZMT is a free public national tool for energy-related planning. See Figure I.45-4.

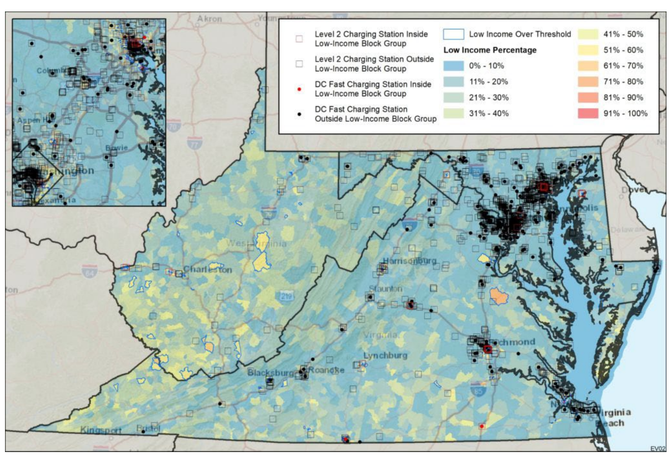

Figure I.45-4. Sample EZMT map showing income levels

So far, the following has been added:

- New and updated data.
    - Transportation: designated alternative fuel corridors, existing EVSE stations, and annual average vehicle traffic.
    - Equity and energy justice: percent low-income, percent minority, population density, multi-family housing density, manufactured housing density, household transportation energy burden, and transit desert index.
    - Energy infrastructure: transmission lines, substations, electric power retail service territories, and many others.
- New suitability models for EVSE planning with an equity emphasis: These models allow EZMT users to generate “heat maps” showing areas more or less suitable for a set of criteria. Most criteria are available for the contiguous 48 states and results are generated at a 250-meter level of detail. Among the 110 criteria available for modeling, the new EVSE and equity topics include:
    - Density of existing EVSE
    - Proximity to designated alternative fuel corridor
    - Annual vehicle traffic
    - Distance to mass-transit hub
    - Household transportation energy burden
    - Percent low-income
    - Percent minority
    - Population density.

With shared funding from the EZMT project, Argonne National Laboratory is developing a case study for EVSE modeling in the tool with an equity emphasis.

Study efforts are underway on port-based electrification opportunities and transportation network company (TNC) activities. In regard to TNC data collection, the project team has the cost of the two EV models that will be procured in the 100-vehicle fleet, with the intention that the utility and rideshare partners will supply mileage and cost of charging data upon implementation in Budget Periods 2 and 3. Washington, D.C.-area regional transit agencies Washington Metropolitan Area Transit Authority and District DOT have been engaged in discussions about integrating mass transportation into EV infrastructure mapping.

Ports Analysis

Active engagement is underway with the Maryland Port. Under the Ports sub-project, data collection has been scheduled for future time periods due to the Port of Virginia’s extended efforts in procuring electric drayage trucks. However, the port officials are eager to have information about battery life, emissions, and costs. In our discussion with the port, we plan to collect EV equipment operational data in year 2 and 3 of the project, which will be used in Argonne National Laboratory’s Alternative Fuels Lifecycle Environmental and Educational Tool (AFLEET) to estimate the equipment’s cost of ownership, emissions benefits, and other operational changes from switching to electric vehicles.

Infrastructure Study, Development and Ecosystem Launch

Environmental questionnaires for 20 project sites were submitted through the U.S. Department of Energy Project Management Center. Charging station deployment and installation is underway at the approved project sites.

Project partners installed 10 of the 20 allotted 150 kW unit chargers at Baltimore/Washington International (BWI) Thurgood Marshall Airport at the cell phone and rideshare lots. BWI is a major international airport and transportation resource with thousands of visitors each day and is centrally located between D.C. and Baltimore. The chargers allow those traveling in and around the area to charge their EVs more quickly than ever. BWI held a ribbon cutting event on May 24, 2021, to announce this accomplishment. The event included the following speakers: Executive Director/CEO of BWI Ricky Smith, Maryland Department of Transportation Secretary Gregory Slater, Baltimore Gas & Electric's CEO Carim Khouzami, Maryland State Senator Pamela G. Beidle, Maryland Public Service Commission Chairman Jason M. Stanek, and DOE Deputy Assistant Secretary for Sustainable Transportation Michael Berube. See Figure I.45-5.

Figure I.45-5. Ribbon-cutting ceremony at BWI Airport

Additionally, during this event the project team formally announced the project's rideshare program. The event received a large amount of positive press and media attention. In addition to the 10 chargers installed at BWI airport, progress continues on siting 8 of the remaining 10 publicly available chargers on state or government-owned property within Maryland. Environmental questionnaires for Annapolis and Baltimore's four sites have been approved and installation is underway.

Ecosystem Mobility Hubs

The project team has held more than 45 meetings with municipalities on EV charging deployment in the three project states and Washington, D.C. The Town of Ashland, VA, signed a contract with an EV infrastructure project partner to install a six-port mobility hub that will be available to the public.

Solar Charger Demonstrations

Purchase orders for solar electric vehicle chargers have been made for James Madison University in Harrisonburg, VA, and the Eastern West Virginia Regional Airport in Martinsburg, WV. The two units are scheduled to arrive late in 2021.

School Bus Chargers

Site preparation work for school bus chargers is underway.

DCFC Corridor

DCFC corridor planning work is underway in West Virginia.

Charger Usage Data

As EV charging stations are installed and activated, Argonne National Laboratory collects usage data and provide baseload ecosystem support. Data collection is underway.

Vehicle and Port Study and Deployment Launch

Rideshare Vehicles

Procurement for 100 rideshare vehicles is underway; 25 vehicles have been ordered for deployment in Maryland. The electric vehicles provide a safe and emission-free option for rideshare in the region. The project team conducted an analysis of available rideshare EV types for this project in Maryland.

West Virginia Demonstration Vehicles

One EV was deployed at the Eastern West Virginia Regional Airport in Martinsburg, WV.

Electric School Buses

The project team launched EV school bus efforts with the selection of several school fleets and the scheduled deployment of two school buses, which enabled further partnership deployment of 25 vehicles in 2021 and a planned-for 300 electric school buses in Montgomery County, MD.

Ports Data

There are monthly standing meetings with the Port of Virginia, Maryland Port Administration and Tradepoint Atlantic. The port partners have established themselves as electrification sounding boards for equipment and fleet vehicles. The project team educated participants on AFLEET capabilities and directed them to educational materials and data around equipment costs and emissions.

Geospatial Data

Significant data analysis is underway with multiple visioning sessions in Budget Period 1 and publication of data and resources through the Argonne National Laboratory partner.

Conclusions

The project team continued to implement the key activities associated with all primary objectives of the project’s first budget year and is achieving milestones in the task areas of electric vehicle infrastructure deployment, educational outreach, and analysis. This project is seeing true collaboration among project partners through meetings, task completion, and mutual assistance. Some of the deployments received positive media attention and many localities in the region are interested in participating. Given this progress, the project is ready to move to the next phase.

Acknowledgements

The project team would like to recognize retired DOE National Energy Technology Laboratory Technical Project Officer Darren Stevenson for his guidance through the first year of this important undertaking.

I.46 Twin Cities Electric Vehicle Community Mobility Network Project (American Lung Association)

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Start Date: October 1, 2020 End Date: December 31, 2023
Project Funding: $13,465,047 DOE share: $6,653,985 Non-DOE share: $6,811,062

Project Introduction

Minnesota's currently modest success transitioning to electric vehicles (EVs) is due in part to several barriers that hinder broader ownership and use of EVs locally – particularly for those with limited or no access to a garage and/or who cannot afford to purchase an EV. Even for drivers whose vehicle use patterns and income fit well with EV ownership, a lack of public charging infrastructure creates a perceived risk and feeds a narrative of "range anxiety," which in turn directs consumers away from EVs. This project deploys electric vehicle supply equipment (EVSE) and EVs in St. Paul, Minneapolis, and the surrounding area (Figure I.46-1). The EVSE deployments include both Level 2 chargers as well as DC Fast Chargers (DCFC). The vehicle deployments support a public carsharing program and dedicated carsharing access at multi-unit dwellings (MUDs). The project will also host ride and drive events as well as community events to foster a community focused EV network.

Figure I.46.1. Evie Bolt at Saint Paul charging station

Objectives

The objective of this project is to deploy electric vehicle charging and EVs, and provide supporting outreach and education, creating a community focused mobility network that reduces barriers to EV adoption.

The project has the following targets, to be completed by the end of 2023:

- Construct 70 highly visible community charging hubs, each with two dual-port Level 2 EVSE, for a total of 280 ports, and 12 additional DC Fast Charging ports.
- Deploy 200 shared EVs: 150 vehicles as a one-way carsharing network and 50 vehicles for use by residents at the MUDs.
- Equip 25 MUDs (both low-income and market rate) with charging infrastructure and shared-EV access.
- Conduct 25 ride and drive events near new charging hubs, reaching an estimated 1,500 community members. Produce 10 million estimated media impressions.

Approach

The approach and methodology for this project are based upon the mission, expertise, innovation, and success of the six partners in advancing EV awareness and use and building strong multi-sector partnerships for success. The project activities are a direct outgrowth of the work carried out to date, existing partnerships and networks, and strong knowledge of what is needed to move the EV market forward.

Twin Cities EV Community Mobility Network (now locally referred to as EV Spot Network & Evie Carshare) supports a highly visible, sustainable EV ecosystem in Saint Paul, Minneapolis, and the surrounding seven county metropolitan region. The project makes significant contributions to overcoming market and other barriers, especially in areas that currently have less access to the benefits of electric vehicles.

All partners involved in the project provide strong experience in building markets and increasing consumer and fleet awareness and acceptance of alternatives to traditional petroleum fuel. The Minnesota Clean Cities Coalition oversees the program budget, timeline, and deliverable completion for each sub-recipient. The City of Saint Paul leads the development of the community charging hubs, DCFC installation, and acquisition of the community carsharing vehicles (Figure I.46-2. Logos for Evie carshare program & EV Spot Network). St. Paul works with Minneapolis to identify the locations for curbside charging equipment in their respective cities, which are placed in public right of ways. The cities manage the process of site selection and any internal regulatory process. Saint Paul also worked with partners to lead the vendor selection processes for installing and operating the Level 2 and DCFC equipment, as well as the EV leasing for the community carsharing program. Over the past year Saint Paul staff and partners issued a Request for Proposals (RFP) to select one EVSE company. After reviewing and meeting with over a dozen companies, St. Paul selected ZEF Energy.

Figure I.46.2. Logos for Evie carshare program & EV Spot Network

The project is creating a network of mostly on-street electric vehicle chargers to serve Evie carshare and public charging for personal electric vehicles. Each EV Spot will include 4-6 on-street parking spots. Most locations will have two dual-port Level 2 chargers, with one charger dedicated to Evie carshare and the other dedicated to public charging. A limited number of locations near regional destinations or freeways will require additional parking spots to provide fast charging. The EV Spots will also include electrical service cabinets in the boulevard, and in some cases an additional transformer cabinet. The network will include 38 EV Spot locations in Saint Paul and 32 in Minneapolis.

Within each neighborhood in the service area, project partners have worked to make the hubs conveniently and centrally located. The team has considered a host of factors in placing these hubs in proximity to affordable housing, multi-family housing units, local businesses, schools, libraries, and recreation centers, while also locating them close to public transit networks and bike-friendly streets. In Minneapolis, the city is coordinating siting with their mobility hubs pilot program. There are many logistical factors as well, including where there is space available and other city planning activities. Finally, the team has considered hyper-local information such as unmarked loading zones and other local curbside activities for which we would find alternative solutions as part of this project.

HOURCAR leads the overall EV carshare project management for both the community system and the vehicles at MUDs. They coordinate the operation of the programs and upkeep of the vehicles. They also support the siting and development of the charging infrastructure to help ensure its suitability for supporting carsharing. Staff are dedicated to the transition of their carsharing fleet from internal combustion engines to EVs and oversee the selection and installation of hardware and development of software necessary to maximize the utility of the carshare network. They also have staff devoted to community engagement for the overall project and the development and operation of the carsharing system at multi-unit dwellings.

Xcel Energy is planning and installing the make-ready infrastructure for the community charging hubs, DCFCs, and the MUDs, as well as the actual charging equipment at the MUDs. They evaluate locations to determine suitability and infrastructure needs and coordinate their portions of the installations.

East Metro Strong leverages its public and private members to lead the team's work in locating new MUDs with which to partner. In addition to private real estate managers, East Metro Strong works with city and county governments, including Economic Development Authorities, Community Development Authorities, and Public Housing Agencies, to locate new EVSE and EV carshare hubs at multi-family housing properties, especially those outside the core of the region.

Results

Leveraging strong partnerships has been the main approach for achieving project objectives. For the charging hubs, sites are located curbside in public right of ways. To date there are 17 sites installed and 15 are activated. This approach reduces regulatory barriers and avoids the need to negotiate seventy-plus individual private leases. Sites have been vetted for feasibility, visibility, and maximum convenience to users. The project team has run community engagement for site selection and program design, so ZEF Energy (the EVSE vendor) is able to provide equipment and services, rather than being responsible for site selection, city procedures, and community engagement.

Similarly, partnerships are key to overcoming a variety of local market barriers. Utility engagement has defrayed costs for infrastructure development. Carsharing programs will expand access to electric vehicles for community members and residents of selected MUDs. Education, outreach, and communications efforts will raise consumer awareness, provide firsthand experience, and increase the use of electric vehicles.

Community Charging Hubs: Level 2 EVSE & DCFC Sites – A network of charging hubs will be installed to provide access to needed Level 2 supply equipment and DCFC at locations in Saint Paul and Minneapolis. The site host as well as local businesses and residents in the area have confirmed each site. Each site will have four Level 2 EVSE charging ports available when completed, which will be available for public use and will supply an EV carsharing program. The cities of Saint Paul and Minneapolis, together with HOURCAR and Xcel Energy, worked to site locations to add charging hubs over a 35-mile service area (Figure -3). The same process was used for the 12 DCFC sites. Each charging hub location was carefully selected using a four-step process including the following:

- Neighborhood selection
- Siting requirements
- Agency coordination
- Additional considerations

Chargers will be tested in English upon installation, and additional languages will be added once testing is completed. 12 DCFC will be placed into service in 2022.

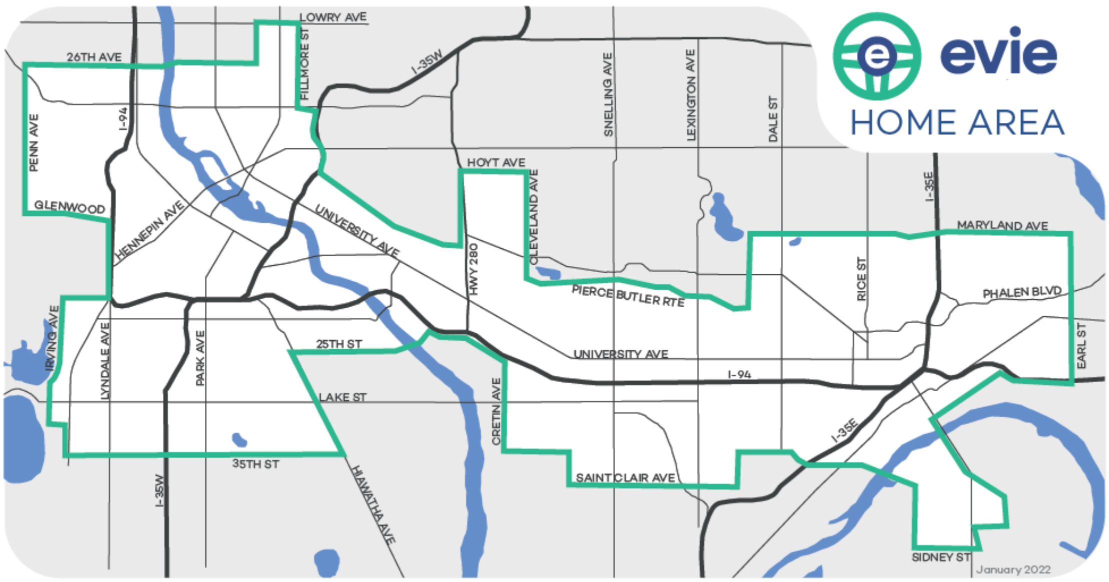

Figure I.46-3. 36 square mile region of Charging Hubs

The Level 2 chargers in the EV Spot Network feature an LED strip at the top of the charger for each plug (Figure I.46-4). The following is a key for how to interpret the colors:

- Blue -- car is plugged in, not charging
- Green -- charger is available/ready to charge
- Orange -- car is charging
- Red -- Don't park/charge here; charger is inoperative, or a street maintenance operation is forthcoming at this location.

Figure I.46-4. L2 Charging decals designed for project

Twin Cities Electric Vehicle Carsharing – To increase access to electric mobility for more of the area’s residents, EVs will be deployed in a one-way carsharing network. 101 Chevy Bolts (leased by City of Saint Paul) are currently in Minnesota with the remaining EV order to be filled by Nissan with the Leaf Plus.

Multi-Unit Development (MUD) – The project team is addressing initiative barriers specific to multi-unit housing locations in the Twin Cities region, as well as additional limitations to purchasing EVs for low- to middle-income residents, through the installation of electric vehicle supply equipment (EVSE) and the launch of a new program to provide shared EVs at selected properties. To date, five of 25 sites have been confirmed. During the Summer of 2021, HOURCAR and partners selected five sites to participate in the first tranche of the Multifamily EV Carshare project. This tranche is geared toward qualified affordable sites where at least 66% of residential units are affordable at 60% Area Median Income (AMI) or below.

Outreach and Education – Vision Flourish and partners are developing messaging, communications, and promotional materials for use across all the components of the project. Outreach campaigns will educate Twin Cities’ residents on the availability of the community charging hubs, the launch of the electric carsharing program, and the benefits of electric vehicles broadly.

Conclusions

The EV Spot Network (formerly referred to as the Twin Cities Electric Vehicle Mobility Network) project supports several key elements necessary to sustain the growth and enduring use of EVs in Saint Paul, Minneapolis, and the surrounding seven-county metropolitan area. Minnesota has ambitious goals for EV adoption. To provide the benefits of EVs to more Minnesotans and to accelerate their rate of use in a long and sustained fashion, new efforts are needed. The main objective of the EV Spot Network is to create the basis for a highly visible, sustainable EV ecosystem in our area. The project has begun to make significant contributions to making the benefits of EV technology broadly available in the Twin Cities region, especially in underserved areas.

The identified solutions in this project are the result of years of work by project partners and additional contributions, insights, and lessons of countless others. This project combines the experience and capabilities of Minnesota’s two largest cities, the largest utility, the nation’s largest nonprofit carsharing system, and the

Clean Cities coalition to complete five mutually reinforcing sub-projects that will rapidly advance the sustained use of EVs by individuals and fleets in the Twin Cities region.

Construction of new, highly visible, curbside public charging infrastructure has begun to provide access to Level 2 charging for residents, visitors, businesses, local governments, and taxi/ride-hailing fleets. To date 15 community charging hubs, each with 2 dual-port Level 2 EVSE, have been installed and will be commissioned in the final quarter of FY21. EVs are now available to Twin Cities residents and visitors through a one-way carsharing network. 101 Chevy Bolts were available to the public in August 2021, until the GM Bolt recall required vehicles to be pulled from public. We anticipate all the vehicles to be back in public use early 2022.

EV education for residents of MUDs is underway by beginning the process of providing infrastructure and carsharing at multifamily locations. Five MUDs in low-income areas have been selected for charging infrastructure and shared-EV access. The project is utilizing education, outreach, and communications to help a wide range of people understand the benefits available to them and their communities through EVs and charging hubs. A few small events have taken place in 2021 but due to COVID-19, some EVSE equipment delays, and the Bolt recall, the team has planned a soft launch in February 2022.

Key Publications

Twin Cities Electric Vehicle Mobility Network Community Engagement and Outreach Report: https://www.stpaul.gov/sites/default/files/2021-04/TCEVMN%20CE%20Report_Final%204.0.pdf
The EV Spot Network website: www.EVspotnetwork.com
The Evie Carshare website: https://eviecarshare.com/
Social media accounts on Twitter, Facebook & LinkedIn: @eviecarshare

I.47 VoICE-MR: Vocation Integrated Cost Estimation for Maintenance and Repair of Alternative Fuel Vehicles (West Virginia University Research Corporation)

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Start Date: October 1, 2020 End Date: December 31, 2023
Project Funding: $2,176,234 DOE share: $1,085,682 Non-DOE share: $1,090,552

Project Introduction

West Virginia University's (WVU) Center for Alternative Fuels, Engines and Emissions, State of West Virginia Clean Cities, Clean Fuels Ohio, the Western Riverside County Clean Cities Coalition, and Wale Associates, Inc. are partnering on a study to develop a tool to estimate the vocation dependent variations in maintenance costs (MC) of medium- and heavy-duty vehicles fueled by alternative fuels, including natural gas, propane, and electricity. South Coast Air Quality Management District (SCAQMD) and Southern California Gas Company (SoCal Gas) have jointly approved a cash contribution towards this study and will be key partners. Vocation Integrated Cost Estimate (VoICE) for maintenance and repair (MR) will compare cost estimates of alternative fuel vehicles (AFVs) with conventional diesel vehicles of the same vocation to illustrate vocation-specific benefits of adopting AFVs. The study will address medium- and heavy-duty vehicles operating in urban delivery, port drayage, school bus, refuse truck and transit bus applications. The overall goal of the cost model estimate tool, however, is to build a user-friendly application for fleets operating nationwide. The study will model the MC of AFVs as a function of duty cycle parameters, which is a critical knowledge gap for fleets that would consider adopting AFVs to replace conventional diesels.

Objectives

The objective of the study is to provide a detailed estimate of the maintenance cost of AFVs in comparison to modern diesel technology counterparts. The global objectives of this study can be summarized as:

1) Maintenance costs incurred by various fleets, as a function of the duty cycle and the seasonal temperature changes in various regions of the country, have seldom been documented. The outcome of this work will link key parameters that characterize vehicle activity, such as percent idle, percent urban operation, percent highway operation, and vehicle weight, to maintenance cost. Furthermore, the study will assess how seasonal ambient temperature affects vehicle duty cycle and consequently contributes to changes in MC. An interactive data driven model will provide fleets with a tool to input key vehicle activity parameters that are characteristic of their fleet operation, to estimate the MC for their choice of AFVs.

2) This study aims to provide feedback to the fleets on best practices that will lower MC for an AFV operating a specific duty cycle. This important outcome will help fleets evaluate their current practices to

determine if they are suitable to the harshness of their vehicles duty cycles, potentially resulting in higher MC.

Approach

To accomplish the global objective of the study, the research work will be conducted using a three-phase approach. SCAQMD and SoCal Gas are partners in this study by providing cash contributions to the project. In addition, SCAQMD has provided access to their database of fleets that have received vehicle purchasing incentives for alternative fuel vehicles. We will be using this fleet information for fleet recruitment activity. SoCal gas is a major stakeholder in alternative fuel infrastructure development. They will participate in this study through their role on the technical steering committee, and will engage Original Equipment Manufacturer participation through their other engine development programs.

Phase 1-Project Initiation and Data Collection

WVU will identify members of the steering committee and develop a periodic schedule for steering committee meetings. WVU will also identify participating fleets and vehicles, establish data collection agreements with fleets, and initiate data collection. The team will collect maintenance cost data through different pathways depending on the nature of documentation used by the different fleets. We have encountered fleets with paper documentation, fleets with electronic maintenance records, as well as fleets that have leased vehicles. For electronic data collection, the project team has developed an online portal through the Amazon Web Server (AWS) to enter maintenance information. The participating fleets can directly enter the data through individual secure login or the project team will assist in data entry. The project team will first digitize paper records and extract appropriate maintenance costs before entering it into the database.

This project does not anticipate a large telemetry data collection activity. We have telemetry data collected from around 200 heavy-duty vehicles (diesel, natural gas, propane and electric) operating in different applications in the state of California. This data will be the primary data for developing the model. However, we do anticipate collecting limited telemetry data from vehicles operating in other parts of the country, such as Pittsburgh, PA and Midwest regions. For this, the project team will use the telemetry system developed by WVU and/or the HEM data logger to collect both GPS and vehicle Electronic Control Unit data. We are targeting a total of 50 fleets, with the total number of vehicles exceeding 100.

Phase 2- Data Classification and Analysis

WVU will classify the maintenance information collected and integrate the telemetry data with the database. WVU will perform data classification and quality checks to remove any anomalous data from the database, and will classify maintenance data according to seasonal temperature changes and vehicle age.

Phase 3- VoICE-MR model development

WVU will develop the VoICE-MR model for gaseous fuels and electric vehicles (EVs). WVU will employ a machine learning-based supervised learning approach for development of the model for the gaseous fuel, while attempting a simpler statistical-based regression approach for EVs.

Results

Due to delays in securing agreements with project partners and vehicle fleets, the tasks of data collection have been delayed. The project team has currently started data collection activity and as a result there are no results to share at this stage.

WVU has processed telemetry data from heavy-duty vehicles sampled prior to the commencement of this project. These telemetry data will be leveraged to link duty cycle and maintenance cost. The results shown in Figure I.47-1 illustrate the differences in duty cycle between an AFV and a conventional diesel vehicle. This is key to understanding the differences in maintenance cost linked to the two different technologies.

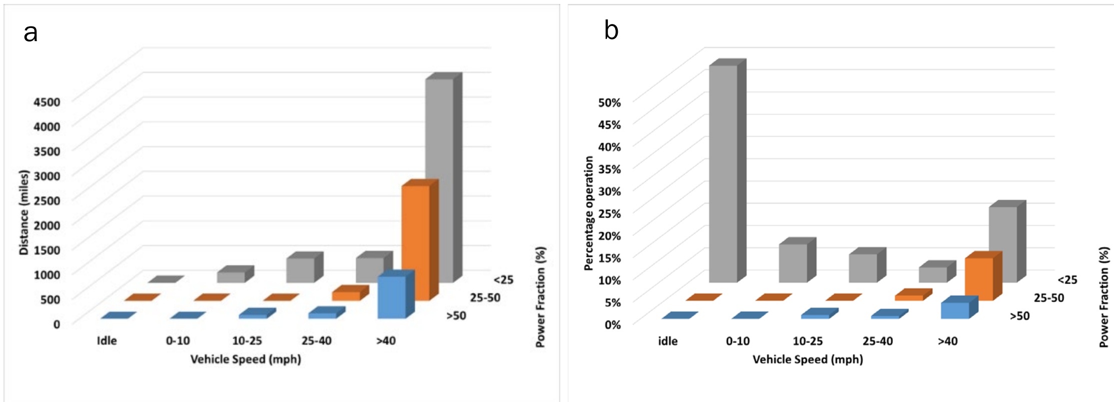

Figure I.47-1. Results of binning of vehicle speed vs. power for a natural gas goods movement vehicle (a) and diesel-powered vehicle (b)

The study is collecting maintenance cost information from fleets that have previously used telematics to log their vehicle activity. Once the project team has completed the MC data collection activity, we expect to apply a machine learning algorithm to correlate vehicle duty cycle and MC.

Conclusions

Analysis of cost data has not been performed yet. It is too early to draw any conclusions.

Acknowledgements

We thank Trev Hall, the National Energy Technology Laboratory Project Manager, for his assistance and direction in keeping this exciting research work moving forward. We thank all of the Clean Cities project partners who have been enthusiastically involved in securing data transfer agreements with various fleets. Finally, we thank all the participating fleets, which have taken a keen interest in this DOE funded research project and have agreed to share their maintenance cost information for this modeling exercise.

I.48 Developing Replicable, Innovative Variants for Engagement for EVs in the USA (DRIVE Electric USA) (East Tennessee Clean Fuels Coalition)

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Start Date: October 1, 2020 End Date: December 31, 2023
Project Funding: $3,611,809 DOE share: $1,801,697 Non-DOE share: $1,810,112

Project Introduction

In early 2020, staff from the East Tennessee Clean Fuels Coalition (ETCF) and Clean Fuels Ohio (CFO) opined, "What if we could get a significant number of largely flyover states together to share in developing plans for building effective Drive Electric programs in all our states?" That question turned into the DRIVE Electric USA proposal that was selected and awarded by DOE's Vehicle Technologies Office in summer 2020.

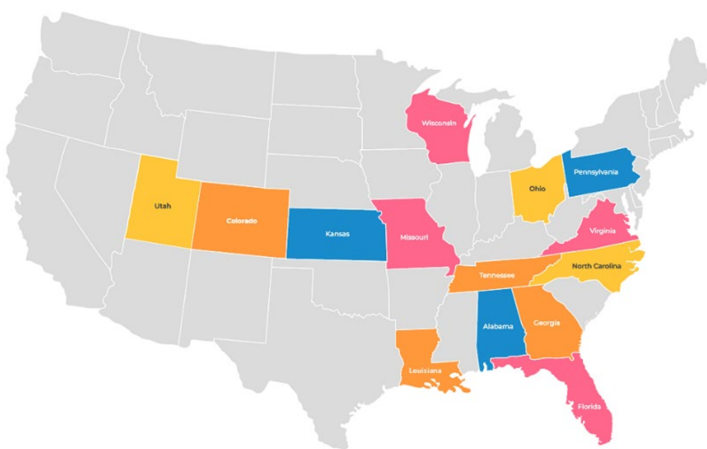

Figure I.48-1. Map of participating states, October 2020

The project runs from October 2020 through December 2023 (39 months) and is comprised of a group of diverse stakeholders, including Clean Cities Coalitions (coalitions) from fourteen states, many transportation electrification-related nongovernmental organizations, electric vehicle supply equipment (EVSE) Original Equipment Manufacturers (OEMs), and other committed partners who are dedicated to raising awareness and adoption of electric vehicles (EVs) across the United States. The project team will use our states as great and dissimilar examples of how to successfully build statewide, successful EV efforts to drive the purchase and use of EVs of all sizes and by general citizens and fleets. See Figure I.48-1 for initial participating states.

Objectives

To accomplish the goal of accelerating statewide, state-led "Drive Electric" initiatives in these states, project leaders and implementers have started educating consumers, utilities, regulators, and government officials and engaging auto dealers and fleet leaders, conducting EV infrastructure planning, and developing local EV chapters. All of this is occurring under the banner of each branded, statewide EV effort, which will be guided by that state's stakeholders.

The "DRIVE Electric USA" project (abbreviated as "DEUSA") will create a Replication Playbook based on outputs and lessons learned that will incorporate appropriate amounts of results from the project work and highlight specific successes from all the participating states. The project also seeks to build successful long-term continuation through funding and partnerships, and that work has already started. Additionally, a 35-company Project Advisory Committee (PAC) has spent much of year one providing input and guiding the coalitions and their statewide efforts toward breaking down barriers as quickly as possible, to accelerate EV adoption in those states. The entire project and the PAC are focused on the following "Priority Areas" of effort that are in the Statement of Project Objectives (SOPO) and very much hard coded into our work tasks and subtasks:

1) Create and strengthen statewide, branded EV initiatives.
2) Educate at least 14,000 consumers through grassroots education initiatives across all states, and develop "chapters" of active participants in every state.
3) Build relationships with dozens of utilities of all types and utility regulators, and build incentives and investment opportunities.
4) Conduct EV infrastructure planning sessions for corridors and urban and rural areas, including a focus on disadvantaged and limited-income communities.
5) Educate state and local government officials.
6) Create certified EV dealer programs for light-, medium- and heavy-duty vehicles.
7) Facilitate EV deployments in fleets.

The goals from year 1 in the project are discussed in the Results and Conclusions sections.

Approach

The project team includes ETCF as the PI while CFO serves as a "supersub" overseeing the administrative management of the 12 other coalitions that are involved in the project. CFO has much experience developing and working in DOE-funded projects, while both coalitions have significant experience working in various collaboratives and groups towards cleaner transportation initiatives.

ETCF and CFO provided leadership, and devised the project and its specific plans to work across the seven Priority Areas and focus on those specific work elements in removing barriers to EV implementation. The project team developed specific tasks and subtasks to allow more and less EV-system-learned coalitions to be able to make solid headway in a) developing transportation electrification partnerships across their states that can serve as an effective cornerstone for future and ongoing progress, and b) beginning to work across the remaining six Priority Areas in addressing EV-adoption barriers that exist in their states.

The project team holds monthly internal meetings to discuss deliverables and documentation and to provide assistance to coalitions in a group format. Additionally, both CFO and ETCF have communicated directly with coalitions to help them overcome issues and barriers in their work. The team has developed a large and significant set of tracking tools to help project leadership as well as individual coalitions see where they stand in completing their deliverables in each of the three project years.

Results

Coalition work in the project has been going well in year one. Here is a list of project outputs that have been completed:

1) Developed a significant project management system via online shared but protected Google docs system that allows all project partners to access and see or download project documents; created templates and a system for coalitions to submit up to monthly completed work and invoices; initiated an internal tracking system for administrative and fiscal oversight as well as completion of tasks and subtasks by partners.

2) Developing a survey of all states to better understand where they were before the project started.

3) Designed and built a project website; developed social media channels for DEUSA, including Facebook, LinkedIn, Twitter, and Instagram (use still in development, though, as we get coalitions to send in snippets of work completed along with photos).

4) Held 37 PAC meetings in 2021.

5) During FY21, ETCF and CFO began the process of reaching out to other states to join in the efforts to develop statewide, branded "Drive Electric" initiatives. The team directly spoke with over 15 coalitions and was able to bring 10 states into the project through the use of a Memorandum of Understanding (MOU). The key part of the plan was to "build successful long-term continuation through funding and partnerships." Table I.48.1 shows a list of the original 14 states in the project and the list of contacted states during project year 1.

6) On a similar front, work has begun toward finding funding that could help those additional coalitions have some funded time to develop their programs. We won't be able to report on this until into year 2 but know that we have begun tackling this in project year 1.

Table I.48.1. Original states, MOU-signed states and interested states

Original 14 States		MOU-signed States	Interested States
1 - Alablama	8 - North Carolina	Connecticut	Arkansas
2 - Colorado	9 - Ohio	Indiana	Maine
3 - Florida	10 - Pennsylvania	Kentucky	Massachusetts
4 - Georgia	11 - Tennessee	Michigan	New Hampshire
5 - Kansas	12 - Utah	MOrigontana	South Carolina
6 - Louisiana	13 - Virginia	New York	Texas
7 - Missouri	14 - Wisconsin	Oklahoma	Vermont
		Washington	West Virginia
		Wyoming	

The deliverables or subtask results that needed to be completed in year 1 are shown in Figure I.48-2. The first thing to note about the table is the coalitions that are shown as having not submitted for any deliverables – there are three of those. There are several reasons why.

1) The Coronavirus has had an impact on this project. The main impact has been in keeping teams from holding public EV Ride & Drives. Some coalitions were better able to execute events based on fewer restrictions, or because they are in less-dense parts of the country. Others – based on local municipal or even their own organization's rules – were barred from holding events. These events were an important element in helping almost all of the coalitions raise cost share that they needed that is matched to every subtask.

Coalition		Alabama CF	Drive Clean CO	Univ. of Central FL	CC Georgia	Metro Energy (KC)	Louisiana CF	St. Louis CC	Triangle CC	**Clean Fuels Ohio**	Eastern PA - ACT	**East Tennessee CF**	Utah CC	Virginia CC	Wisconsin CC
State		AL	CO	FL	GA	KS+ MO	LA	MO	NC	OH	PA	TN	UT	VA	WI
Subtasks - Year 1															
0.1 - A	Execute Sub Partner Contract.		x	x	x	x	x	x		x	x	x	x	x	x
1.1 - A	Create a statewide DRIVE Electric Initiative plan.		x	x	x	x	x	x		x	x	x	x	x	
1.1 - B	Create a branded web platform for the statewide DRIVE ELECTRIC initiative.		x	x	x	%	x	%		x	x	x	x	x	
1.1 - C	Host at least one stakeholder feedback convening.		x	x	x	x	x			x	x	x	x	x	
1.2 - A	Identify and create at least two (2) consumer grassroots DRIVE ELECTRIC initiative chapters in your state.		x		x		x	%		x	x	x	x	x	x
1.2 - B	Identify Consumer Chapter Leaders and Co-Chairs and host at least one formal convening of each chapter.		x		x					x	x	x	x	%	x
1.2 - C	Document direct engagements with at least 200 consumers.		x		x	x				x	x	x	x	x	x
1.2 - D	Complete a written report (template provided) on overall chapter activites and outcomes for the year.		x		x	x				x	x	x	x	x	
1.3 - A	Identify the main utility service providers and regulators in your state, with contacts.		x	x	x	x	x	x		x	x	x	x	x	x
1.3 - B	Hold at least two convenings with utilities and regulators and document engagements.		x		x		x			x	x	x	x	x	
1.5 - A	Create a state and local policy plan.		x				%			x	x		x	%	
1.5 - B	Create state-specific EV and EVSE best practices education materials to use with government officials.		x		x		x			x	x		x	x	
1.6 - A	Create state specific EV Dealer Engagement Action Plan.		x		x	x	x			x	x	x	x	x	
1.6 - B	Develop list of target dealers and dealer contacts for the state.		x	x	x	%	x			x	x	x	x	x	x
1.7 - A	Gather and refine existing outreach and education materials to support Fleet EV education activities		x	x	x		x			x	x	x	x	x	
1.7 - B	Develop list of at least 50 target fleets in the state for outreach and educational engagement.		x	x	x	x	x			x	x	x	x	x	x
1.7 - C	Directly engage at least 3 fleets in EV and EVSE deployment education.		x	x	x		x			x	x	x	x	x	

Figure I.48-2. Specific Subtasks, and Completed and Invoiced Subtasks by Coalition/State as of Late Fall 2021

2) This is not a full year's data.

3) It took longer for some coalitions/states to get their contracts signed due to more complicated review and signature chains in university or Council of Governments-type organizations than in nonprofits.

4) Some states, such as North Carolina, have one coalition lead with one or more other coalitions that are in the state participating. Getting a second round of contracts signed required additional time.

5) Some coalitions – including Alabama Clean Fuels – have basically been waiting to submit for a larger set of subtasks. In their specific case, they invoiced very recently for the entire set of subtasks for year 1.

With that stated, most of the coalitions have well over 50% of their subtasks completed with invoices submitted and approved. There are a few cases where coalitions have gotten behind on completing subtasks. It should be known that CFO did a great job communicating with coalitions last year to determine whether they needed help, and ETCF assisted them in quite a few of those conversations as project PI, depending on the issues or questions. In some cases, that included specific calls to those coalitions with all of ETCF, CFO and that coalition's staff in the virtual meeting. Although it is just a few coalitions that are still lagging, the leadership coalitions built out a plan at the end of the year on what the benchmarks would be if a coalition cannot reach a milestone towards finishing their year 1 work. That benchmarking includes percent completion marks they must meet to continue in the project. They are also required to write a plan for how they will catch up and have all of their year 1 subtasks completed by the end of June 2022 and turn that into CFO and ETCF by the end of March 2022. We do not want to remove a coalition from the ranks; however, if this for some reason needs to take place, we have done the legwork and have 10 other states that are interested in funding to work on this project. Finding a replacement will be easy, although we will need to recraft some of their work since they will only have two years in which to complete it.

Of the 14 states, eight have completed, invoiced and been approved for 75-100% of their subtask deliverables.

Conclusions

There are two ways we can measure project achievements and success: outputs and outcomes. For the outputs, the project team is making good headway getting deliverables completed, and has a plan to help those that are struggling to catch up. Per the benchmarks noted above, we are aiming to have 100% of the year 1 deliverables completed by end of June 2022. Based on a) the length of this project, b) the number of different subtasks that are integrated which include a wide variety of work by the coalitions, c) the difficulty of some of the subtasks (e.g., building a statewide partnership), and d) issues like COVID-19, we believe the project team is doing well.

As for outcomes, the project team is still getting full data from year 1 from coalitions and is not yet ready to show some of the more numeric goals that are in the project, such as:

- ✓ Develop at least 100 social media engagements and 20,000 media impressions that were generated by the initiative.
- ✓ Identify and create at least two consumer grassroots Drive Electric chapters in each state.
- ✓ Host EV consumer outreach and education activities and document at least 200 consumers directly engaged.

Summaries from across the deliverables will be available once the project team has had the time to aggregate all the information across the 14 different state efforts.

Other important deliverables for the coalitions/states include developing a statewide Drive Electric plan, holding at least two convenings with utilities and/or regulators in their states, developing state and local policy plans, and developing lists of both a) target dealerships for creating "certified EV dealer" programs and b) fleets they plan to engage in EV discussions across all vehicle sizes. Two coalitions have already had their statewide roadmaps loaded onto the project website (under "Resources") and several others will be loaded in the coming weeks. These roadmaps point to newer collaborations across partners in each state that are building awareness and engagement at multiple levels.

Key Publications

Drive Electric Statewide Stakeholder Committee Guidance

EV Consumer Education Guidance

Local Chapter Development Guidance

Utilities and Regulators Guidance

EVSE Planning Best Practices Guidance

Local EV Policy Guidance

State EV Policy Guidance

Policymaker Education Best Practices

Acknowledgements

We are very grateful for the partnership with CFO in managing this grant. Multiple staff there have been instrumental in assisting in effective project development, planning and execution. Thanks to them as well as to all the coalitions that have been involved to help us all bring about valued and helpful statewide "Drive Electric" programs.

I.49 Helping Rural Counties Transition to Cleaner Fuels and Vehicles (Transportation Energy Partners)

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Start Date: October 1, 2020 End Date: June 30, 2024
Project Funding: $2,160,562 DOE share: $1,078,581 Non-DOE share: $1,081,981

Project Introduction

This project will provide education and technical assistance to help public and private sector fleets in 24 rural and underserved counties transition to cleaner fuels and vehicles.

While an increasing number of urban communities are exploring alternative fuels and advanced technology vehicles, most rural county governments continue to use traditional gasoline and diesel to power their fleet vehicles. Moreover, significant barriers challenge county leaders who may be interested in exploring new technologies. Rural county governments often lack the staff capacity to learn about new technologies, implement new training and maintenance systems, and educate their work forces. The lack of funding and financing options, combined with staff capacity to research and pursue existing incentives, can also be a significant barrier. Even when there is a positive return on investment in terms of reduced fuel and maintenance expenses, the upfront costs required to purchase alternative fuel vehicles and install fueling infrastructure can prevent many county governments from making the transition.

Transportation Energy Partners will coordinate and support Clean Cities coalitions in eight states to identify and work with rural county leaders to understand and seek to overcome these and other barriers and find models that work for increasing adoption of cleaner fuels and vehicles.

Objectives

The objective of the project is to create models for effectively transferring advanced clean fuel and vehicle technologies to underserved county governments and rural communities and then share those models and lessons learned through a nationally distributed Replication Playbook.

Approach

The project team, led by Transportation Energy Partners, with Clean Fuels Ohio as a key administrative partner, will provide outreach, education, and technical assistance to government fleets in rural regions in Ohio, Indiana, Wisconsin, Virginia, Alabama, Utah, Oregon, and Washington. The project will span at least 24 counties to help them transition government fleets and private fleets in their communities to cleaner fuels and vehicles. Replicable successful strategies and lessons learned will be circulated to other states and regions across the country. The project includes three major areas of activity:

Outreach and Education: Within the first budget period, the project team will conduct outreach and education to county government leaders, with the objective of identifying at least 24 county governments that will receive technical assistance.

In-Depth Technical Assistance: Within the second budget period, the project team will provide technical assistance, including workshops, fleet assessments, and vehicle demonstrations, to help county and private fleets transition to cleaner fuels and vehicles.

Dissemination of Project Findings: Within the third budget period, the project team will develop and disseminate a Replication Playbook to highlight successes and provide an action plan to project states, county leaders, rural communities, and fleets across the country.

Results

Complications associated with the COVID-19 pandemic prompted the project team to submit a No-Cost Time Extension (NCTE) to extend the first phase by six months, until June 30, 2022.

Despite these challenges, the project team has completed the following two milestones:

- Milestone: Assembled a Project Advisory Committee (PAC) and held two quarterly PAC meetings made up of Clean Cities Coalitions Partners (Table I.49.1) and Industry Partners (Table I.49.2) representing all alternative fuel types.
- Milestone: Identified and documented 15 or more rural leaders in each of the eight pilot states to further prioritize providing on-the-ground assistance.

Table I.49.1. Clean Cities Coalition Partners

Organization	State
Alabama Clean Fuels Coalition	Alabama
Drive Clean Indiana	Indiana
Clean Fuels Ohio	Ohio
Columbia-Willamette Clean Cities	Oregon
Utah Clean Cities	Utah
Virginia Clean Cities	Virginia
Western Washington Clean Cities	Washington
Wisconsin Clean Cities	Wisconsin

Table I.49.2. PAC Member Industry Stakeholders

Company	Focus
Alliance AutoGas	Propane
Altec	Anti-Idling & Hybrid Electric
Dominion Energy	Electric / Natural Gas
ECO Vehicle Systems	Propane
Electric Drive Transportation Association	Electric
Ingevity	Natural Gas
Landi Renzo	Natural Gas
National Biodiesel Board	Biodiesel

Company	Focus
NGVAmerica	Natural Gas
Propane Education & Research Council	Propane
Renewable Energy Group	Biodiesel
Roush CleanTech	Electric / Propane
Toyota	Hydrogen

The project team has made significant progress on several other milestones:

1. Clean Cities Coalition partners in the 8 target states conducted 6 outreach events.
2. Secured signed agreements to provide several demonstration vehicles for the project, including:
    a. Alliance AutoGas: One 2020 F-150 XLT propane powered crew cab pickup.
    b. Altec: 2 or 3 medium/heavy duty bucket trucks that include the JEMS plug-in alternative fuel solution.
    c. Landi Renzo: 1-2 Ford natural gas pick-up trucks.
3. Exhibited at the National Association of Counties' annual conference and plan to exhibit at NGVAmerica's October 2021 national conference, where the team will speak about the project with county leaders and natural gas industry stakeholders, respectively.

Conclusions

The Helping Rural Counties Transition to Cleaner Fuels and Vehicles project is on track to accomplish all of its goals and objectives with the planned budget. While the project is only in the middle of the outreach phase, the project team's initial outreach and engagement with rural transportation leaders has uncovered significant interest in alternative fuels and vehicles. The project team has begun to see and learn more about barriers county leaders face when considering alternative fuels and fleet vehicles. Clean Cities coalitions and industry partners are working on how to approach those challenges in the technical assistance phase of the project.

Acknowledgements

We want to thank our partners at Clean Fuels Ohio for their incredible administrative and technical support for the project so far, as well as our incredible Clean Cities Coalitions and industry partners for helping make important strides in reaching rural communities to engage them in our project and encourage exploration of cleaner fuels and vehicles.

I.50 NFPA Spurs the Safe Adoption of Electric Vehicles through Education and Outreach (National Fire Protection Association)

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Start Date: October 1, 2020 End Date: December 31, 2023
Total Project Cost: $ 1,356,176 DOE share: $678,087 Non-DOE share: $678,089

Project Introduction

Even as the popularity of electric vehicles (EV) and their charging infrastructure has been increasing across the U.S., numerous barriers continue to impede their true potential for rapid growth in contrast to other countries such as Norway, Iceland, Sweden, and the Netherlands. According to CleanTechnica.com, 2018 was the best year in the U.S. for EV sales; however, they have slowed ever since, even in California—long considered at the forefront of adoption. The challenges are numerous: a general lack of public knowledge around EV systems themselves, a deficiency of local incentives to purchase EVs, range anxiety and the necessity for more charging station installations, the need for EV maintenance garage and charging installation safety practices, gaps in code compliance education, insurance concerns, emergency responder risks associated with damaged lithium-ion batteries, and now, COVID-19, which remains on the center stage. Few U.S. communities have taken the time to assemble their local EV ecosystem (local government, utilities, electrical code officials, manufacturers/dealerships, fleet owners, garages/maintenance facilities, insurance companies, the fire service, EMS, law enforcement, and vehicle owners) to assess their EV preparedness and to develop a plan to integrate, educate, and incentivize this emerging technology into their municipalities, which would raise awareness and speed the adoption of EVs across the country. The National Fire Protection Association (NFPA) believes we, in partnership with the U.S. Clean Cities Coalitions (CCC) network and each community's EV ecosystem stakeholders, will make a significant contribution to jump-starting EV adoption again across the U.S through this project.

Objectives

NFPA believes that increased community preparedness planning and collaboration among ecosystem stakeholders will result in a greater understanding of these vehicles and their benefits, more incentives for ownership, increased safety, and a more accommodating infrastructure. Once that has been achieved, increased EV adoption on our nation's roadways is inevitable.

NFPA's goals for this project are to:

1) Augment its world-class web-based EV training programs to include additional modules for all EV ecosystem stakeholders for whom NFPA training has not been previously available (e.g., charging station installers, code officials, utilities, dealerships, fleet owners, garages/maintenance facilities, insurance companies, and vehicle owners). NFPA will also expand its existing crash reconstruction and tow and salvage operator programs to reflect the latest safety knowledge and tactics.

2) Develop a U.S. CCC digital facilitation toolkit (consisting of a lesson plan, PowerPoint, videos, and scenario/assessment worksheets) and an EV public overview course (expounding on the make-up, benefits, and safety aspects of these vehicles).

3) Advise and assist selected CCCs that will be responsible for conducting approximately 30 Community Preparedness Assessment Workshops to which they will invite their local communities' EV ecosystem stakeholders. These workshops will be held over a two-year period across the country, bringing together CCCs and EV ecosystem stakeholders to set up cooperative plans and provide education that will spur on greater private and public acceptance of purchasing and accommodating these vehicles in each community.

Approach

To achieve the goal for this 39-month project, NFPA detailed fifteen (15) tasks that support successful completion of the established project objectives. See Table I.50.1: Project Approach.

Table I.50.1. Project Approach

Project Tasks	Description
Project Management and Planning	Develop and maintain the Project Management Plan (PMP).
Kickoff Meeting	Participate in a project kickoff meeting with the DOE within 30 days of project initiation.
1) Hire Subject Matter Experts (SMEs) Knowledgeable in EV & EVSE Technology	Hire experienced EV safety SMEs to research and collect content.
2) Hire a Training Development Team	Locate & contract with an experienced web training developer.
3) Conduct Virtual Project Kickoff Meeting	Organize, invite, and moderate the project kickoff meeting attended by project SMEs and project partners with the goal of confirming project scope and determining gaps in existing EV knowledge.
4) Collect Existing EV Content, Research, and Testing	Collect and refine existing EV content including research, testing, codes & standards, and other pertinent literature.
5) Develop EV Workshop Toolkit	Conceptualize and build a comprehensive and highly engaging Electric Vehicle Community Preparedness Assessment Workshops curriculum and toolkit
6) Develop/Revise Curriculum Outlines for EV Training Video Modules	Build comprehensive EV training video module curriculum outlines for code officials, charging station installers, utilities, fleet owners, manufacturers/dealers, garage maintenance facilities, insurers, and the public/vehicle owners. Revise existing outlines for NFPA's crash reconstruction and tow and salvage operator programs.
7) Develop/Revise Storyboards and Scripts for EV Training Video Modules	Develop scripts and storyboards for the code official, charging station installer, utility, fleet owner, manufacturer/dealer, garage maintenance facility, insurer, and public/vehicle owner video modules. Revise scripts and storyboards for NFPA's crash reconstruction and tow and salvage operator programs.
8) Produce EV Training Video Modules	Produce the final EV Training video modules for the code official, charging station installer, utility, fleet owner, manufacturer/dealer, garage maintenance facility, insurer, and public/vehicle owner audiences. Update NFPA's existing crash reconstruction and tow and salvage operator programs.

Project Tasks	Description
9) Develop EV Workshop Communication and Delivery Plan	Develop a nationwide Electric Vehicle Community Preparedness Workshop Communication and Delivery Plan detailing workshop regions/location, and a master plan for community outreach and engagement.
10) Final EV Workshop Communication and Delivery Plan Completed	Deliver a final EV Workshop Communication and Delivery Plan to effectively propogate the planning sessions and courses.
11) Coordinate and Schedule ≥15 Electric Vehicle Community Preparedness Assessment Workshops	Coordinate and schedule Electric Vehicle Community Preparedness Assessment Workshops in pre-determined regions/locations (found in the master plan for community outreach and engagement).
12) Deliver ≥15 Electric Vehicle Community Preparedness Assessment Workshops	Coordinate with event host coalitions before, during, and after Electric Vehicle Community Preparedness Assessment Workshops to ensure successful delivery of approximately 15 workshops. This includes pre-event training and preparation, day of event logistics, and post event feedback.
13) Compile Feedback	Collect participant and host feedback & evaluations from each coalition host and incorporate into a milestone report.
14) Coordinate and Schedule ≥15 additional Electric Vehicle Community Preparedness Assessment Workshops	Coordinate and schedule Electric Vehicle Community Preparedness Assessment Workshops in pre-determined regions/locations.
15) Deliver ≥15 additional Electric Vehicle Community Preparedness Assessment Workshops	Coordinate with event host coalitions before, during, and after Electric Vehicle Community Preparedness Assessment Workshops to ensure successful delivery of events. This includes pre-event training and preparation, day of event logistics, and post-event feedback.

Results

During the first budget year of this project, NFPA accomplished all the goals that it had set. NFPA hired three experienced EV Subject Matter Experts (SMEs) and an eLearning development firm to create the training courses. NFPA program managers held virtual kickoff meetings with the development team, and subsequently collected and catalogued all NFPA's research information, existing EV safety content, videos, photos, animations, storyboards, scripts, and testing results from the past 12 years, for use in the course development phase. The SMEs split up the eight new training areas (insurance adjusters, EVSE installers, code officials, utilities, fleets, auto manufacturers, dealers, and mechanics), the two existing programs being updated (crash reconstruction, and tow and salvage), and the EV Workshop Toolkit. The development team held many meetings with the SMEs, obtaining specific information and content from each SME on their assigned sectors. Each course now has a detailed content outline, and NFPA has approved the eLearning developer's high-level design strategy, user interface designs, and prototypes for all courses.

NFPA decided that a large percentage of the EV workshop materials will be derived from the 10 training courses' content and curricula to ensure consistency of messaging. The eLearning developer has delivered a detailed 15-page workshop outline including activity and media examples, which is current under review for approval.

NFPA has also initiated efforts for its EV Community Preparedness Communication and Delivery Plan by hosting planning meetings with our partnering Clean Cities Coalitions. They have submitted a draft communication and delivery report to NFPA for review and approval. Included in this report are 30+ proposed workshop host coalitions and communities for virtual events (pending DOE approval) that will take place during the second and third performance periods of this project. NFPA identified Workshop hosts through the deployment of a nationwide Clean Cities Coalition survey that measured each coalition interest level and preparedness for such an event. See Table I.50.2.

Table I.50.2. Proposed Workshop Locations

Coalition/Host
Alabama Clean Fuels Coalition
Central Florida Clean Cities
Central Oklahoma Clean Cities
Centralia Clean Fuels Coalition (NC)
Chicago Area Clean Cities
Clean Communities of Central New York
Clean Fuels Ohio
Dallas-Fort Worth Clean Cities
Delaware Clean Cities Coalition
Drive Clean Colorado
Drive Clean Indiana
East Bay Clean Cities (CA)
East Tennessee Clean Fuels Coalition
Eastern Pennsylvania Alliance for Clean Transportation
Empire Clean Cities
Georgia Clean Cities
Kansas City Regional Clean Cities
Kentucky Clean Fuels Coalition
Land of Sky Clean Vehicles Coalition (NC)
Louisiana Clean Fuels
Michigan Clean Cities
Middle-West Tennessee Clean Fuels Coalition
North Dakota Clean Cities
Northern Colorado Clean Cities
Pittsburgh Region Clean Cities
Southeast Louisiana Clean Cities
St. Louis Clean Cites
Triangle Clean Cities (NC)
Tulsa Area Clean Cities
Utah Clean Cities
Virginia Clean Cities
Western Riverside County Clean Cities Coalition (CA)
Wisconsin Clean Cities
Yellowstone-Teton Clean Cities

Lastly, to support the marketing and promotion of these EV Community Preparedness workshops, NFPA has secured the web domain www.ReadyForEVs.com (under development), which will house workshop-related materials and, eventually, workshop registration.

Conclusions

NFPA is proud to report that the project has met or exceeded every objective initially set forth in the Statement of Project Objectives during budget period 1.

- NFPA has collected 12+ years of training curriculum, research findings, safety data, videos, and animations which has led to the development of more than 200 pages of detailed course outlines and curricula.
- NFPA has developed 10 prototype EV community preparedness online training tracks.

- NFPA has developed and approved a 15-page EV Community Preparedness Workshop Outline and media prototypes.
- Through our partner CCCs, NFPA has conducted targeted Clean Cities Coalition outreach to identify 30+ suitable EV Community Preparedness virtual workshop hosts.
- NFPA has developed a draft EV Community Preparedness Communication & Delivery Plan that includes detailed outreach and communications activities to ensure successful execution of workshop events during the next budget periods 2 and 3 of this project.

I.51 Creating the NFPA Distributed Energy Resources Safety Training (DERST) Program (National Fire Protection Association)

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Start Date: June 1, 2021 End Date: May 31, 2024
Total Project Cost: $ 1,182,966 DOE share: $1,039,244 Non-DOE share: $143,722

Project Introduction

Distributed Energy Resources (DERs) are small geographically dispersed electricity generators that are connected to a local distribution system. DERs can include solar panels, energy storage systems, small gaseous fueled generators, electric vehicles, and controllable loads, such as HVAC systems and electric water heaters. First responders will confront DERs in abnormal events such as fires, chemical releases, mechanical damage, water immersion, etc.

During an emergency event, the National Fire Protection Association (NFPA) wants to ensure responders are properly trained to make correct tactical decisions, so as to optimize protection of life, ensure incident stabilization, and conserve property. First responders must understand the control systems and the individual technologies involved with DERs, as well as their interconnections and how to approach an incident scene. NFPA is in the process of developing a suite of solutions to support the rapid growth of clean energy technologies, by training and educating firefighters, first responders, and other relevant emergency response professionals. Ensuring that these stakeholders understand DER technologies—especially the inherent risks and ramifications of responding to DER incidents—will be key to furthering acceptance and implementation of DERs in the U.S.

For more than a decade, NFPA has been committed to developing and delivering DER safety training (DERST) for our nation’s emergency responders, currently offering the most popular U.S. responder programs on energy storage systems (ESS), photovoltaics (PV), electric vehicles (EVs), and electric vehicle power supply equipment (EVSE). NFPA’s objective is to take its existing DER training resources to a whole new level by 1) updating and modularizing objective-based classroom training courses for fire departments across the country; 2) creating a multi-player serious gaming DER incident simulator (the first of its kind—think flight simulator for pilots), and 3) developing a unique DER props guide for setting up the fire service field evolutions training (outdoor department training held at academy field settings). Together, these resources will provide emergency responders nationwide with engaging, innovative, and cutting-edge training and simulations on pre-planning DER installations and effectively managing DER incidents. The result will be increased familiarity, greater levels of preparedness, and increased acceptance and promotion of DER technologies across the US.

Objectives

The objective of this project is to research, develop, and deploy a suite of Distributed Energy Resources Safety Training (DERST) educational programs and tools for battery ESS, solar/PV systems, EVs and their charging infrastructure (EVSE), and building efficiency/retrofit technologies. NFPA will explore scenarios that consider the interaction of these technologies when encountered in the field. The DERST will be primarily targeted to firefighters, first responders, public safety officials, and other relevant emergency response professionals. In support of this objective, NFPA is currently working on:

1) Gathering the latest DER safety research and studies.
2) Conducting field testing and collecting data and best practices using the latest DER equipment and vehicles in controlled emergency fires and incidents.
3) Updating and modularizing our existing train-the-trainer programs for the fire service and emergency medical service on ESS, PV, and EV/EVSE, and distributing them across the country.
4) Creating a multi-user and role, scenario-based serious gaming platform for fire departments to train together on interactive, real-world, multiple DERs in the same structures (think flight simulator-style training for a team of firefighters).
5) Developing a DER field evolution prop guide for instruction and safety when conducting live DERST tactics training at any fire academy or outdoor training center, and deploying it nationwide.

Approach

To achieve the goal for this 36-month project, NFPA detailed eleven (11) tasks that supported successful completion of the established project objectives. See Table I.51.1: Project Approach.

Table I.51.1. Project Approach

Project Tasks	Description
Project Management and Planning	NFPA shall develop and maintain the Project Management Plan (PMP). The content, organization, and requirements for revision of the PMP are identified in the Federal Assistance Reporting Checklist and Instructions. The Recipient shall manage and implement the project in accordance with the PMP.
Kick-Off Meeting	NFPA will participate in a project kickoff meeting with the DOE within 30 days of project initiation.
1) Hold Partners Kickoff Meeting	Assemble partners and stakeholders for a kickoff meeting, determining issues, risks, responsibilities, rules, project schedule and milestones.
2) Conduct DER Fire Testing	Coordinate and conduct state-of-the-art incident testing DERs in controlled emergency fires and incidents. This testing will include burning an actual residential structure with multiple DER equipment involved in the fire (including PV, ESS, & EVSE) and uncover hazards and best practices for extinguishing the structure and DERs effectively and safety.
3) Collect the Latest DER Safety Research	Review and collect the latest DER literature, gathering up-to-date testing, tactics, codes, standards, regulations, and best practices to inform curriculum development.
4) Revise and Update Existing Train-The-Trainer Classroom Courses	Modularize and enhance the classroom training with the latest DER tactics.
5) Analyze and Document DER Fire Test Findings	Following the completion of the DER Fire Testing, the recipient will collect and synthesize all available data received from the burn testing.

Project Tasks	Description
6) Dissemination of Classroom Training Materials	DER safety classroom modules will be propagated across the country to all state and local fire training academies for their usage.
7) Onboarding of Serious Gaming Development Vendors	Issue a request for proposals for a qualified eLearning/instructional design and development vendor.
8) Development of Serious Gaming DER Safety Simulator	Conceptualize and develop a multi-player, multi-role, multi-venue, multi-interconnected-DER incident gamified training tool.
9) Comprehensive Review of Gaming Simulator	Evaluate the Serious Gaming DER Safety Simulator from a scientific, technical, and responder tactics standpoint during a multi-tiered beta review process prior to delivery.
10) Field Evolution Activities and Props Guide Development	Conceptualize, design, and develop a unique guide to field evolution activities and prop selection that aids departments setting up outdoor field evolutions at fire academies and training centers.
11) Field Evolution Activities and Props Guide Dissemination	Disseminate completed field evolution guide to state and local fire training academies through a nationwide outreach campaign.

Results

During the first five months of this project, NFPA has met all project goals and objectives. Initially, NFPA held kickoff meetings with subrecipient partners University of Texas, Austin (UT-Austin), the North American Fire Training Directors, and Argonne National Laboratory (Argonne), to introduce those working on the project, provide channels of collaboration, and outline the scope, objectives, goals, responsibilities, chain of authority, and government rules for operating as subrecipients. During the first five months of the project, UT-Austin worked with local fire departments to identify possible locations to hold residential structure burn testing. UT-Austin has now started planning the next steps for one of the most promising sites.

NFPA and UT-Austin have narrowed the burn test location to two potential structures. The first, located at 1140 Shady Lane, Austin, TX, is not ideal, as it does not have a garage. Having a garage to start a fire in would be preferable, as that would be where most homeowners would place an EV, charging station, and energy storage. The second residential structure—now the prime candidate—is located at 4612 Pinehurst Drive South, Austin TX (Figure I.51-1).

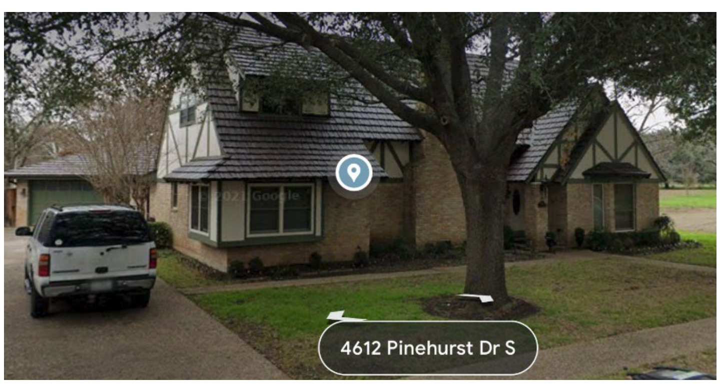

Figure I.51-1. Primary Property Focus for Burn Test/Courtesy of Google Maps

This structure has a garage—though it is not directly attached to the house. A connecting passage between the house and the garage could be constructed for the purposes of this test. It is in the budget to do so, and this will be considered if a suitable residential structure that has a built-in garage as part of the first floor of the structure is not found in the next couple of months. A search will continue for another eight weeks for additional options.

When a property is chosen, this project's burn testing will be conducted by UT-Austin to obtain data, information, metrics, and video footage to be analyzed. This vital safety data will be used for subsequent modeling, which will be incorporated directly into the gamification experience developed in the second budget period of the project to create a more realistic simulation experience, rather than generating random flames, explosions or wind currents.

Figure I.51-2. Solar Panels for Burn Test/Courtesy of UT-Austin

NFPA and UT-Austin have acquired a donation of solar cells to mount and connect on the proposed burn-test property (Figure I.51-2) and we continue to search for an energy storage system and an EV to purchase for the test. NFPA did purchase an energy storage system (LG Chem RESU10H 9.8kWh Primary Lithium-Ion Battery System); however, the order was recently canceled by the vendor due to supply chain issues. The EV NFPA plans to purchase will be placed in a garage and take part in the fire, as the cause of the blaze and/or as a victim of the fire, to see how the vehicle and its batteries react. The used EVs being considered for purchase are a Tesla 3, Hyundai Kona Electric, or a GM Bolt, based on their high-powered battery packs. Argonne has begun gathering the latest technical data sheets and safety information on distributed energy components used, which will be incorporated into the content of the gamification experience in the second period of the grant. They are also providing advice and direction on burn test planning.

Conclusions

NFPA is proud to report that the project has met or exceeded every objective initially set forth in the Statement of Project Objectives (SOPO) during the first five months of budget period 1.

- NFPA held kickoff meetings with each subrecipient working on this grant, including the University of Texas, Austin, the North American Fire Training Directors, and Argonne National Laboratory, to introduce collaboration among participants, define the scope, objectives, goals, and responsibilities, and to outline the chain of authority and government rules under a DOE grant.
- UT-Austin has initiated the search with local fire departments for possible structure burn-down properties for NFPA's residential structure burn test, identifying two. The structure that is currently a prime candidate is located at 4612 Pinehurst Drive South, Austin, TX, and discussions are now centering on securing this property for our tests.

- NFPA and UT-Austin have also arranged a donation of solar cells for the project and NFPA continues to look for an energy storage system to purchase, since our planned purchase was disrupted by supply chain issues. NFPA and Argonne continue to search for a used EV—a Tesla Model 3, Hyundai Kona Electric, or a GM Bolt - daily.

- Argonne National Laboratory has begun gathering the latest technical data sheets and safety information on distributed energy components, which will be incorporated into the content of the gamification experience in the second period of the grant. They are also providing advice and direction on burn test planning.

II. National Laboratory Projects

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

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Start Date: October 1, 2020 End Date: September 30, 2021
Project Funding (FY21): $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 30 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 to people in a variety of formats on 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) 2021, the AFDC boasted a 49% increase over FY 2020 in page views, with more than 6 million visitor sessions and 4.8 million unique visitors. Those visitors accessed pages on the AFDC website more than 17.8 million times. Visits to the site included an average of 12% returning visitors and 88% 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, 40% of all EERE website page views are from AFDC pages. Additionally, 14 of the top 30 most-viewed pages in the EERE portfolio are AFDC pages. Figure II.1-1-1 illustrates the AFDC's steady growth in FY 2021 compared to FY 2020.

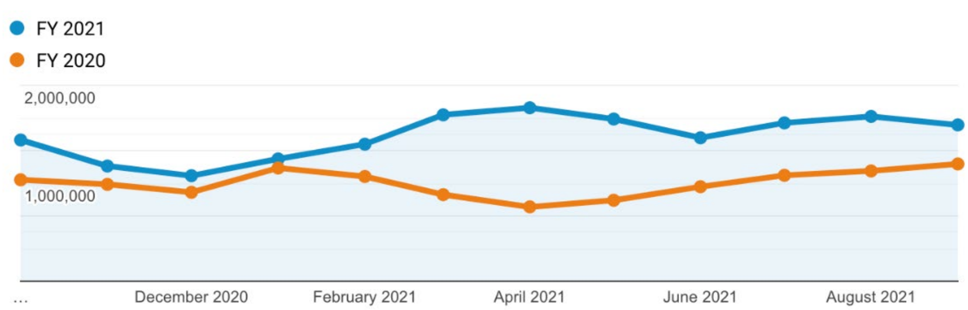

Figure II.1-1. Page views in FY 2021 compared to FY 2020

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 2021 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.

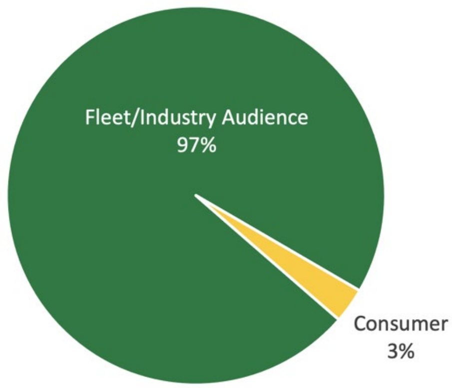

Figure II.1- 1. Sources of AFDC visits based on the top 40 referrals

Some of the top referrers in FY 2021 included several vehicle Original Equipment Manufacturer (OEM) sites linking to the laws and incentives information, with GMC leading the referral count. In FY 2021, the Federal and State Laws and Incentives pages were viewed 4.1 million times, particularly via referrals from numerous vehicle manufacturers. During FY 2021, there were more than 7,700 websites linking to the AFDC, resulting in 1.3 million 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 2021.

Table II.1.1. Top 20 Referrers to the AFDC Website in FY 2021

Referrer	Sessions
gmc.com	125,119
vw.com	119,057
toyota.com	105,228
ford.com	98,378
bmwusa.com	85,891
shop.tesla.com	78,972
kandiamerica.com	39,635
tesla.com	39,303
automobiles.honda.com	37,427
cadillac.com	35,882
miniusa.com	16,031
onlineev.com	16,545
m.facebook.com	14,230
subaru.com	14,725
fueleconomy.gov	14,865
washingtonpost.com	12,049
porsche.com	10,167
edmunds.com	9,574
energysage.com	9,138
search.usa.gov	15,228

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 over time, 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 2021, interest in fuels and vehicles information accounted for 34% of the total page views on the AFDC, compared to 32% in FY 2020. Historical data shows that the most frequently accessed pages by fuel type vary from year to year. In FY 2021, electricity was the most popular topic in terms of page views for fuels and vehicles information with 38% of the total traffic, followed by ethanol with 25% of the total page views.

Figure II.1-3 depicts the breakdown of interest in content by fuel type in FY 2021.

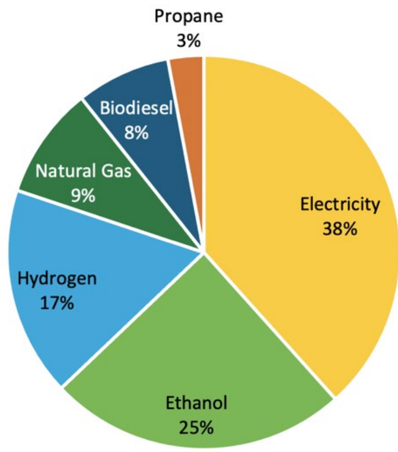

Figure II.1-2. Interest in fuels and vehicles information by subject based on page views in FY 2021

As shown in Figure II.1-4, 41% of the queries for fueling station locations involved electric charging. This is an increase over electric charging's 28% share in FY 2020.

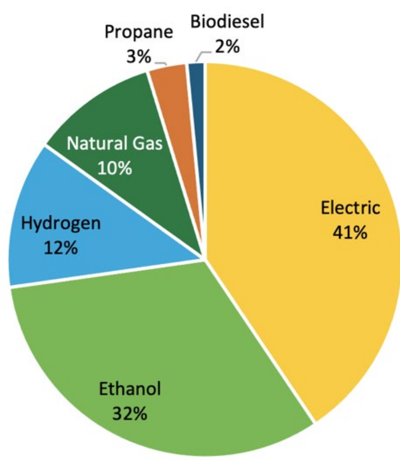

Figure II.4-1. Interest in stations information by subject based on page views in FY 2021

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 15,200 views in FY 2021; 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 2021, the EVI-Pro Lite tool saw a 249% increase in page views compared to FY 2020. The Laws and Incentives Search and the Vehicle Search tool also saw a significant increase in page views compared to FY 2020. Together, the tools accounted for 68% of the total page views on the AFDC in FY 2021, which was up from 67% in FY 2020.

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

Tool	FY 2021 Page Views	FY 2020 Page Views	% Change
Alternative Fueling Station Locator	6,099,770	4,396,841	39%
Laws and Incentives Search	4,054,636	2,122,904	91%
Maps and Data Search	828,238	623,395	33%
Vehicle Cost Calculator	664,647	558,298	19%
Vehicle Search	270,794	137,559	97%
State Information Search	77,461	56,232	38%
Case Studies Search	46,209	41,569	11%
Publications Search	35,586	31,710	12%
Fuel Properties Comparison	34,145	28,182	21%
EVI-Pro Lite	30,407	8,714	249%

Several of these tools are available as widgets that allow users to embed the tools on their own websites. In FY 2021, the Alternative Fueling Station Locator widget was the most popular widget, with more than 682,000 page views while embedded on other websites, accounting for 11% 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 2021 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 2021

Data	API Requests	Unique API Users	Downloads
Alternative Fueling Stations	29,255,053	4,192	3,924
Laws and Incentives	42,461	41	4,117
Vehicles	48,251	44	1,916

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 29.2 million requests in FY 2021, which was up from about 25.6 million requests in FY 2020.

The laws and incentives API received more than 42,000 requests in FY 2021. 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 2021 was the fuel properties comparison chart, with more than 34,000 downloads. The high-resolution images for vehicle illustrations had more than 369,000 downloads.

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, 2020 End Date: September 30, 2021
Project Funding (FY21): $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, 10 major vehicle types and 27 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) 2020 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 10,300 individuals for the spreadsheet and 7,500 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) 2021, the AFLEET Tool had several factors that needed updating. Similar to the 2020 revision, AFLEET required an annual update to match new modeling results from GREET [2]; new fuel price data from the Alternative Fuel Price Report (AFPR) [3], and the Energy Information Agency (EIA) [4]. In addition, to update vehicle operation air pollutant emissions of LDVs and HDVs, as well as off-road equipment, Argonne utilized state-level emission factors generated from the U.S. Environmental Protection Agency's (EPA's) MOVES model, which recently underwent major revisions for the first time in six years [5]. New cost data on factors such as insurance, maintenance, repair, and fees for a wide range of LDVs and HDVs, for both conventional and alternative fuels, became available from a VTO-funded study [6]. Off-road equipment cost analysis was developed for the 2020 revision building off the 2019 revision, which added off-road equipment emissions analysis.

Approach

Argonne used the GREET 2021 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. 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.

Starting in AFLEET 2017, Argonne implemented the option to use diesel in-use multipliers to allow users to adjust the default emission rates from MOVES2014 for diesel vehicles. Argonne implemented this feature because recent analyses found that diesel in-use NOx emissions are much higher than their laboratory certification results, and that MOVES2014 was underestimating their estimates of real-world emissions due to a lack of testing data. In 2020, EPA released a new version of MOVES (MOVES3), which incorporated significant updates from the previous version, MOVES2014. For example, MOVES3 updated gasoline LDV emission rates for hydrocarbon, carbon monoxide, and nitrogen oxides (NOx) based on millions of test results from in-use testing data and inspection and maintenance data from the State of Colorado. In addition, MOVES3 included major improvements to model year 2010 and newer diesel HDV running emission rates based on manufacturer-run in-use testing data from hundreds of trucks. With these updates in MOVES3, the diesel in-use multiplier is no longer is applied to HDVs, as EPA specifically focused on this issue in its update. However, EPA did not examine diesel LDV NOx, so the existing multiplier of 5.0 remains in AFLEET 2020. Figure II.2.1 shows the relative NOx emissions in MOVES3 versus the MOVES2014 baseline for each of the 10 major vehicle types in AFLEET. For all HDV types, the NOx emissions are much higher in MOVES3 than previously estimated.

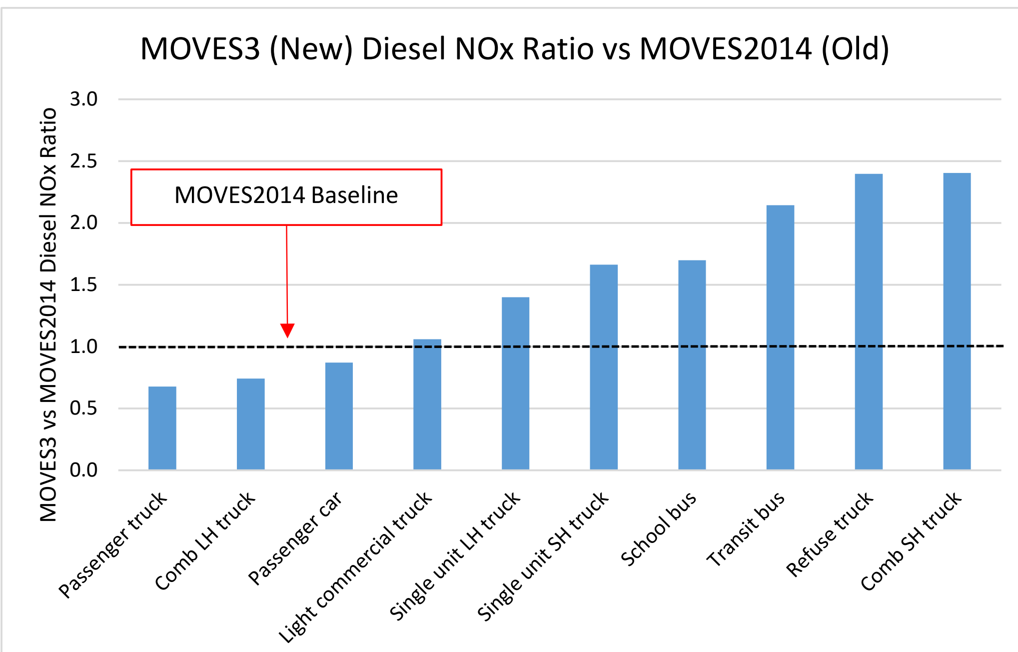

Figure II.2-1. MOVES3 vs MOVES2014 NOx Emission Rate Comparison

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 fuel types. This effort required analyzing the specifications by fuel type to ensure 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 MOVES3. 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.

Results

During FY 2021, users downloaded the AFLEET Tool about 900 times, and the accompanying AFLEET user manual about 2,200 times. To date, 10,300 individual users have downloaded the tool. The user-friendly AFLEET online tool released in FY 2019 had more than 7,500 new users.

Conclusions

In FY 2021, 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.

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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 (FY21): $4,400,000 DOE share: $3,000,000 Non-DOE share: $1,400,000

Project Introduction

The U.S. Department of Energy, MathWorks, and General Motors have joined forces with more than 20 government and industry sponsors to establish the EcoCAR Mobility Challenge, a four-year DOE Advanced Vehicle Technology Competition (AVTC). This workforce development program will seed the industry with more than 2,000 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 third year, culminating with distributed vehicle testing in May 2021 and a virtual awards ceremony in June 2021 where government and auto industry representatives presented teams with 49 awards in various categories.

Objectives

The objectives for the EcoCAR program are as follows:

- 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.

Table II.3.1 lists the universities participating in the EcoCAR mobility challenge, along with the abbreviations used in this report.

Table II.3.1. EcoCAR Mobility Challenge Year 3 Student Participation by Major

University	Abbreviation
Embry-Riddle Aeronautical University	ERAU
Georgia Institute of Technology	GT
McMaster University	MAC
Mississippi State University	MSU
The Ohio State University	OSU
University of Alabama	UA
University of Tennessee	UT
University of Washington	UW
University of Waterloo	UWAFT
Virginia Tech	VT
West Virginia University	WVU

Approach

Fiscal Year (FY) 2021 roughly aligned with the third 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. 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) mimics General Motors' own VDP and provides developmental goals for the teams and their vehicles.

Each year of the competition, teams are provided with a detailed set of technical goals for their vehicle development process. These goals are useful to provide uniform expectations across all teams for vehicle development milestones throughout the four-year competition series. A summary of these goals is provided below:

- Propulsion System goals (75% complete)
    - Complete and reliable integration of all vehicle components.
    - Updated controller and plant models to reflect use in Model in the Loop, Hardware in the Loop, and in-vehicle development.
    - Vehicle propulsion system is fully functional with basic energy management strategy.
    - Vehicle propulsion controller contains basic fault detection.

- Functionality on team vehicle at competition:
  - Propulsion system should be reliable, breakdowns should be uncommon.
  - Propulsion system supervisory controls should be initially refined for fuel economy.
  - Vehicle ride quality, drive quality, and emissions should be maintained.
- CAV System goals (50% complete)
  - CAV controller is updated with basic functionality and fault mitigation.
  - Simulate linear autonomy and energy consumption on Vehicle-to-Vehicle (V2V)-equipped highways.
  - Functionality on team vehicle at competition:
    - Basic CAV control interfaces and safety checks.
    - Reliable forward perception capable of tracking two or fewer target vehicles.
    - Baseline-functional linear autonomy with ability to perform functional overrides, command friction brakes and ACC torque, and follow simple drive profiles.

The impacts of the COVID-19 pandemic continued to be felt through Year 3 of the EcoCAR Mobility Challenge. Restrictions on travel and in-person gatherings significantly altered regular operations of all EcoCAR teams and drastically changed what activities the EcoCAR program was able to offer to students. Several high-value competition activities normally conducted in-person had to be adapted to a virtual format.

EcoCAR training workshops and sponsor recruiting events

The training normally offered through multi-day, cross-disciplinary, in-person workshops was decomposed and transitioned to a virtual format. The training was delivered over the course of the semester rather than a compressed 3-day timeframe. In-person sponsor recruiting events that typically happen during EcoCAR training workshops were also transitioned to a virtual format using the Brazen digital recruiting fare platform.

Vehicle Technical Inspection for EcoCAR team vehicles

Team vehicles are normally subject to in-person inspection by competition organizers at least once per year. This requires a competition representative to be physically present with the vehicle, which was not feasible during FY21. As a workaround, competition organizers developed extensive training to teach student team members how vehicle inspections are conducted and communicate the inspection criteria used to identify critical safety issues. The end goal was to equip students to inspect their own vehicle during this interim period where it was not possible to arrange an inspection by a competition representative.

EcoCAR team local outreach activities

EcoCAR normally maintains 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 normally engaged with recruiting and STEM outreach, including outreach to underrepresented minority groups. These outreach activities are typically done through in-person interactions, which were not possible during FY21. As a workaround, EcoCAR teams conducted outreach activities through virtual means, such as virtual meetings with student classes at local schools.

Pre-competition event to support specialized vehicle testing event for EcoCAR teams

Nominally, Year 3 of the EcoCAR Mobility Challenge calls for an in-person vehicle testing event to spur on team vehicle development. Many EcoCAR teams have limited access to adequate testing facilities, so a midyear testing event also ensures all teams have at least some access to full-feature test facilities. In lieu of an in-person testing event prior to Year 3 competition, teams were provided with "test grants" to enable the purchase of test time at a robust vehicle testing facility in the team's region.

Year-end competition design presentations and vehicle evaluation

Typically, Year 3 of EcoCAR would include a full array of vehicle testing events conducted at a General Motors Proving Ground. Students would also be challenged to deliver several technical design presentations to industry judges in a conference room setting. COVID-19 restrictions prohibited either in-person activity from taking place. Instead, year-end vehicle testing was conducted in a distributed fashion; the competition organizers developed event test procedures that were scalable to any test facility and executable by teams. This enabled teams to complete requisite vehicle validation testing at regional test locations with limited travel required. Presentations were transitioned to a virtual format using the 6Connex virtual conference platform.

Results

Student participation and employment outcomes

The program was successful in achieving its core objective: training the next generation of automotive engineers, communicators, and business leaders. Table II.3.2 summarizes student participation to date; a total of 2432 students have participated in the three years to date of the EcoCAR Mobility Challenge.

Table II.3.2. EcoCAR Mobility Challenge Student Participation by Major (to date)

	Total	% of Total	STEM?
Mechanical Engineering	949	39.0%	Y
Electrical/Computer Engineering	566	23.3%	Y
Computer Science	212	8.7%	Y
Mechatronics Engineering	135	5.6%	Y
Other STEM Majors	376	15.5%	Y
Non-STEM Majors	194	8.0%	N
Total	**2432**	**100%**	--

EcoCAR students secured internships, co-ops, and full-time jobs at a wide variety of companies; a total of 182 employers hired an EcoCAR student during the 2020-2021 academic year (Aug 2020 – Aug 2021). EcoCAR students found employment in a vast array of industries and geographic locations, but automotive industry companies are the number one employer of EcoCAR students and hired students at a rate two times higher than any other industry sector. Research also shows that EcoCAR students who accepted full-time jobs during this time period out-earned their peers by $2400-$15600 depending on major, as shown in Figure II.3-1.

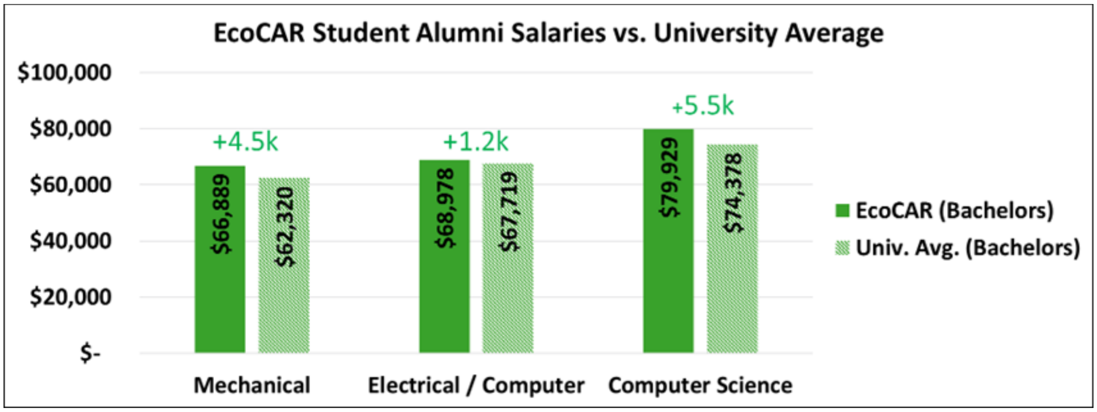

Figure II.3-1. Salary comparison of EcoCAR graduates and their peers

EcoCAR training workshops, sponsor recruiting events, and vehicle inspections

To fill the void left by the inability to conduct in-person events, EcoCAR launched the Career-Connected Learning initiative (CCL). This broad-reaching initiative bundles together several key aspects of the EcoCAR program into a cohesive branded year-long activity center. Figure II.3-2 summarizes the activities conducted under the CCL umbrella and the final outcomes of those activities by the end of EcoCAR Year 3.

Figure II.3-2. Summary of Career-Connected Learning activities and end results

EcoCAR team local outreach activities

In year 3 of the EcoCAR Mobility Challenge, teams were forced to conduct all outreach activities virtually due to COVID-19. Despite this challenge, EcoCAR teams still conducted 25 youth outreach events, reaching a total of 1358 students.

Pre-competition event to support specialized vehicle testing event for EcoCAR teams

EcoCAR teams were able to use "test grants" to break down barriers inhibiting vehicle testing during Year 3. As a result, almost every team was able to accumulate at least 100 miles of testing and the majority of teams exceeded the competition goal of accumulating 400 test miles during the academic year (August 1, 2020 through April 30, 2021). Figure II.3-3 provides a breakdown of test mileage accumulation by team during this timeframe.

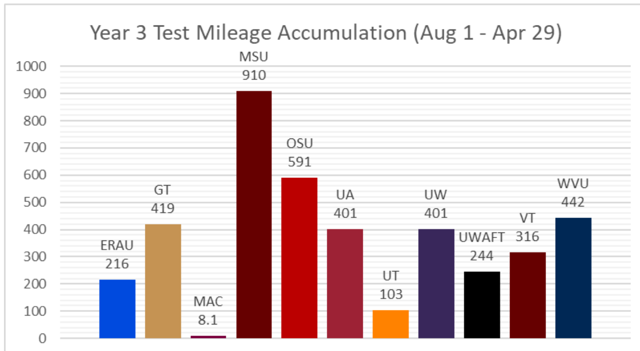

Figure II.3-3. EcoCAR Mobility Challenge team test mileage accumulation during 2020-2021 Academic year

Year-end competition design presentations and vehicle evaluation

The final competition for Year 3 of the EcoCAR Mobility Challenge featured seven virtual presentations evaluated by a total of 55 judges from government and industry. Additionally, four other awards were presented to teams based on written submissions. Table II.3.33 summarizes the top three overall teams and the teams with the best Project Management and Communications programs.

Table II.3.3. Summary of Award Winners from Year 3 EcoCAR Mobility Challenge Final Competition

Award	Winner
1st Place Overall	UA
2nd Place Overall	OSU
3rd Place Overall	WVU
1st Place Project Management Program	UA
1st Place Communications Program	WVU

Conclusions

The continuation of the COVID-19 pandemic drastically altered the operations and activities of the EcoCAR mobility challenge. EcoCAR universities were required to comply with varying limits on in-person interaction and lab/garage access due to the continuation of the COVID-19 pandemic. EcoCAR organizers also reimagined EcoCAR training and testing activities to pivot from in-person training and testing workshops, which have traditionally been the backbone of the AVTC program. As a result, Year 3 of the EcoCAR Mobility Challenge was markedly different from any AVTC competition, but was successful nonetheless. The program was able to leverage 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 3 VDP goals.

Through three years, this highly successful workforce development program has already exposed more than 2,400 students to 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 funds multiple graduate research assistant positions on each EcoCAR team, each year of the program. This includes engineering graduate research assistants (from multiple disciplines), as well as a Project Manager and a Communications Manager. Table II.3.44 summarizes the publications produced as a result of this funding during FY21.

Table II.3.4. Summary EcoCAR Team Publications (FY 2021)

Team	Publication/Presentation Title	Author Name	Conference / Journal
ERAU	Object Tracking Comparison for Automated Vehicles Using MathWorks Toolsets	Alex Bassett	SAE WCX
ERAU	A Novel Covert Path Planner Using A-Star and Akima Splines	David Cicotte	ACIRS 2021
ERAU	Simulation Environment to Assess Human Reaction in Autonomous Vehicle Takeover Events	Andrew Ferree	IEEE
ERAU	Automated Scenario Generation Using Halton Sequences for the Verification of Autonomous Vehicle Behavior in Simulation	Andrew Ferree	ERAU
ERAU	A Comprehensive Mapping and Real-World Evaluation of Multi-Object Tracking on Automated Vehicles	Alex Bassett	ERAU
ERAU	Object Tracking Comparison for Automated Vehicles Using MathWorks Toolsets	Alex Bassett	SAE WCX
ERAU	A Novel Covert Path Planner Using A-Star and Akima Splines	David Cicotte	ACIRS 2021
ERAU	Simulation Environment to Assess Human Reaction in Autonomous Vehicle Takeover Events	Andrew Ferree	IEEE
ERAU	Automated Scenario Generation Using Halton Sequences for the Verification of Autonomous Vehicle Behavior in Simulation	Andrew Ferree	ERAU
ERAU	A Comprehensive Mapping and Real-World Evaluation of Multi-Object Tracking on Automated Vehicles	Alex Bassett	ERAU
MSU	Design and Optimization of a mild Hybrid Electric Vehicle with Energy Efficient Longitudinal Control	Amine Taoudi, Moinul Shahidul Haque, Andrea Strzelec, Randolph Follett	SAE International Journal of Alternative Powertrains
OSU	Characterization and Analysis of BAS Torque Capabilities	Ron Smith	The Ohio State University
OSU	Dynamic Thermal Model for an Electric Motor and Inverter System	Kerri Loyd	The Ohio State University

Team	Publication/Presentation Title	Author Name	Conference / Journal
OSU	Integration and Testing of a Basic Hybrid Control Strategy and Analysis of Refinement Method to Improve Fuel Economy	Hari Ranga	The Ohio State University
OSU	Design and Implementation of Longitudinal and Lateral Controllers in an SAE Level 2 Autonomous System	TJ Kirby	The Ohio State University
OSU	Enhancement to Perception System and Sensor Calibration	Kanna Venkateshwara Sundaraman	The Ohio State University
OSU	Encryption, Transmission, and Validation of Vehicle to Everything Data with DSCR Radios	Vinayak Sonandkar	The Ohio State University
OSU	Real-Time Look-Ahead Optimal Energy Management Strategy for Hybrid Electric and Connected Vehicles	Wilson Perez	The Ohio State University
UT	Radar-Camera Sensor Fusion for Joint Object Detection and Distance Estimation in Autonomous Vehicles	Ramin Nabati, Hairong Qi	12th Workshop on Planning, Perception and Navigation for Intelligent Vehicles, IROS 2020
UT	CenterFusion: Center-based Radar and Camera Fusion for 3D Object Detection	Ramin Nabati, Hairong Qi	WACV 2021
UT	Cftrack: Center-based Radar and Camera Fusion for 3D Multi-Object Tracking	Ramin Nabati, Landon Harris, and Hairong Qi	Submitted to IEEE IV21
UW	On Implementing Optimal Energy Management for EREV Using Distance Constrained Adaptive Real-Time Dynamic Programming	Aman V. Kalia and Brian Fabien	mdpi.com open access journal Electronics Volume 9 Issue 2 special topic "Optimization Base Energy Management Stategy for Hybrid-Electric Vehicles"
UWAFT	A Review of Range Extenders in Battery Electric Vehicles: Current Progress and Future Perspectives	Asad Bhatti	World Electric Vehicle Journal
VT	Analysis of Connected and Automated Hybrid Electric Vehicle Energy Consumption and Drive Quality	Christian Tollefson	SAE International
VT	Willans Line Based Equivalent Consumption Minimization Strategy for Charge Sustaining Hybrid Electric Vehicle	Christian Tollefson	Virginia Tech thesis
WVU	Implementation of Radial Basis Function Artificial Neural Network Into An Adaptive Equivalent Consumption Minimization Strategy For Optimized Control Of Hybrid Electric Vehicle	Thomas Harris	WVU ETD - ProQuest Dissertations and Theses

References

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

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

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Start Date: October 1, 2020 End Date: September 30, 2021
Project Funding (FY21): $792,000 DOE share: $792,000 Non-DOE share: $0

Project Introduction

The National Renewable Energy Laboratory's (NREL's) Transportation Technology Integration group, within the Transportation & Hydrogen Systems Department, provides technical and analytical support to the Vehicle Technologies Office's (VTO's) Alternative Fuels Regulatory activity, which is mandated by federal legislation. Specifically, NREL supports DOE's implementation of Sections 507(o), 501, and 508 of the Energy Policy Act of 1992 (EPAct) through the provision and management of information products and other technical, program, policy, and regulatory analyses. EPAct Sections 507(o) and 501 mandate that covered state and alternative fuel provider fleets (respectively) acquire alternative fuel vehicles (AFVs) as specific percentages of their new light duty vehicles. EPAct Section 508 requires DOE to establish a vehicle credit trading program to provide compliance flexibility to covered fleets. In Fiscal Year 2021, NREL's work focused on two areas: State & Alternative Fuel Provider program support, and rulemaking and regulatory activities. In addition to project management and operational functions, NREL's role is to analyze, make recommendations and implement means to streamline this congressionally-mandated program. NREL also integrates work across several related alternative fuel programs to leverage resources and ensure that researchers have access to the latest developments and knowledge within related DOE research and development programs.

Objectives

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

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

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

Approach

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

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

Results

Covered fleets report at the end of a calendar year for the preceding Model Year (MY), e.g., the reports submitted by December 31, 2020, covered MY 2020 vehicle acquisitions. In reports submitted at the end of 2020, 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 2020 acquisition requirements by more than 28%. 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 2020 petroleum use reduction requirements by more than 22%.

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 significantly from a little less than 8.3 million gallons in MY 2019 to over 17 million gallons in MY 2020. The biodiesel gallons reported by alternative fuel provider fleets was a program high. At the same time, DOE also saw a drop in total biodiesel credits earned, with fleet earning a total of 1,655 credits in MY 2020 for using biodiesel, a decrease from 2,414 credits earned in MY 2019. The divergence in the increase in reported amount of biodiesel used and the decrease in credits earned is due to fleets reporting more biodiesel than that for which they actually earn credits (i.e., fleets may earn credits for only up to half of their acquisition requirements).

Fleets reported a decrease in the number of reported creditable light-duty vehicles acquired (12,015) in MY 2020, which includes light duty AFVs, non-AFV hybrid-electric vehicles (HEVs), and neighborhood electric vehicles (NEVs), when compared to MY 2019 (18,053). MY 2020 marked the eighth 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 728.5 credits for partial-credit vehicles and 325 credits for investments in alternative fuel infrastructure and non-road equipment in MY 2020 (a 19% increase, for the three categories combined, over MY 2019 (885.5)).

Conclusions

The data for MY 2020 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 (ORNL)

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Start Date: October 1, 2020 End Date: September 30, 2021
Project Funding (FY21): $2,400,000 DOE share: $2,400,000 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* and manages the FuelEconomy.gov website 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 44,000 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 EPA, the Program publishes an electronic version of the *Guide* in the fall and sends letters and emails to new-car dealerships, libraries, and credit unions notifying them that the new *Guide* is available and providing a URL to its location on FuelEconomy.gov. 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 *2021 Fuel Economy Guide* currently contains information for 1,282 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 44,000 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 [1], 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 has features that address underserved populations. Most of the website information is available in Spanish, and the MotorWeek videos are shown on the V-me Spanish language channel. Tools that benefit low-income consumers include the Used Car Label tool, Fuel Savings Calculator, Trip Calculator, and Fuel-Saving Tips.

FuelEconomy.gov provides users with several search tools to help them find specific vehicles or vehicles that meet their desired 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.
- *GHG Emissions Calculator*. Estimates upstream GHG emissions rates for plug-in electric vehicles based on the user's vehicle and ZIP code.

FuelEconomy.gov makes much of its fuel economy information available to other websites, researchers, and other organizations via web services and data download. Edmunds, Chrysler.com, 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. DOE's Vehicle Cost Calculator uses 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. The program is currently expanding its web services data to include plug-in electric vehicle tax credit information.

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.

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 over the years to develop 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 2021, the FEI Program continued to help DOE meet its statutory requirement to produce an annual *Fuel Economy Guide* for light-duty vehicles. Model year 2021 was the fourth 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 newest *Guide* 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 2021 *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 2022 *Guide* available to the public on FuelEconomy.gov, as of the second quarter of FY 2021. This preliminary version contains data for model year 2022 vehicles already released by manufacturers. The 2022 *Guide* will be finalized and distributed in the first quarter of FY 2022.

Since its launch in 1999, FuelEconomy.gov has hosted more than 520 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 2021, FuelEconomy.gov hosted more than 30 million user sessions, more than 329 million page views, and more than 83,000 daily visits on average.

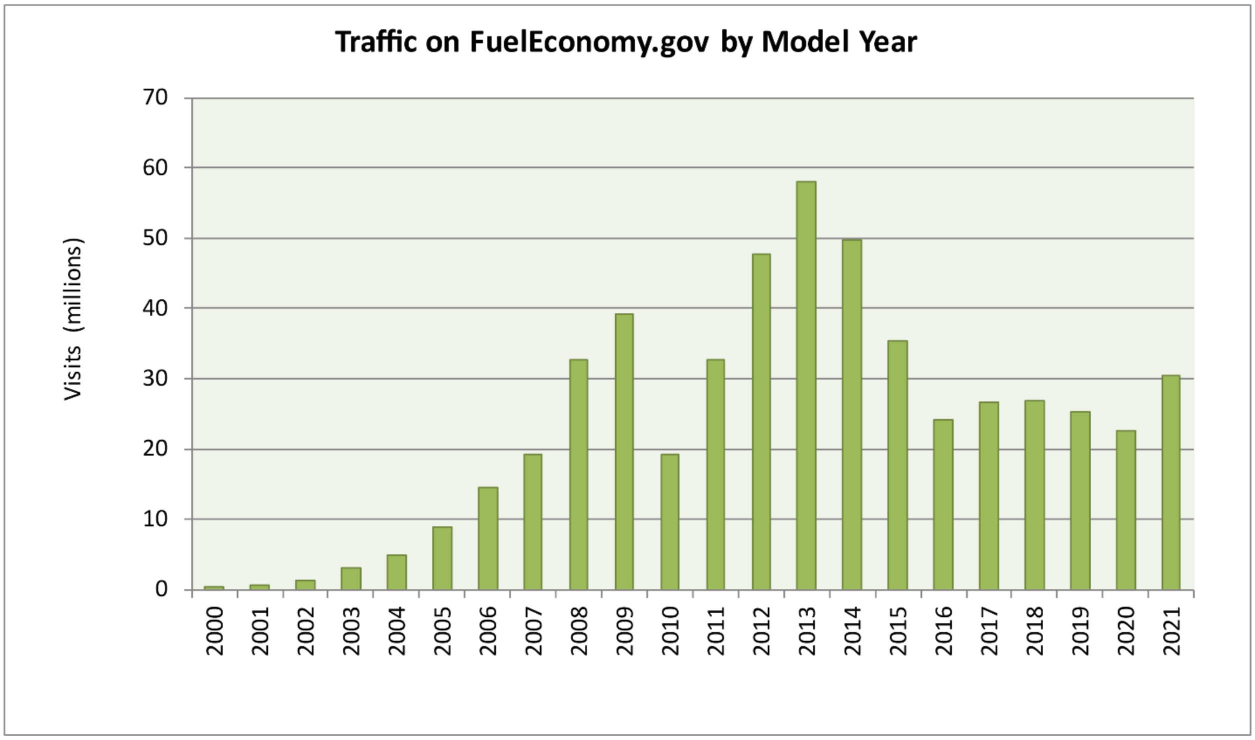

Figure II.5-1. Traffic on FuelEconomy.gov grew steadily after its initial launch in 1999, peaking in 2013 when fuel prices were high.

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 50,800 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 redesigned the tool 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.

Late in FY 2021 ORNL secured permission from DOE to release an official ORNL app in the Apple App Store and Google Play store. The app is expected to be released in 2022. In addition to weekly fuel economy data updates, ORNL updated/improved other parts of the website: GHG Emissions Calculator eGRID data, Power Profiler data, Federal tax incentive data, NHTSA vehicle safety data, EPA GHG and smog ratings data, and other routine content updates. ORNL also made changes to the website in response to user feedback.

MotorWeek segments completed in FY 2021 included four related to electric vehicles (Cherokee Nation EV Initiative, Green Commercial Lawn Mowers, California Farms Go Green with Zero-Emission Electric Tractors, and EVSR Electric Race Cars), one on hybrids (Aging Hybrid Vehicles Charge Forward with New Batteries), and one segment on alternative fuels (Connecticut Takes Pride in Alternative Fuels).[2] Filming began for an entire show devoted to EVs that will air in FY 2022. In addition, the page that displays MotorWeek videos on FuelEconomy.gov was re-designed to be more mobile-friendly.

Two fuel economy research projects were underway in 2021: a fuel stabilizer study and a stop-start fuel economy study. The first study completed testing in FY 2021, and ORNL delivered a presentation documenting the results to DOE. The study concluded that aftermarket additives can enhance resistance to oxidation and aid in reducing deposits but are not needed to keep gasoline within specifications for 12 months. Thus, consumers need not be concerned about gasoline aging in their fuel tanks as long as they use the engine enough to refill the tank once a year. The second study, which evaluates the effects of the auto stop-start feature on fuel economy, is nearly complete. ORNL will document results from both studies through journals and on FuelEconomy.gov in future fiscal 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 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 1,850 times in the technical literature. Finally, the FEI Program responded to over 600 email inquiries submitted by media and users through FuelEconomy.gov in FY 2021.

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 2021, 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.

Key Publications

U.S. Department of Energy and U.S. Environmental Protection Agency. 2020. *Model Year 2021 Fuel Economy Guide.* https://www.fueleconomy.gov/feg/pdfs/guides/FEG2021.pdf.

References

[1] Safercar.gov, https://www.safercar.gov.

[2] CleanCitiesTV, https://www.youtube.com/user/CleanCitiesTV.

Acknowledgements

The ORNL and University of Tennessee team acknowledge the steadfast support of the Department of Energy and the Environmental Protection Agency. Thanks also to auto industry partners and consumers for their valuable feedback and questions. Many consumers share their personal fuel economy on the *MyMPG* tool, which is also appreciated.

II.6 Technical Assistance/Technical Response Service (National Renewable Energy Laboratory)

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Start Date: October 1, 2020 End Date: September 30, 2021
Project Funding (FY21): $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 informs decision making, and 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.

Across the nation, fleets of all sizes continue integrating alternative fuels, advanced vehicles, and fuel-saving measures into their operations. These changes 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 information and a list of resources to in-person assistance from a subject matter expert on how a particular technology functions. Technical assistance also helps with planning, implementation and operational challenges facing end users. Through these trusted, and proven 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, proactively pursues solutions, 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 update or 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 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. Constant attention to evolving topics ensures the TRS staff are well informed and able to field the most difficult questions.

For inquiries that require specific expertise, 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 electricity, natural gas, hydrogen, propane, and biofuels, such as ethanol and biodiesel. 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 make informed decisions and tackle difficult technical and implementation challenges. Building on extensive experience, Tiger Teams 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) 2021 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 CNG is required to have an odorant when used in natural gas vehicles. The TRS stated that CNG is required to have an odorant when the gas is pumped into the local distribution network of pipelines. TRS staff recommended reviewing the National Fire Protection Association 52 fuel requirements and summarized key sections.

A state government representative asked what tools are available for conducting emissions and Total Cost of Ownership comparisons between plug-in electric vehicles (PEVs) and conventional vehicles. The TRS recommended using Argonne National Laboratory's (ANL's) AFLEET tool and provided guidance on completing the calculations. Additionally, TRS referred the client to the Alternative Fuels Data Center (AFDC) Vehicle Cost Calculator and Emissions from Hybrid and Plug-In Electric Vehicles pages, and included links to additional emissions and cost estimate tools from FuelEconomy.gov.

A state government representative also asked which states are revisiting their motor fuel excise tax structure, which states tax electricity as an alternative fuel, and whether motor fuel excise taxes apply to residential charging. The TRS provided data on states that tax electricity as a motor fuel, assess PEV fees, and have a road usage fee program, sourced from the AFDC Laws and Incentives database. Additionally, the TRS summarized that most states have assessed a PEV fee; some states tax motor fuel, including electricity; a few have implemented road usage fees; and others have taken no legislative action. TRS also noted that state motor fuel excise taxes do not apply to residential charging and that additional information on motor fuel excise taxes could be found in NREL's *Motor Fuel Excise Tax* fact sheet, and *Primer on Motor Fuel Excise Taxes and the Role of Alternative Fuels and Energy Efficient Vehicles*.

A representative from the Department of Transportation asked for examples of how individuals and smaller businesses in rural America have benefited from EVs**.** TRS referred the representative to AFDC case studies for examples of how EVs provide cost savings to individuals and how electric vehicle supply equipment (EVSE) helps generate additional business for site hosts. The response included several EV driver testimonials, sourced from incentive program websites and industry associations. Additionally, the TRS noted that Forth Mobility and project partners recently received funding from the DOE for the Clean Rural Shared Electric Mobility Project to demonstrate that round-trip EV car sharing can serve rural communities while benefitting low-income residents and local businesses.

A representative from the Department of Veterans Affairs asked for information on how federal agencies have installed EVSE at their sites. The TRS provided examples of several federal government agencies that have installed EVSE, and for guidance on PEV charging at government-owned and leased buildings, referred the questioner to NREL's *EVSE Tiger Team Site Assessment Findings from Army Facilities* report, *Federal Energy Management Program's (FEMP) Federal Workplace Charging Program Guide*, and DOE's *Implementing Workplace Charging within Federal Agencies* report. Additionally, TRS referred the caller to FEMP's PEVs for Federal Fleets page and suggested contacting FEMP directly. Lastly, the TRS referred to EVSE procurement and installation resources from the U.S. General Services Administration.

A Clean Cities coordinator received a request from a state legislator about state-level best practices to promote EVSE installations at multi-unit dwellings (MUD). The TRS compiled a list of state policies and incentives for promoting EVSE installations at MUDs. Additionally, The TRS noted that utilities can assist with incentivizing EVSE at MUDs and included utility-based programs across the country that target MUD EVSE infrastructure development.

A Clean Cities coordinator inquired whether aftermarket idle reduction devices invalidate the warranty of new vehicles. A police chief within the coalition area was considering installing idle reduction devices on recently purchased vehicles. The TRS replied that adding aftermarket parts will not void the warranty of a vehicle and referred to the Magnuson-Moss Warranty Act of 1975, which states that OEMs cannot void a warranty for using aftermarket parts or making modifications on a vehicle. An OEM must be able to prove that the device or modification caused the need for repairs and can only deny coverage for that part. For more information, TRS referred the caller to the Federal Trade Commission Auto Warranties and Service Contracts page.

A representative from private industry inquired whether historical and forecast data on the total number of fuel cell electric vehicles (FCEV) in the U.S. was available. The TRS referred the client to ANL's *Light Duty Electric Drive Vehicles Monthly Sales Updates*, which include monthly, annual, and historical FCEV counts in the United States. Additionally, TRS referred the client to data on FCEV sales, sourced from the California Fuel Cell Partnership and the California Air Resources Board, and the *EPA Automotive Trends Report 2020* for the most recently published market data.

A representative from private industry inquired about federal regulations for ethanol blender pumps. The TRS explained that there are no federal regulations related to blender pump equipment, but standards development organizations are responsible for leading the development of key codes and standards for AFVs and infrastructure. The TRS referred the caller to the AFDC Codes and Standards Resources page, the *Handbook for Handling, Storing and Dispensing E85*, and the *AFDC Ethanol Equipment Options* for lists of compatible equipment. Additionally, the TRS referred the caller to industry association resources on fueling infrastructure.

A representative from an OEM asked for a list of auxiliary power unit weight exemptions by state. For information on states that have enacted weight exemptions for idle reduction equipment, the TRS referred the representative to the AFDC Laws and Incentives database and provided guidance on how to identify relevant entries. TRS attached a spreadsheet of idle reduction weight exemptions, and explained that some states have allowed for the weight exemption by enforcement policy rather than by law; these policies are not captured in the AFDC database. TRS referred the representative to the Federal Highway Administration Compilation of Existing State Truck Size and Weight Limit Laws page for states that have allowed for the weight exemption by enforcement policy.

An individual from a DOE national laboratory asked for examples of pricing structures for major charging networks. TRS provided an updated list of pricing structures for the major charging networks, including Blink, ChargePoint, Electrify America, EV Connect, EVgo, Greenlots, OpConnect, SemaConnect, and Volta. The TRS summarized pricing structures and major updates since the list was first developed in 2019.

Technical Assistance Activities

Electrification of school buses is a topic of significant interest. The National Association for Pupil Transportation (NAPT) partnered with NREL to develop a seven-part program to raise the level of knowledge about EV school buses. NAPT and NREL worked closely to develop the topics. The program covers basic information about buses and charging, and is designed to help fleet professionals understand the requirements associated with acquiring EV school buses and making well-informed decisions.

A federal agency requested technical assistance related to establishing Level 1 workplace charging. Technical experts answered questions and provided information on technology-based decision-making, such as surveying employee interest; fee structures for program participants; and vehicle efficiency measures. They also shared insight on maintenance requirements for the bring-your-own-device program type and made recommendations on how to gauge the current and future levels of interest in workplace charging at the federal facility, to implement an effective pilot project in the near future.

Codes and standards work is an important part of proactive technical assistance. Subcontracted experts are participating in the committee that will update NFPA 52 and 30. The updated codes will address gaps and contradictory language in the current codes, and will help code officials more easily interpret and enforce the codes.

A municipality requested assistance related to its public facing EVSE. The city was evaluating training for its front-line staff to maintain and repair EVSE. The current approach of using third party contractors was not sustainable, and the city viewed the situation as pivotal to increasing skills and competencies in its fleet staff and evolving its workforce capacities in tandem with the growth of EVSE. Through multiple telephone consultations the city was able to decide next steps to pursue education and training for its staff.

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-Communities (National Renewable Energy Laboratory)

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Start Date: October 1, 2020 End Date: September 30, 2021
Project Funding (FY21): $700,000 DOE share: $700,000 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 the effectiveness of mobility services. The U.S. Department of Energy (DOE) Energy Efficient Mobility Systems (EEMS) Program collaborates closely with the Technology Integration (TI) Program and 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, and shared (ACES) and fully integrated across modes. EEMS and TI support research, development and deployment activities that advance such technologies and other opportunities to increase mobility energy productivity [1] in communities.

As a part of an interagency memorandum of understanding, 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, retitled in 2021 as "Technologist in Communities" to better reflect the size range of community partners) with Columbus, Ohio, after the City of Columbus' Smart Columbus project won the DOT Smart City Challenge in 2016. The TIC has worked with the city and its partners throughout the life of the Smart Columbus project, beginning in 2016, with plans to continue technology advisement through the end of fiscal year (FY) 2022. The TIC program has since grown to several additional Smart City engagements.

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, enhance charging infrastructure to support plug-in electric vehicle adoption, and provide a cleaner and more efficient electric grid. Smart Columbus has completed the initial grant activities, and has refocused into phase 2, integrating the work of the initial phase of funding with new initiatives informed by community stakeholders that include stronger focus on communication technologies, quality of life, and equity improvements. Although delayed by the COVID-19 pandemic, Smart Columbus 2.0 is well underway, continuing to provide leading practice for Smart City implementations.

The TIC program continues to interact with Smart Columbus, and has expanded its liaison and support functions to serve additional smart community initiatives. These initiatives span rural projects seeking to enhance mobility/energy solutions; cities with significant disadvantaged communities such as St. Louis, Baltimore, and Cleveland; New York State Energy Research & Development Authority (NYSERDA) Clean Transportation prizes; and activities in various other communities seeking to leverage ACES technologies for equitable and energy-efficient mobility solutions.

Objectives

In FY 2021, the TIC continued to support the City of Columbus in its Smart City endeavors, serving as a liaison on energy and mobility issues and expanding into other topic areas. The TIC facilitates feedback between DOE's EEMS and Technology Integration (TI) research programs and the city to inform modeling, data analysis, and demonstrations conducted in collaboration with national laboratories. As projects have matured and been deployed, the opportunities for data sharing have increased, both within the grant-funded programs and in several initiatives that have emerged beyond Smart Columbus. These include initiatives such as curb management, mobility scholarships for the underserved, and full taxi electrification. The TIC objectives in all these initiatives are to encourage and support deployments of Smart City technologies that improve energy efficiency, promote equity, and lead to a more sustainable transportation system. In so doing, the TIC strives to act as a liaison between the Smart Cities and the DOE and national laboratories information resources and technical expertise, as well as to provide data and lessons learned from Smart Cities to DOE that can be subsequently used to further research and assist other Smart City initiatives.

Approach

TIC support of Smart Columbus and emerging initiatives includes a variety of activities, methods, and approaches, as outlined below:

- Maintain a direct presence at adequate frequency to develop and sustain a working relationship and serve as a liaison. Although the COVID-19 pandemic has limited physical presence since March 2020, collaboration continues through webinars.
- Provide access to DOE and national laboratory resources as appropriate to meet needs within the Smart Community portfolio of projects and interests.
- Advocate for energy metrics and performance measures as part of Smart Community efforts and assist in the implementation of such metrics through case studies and demonstrations.
- Encourage data sharing, innovative uses of data, and access to critical data streams associated with advanced mobility, such as connected/automated vehicles, automated electric shuttle demonstrations, automated mobility districts, and micromobility using such tools as the Mobility Energy Productivity (MEP) metric, the Route Energy Prediction Model (RouteE), and the Open Platform for Agile Trip Heuristics (OpenPATH).
- Support city data initiatives like the Smart Columbus Operating System, and promote access to vital regional data sets housed at the city and with the city's partners, encouraging integration into the Livewire Data Platform.
- Be a communications broker between communities, partners, DOE, and national laboratories.

- Promote opportunities for collaboration between Smart City/Smart Community initiatives and both the EEMS and TI programs.

As a byproduct of Smart Columbus, several new initiatives have emerged that synergize with the Smart Columbus themes. These include activities within the city such as enhanced parking and curb management initiatives; at the Central Ohio Transit Authority with initiatives to solve employer labor access issues; at the Ohio Department of Transportation with the formation of DriveOhio to promote ACES activities within the state; and at Clean Fuels Ohio and their 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 and soon-to-be-built private mobility hub. Not only have the Smart Columbus grant activities yielded significant results in the past few years, but the momentum generated by the grant has begun to spur other significant Smart City and Smart Community initiatives within the state. Similar initiatives are sprouting in other community engagements as TIC expands its collaboration footprint.

Results

Current TIC project progress, accomplishments, and results include:

- **Smart Columbus Program:** The NREL TIC team continues to engage with the Smart Columbus team, including sharing information and transferring knowledge to support emerging efforts. Jordan Davis, Director of Smart Columbus, shared information on the objectives for future work in Columbus with extensions to improve economic viability and quality of life, to be fostered by improved broadband and communication infrastructure in the region. A strong emphasis on equity and environmental justice issues is integrated into the plans for Smart Columbus 2.0, aspects of which are leading the way for similar developments in other cities in alignment with larger DOE objectives. Columbus, as a thought and applications leader in curb space management, continues to be a valuable partner in exploring this topic area. The city solicited private industry through its issuance of a comprehensive request for proposals on a spectrum of curb management capabilities. Columbus also continues to be a rich source of Smart City lessons learned that are freely shared with other cities. On numerous occasions, NREL has connected aspiring Smart Communities with key contacts at Columbus, who have always graciously shared knowledge and advice.

- **NYSERDA:** The NREL TIC team has been engaged with NYSERDA in developing Clean Transportation Prizes, an investment of over $80 million in direct funding to New York communities toward sustainable and equitable mobility. This relationship enables DOE to learn from implementation of the projects, and allows NYSERDA to benefit from DOE's vast expertise and resources to maximize the benefits and success of their program. The TIC is developing a fellows program to function as an extension of TIC, with early career professionals as "boots-on-the-ground support" trained and advised by the NREL team to support the 10 (projected) grand prize projects. The fellows will work directly with the awarded teams, supporting relationship-building, networking, and communications back to NYSERDA, NREL, and DOE. NREL will provide mentorship, training, and first-line support to the embedded staff. NYSERDA will directly fund the positions, while DOE will support NREL through the TIC program for management of the program. TIC support of the NYSERDA projects also includes:
    - Emphasis on metrics and data support: Similar to NREL's support of Smart Columbus, NREL personnel will provide prize participants a direct conduit to DOE and national laboratory tools (e.g., Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies [GREET], MEP, RouteE, OpenPATH, and equity tools), data (various aspects of the Alternative Fuels Data Center and knowledge bases), and expertise.
    - Community resource collaboration: This will complement an annual conference hosted by NYSERDA and patterned on the TIC rural mobility forum, in which grantees are invited to a

quarterly support forum where internal (grant awardees) and external (other speakers and initiatives of import) participants share their experiences and insights. NREL will facilitate a recurring forum for awardee projects, at a cadence to be determined through coordination with NYSERDA

- Emphasis on case studies: Develop NYSERDA specific case studies and share externally, and share relevant external case studies with NYSERDA program participants. Although case study topics are not prescribed, relevant topics will be identified as the program evolves.

- **Cities with significant disadvantaged communities:** The NREL TIC team supported a proposal to the Civic Innovation Challenge, leading to a TIC initiative to support cities with significant disadvantaged communities. The TIC team has conducted conversations with stakeholders and potential partners in Cleveland, St. Louis, and Baltimore, seeking to make positive changes to mobility to improve outcomes for residents. Common themes include the need for better connection between neighborhoods with long-standing elevated unemployment and areas of concentrated employment where labor needs are often unmet. As part of a semester-long course in applied humanitarian engineering at the Colorado School of Mines, the NREL TIC team has facilitated connections between an engaged group of advanced senior engineering students and multiple stakeholders, to identify community mobility needs and explore potential solutions.

- **Automated mobility for public transportation:** In FY 2020, NREL published *The Automated Mobility District Implementation Catalog: Insights from Ten Early-Stage Deployments* [2], which contains a collection of known automated shuttle projects and shares data and lessons learned. NREL prepared a draft of the next edition during FY 2021, with anticipated publication early in FY 2022. This second edition not only provides summaries of the new developments and lessons learned over the past year and a half for the 10 early-deployment automated mobility demonstration projects, but it also assesses the various regulatory and technical issues that have emerged from the first series of automated shuttle and car service demonstration pilots.

- **MEP case study for employment access in the Linden neighborhood:** Through interaction with Smart Columbus, NREL authored a case study for connecting a disadvantaged community with a vibrant employment hub. The case study examines the Linden neighborhood, a historically underprivileged area near central Columbus, and the Rickenbacker employment district, a warehouse and distribution center teeming with a concentration of jobs but with limited public transit connectivity. See Figure II.7-1. Transit routes between Linden and Rickenbacker require more than 90 minutes each way, whereas by car the trip is less than 30 minutes. Reasonable employment access between the two locations necessitates private car ownership, which not all potential employees have. In this case study application of the MEP metric, the TIC team explored how various mobility investments may affect the interconnection between Linden and Rickenbacker, with the case study informing both employment access and appropriate implementation of the MEP tool within a city. Results show that an employer-subsidized shuttle could be competitive with driving alone in terms of time, cost, and energy for employees or prospective employees living in Linden. The TIC team presented findings to Joanna Pinkerton, President and CEO of the Central Ohio Transit Authority, and her team. Ms. Pinkerton received the presentation enthusiastically, eager to adapt the Central Ohio Transit Authority's strategies as informed by the case study, and provided numerous ideas for additional case studies that could address specific challenges. In her leadership role at the American Public Transit Association, Ms. Pinkerton could foster an expansion of applied MEP-informed case studies to identify and pose potential solutions for numerous transit challenges on a national scale.

Figure II.7-1. Relative locations of the Linden neighborhood and Rickenbacker industrial park in Columbus, Ohio

- **New mobility in rural America (DOE):** The NREL TIC team continues to support and coordinate communication/information exchange among the five rural mobility projects awarded through DOE's 2019 Advanced Vehicle Technologies Research Funding Opportunity Announcement (FOA), through regular engagement and quarterly online forums. Many of these projects experienced delays due to the pandemic but are each now underway. NREL plays an active research support role in two of the five projects and has relationships with the other three awardees. Rural mobility support by the NREL TIC team was highlighted in an NREL news feature "Country Roads, Take Me Home—in an Electric Car: Demonstration Projects Bring New Transportation Options to Small Towns" [3]. The story was picked up by external media, including National Public Radio and *Farm and Dairy* magazine. An economic development lead in the small community of Dubois, Wyoming, saw the story and contacted the TIC team to find out how their town might become involved, noting mobility challenges in connecting people with jobs and curious how new mobility solutions might help.

- **Innisfil case study:** NREL conducted a case study exploring novel application of the framework for on-demand ride-hailing services to function as a scalable public mobility service. The town of Innisfil in Ontario, Canada, has adopted a public transit system based on mobility-as-a-service principles, namely the use of ride-hailing as the basis for providing public mobility. In partnership with Uber and other service providers, the town of Innisfil provides subsidized services for its citizens, providing greater options for travel to community destinations such as libraries, food banks, and mobility hubs. During the pandemic, the town was able to swiftly transition the service to transport people to vaccination locations, distribute groceries, and connect people with essential medical services. NREL presented the case study, entitled "Sustainability, Scalability, and Resilience of the Innisfil Public Mobility Experiment", to representatives of the City of Innisfil and to Ryerson University and Uber staff. The presentation was very warmly received, with strong interest in further case studies to inform possible implementation of similar applied projects elsewhere. The case study was also accepted for presentation at the Behavior, Energy & Climate Change Conference in November. Municipalities seeking similar services have tendered inquiries on the impacts and outcome of the Innisfil program.

- **Leveraging emerging mobility data sources to assess traffic signal performance:** Previously, **t**hrough TIC involvement, the Ohio Department of Transportation had procured leading-edge vehicle trip data from INRIX. Subsequently, NREL partnered with Wayne State University to leverage this investment by the Ohio Department of Transportation to demonstrate traffic signal performance assessment without the need for deploying sensors, often referred to as automated traffic signal performance metrics. In 2021, INRIX integrated automated traffic signal performance measures (ATSPMs) into their data products and announced that these measures can now be procured anywhere in the United States, to the benefit of any community. Furthermore, NREL and INRIX are in discussion to develop and integrate energy measures into ATSPMs through continued collaboration. Dr. Steve

Remias, formerly with Wayne State University, is now on staff with INRIX, and NREL and INRIX are preparing a memorandum of understanding on innovative energy applications for transportation data.

- **The Ohio State University EmPOWERment Program:** This program offers interdisciplinary training in energy system modeling, data science, energy policy, business, and energy technologies to the next generation of innovative leaders in sustainable energy. TIC serves on the EmPOWERment Program's External Advisory Council. In 2021 NREL offered feedback on the background and skills needed for innovative energy research, and connected prospective interns with NREL staff. The NREL TIC team was invited to design a student project to support applied mobility research, set for the spring 2022 semester.

- **COVID-19 data science:** The COVID-19 research led by NREL and funded by TI has come to completion. If called upon to perform additional work in this area, updates will be provided in future reports.

Conclusions

During FY 2021, TIC continued to collaborate with several Smart City initiatives in Columbus and the surrounding region, and expanded to select opportunities in other aspiring Smart Communities. Smart Columbus has shifted its energy to the next phase of the effort, extending the goals of the initial phase to future objectives and setting a future vision informed by prior work. Relative to the initial phase, the goals are particularly strengthened with respect to better serving historically disadvantaged communities and addressing inequities within the Columbus region. Smart Columbus has accomplished several mature projects, and is now sharing with other cities and states. As the Smart Columbus initiative begins its next phase, what has been learned through the program will continue to inform efforts at multiple locations. Shaping the TIC program for FY 2022 activities, with the TI program NREL has identified themes and priorities including:

- Continued engagement in the next phase of the Smart Columbus program, with emphasis on employment access, equity, and leading technical solutions in curb management.

- Cities with significant disadvantaged communities (e.g., Cleveland, St. Louis, Baltimore).

- Rural mobility, workforce mobility, and access to jobs.

- Support for NYSERDA engagement.

- Automated public mobility, appropriately applied.

- Objective data analysis from Energetics and CALSTART under FOA awards, collection and analysis of behavior data via OpenPATH, and analysis of data from Smart City advanced mobility demonstrations.

Key Publications

J. Sam Lott, S.E. Young, and Lei Zhu. 2021. "Safe Operations at Roadway Junctions – Design Principles from Automated Guideway Transit." 2021 SAE Business of Automated Mobility, June 2021.

J. Sam Lott and S.E. Young. 2021. "A Safety and Management Framework to Enable Automated Mobility Districts in Urban Areas." 2021 American Society of Civil Engineers International Conference on Transportation and Development, June 2021.

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.

[2] Stanley Young and J. Sam Lott. 2020. *The Automated Mobility District Implementation Catalog: Insights from Ten Early-Stage Deployments*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-76551. https://www.nrel.gov/docs/fy20osti/76551.pdf.

[3] Anya Breitenbach. 2021. “Country Roads, Take Me Home—in an Electric Car: Demonstration Projects Bring New Transportation Options to Small Towns.” *NREL News & Feature Stories*, October 13, 2021. https://www.nrel.gov/news/features/2021/country-roads-take-me-home-in-an-electric-car.html.

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