U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Technology Integration

2022 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
AEO	Annual Energy Outlook
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
AV	autonomous vehicle
AVTC	Advanced Vehicle Technology Competition
BEV	battery-electric vehicle
BMS	Behavioral Micro-simulation
BSSD	Blue Springs School District
CACC	Chicago Area Clean Cities
CAN	Controller Area Network
CARB	California Air Resources Board
CARTS	Capital Area Rural Transportation System
CAV	Connected and Automated Vehicle
CBO	community-based organization
CCOG	Centralina Council of Governments
CDF	cumulative density function
CFO	Clean Fuels Ohio
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
CTS	Contract Transportation Services
DAS	data acquisition system
DC	direct current
DCC	Drive Clean Colorado
DCFC	direct current fast charger
DERST	Distributed Energy Resources Safety Training
DEUSA	Drive Electric USA
DNL	Dynamic Network Loading
DOE	Department of Energy
DOT	Department of Transportation
DRIVE	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
EPA	Environmental Protection Agency
EPAct	Energy Policy Act of 1992
ERAU	Embry Riddle Aeronautical University
ESS	energy storage system
ETCF	East Tennessee Clean Fuels
EV	electric vehicle
EVI-Pro	Electric Vehicle Infrastructure Projection
EVSE	electric vehicle supply equipment
EVWATTS	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
FSEC	Florida Solar Energy Center
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
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
ICE	internal combustion engine
IEEE	Institute of Electrical and Electronics Engineers
IRB	Institutional Review Board

KCI	Kansas City International Airport
KCMO	Kansas City, Missouri
KDOT	Kansas Department of Transportation
KU	Kansas University
kW	kilowatt
kWh	kilowatt-hour
LDV	light duty vehicle
LNG	liquefied natural gas
LSCFA	Lone Star Clean Fuels Alliance
LSEV	low speed electric vehicle
M2M	Michigan to Montana
MaaS	Mobility as a Service
MAC	McMaster University
MAC-POST	Mobility Data Analytics Center – Prediction, Optimization and Simulation Toolkit
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
MMDUE	Multi-modal Dynamic User Equilibrium
MOU	memorandum of understanding
MOVES	Motor Vehicle Emission Simulator
MPG	miles per gallon
mph	miles per hour
MPO	metropolitan planning organization
MST	Missouri University of Science and Technology
MSU	Mississippi State University
MUD	multi-unit dwelling
MY	model year
NASEO	National Association of State Energy Officials
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
OEM	original equipment manufacturer
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
POI	point of interest
psig	Pounds per square inch gauge
PSU	Penn State University
RAMP	Rural County Mobility Platform
RBE	Roads, Bridges and Engineering Department
RFP	request for proposals
RNG	renewable natural gas
ROADMAP	Rural Open Access Development Mobility Action Plan
RPI	Rensselaer Polytechnic Institute
SAE	Society of Automotive Engineers
SAFP	State and Alternative Fuel Providers
SCAQMD	South Coast Air Quality Management District
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
TBCCC	Tampa Bay Clean Cities Coalition
TCO	total cost of ownership
TI	Technology Integration
TIC	Technologist in Communities
TNC	transportation network company
TPO	transportation planning organization
TRB	Transportation Research Board
TRS	Technical Response Service
TSP	transportation service provider
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
ULSD	ultra-low sulfur diesel
USPS	United States Postal Service
UT-Austin	University of Texas at Austin
UW	University of Washington
UWAFT	University of Waterloo Alternative Fuels Team

V2V	vehicle to vehicle
V2X	vehicle to everything
VDP	Vehicle Development Process
VMRS	Vehicle Maintenance Reporting Standards
VoICE-MR	Vocation Integrated Cost Estimation for Maintenance and Repairs of Alternative Fuel
VSP	vehicle specific power
VT	Virginia Tech
VTO	Vehicle Technologies Office
WestSmart EV	Western Smart Plug-in Electric Vehicle Community Partnership
WU	Waynesburg University
WVU	West Virginia University

Executive Summary

The 2022 Technology Integration Annual Progress Report covers 57 multi-year projects funded by the Vehicle Technologies Office. The report includes information on competitively awarded projects, ranging from multi-state “Drive Electric” initiatives to development of heavy-duty fuel cell electric powertrains to rural electric vehicle shuttle systems for National Parks and gateway communities.

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 18 billion tons of freight—about $55 billion worth of goods each day[1]—and move people more than 3 trillion vehicle-miles.[2] Growing our economy requires transportation, and transportation requires energy. The transportation sector accounts for approximately 30% of total U.S. energy needs[3] and the average U.S. household spends over 15% 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 transportation sector has historically relied heavily on petroleum, which supports over 90% of the sector's energy needs today,[5] and, as a result, surpassed electricity generation to become the largest source of CO_2 emissions in the country.[6] The Vehicle Technologies Office (VTO) will play a leading role to decarbonize the transportation sector and address the climate crisis by driving innovation within and deployment of clean transportation technologies.

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; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas and criteria emissions; 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 R&D; Electrification R&D; Materials Technology R&D; Decarbonization of Offroad, Rail, Marine, and Aviation; 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) 2022. The APR presents descriptions of each active project in FY 2022, including funding, objectives, approach, results, and conclusions.

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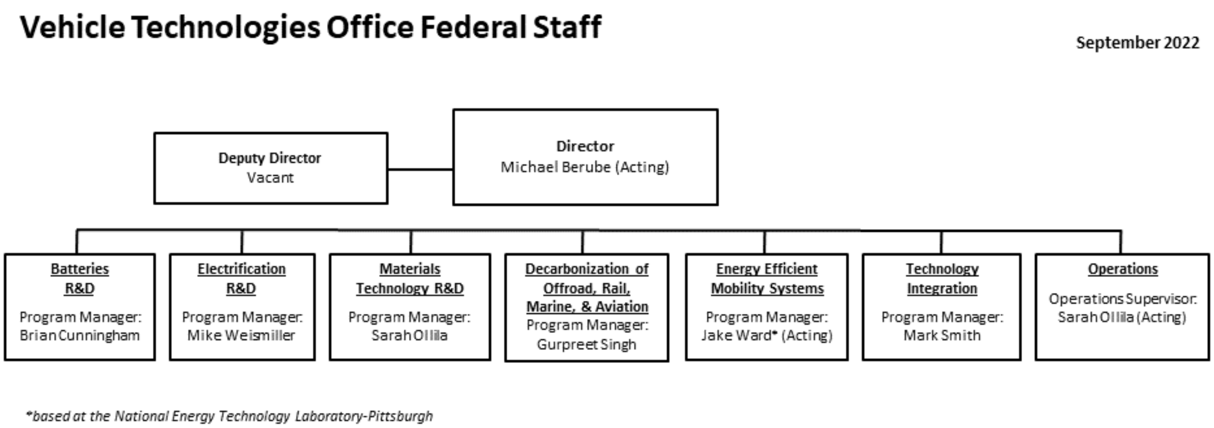
[1] Bureau of Transportation Statistics, DOT, Transportation Statistics Annual Report 2020, Table 4-1, https://www.bts.gov/tsar.
[2] Davis, Stacy C., and Robert G. Boundy. Transportation Energy Data Book: Edition 39. Oak Ridge National Laboratory, 2021, https://doi.org/10.2172/1767864. Table 3.8 Shares of Highway Vehicle-Miles Traveled by Vehicle Type, 1970-2018.
[3] Ibid. Table 2.2 U.S. Consumption of Total Energy by End-use Sector, 1950-2018.
[4] Ibid. Table 11.1 Average Annual Expenditures of Households by Income, 2019.
[5] Ibid. Table 2.3 Distribution of Energy Consumption by Source and Sector, 1973 and 2019.
[6] Environmental Protection Agency, Draft U.S. Inventory of Greenhouse Gas Emissions and Sinks, 1990-2019, Table 2-11. Electric Power-Related Greenhouse Gas Emissions and Table 2-13. Transportation-Related Greenhouse Gas Emissions.

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 11 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)

Ted Barnes, P.E. Principal Investigator
Gas Technology Institute
1700 South Mount Prospect Road
Des Plaines, IL 60018
E-mail: tbarnes@gti.energy

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

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 (I-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 Cities Directors 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 programs, commissioning additional vehicle charging and fueling stations, deploying AFVs, and providing the education and training necessary to establish a sustainable market for alternative fuel vehicles along I-94. This is to 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 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 AFVs and the installation of fueling stations. Team members include Greater Lansing Area Clean Cities, South Shore Clean Cities, Illinois Alliance for Clean Transportation (formerly 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), and Energy Hunters, LLC.

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 AFVs 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 13 electric vehicle (EV) DC fast chargers, 2 publicly accessible CNG fueling stations, 1 propane station, and 40 CNG long-haul trucks along the corridor.
- Identify and deploy aforementioned chargers/stations/vehicles to fill gaps along the corridor to 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 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 driver 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 during the 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, metropolitan planning organizations, 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 regular 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 numerous 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). These gaps include western Michigan, central Wisconsin, and areas along I-94 west of Minnesota, including most of North Dakota and Montana. When evaluating opportunities for deploying additional infrastructure along I-94, the M2M team attempts to direct project resources in such a way that identified gaps are addressed.

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 project, some of these partners withdrew for business reasons. This forced GTI and the Clean Cities directors 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 2022.

EV Fast Charging Station Deployment

To date, EV charging station partner ZEF has installed and commissioned nine DC fast charging stations along the I-94 corridor. M2M partner Ozinga Energy installed one DC fast charger station along I-94 in Sturtevant, Wisconsin. Most recently, new M2M partner Energy Hunters, LLC installed DC fast charger station infrastructure along I-94 in the Minnesota cities of Ashby and Barnesville, as well as in Jamestown, North Dakota. Table I.1.1 is a summary of the partial reporting of kilowatt-hours supplied during 2022, at the stations deployed by ZEF and Ozinga Energy. Some of the ZEF 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. M2M Charging Stations Tracking Report-Oct 2021-June 2022 (*DCFC–DC Fast Charger)

kWh		10/ 2021	11/ 2021	12/ 2021	1/ 2022	2/ 2022	3/ 2022	4/ 2022	5/ 2022	6/ 2022	TOTAL kwh
1	Moorhead DCFC*	2,000	2,250	1,900	1,007	504	544	1,204	1,160	1,104	11,673
2	Moorhead Level 2	163	163	166	20	31	187	298	60	218	1,306
3	Fergus Falls	1,014	609	300	64	526	173	728	338	979	4,731
4	Alexandria CCS/CHAdeMO DCFC	1,864	1,436	962	672	520	775	1,177	1,980	2,495	11,881
5	Alexandria Level 2	12	35	67	6	20	4	30	29	80	283
6	Saint Cloud CCS/CHAdeMO DCFC	150	610	1,235	1,311	1,018	764	698	596	658	7,040
7	Hudson CCS/CHAdeMO DCFC	423	303	205	219	256	213	291	221	320	2,451
8	Hudson Level 2	351	330	678	607	543	730	678	469	828	5,214
9	Eau Claire DCFC	-	-	-	-	-	-	-	-	5	5
10	Tomah DCFC	1,800	1,440	1,560	-	-	-	-	-	-	4,800

kWh		10/ 2021	11/ 2021	12/ 2021	1/ 2022	2/ 2022	3/ 2022	4/ 2022	5/ 2022	6/ 2022	**TOTAL kwh**
11	Dickinson DCFC	-	-	-	19	55	19	42	88	289	512
12	Dickinson Level 2	-	-	-	-	-	71	60	127	52	310
13	Black River Falls DCFC	-	-	-	-	-	-	-	62	407	469
14	Black River Falls Level 2	-	-	-	-	-	7	17	16	67	107
15	Sturtevant DCFC							529	1,061	1,164	2,754

From the data provided in Table I.1.1, one can see that the use of the chargers varies among stations and by month. ZEF provided this photo of the charging station recently commissioned in FY 2022 Dickinson, North Dakota (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, in April 2022 they commissioned a DC fast charger EV public charging station near I-94 in Sturtevant, Wisconsin. A photograph of this installation is shown in Figure I.1-3.

Figure I.1-3. EV charging station installed and commissioned by Ozinga Energy at Sturtevant, WI

In FY 2022, GTI executed a contract with Energy Hunters, LLC (EH) to purchase, deploy, install, commission, operate, maintain, and manage three networked DC fast chargers located at CENEX fueling stations in the following cities/states: 1) Jamestown, North Dakota, 2) Barnesville, Minnesota and 3) Ashby, Minnesota. For each of the three locations, EH installed Tempus chargers manufactured by BlueSky Energy Technologies. Each charger power unit features two charging ports that provide universal compatibility with the EVs and open-source software. Each of the three sites will be capable of charging four EVs at the same time. EH's configuration provides 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. A photograph of the installation at CENEX station in Barnesville, Minnesota is provided below in Figure I.1-4.

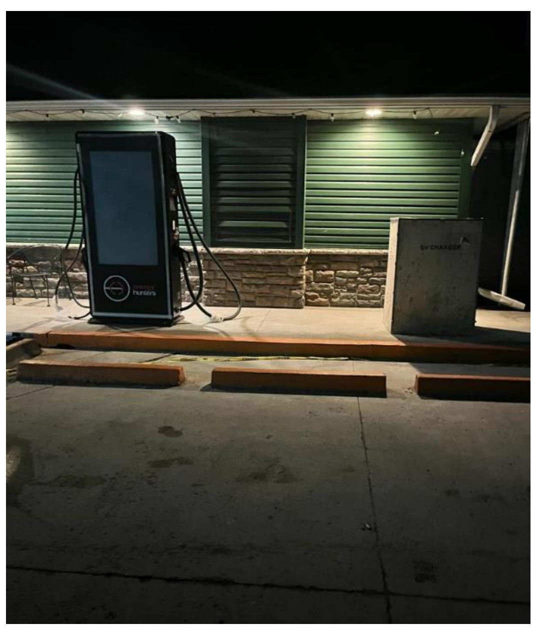


Figure I.1-4. EV charging station

Propane Station Deployment

As shown in Figure I.1-5, ALCIVIA (formerly Landmark Services Cooperative) completed construction of a new public propane fueling station at Cottage Grove, Wisconsin. ALCIVIA will fuel its propane vehicles at this station and reported the following statistics before closeout of their agreement:

- 10/01/21 – 12/31/21 486 propane gallons (368 gasoline gallon equivalents, or GGEs)
- 01/01/22 – 03/31/22 463 propane gallons (350 GGEs)

Figure I.1-5. ALCIVIA propane fueling station

CNG Truck Deployment

The project began CNG truck deployment with Contract Transport Services (CTS) out of Green Bay, Wisconsin. 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. The CTS trucks deployed under this project have traveled well over 15,000,000 cumulative miles and used over 3,000,000 GGEs of CNG.

Veriha Trucking received grant support to purchase an additional 10 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 GGEs.

Sustainable Corridor Planning

The M2M team members continue to work and 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, Illinois Alliance for Clean Transportation (formerly 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 or LNG, propane, 20% biodiesel/80% diesel blends or B20, 85% ethanol/15% gasoline blends or E85, electricity, and hydrogen. 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 directors 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 AFV 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 directors 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 launched a website for the project at https://m2m94corridor.com/ . Information on this site includes 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 were conducted during FY 2022:

- Illinois Fire Service provided first responder training on AFVs to 25 fire fighters at Green Drives Expo in May 2022 https://cleancities.energy.gov/events/28487. The Illinois Alliance for Clean Transportation (formerly Chicago Area Clean Cities) supported the development of this training with grant funding. The training is available to others by Illinois Fire Service's vehicular rescue program (https://www.fsi.illinois.edu/content/courses/programs/description.cfm?course_id=1348).

- Greater Lansing Area Clean Cities (GLACC) exhibited M2M at Government Fleet Expo in Detroit in May 2022. GLACC nominated Port Huron to Detroit for alternative fuel station designations along with a portion of I-94 designated as "pending" for hydrogen fueling.

- Minnesota Clean Cities Coalition (MC3) exhibited with M2M project information at Minnesota Safety and Health Conference in Prior Lake, Minnesota.

- Wisconsin Clean Cities promoted M2M through its Transportation and Innovation Expo held April 2022 in Madison, Wisconsin.

- North Dakota Clean Cities exhibited at a Bismarck, North Dakota EV Tailgate event in June 2022 and promoted M2M project.

Socio-Economic Benefits Analysis – GLACC contracted with Michigan State University which completed and issued the analysis titled, "The Economic Impact of Conversion of Internal Combustion Engines to Electric Vehicles and AFVs 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 June 2022, there were 68 followers on Facebook and 108 followers on Twitter.

Conclusions

The M2M Corridor Project has accomplished its goals and objectives within the planned budget and period of performance ending September 30, 2022. With support under this award, the project deployed 13 EV DC fast chargers, 2 publicly accessible CNG fueling stations, 1 propane station, and 40 CNG long-haul trucks along the corridor. Results are paving the way to establishing a sustainable alternative fuels corridor along I-94. Project accomplishments and Corridor impacts include:

- 421,524 GGE dispensed.

- 3,272,412 GGEs displaced.

- Overall GHGs reduction = 14,079 tons.

- Overall NOx reduction= 47,537 lbs.

- Overall Petroleum reduction= 33,398 barrels.

Acknowledgements

The M2M Corridor Project Team would like to acknowledge the guidance and involvement of its DOE Project Manager, Mr. David Kirschner.

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

Jose Holguín-Veras, Principal Investigator
Rensselaer Polytechnic Institute
110 8th Street
Troy, NY 12180
E-mail: jhv@rpi.edu

Mark Smith, DOE Program Manager
U.S. Department of Energy
E-mail: mark.smith@ee.doe.gov

Start Date: October 1, 2017 End Date: September 30, 2022
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 an Integrated Transport Energy Model that consists of 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 Rensselaer Polytechnic Institute (RPI) using GPS archival data. Recently, GMU informed RPI that the development of these procedures was not successful. RPI, GMU, and Argonne National Laboratory (ANL) discussed option to bypass the issue. In this context, a decentralized Integrated Transport Energy Model was the most practical option. Instead of a single piece of software, the various pieces of software will be run separately; the Behavioral Micro-simulation (BMS)-EEL output can be prepared to serve as inputs for SVTrip and Autonomie.

Results

During the past year, the team worked on the development of simulation tools to model supply chains. The focus was on the integration of the simulation tool developed by the RPI team, the BMS, with the partner's tools, SVTrip and Autonomie, and the elaboration of study cases to assess the effectiveness of EEL initiatives. In parallel, the team finalized the distribution and data collection of the survey to commercial establishments to assess the willingness to adopt initiatives that would increase EEL. Lastly, the team engaged the private and public sectors for the development pilot tests for the project. After a thorough assessment of possible partnerships, the team conducted four pilot tests which are discussed below in the Pilot Test section.

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.

The BMS-EEL is composed of two modules: (i) the BMS-B2B that considers freight flows between commercial establishments, and (ii) the BMS-B2C that accounts for the freight activity associated with deliveries of e-commerce purchases to households. The two modules have dedicated codes due to the different dynamics of deliveries to commercial establishments and to households. Therefore, the 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).

During the past year, the RPI team worked on two fronts: the elaboration of study cases using both the BMS-B2B and the BMS-B2C, and the integration of the BMS with ANL's tools, SVTrip and Polaris, to estimate energy consumption. The RPI team developed a code that takes as input the tours simulated by the BMS and uses OpenStreetMap networks and travel speeds inferred by archival GPS data to refine the level of detail of the tours to a network link level. This effort was necessary to overcome the challenge of obtaining 1Hz frequency GPS data to calibrate ANL's tools and fulfill the integration of the BMS with their tools. The outcomes are delivery tours described in detail with average travel speeds, free flow speeds, and stopped times due to traffic signals for each street segment of the path. The integration was a success and ANL was able to estimate fuel consumption of the delivery tours simulated by RPI's BMS.

For the BMS-B2B module, the team finalized the two study cases in the Capital District. The first one tests the effect of locating and relocating a large distribution center. The purpose of this case study is to provide insights into the effects that facility location in urban areas has on urban freight systems. The study case adding a large new distribution center [in response to increased demand for freight shipments to and from establishments in the Wholesale Trade sector (NAICS 42)] considers two alternative locations. The case considering relocating existing freight activity from one location to another one responds to policies incentivizing the densification of freight activity in urban areas. This case shows that there is a tradeoff between minimizing the costs from freight vehicle travel (locating closer to the major delivery areas) and minimizing the impacts on local communities (locating farther from the city center).

The second study case tests the implementation of off-hour deliveries (OHD). This case considers a specific area of the Capital Region, i.e., downtown Albany, and industry sectors to implement OHD based on having large commercial activity and feasibility, respectively. Furthermore, since not all trips that are eligible to happen during off-hours will actually occur, RPI considered different levels of penetration of the initiative: 25%, 50%, and 75%. Thus, a 25% OHD penetration means that 25% of the eligible trips occur during off-hours. Table I.2.1 shows preliminary results of fuel savings obtained with the off-hours delivery study case in downtown Albany. If 75% of the commercial establishments in downtown Albany received deliveries at night, there could be approximately 1,300 gallons of diesel and 14,000 vehicle-miles traveled savings on a single day of operations.

Table I.2.1. Daily Fuel Consumption and Vehicle Miles Traveled (VMT) for the Off-hour Delivery Case Modeled by the BMS-B2B

Scenarios	Total Fuel (gal.)	Savings in Fuel (gal.)	Total VMTs	Savings in VMTs
1) Base Case	84,890	-	856,812	-
2) 25% of deliveries in the off-hours	84,845	45	855,940	872
3) 50% of deliveries in the off-hours	84,038	853	848,396	8,416
4) 75% of deliveries in the off-hours	83,582	1,308	842,509	14,303

For the BMS-B2C, the study case was designed to assess the impacts of delivery consolidation on households. Delivery consolidation happens when the receivers agree to have multiple packages delivered at once instead of one delivery per package, saving delivery trips to that household. One example of this strategy in real life is the “Amazon Day” initiative in which consumers have the option to receive all Amazon packages on a select day of the week. To test the effect of this type of initiative, the study case consists of five scenarios: (1) a base case in which no consolidation schemes are applied, (2) consumers choose one day of the week of their preference to receive all deliveries, (3) consumers choose two days of the week of their preference to receive all deliveries, (4) all packages of the week are delivered in one day chosen by the carrier, and (5) all packages are delivered in two days of the week chosen by the carrier. Results show that all consolidation scenarios lead to a reduction in total deliveries and, therefore, in the total number of tours needed to complete operations. In the most efficient scenario, consolidation to once per week with a fixed day by the carrier, the number of delivery tours decreased 13.21% in comparison to the base case.

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. To account for the effects of the pandemic, the team updated the original survey to include questions regarding the impacts of COVID-19 in addition to the original focus on how receivers would react to the implementation of EEL initiatives. The final questionnaire is divided in two sections. The first part is a revealed preference survey that asks about operational characteristics (e.g., number of stops, average tour length or load factors). The second part is a stated preference survey that focuses on assessing the willingness to participate in EEL initiatives. The initiatives were 1) trusted vendors to OHD, i.e., vendors that the receivers trust to make unassisted off-hour deliveries to their establishments; 2) service providers in the OH, i.e., companies that are allowed to make service calls in the off hours, such as elevator or office equipment repair; 3) increase order sizes to reduce the number of the deliveries; 4) consolidate all orders from the same vendor; 5) purchase supplies from vendors that use electric/hybrid vehicles; 6) appointment systems for delivering cargo; 7) coordinate purchases with nearby establishments; 8) deliveries to Urban Consolidation Centers, and last mile of delivery done using electric bikes; and 9) eco-transfer program.

The team implemented the questionnaire in Qualtrics, and several members of the industry advisory group pilot tested it. For the distribution of the survey, the team acquired data from establishments in the Capital District and in New York City from Data-Axle (a company dedicated to providing establishment data across the US). From October 2021 to April 2022, the team dedicated efforts to distributing the survey. The strategy was threefold: deliver postcards to establishments in person, send postcards by mail, and send emails with links to the survey. The team delivered about 500 postcards in person to businesses in the Capital District (Cohoes, Troy, Latham, Schenectady, Amsterdam, Saratoga Springs, Clifton Park, Albany, and Colonie). Additionally, the team mailed over 1,000 postcards to establishments in the Capital District, and over 1,300 postcards to NYC, including 890 postcards to Manhattan and 360 postcards to Brooklyn. Using the email list obtained from the Data-Axle database, the team emailed approximately 1,100 establishments in the Capital District and 2,000 establishments in New York City. Lastly, the team distributed the survey to the members of the Council of Supply Chain Management Professionals (CSCMP) in the Capital District. To incentivize respondents, the team offered a gift card as a token of appreciation for taking the time to do the survey. After all the implementation efforts the team received 51 valid answers to the questionnaire.

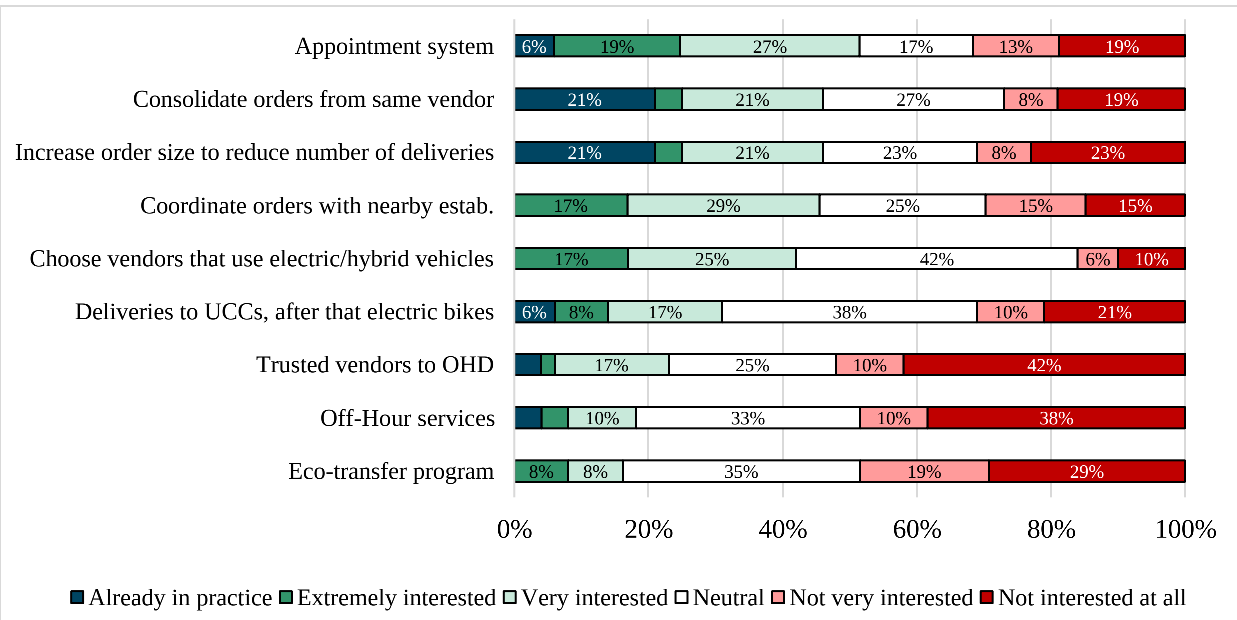


Figure I.2-1. Willingness to participate in EEL initiatives.

Regarding the second section of the survey, Figure I.2-1 shows the willingness to participate in nine different energy EEL initiatives for the Capital District observations. The results show how approximately one-fifth of the establishments have already increased order sizes to reduce the number of deliveries and consolidate all orders from the same vendor. The three initiatives that the private sector is most interested in are 1) using an appointment system to schedule time of arrival of deliveries; 2) coordinating purchase orders with other nearby establishments to get better prices and reduce the number of freight delivery trips to our area; 3) purchasing supplies from vendors that use electric/hybrid vehicles.

Pilot Tests

Throughout the duration of the project, the team has been in conversation with both public and private sector representatives to discuss the possibility of conducting pilot tests to support the evaluation of EEL in the I-87 Corridor. In total, the team explored more than 20 promising pilot tests with at least six public sector agencies and eight private sector companies. The topics included the following:

- Vehicle routing.
- Micro-distribution.
- Micro-consolidation centers.
- Home delivery consolidation.
- Evaluation of Class 8 electric trucks for urban deliveries.
- Loading dock management systems.
- Off-hour deliveries with trusted vendors.
- Delivery/Cargo consolidation.
- Mode shift programs.
- Evaluation of freezer blankets.
- Tandem trailer operations.
- Container on barge services.
- Neighborhood loading zone programs.
- Green loading zones.
- Parking management programs including for service vehicles.
- Delivery programs for city owned buildings.
- Evaluation of an electric vehicle subsidy program.

For each of the pilots identified, the team had meetings with the appropriate stakeholders to determine potential for improving the environment while being an initiative that would be embraced by the private sector. In most of the cases the impact on EEL was determined to be worthy of further exploration. Based on the project schedule, the team did not begin formally soliciting pilot test candidates until late in 2019 with a proposed start in the spring of 2020. The COVID-19 pandemic significantly delayed the pilot test outreach process beginning in March 2020. Most companies and agencies had to pivot their operations to adapt to a new way of doing business and participating in pilot tests was not of primary importance. The project team continued to work internally to identify and evaluate suitable pilot tests but any formal outreach on the topic was put on hold until early in 2021. The stakeholders identified for these pilot tests were all eager to participate and share experiences; however, most were not able to commit to meeting the timeline required by this project due to workforce challenges prompted by COVID-19.

Although COVID-19 delayed the pilot testing schedule, there were still numerous pilot test opportunities that became possible for further exploration. Through conversations with stakeholders and DOE staff, the team identified several pilot tests to pursue. These pilot tests represent a range of initiatives that could be implemented within the I-87 Corridor and be transferable to many other corridors across the United States. The selected pilot tests are initiatives that are business friendly and have not been thoroughly studied by others, making them excellent pilot test candidates. A summary of each is presented below.

Pilot #1: Cargo Consolidation: The objective of this pilot was to evaluate cargo consolidation closer to the port of entry (Port of New York and New Jersey) instead of shipping all 20-foot and 40-foot containers to the company warehouses near Albany, New York. This pilot test aims to reduce the number of trips required including empty trips traveling the entire length of the corridor, which is over 150 miles, by using a warehouse near the port to consolidate cargo into 52-foot trailers. This pilot test demonstrated the potential for ordinary receivers to implement freight demand management initiatives to increase the energy efficiency of their logistic operation, with the potential to save money. The results of the pilot test show that the cargo consolidation operation:

- Reduces empty miles.
- Improves the efficiency of the freight network/system.
- Is cost competitive.
- Decreases carbon emissions corresponding to empty miles.

The pilot test shows other companies that opportunities exist to consolidate their cargo for drayage operations in larger trailers for more energy-efficient logistics. The pilot test showed that the cargo consolidation option is feasible because: (i) it is easy to schedule appointments at a terminal for the pickup and return of containers; (ii) over-the-road (OTR) trucks tend to have better fuel economy than drayage trucks because of the network they travel, decreasing the operational carbon footprint if they are used on longer hauls; (iii) transloading shipments also offers opportunities to perform sorting/segmenting/product value add inside the transload facilities; and (iv) the decreased reliance on regional dray drivers for terminal moves to the door creates an opportunity to use transload operations and OTR trucks.

Pilot #2: Tandem Trailer Operations on the New York State Thruway: Tandem trailers or Longer Combination Vehicles (LCV) consist of a single power unit pulling two trailers. In New York, these operations are only allowed on the New York State Thruway (I-87 and I-90). Although the use of tandem trailers is not new, the team was compelled to document the energy efficient characteristics of the initiative since one power unit pulling two trailers is more efficient in terms of energy, emissions and cost than having two separate power units. By working with carriers operating in the I-87 corridor and the Trucking Association of New York, the team was able to collect and analyze detailed GPS data and deploy a survey to qualitatively document the attitude of the private sector towards the use of tandem trailers in New York.

Although tandem trailers do not work for all carriers, their use can realize tremendous savings related to equipment, labor, fuel, and the emissions. The team found that operating a tandem trailer combination is about 59.1% more efficient than operating two separate trucks with single trailers. Allowing and fostering the use of tandem trailers is a great example of a collaborative EEL opportunity, with considerable benefits for both the economy and the environment.

The implementation of cashless tolling on the NYS Thruway improved traffic conditions near interchanges by removing toll plazas, which in turn translated into safety and environmental improvements for many types of system users. However, one user group that was negatively impacted by the switch to cashless tolling was carriers utilizing tandem trailers. While cashless tolling did not negatively impact all tandem trailer users, a survey of registered tandem operators found that prior to cashless tolling 87.5% of them were satisfied with the NYS Thruway tandem trailer program, but two years after the switch to cashless tolling 60% were dissatisfied with the program. Most of the dissatisfaction was a result of the extra miles required to access tandem trailer makeup and breakup lots. These extra miles traveled cost the carriers time and money, but also caused extra pollution and wear and tear on the infrastructure.

Pilot #3: Use of Freezer Blankets to Optimize Deliveries of Frozen Goods: A freezer blanket is a large blanket that provides insulation to maintain cool temperatures for perishable items. Freezer blankets can be used to keep cargo warm or cool. This ensures that the products remain in good condition until the receiver arrives and properly handles and stores the cargo. Utilizing freezer blankets can be advantageous for fleets that haul a variety of goods such as frozen, perishable, and general dry commodities by utilizing fewer vehicles to make these trips. This could be the case for food and grocery deliveries that need to place cargo in different environments and typically require different trailer/body styles (i.e., refrigeration versus dry van). The purpose of this pilot test was to investigate the feasibility, potential energy efficiency gains, and cost reductions of using freezer blanket technology in relation to the grocery sector. The data used was from a multi-year deployment of freezer blankets at Price Chopper Supermarkets. Price Chopper was able to consolidate their dry, refrigerated, perishable, and frozen grocery loads into 'all-in-one' deliveries to select stores by utilizing freezer blankets on some of the goods. The results indicate that freezer blankets can act as a low-cost solution to consolidate various types of goods including frozen and perishable items that require different temperatures and need to be carefully monitored to ensure food safety. The reduction in delivery stops for the Price Chopper stores ranged from 8% to 56% per store with the average reduction being 34.7%. This reduction in trips is substantial considering the investment in freezer blankets is relatively small compared to the operational and environmental savings.

Companies looking to utilize freezer blankets or similar technologies should carefully examine their operations to identify the best routes, stores, and products to include. Additionally, there are other applications where freezer blankets could be utilized, such as to support deliveries made in the off-hours (overnight), when a driver delivering to a restaurant might not have access to a refrigerator or freezer.

Pilot #4: Assessment of Local Deliveries Using Various Vehicle Types: The purpose of this case study is to investigate how companies operating locally within the I-87 Corridor could potentially change their vehicle types to foster EEL. The team partnered with a local manufacturing company near Albany, New York that utilizes several warehouses within a 20-mile radius. To support the manufacturing efforts the company strategically uses warehouses and a small fleet of trucks to transfer cargo between locations. Using the GPS data collected, and publicly available emission models, the team concluded that battery electric vehicles (BEV) and hydrogen fuel cell electric vehicles (FCEV) have the potential to outperform traditional diesel-powered trucks in terms of emissions and fuel costs. However, these vehicles have a much higher upfront fixed cost and require other resources that are not readily available today. Improvements to the refueling/recharging infrastructure, including the power supply system, need to be made to ensure that the trucking community can fully consider a switch to these types of alternative fuel vehicles. Forward thinking companies that are able to start converting their fleets to BEVs or FCEVs are helping to evolve the market; however, it should be noted that these types of vehicles tend to be first rolled out by large carriers, with the change trickling down to smaller and smaller carriers. It is also important to note that as technologies continue to emerge and develop, there will not likely be one silver bullet that will be the best alternative and alternative fuel vehicles might not work for all applications. Companies are likely to use sound judgment in choosing the alternative that makes the most sense for their operations. If costs of BEVs and FCEVs drop it will become more likely that adoption will take place naturally. Otherwise, the implementation of incentives and emission regulations may be the only option. It should be noted that if this does not occur naturally with the support of industry there will be industry resistance, especially if regulations are placed on diesel powered trucks, which can still be operated efficiently.

Conclusions

One of the most challenging obstacles in this project was the COVID-19 pandemic that generated major setbacks, particularly with the collaborations with the private sector that understandably wanted to prioritize the heath of their associates and the recovery from the economic crisis. One of the setbacks during the COVID-

19 pandemic was the impossibility of collecting fine resolution GPS data. GMU required this data to develop truck-specific procedures to estimate the second-by-second speed profiles needed to subsequently estimate fuel consumption with Autonomie. As an alternative, RPI and ANL developed a strategy to bypass the need to replicate second-by-second speed profiles in the integration of the tools—BMS, SVTrip, and Autonomie. During the past year, both teams successfully collaborated to integrate the tools. The RPI team also developed study cases to assess the effectiveness of EEL initiatives using the BMS. Three study cases were developed: 1) one to assess the effectiveness of land use initiatives, 2) another to estimate the benefits of off-hour deliveries, and lastly 3) one to model the advantages of consolidating e-commerce deliveries to households. All study cases were simulated with the BMS tool developed by RPI, and the results served as input to ANL's tools to estimate energy consumption.

The COVID-19 pandemic also presented a setback for behavioral modeling. After waiting to deploy the survey to commercial establishments under "normal" conditions, the team was finally able to distribute the survey starting in October 2021. The distribution process lasted approximately six months. The team adopted three approaches to distribute the survey—in-person, by mail, and by email—reaching over 3,000 establishments in the Capital District and NYC. Respondents mentioned that they were inclined to adopt EEL initiatives. Some efforts are already in practice for some of the respondents, such as consolidating deliveries from the same vendor. Other initiatives have a positive perception from the establishments that participated in the survey, such as purchasing from vendors that deliver with electric vehicles or implementing an appointment system to receive their deliveries.

Lastly, the past year was dedicated to conducting pilots with partners from the public and private sectors. Even though the COVID-19 pandemic pushed back the pilot testing schedule, there were still numerous pilot test opportunities that became available for further investigation. The RPI team decided to pursue four pilots: 1) cargo consolidation, 2) tandem trailer operations on the New York State thruway, 3) use of freezer blankets to optimize deliveries of frozen goods, and 4) assessment of local deliveries using various types of vehicle types.

Summarizing the efforts done last year:

- Successfully developed and implemented a strategy to integrate the tools developed by RPI and ANL.
- Used the BMS-B2B and the BMS-B2C to test three study cases in the Capital District.
- Implemented three pilots and evaluated a fourth.

I.3 Accelerating Alternative Fuel Adoption in Mid-America (Metropolitan Energy Center)

Miriam Bouallegue, Principal Investigator
Metropolitan Energy Center
300 E 39th St.
Kansas City, MO 64111
E-mail: miriam@metroenergy.org

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

Start Date: October 1, 2017 End Date: September 30, 2023
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, compressed natural gas (CNG), and electric vehicles (EVs).

Objectives

The project's objectives are to establish alternative fuel options with EV charging, biodiesel and 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 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, including no-cost time extensions to enable the completion of critical corridor installations.

Grain Valley School District (GVSD): GVSD's 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, Kansas (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 remained low (at least until mid-2021) so they did not see the savings they expected. One problem with the 2019 deployment is that the vehicles have insufficient power, creating issues getting in and out of the landfill with the trucks when the ground is wet or snowy. For the 2020 trucks, they purchased 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 Directors, 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. In FY 2022, the airport deployed four additional CNG vehicles.

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 for the time-being and is reducing its fleet size in line with an airport redesign. With that in mind, it ordered four additional CNG buses in Q4 2019. Due to the COVID-19 pandemic manufacturing delays, delivery was delayed until mid-2021. Although the buses were delivered in FY 2021, deployment was delayed until spring 2022 due to lack of available bus drivers at the airport as a result of labor shortages associated with the COVID-19 pandemic. 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 to expand the airport's electrification efforts in light of new city ordinances and objectives to promote electric vehicles and sustainability in the city's fleet. The plan is for the shuttle buses to use the inductive charging while they are loading and unloading passengers. KCI explored the possibility of 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; however, this proved to be cost-prohibitive.

The City of Kansas City, Missouri (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 seven 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. Although Chevrolet recalled the Bolts in late 2021, the city kept the vehicles deployed on a limited basis until the battery packs could be replaced in early FY 2022. 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. With these deployments now completed in 2021, KCMO's project is essentially complete, except for continued 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 pulled out of 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 DCFC development by 24-7 and other fuel retailers, a group of stakeholders led by the state Petroleum Marketers Association lobbied the Kansas legislature to consider a bill that enables private companies to charge customers on a kWh basis in the state of Kansas. MEC provided subject matter input as requested, 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 two public 100kW stations installed in March 2021. See Figure I.3-1. Each unit supports one car to charge at 100 KW (or the car's limitation) or two cars charging at 50 KW (or the cars' limitations). It sits on the I-135 spur, which is a major corridor between Wichita and Salina with multiple commuting populations in between. 24-7 held a ribbon-cutting ceremony in 2021 with Kansas Department of Transportation (KDOT) and McPherson Chamber of Commerce participating. Attendees included staff from U.S. Senator Marshall's office. Also in 2021, 24-7 completed construction on the new Goodland, Kansas, store. There is now a 12,000–gallon biodiesel tank and inline blender to supply retail biodiesel blends to 24-7's western stores, along with DCFC 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 were delayed. In 2022, 24-7 worked on getting timelines from its suppliers but faced difficulties due to uncertainties over pricing and availability. This ongoing delay was considered a project risk, since our deadline to complete final installations was prior to the end of September 2022. MEC submitted and received an extension request from DOE in late 2022 to continue 24-7's work in Colby. The equipment has been delivered and work at the

Figure I.3-1. The 24-7 Travel Store in McPherson, Kansas installed DCFC (Photo Credit: Tami Alexander)

Colby site is in progress. 24-7 hopes to complete their work in Colby ahead of schedule, ideally in first quarter 2023. This is a critical corridor location, since there are no other biodiesel fueling stations between WaKeeney, Kansas, and Denver, Colorado along I-70, a distance of approximately 300 miles. Currently, there is only one other non-Tesla charging location in Colby, Kansas, and the next closest charging station is in Goodland, Kansas or Hays, KS, with a distance of almost 150 miles between them.

Winter weather is a challenge for biodiesel blends, as biodiesel gels at significantly higher temperatures than ultra-low-sulfur diesel (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. At one point the price of soybeans rose high enough that the price for biodiesel was forecast to surpass that for diesel, which could have affected the blend ratio. In reality, the price of diesel also rose enough for 24-7 to continue blending biodiesel for a financial advantage. In another leveraged project, 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.

Blue Springs School District (BSSD) originally planned to add time-fill CNG stations to its bus lot; however, when the Superintendent and Assistant Superintendent for Operations of BSSD both retired, 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 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, which is located within the City of Lawrence, Kansas, biodiesel production ground to a halt in March of 2020. MEC had brokered an agreement with the city 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 2020-21 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. 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. KU was 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 started. However, repeated failures to meet fuel spec and continuing difficulties resulting from COVID meant this deployment was indefinitely delayed. 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.

KU Research – Hydrogen Study. In late 2021, MEC expanded KU's scope of work to include hydrogen infrastructure integration research and brought them on as grant subrecipient. The study is 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 researched the literature and provided 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 submitted the completed study to DOE in 2022, and the university plans to submit the final paper to technical publications.

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 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 2021 at the beginning of the fall semester.

The City of Olathe, Kansas, was also added as a subrecipient under this project in 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.3-2 for an image of an Olathe EV charging at the solar-powered EVSE station during the city's community workshop.

Figure I.3-2. The City of Olathe, Kansas new EV and EVSE. (Photo credit: Jeff Windsor)

The city also added six electric Chevy Bolts to its 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 were out of service as the city waited for Chevrolet to replace the recalled battery pack but are now back in service.

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 in 2021. The project scope was for the KC Library to purchase one electric bookmobile. The KC Library planned to charge the vehicle using existing outlets and did not anticipate installation of any infrastructure. Contract execution and procurement was expected in early 2022 with deployment in summer 2022; however, in mid-2022, the KC Library determined that they could not provide the necessary cost-share for the project and terminated their plans to participate. These funds were reallocated to the final corridor installations planned by subrecipient 24/7.

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 in the future. MEC saw much more successful outcomes since making this shift in response to the local market. MEC is also increasing electrification of municipal fleets and is assisting the cities of Olathe, Kansas, and Kansas City, Missouri, with electrifying their fleets beyond this project. This innovation is bringing 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 2023 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, which caused the project to 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 and 2023.
- 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.4 Drones, Delivery Robots, Driverless Cars, and Intelligent Curbs for Increasing Energy Productivity of First/Last Mile Goods Movement (Carnegie Mellon University)

Constantine Samaras, Principal Investigator through August 30, 2021
Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA 15213
E-mail: csamaras@cmu.edu

Sebastian Scherer, Principal Investigator since September 1, 2021
Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA 15213
E-mail: basti@andrew.cmu.edu

Sean Qian, Co-Principal Investigator
Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA 15213
E-mail: seanqian@cmu.edu

Mark Smith, DOE Program Manager
U.S. Department of Energy
E-mail: mark.smith@ee.doe.gov

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

Project Introduction

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 with the continued growth of e-commerce. 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. At the same time, both on-road electric vehicle (EV) and driverless automated vehicle (AV) technologies are advancing rapidly. 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 still 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.

The team has designed and executed experimental protocols for both quadrotor drones and ground delivery robots to empirically measure the energy use of various designs and sizes, carrying a range of payloads through various campaigns and altitudes in previous research years. The combined empirical, simulation, and modeling methods enable identification of pathways to improve the energy productivity of goods delivery. The quadrotor drones the team used have vertical take-off and landing (VTOL) capabilities. However, they are inefficient during the forward flight due to the requirement to counter gravity. On the other hand, fixed-wing vehicles (e.g., airplanes) are very efficient in forward flight and can fly much longer ranges than multirotors but lack VTOL capabilities and usually require runways for take-off and landings. As the third class, hybrid VTOL unmanned aerial vehicles, or UAVs, (VTOL UAVs) combine VTOL capabilities with efficient forward flight by using propellers to hover, take-off, and land vertically and wings for efficient long-range cruising. The team envisions a more efficient energy performance of this vehicle type. As for the ground delivery robots, the team envisions intelligently managed curb spaces to be a set of parking spaces dedicated to delivery vehicles where individual parking spaces can be reserved before a specific deadline. A central managing and scheduling authority can then optimally sequence the arrival of delivery vehicles based on the set of parking reservations with an objective of minimizing the number of unscheduled delivery vehicles.

Objectives

The objective of the project is to use empirical testing, life cycle assessment, and systems analysis to research and demonstrate energy improvement when using goods delivery drones, ground delivery robots and automated vehicles compared to a baseline network. 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 demonstrating additional improvement in energy productivity.

To further investigate the revised air drone energy performance, the team developed a hybrid VTOL UAV with a data logger integration to collect flight data for energy analysis. The team also developed the corresponding delivery mechanism for the last mile delivery. As for intelligently managed curb spaces, the team focused on comparing two vehicle arrival strategies, a first come first served, uncoordinated approach and a coordinated or optimal schedule of delivery vehicle reservations.

Approach

The team's hypothesis is that the timing of transition, flight path, payload, flight altitude and speed affect the energy use of the VTOL UAVs, and this needs to be analyzed and optimized. Researchers, firms, and stakeholders also need an understanding of the comparative advantages of VTOL system designs to maximize overall energy productivity and potential. The team selected a commercial fixed rotor VTOL UAV and developed upon it leading to an integrated VTOL system. See Figure I.4-1. The data logger which was designed and used for the quadrotor delivery drone is integrated so that the testing environment conditions of wind speed, temperature, and other factors as well as the voltage and current, GPS location, speed, wind speed, and VTOL movement characteristics of onboard sensors, can be recorded. This enabled the team to estimate the energy used for each flight at a high resolution. Based on the integrated VTOL platform, the team designed and executed a specific experimental protocol to empirically measure the energy use when carrying a range of payloads through various campaigns and altitudes. As for the delivery, the team developed a visual servo control system running onboard the VTOL UAV which can detect and track the landing site in the final delivery phase. The team also designed an automatic release mechanism to drop the payload through a string.

Figure I.4-1. Developed delivery VTOL UAV (Photo: CMU Team)

The team assumed that unscheduled delivery vehicles will double-park and obstruct a lane of traffic while they complete their unload/loading procedure which will result in additional traffic congestion and inefficient fuel/energy consumption. This needs to be studied and especially compared with the coordinated or optimal schedule of delivery vehicle reservations. For the coordinated perspective, the team developed a hybrid approach leveraging and adapting two optimization formulations which solve the parking slot assignment problem [1][2]. Key outputs from the optimization solution are the schedule of parking events and the total minutes of double parking. The schedule of double-parking events was converted to total minutes of lane obstruction and input into a deterministic queuing model where surrounding traffic flow was reduced during the duration of lane obstruction events. Key outputs from the queuing model include the total vehicle minutes of delay for surrounding vehicle traffic in the queue near the delivery vehicle curb space, which was further scaled to estimate the total excess fuel consumption. The team was able to compare differences in metrics between uncoordinated and coordinated parking scenarios.

The team examined a range of scenarios from 1 to 7 parking spaces, 1 to 200 delivery vehicles (in 5 vehicle increments) and various settings of reservation flexibility between 0 and 30 minutes. The team explored metrics from each scenario over 20 replications where each replication was based on a unique set of delivery vehicle parking requests. The set of delivery vehicle requests were derived from empirical observations of a smart loading zone pilot project by commercial company Coord in Aspen, Colorado [3]. The team also explored delivery schedules based on video camera observations collected in downtown Pittsburgh from Street Sense Inc. as a sensitivity analysis.

Results

In FY 2022, the team designed the VTOL UAV delivery drone system based on a commercial platform. Figure I.4-2 shows the functional architecture diagram. The system takes the target delivery location and the undelivered package as the inputs at the starting location, and outputs the delivered package at the target location and flight metrics that are logged during flight. Major subsystems are flight control, perception, and delivery mechanism. Based on the system functionality, the team designed the overall cyber physical system. See Figure I.4-3. The diagram includes the major software and hardware components as well as the flow of information, energy, and material. The diagram closely parallels the functional architecture.

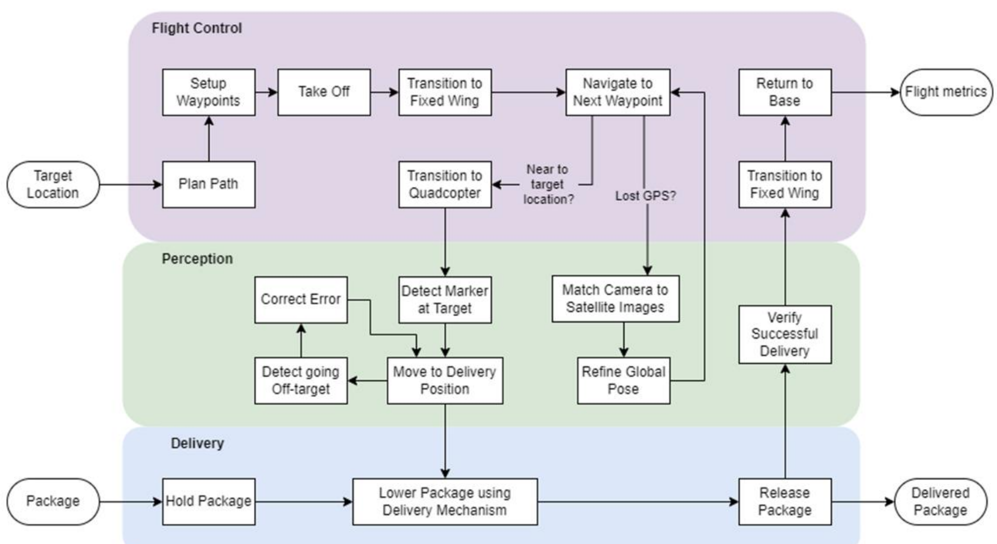


Figure I.4-2. Functional architecture diagram of the designed delivery VTOL UAV

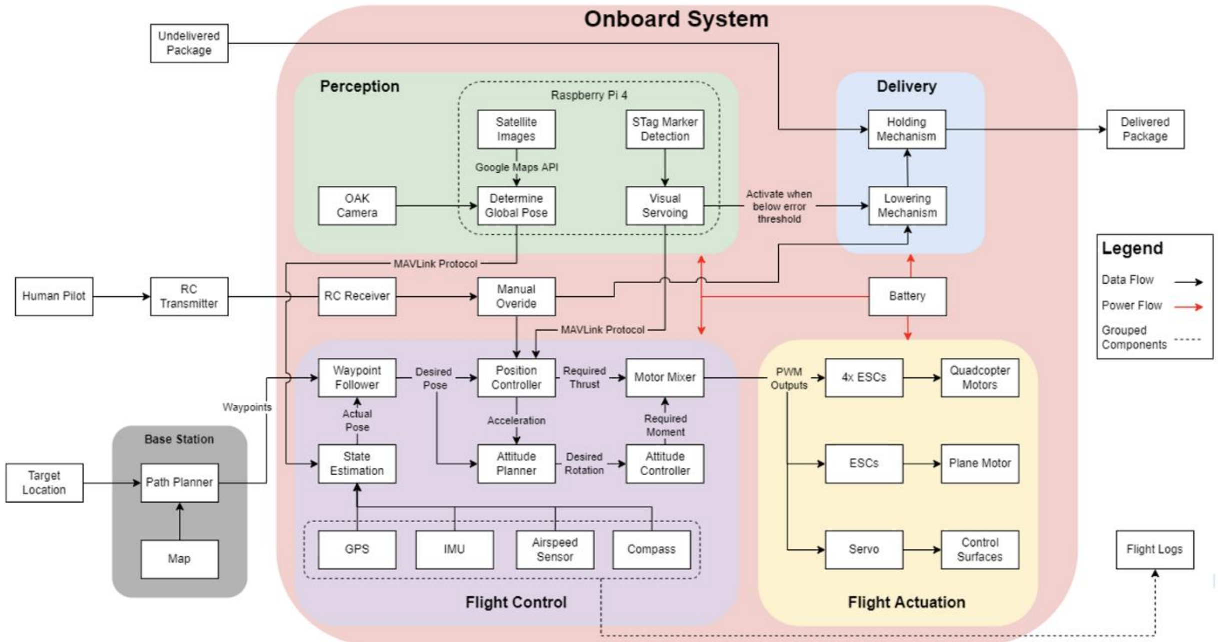


Figure I.4-3. The cyber physical architecture of the designed delivery VTOL UAV

The team completed about 80 successful tests (in total about 7 hours flight time) of the VTOL UAV with various altitude, cruise speed, flight pattern, and payload. Recall that the team previously collected data from about 200 flight tests (in total about 10 hours) using a quadrotor vehicle. This also indicates that the VTOL UAV is more energy efficient with longer flight range and time. The team designed and compared two flight patterns. See Figure I.4-4. Using the test results, the team characterized how conditions, vehicle design, and payloads affect energy use. Specifically, the team assessed the parameters collected (positional parameters, wind speed, and power) by comparing flights that share the same setup (programmed altitude, programmed speed, and payload mass).

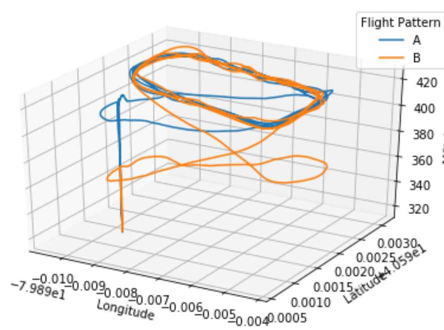


Figure I.4-4. Flight patterns: A. Take off to a specific altitude and directly transition to fixed-wing mode, then continue the cruise flight; B. Hover at half the takeoff altitude of A and climb the remaining half in fixed wing.

Figure I.4-5 shows examples of flights grouped by similar altitude, payload, and speed under flight pattern A. For instance, flights 21, 25, and 45 show altitude (Figure I.4-5(a)) and ground speed (Figure I.4-5(b)) during cruise that oscillate around the programmed parameters of 100m and 22m/s with 400g payload, respectively. Figure I.4-5(c) shows the influence of wind that naturally varies the airspeed reading among flights. On the other hand, Figure I.4-5(d) shows the power demand. It is clear the fixed-wing mode (about 80s-350s) consumes significantly lower energy compared to the multirotor phase. The power demand is kept consistent for all three flights. Figure I.4-6 shows the vehicle attitude is also consistent during the flights.

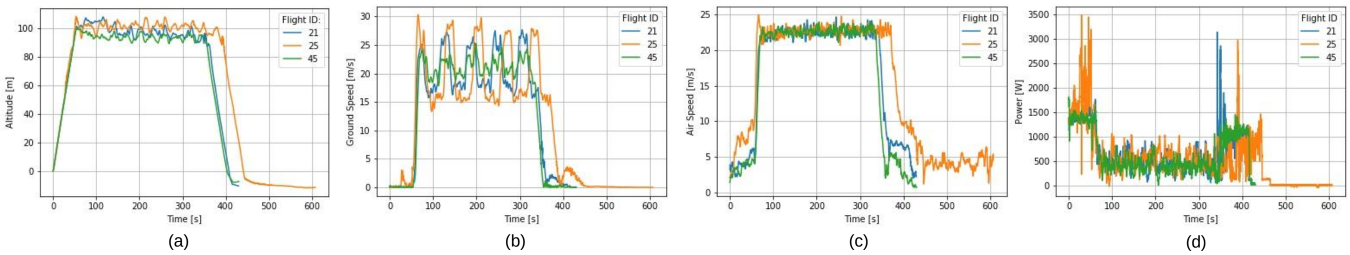


Figure I.4-5. (a) Altitude; (b) Ground Speed; (c) Air Speed and (d) Power from 3 individual flights operating at cruise speed of 18m/s, altitude of 100m and payload of 800g.

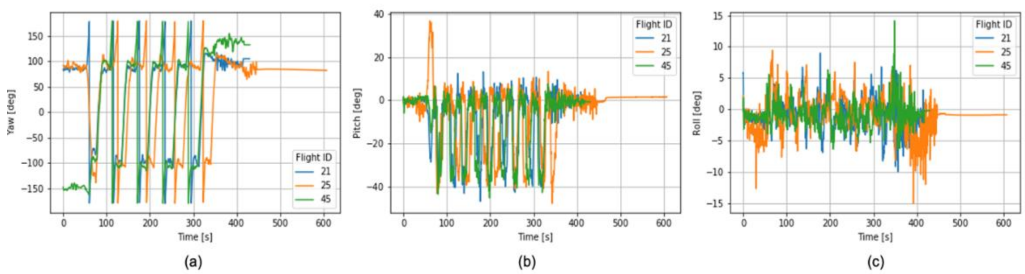


Figure I.4-6. Euler angles from 3 individual flights operating at cruise speed of 18m/s, altitude of 100m and payload of 800g: (a) Yaw; (b) Pitch, and (c) Roll.

We also analyzed the impact of the payload on the power demand. Figure I.4-7 shows the power readings for three individual flights with similar setup but different payloads (0, 400g, 800g). It is obvious that heavy payload results in higher power consumption. We then computed the total energy consumption of each flight by numerically integrating power over time. In fact, the average energy consumption for 22m/s at 100m altitude with flight pattern A is 297005.71J, 298785.84J, and 343415.84J for payload 0g, 400g, and 800g, respectively.

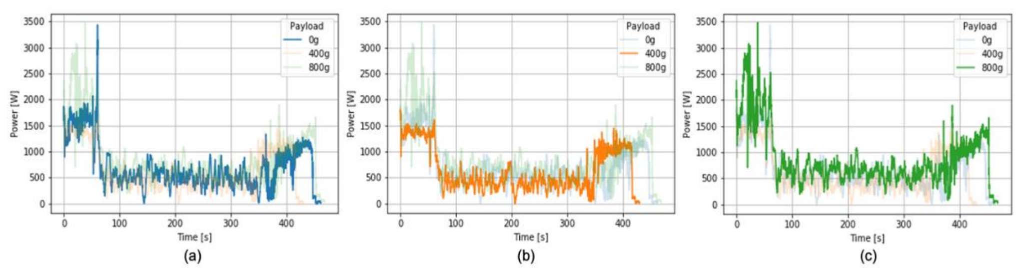


Figure I.4-7. Power readings for 3 individual flights with similar commanded altitude and ground speed but different payloads plotted with emphasis to highlight the difference in power consumption.

Furthermore, the team compared the total energy consumption of flights with the same control variables. The mean relative energy amplitude across the flight groups was 17.7% with a standard deviation of 9.5%. Moreover, 95% of the groups had a relative energy amplitude of less than 28.9%. The maximum energy amplitude was observed by flights 37, 39, and 29. An in-depth analysis shows that while the flights had different cruising speeds and different flights times, they all had significantly more power draw during fixed wing flight than most other flights. All three flights showed large variations in airspeed during fixed wing flight which were caused by large gusts of wind. These large variations in airspeed also corresponded with higher power spikes as the front motor would attempt to maintain a constant airspeed, which caused an increase in total energy draw for those flights.

The team also analyzed the altitude to compare for deviations against the target altitude. Out of all 72 flights the average cruising altitude deviation from the desired altitude was 2.48 meters with a standard deviation of 1.896 meters.

As for the last mile delivery, the team designed the delivery mechanism based on a servo release mechanism. The package is held and released by a string. Figure I.4-8 shows a delivery test and the corresponding marker detection, tracking, and visual servo control. The VTOL UAV was in the delivery phase trying to approach the dropping site holding a desired relative position with respect to the marker.

Figure I.4-8. (a) **Delivery VTOL UAV during testing with landing pad marker on the ground** (**Photo: CMU Team**) **(b) Marker detection, tracking and visual servo control during the VTOL delivery phase.**

For the intelligently managed curb space, the team is examining results from the study with several preliminary graphics discussed below. Figure I.4-9 shows that additional schedule flexibility (from 0 to 5 minutes) in the reservation requests can significantly increase the reduction in total double-parking minutes, up to between 3 and 7 minutes per hour per parking space.

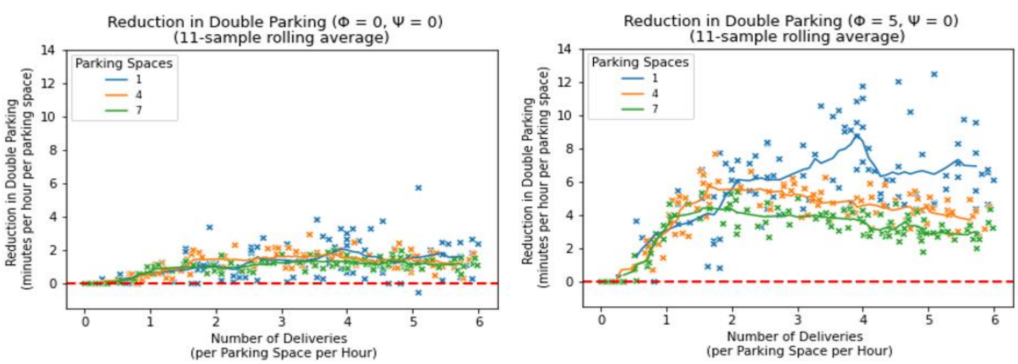
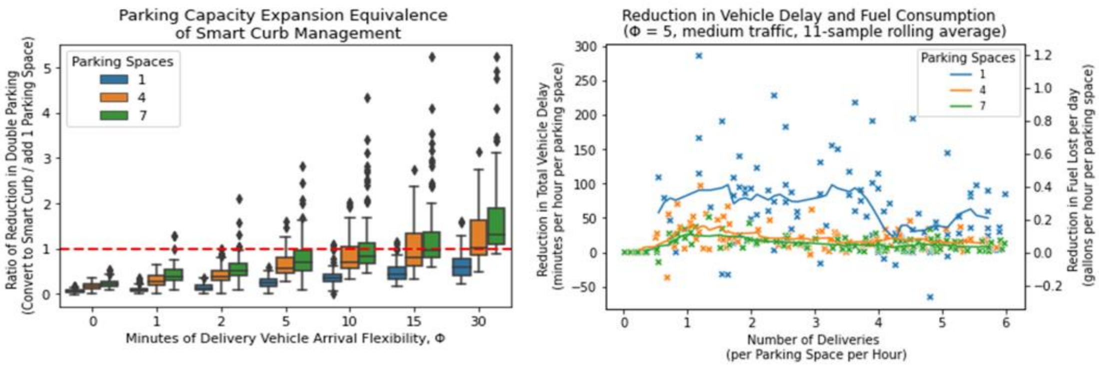


Figure I.4-9. Comparison of the reduction in double-parking minutes per hour per parking space with zero and five minutes of vehicle reservation flexibility

Figure I.4-10(a) shows the comparison of reduction in total double parking between two options, converting the current traditional parking spaces to an intelligently managed system or adding one additional parking space. Ratios above the red dashed line indicate that converting to an intelligently managed system reduces double-parking more than adding one additional parking space. Figure I.4-10(b) shows one example of the reduction in vehicle delay and fuel consumption given five minutes of schedule flexibility and medium surrounding vehicle traffic. The figure shows that the maximum reduction in fuel consumption with an intelligently managed system is estimated to be between 0.1 and 0.3 gallons per hour per parking space.



(a) (b)

Figure I.4-10. (a) The ratio of reduction in double parking between converting existing parking spaces to an intelligently managed system or adding one additional parking space; (b) The reduction in vehicle delay and fuel consumption given five minutes of schedule flexibility and medium traffic.

In FY 2022, the team published an energy analysis paper in Patterns, published a VTOL vehicle control paper in the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), published a curb space optimization paper in Bridging Transportation Researcher Conference, and submitted an energy consumption and GHG emissions analysis paper to Transportation Research Board. The team also disseminated the results to stakeholders at several conferences and University lectures in 2022, including Transportation Research Board of the National Academies Annual Meeting, the IEEE Robotics and Automation Society, Carnegie Mellon Energy Week.

Conclusions

In FY 2022, the team made progress on the project, and the results from this year align with the proposed project objectives. The team developed a VTOL UAV platform, which is a hybrid configuration that takes advantage of both the quadrotor and the fixed-wing, which is more energy efficient. Publicly available real-world data on VTOL is extremely limited, almost missing. The team collected and about to publish the energy use dataset for this new type of flying vehicle, which will provide insights to entrepreneurs, researchers, designers, and decision-makers on understanding the effects on transition timing, flight path and the delivery mechanism on the energy use of the delivery VTOL UAVs. For intelligently managed systems, the team has modeled the ideal performance of the delivery vehicle parking spaces under the assumption that vehicles will arrive precisely as scheduled. To test the robustness of this assumption, the team explored several excursions including adding a scheduling buffer between reservations and randomly adjusting arrivals from the optimal schedule to add more realism.

Key Publications

Rodrigues, T. A., Patrikar, J., Oliveira, N. L., Matthews, H. S., Scherer, S., & Samaras, C. “Drone Flight Data Reveal Energy and Greenhouse Gas Emissions Savings for Very Small Package Delivery”, 2022, Patterns.

Mousaei, M., Geng, J., Keipour, A., Bai, S and Scherer, S, “Design, Modeling and Control for a tilt-rotor VTOL UAV in the Presence of Actuator Failure”, 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IEEE, 2022.

Mousaei, M., Keipour, A., Geng, J., & Scherer, S. (2022). VTOL Failure Detection and Recovery by Utilizing Redundancy. 2022 IEEE International Conference on Robotics and Automation (ICRA), workshop. IEEE, 2022.

Burns, A. J., Samaras, Constantine, Michalek, J. J., (2022) Smart Curbspace Optimization Reduces Congestion-related Fuel Consumption from Double-Parked Delivery Vehicles. Bridging Transportation Researcher Conference, 2022. Presentation

Rodrigues, T. A., Patrikar, J., Oliveira, N., B., Matthews, H. S., Scherer, S., & Samaras, C. (2022). Energy Consumption and Greenhouse Gas Emissions of Autonomous Robots as an Alternative for Last-mile Delivery. Transportation Research Board (TRB) Conference, Poster presentation.

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I.5 Integrating Microtransit with Public Transit for Coordinated Multi-Modal Movement of People (Ford Motor Company)

Yifan Chen, Principal Investigator
Ford Motor Company
Research and Innovation Center
2101 Village Rd.
Dearborn, MI 48121
E-mail: ychen461@ford.com

Samitha Samaranayake, Co-Principal Investigator
Cornell University
373 Pine Tree Rd.
Ithaca, NY 14850
E-mail: samitha@cornell.edu

Mark Smith, DOE Program Manager
U.S. Department of Energy
E-mail: mark.smith@ee.doe.gov

Start Date: October 1, 2018 End Date: September 30, 2023
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. This project aims to improve the state of the art in first/last mile connectivity to mass transit via a fully integrated microtransit system. First, the team will develop, optimize, and test models in a simulation environment. Second, the team will conduct two pilot projects, working together with transit operators, to field-test the models developed with the simulation.

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:

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

- Two field experiments in Seattle, Washington in collaboration with King County Metro (KCM) providing first/last mile connections to public transit, one using microtransit and the other micromobility, such as e-scooters and e-bikes, operations.
- 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 dedicated several tasks to algorithm development, broadly segmented into simulation and survey tasks. Through the simulation, we developed demand models specific to our pilot program locations in the Seattle area. These models were used to 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. Along that line, we conducted a survey to understand user preferences and used the result to calibrate the simulation model. For our next workstream, we demonstrated the algorithm in a real-word pilot program, using dynamic microtransit software from The Routing Company (TRC) and in collaboration with KCM, in the Seattle metropolitan area. In addition, we planned and will launch a micromobility pilot that offers transit riders in the same area a range of micromobility services as a substitute for the microtransit service. The final workstream of this project will focus on a cost-benefit analysis with an impact assessment in areas of energy efficiency and gains in rider mobility. We will begin the final workstream in Q1 of 2023 and plan to complete the work in Q3 of 2023.

Project modifications

Due to an insurmountable technical issue with the original software supplier (related to the implementation of the Cornell algorithm), we made a major modification to the project in 2021 and brought in TRC to accomplish the same goal. The modification had some implications on the second city’s willingness to support the second microtransit pilot. Coupled with other challenges, such as the long lead time to launch a pilot and the need for local financial resources to match the DOE funding, finding another city that met both the grant criteria and timeframe has proven very difficult.

In Q1 of 2022, the project team proposed to leverage the funding allotted for the second city pilot to run a micromobility pilot in the same Seattle metropolitan area. This proposal was approved by DOE. As a result, we selected Bytemark to aggregate several e-scooter and e-bike operators to provide participants of the pilot with the micromobility option to connect to their transit rides.

Results

2021 was marked by significant progress in (1) microtransit simulations conducted for KCM; (2) rider behavioral understanding for calibrating the simulations; and (3) the launch of the first city pilot in the Seattle metropolitan area. 2022 saw major progress made in (1) integration of rider behavior and microtransit services into simulation modeling; (2) continuation of the first city pilot with amazing growth in user participation in the second half of the year, owing to some targeted marketing campaigns; and (3) successful planning and preparation for an anticipated launch of the micromobility pilot in November.

Simulation Modeling

In collaboration with KCM, Cornell University continued to advance simulation modeling work. This included an algorithm that optimizes passenger vehicle matching under user behavior considerations. The model embeds a discrete choice model and trains a Markov Decision Process (MDP) to learn future values. Initial experiments are being conducted with NYC taxi data. Two metrics are used, i.e., matching rate (shown in pale colors in Figure I.5-1) and service rate (shown in bright colors). Matching rate is defined as the percentage of requests that are matched with vehicles, and service rate is defined as the percentage of requests that are served once customers accept the offers. Compared to the baseline 1 which does not consider the behavior aspect or future value, our algorithm shows higher service rates while the matching rate decreases, indicating that our algorithm gives offers that are more likely to be accepted by customers. Baseline 2, which only considers future value, has a lower service rate than baseline 1, which might be because of bias from not considering the behavior aspect. The Cornell team is trying to upgrade the training model for MDP to improve performance and make the model more robust to datasets with different distributions.

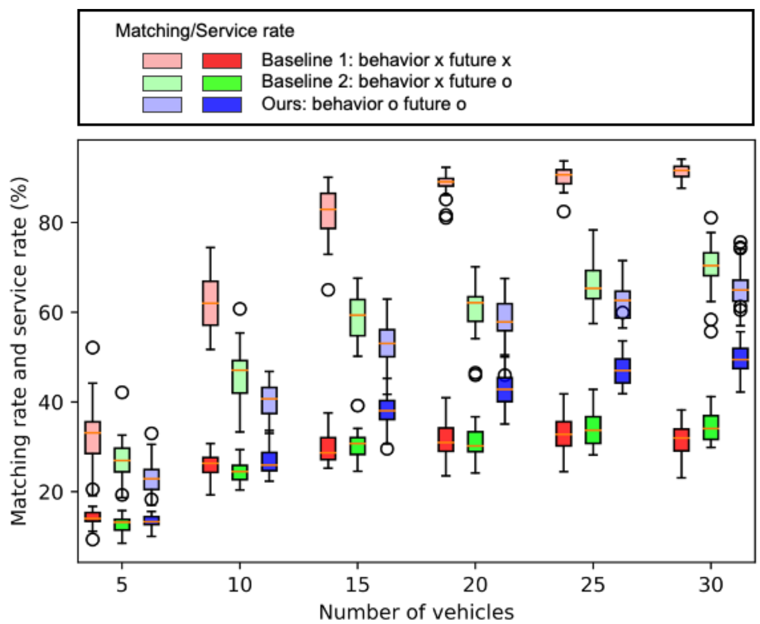

Figure I.5-1. Results from integrating user behavior considerations for better passenger vehicle matching

Additionally, the Cornell team proposed a rolling-horizon based temporal decomposition method for scheduling paratransit services. In this problem, the set of trip requests is known in advance (e.g., the day before) and needs to be scheduled collectively. The model was tested on a Chattanooga paratransit dataset and randomly sampled data from the NYC taxi trip dataset to show scalability. Figure I.5-2 shows the experimental results tested on 30 different days with randomly sampled requests in the NYC dataset. Scenario 1 has an average of 129 requests, which is similar to the Chattanooga dataset. Scenario 2 has an average of 2,587 requests to show scalability. We compared our solver to the baseline solver using Google OR-Tools. In Scenario 1, our solver performed as well as the baseline solver. However, in Scenario 2, our solver performed well while the baseline solver failed to find any feasible solution within the reasonable time limit of 1 second per request. The paper for the novel rolling horizon framework has been accepted at the 2023 AAAI conference.

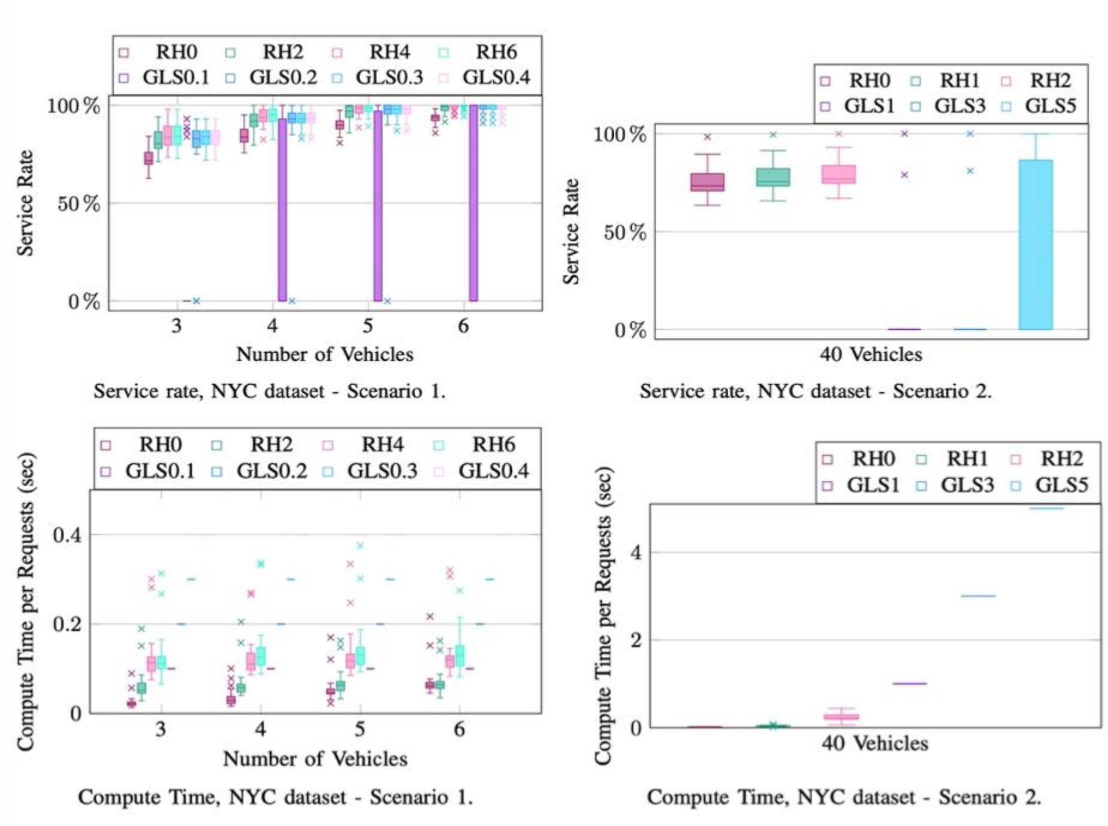

Figure I.5-2. Results from rolling-horizon based temporal decomposition for paratransit scheduling

To support the micromobility pilot, the Cornell team focused on using quantitative modeling to provide insights into key operational questions that cities and transit agencies face when managing e-scooter programs. Specifically, the team explored how contracts with e-scooter providers and regulations should be structured. Two key questions of concern are:

- How to provide incentives for multi-modal commuting.
- What the right trade-off looks like, since stakeholders have multiple objectives (e.g., maximizing system trips, improving access to public transit),

To answer these questions, the Cornell team proposed and analyzed a novel stylized model that captures the key dynamics of e-scooter operators. The team considered two regions – the city center and a neighborhood. The city center has a higher rate of demand throughout the day but is already well served by transit. The neighborhood has demand patterns strongly influenced by commuting (to the city center) and is less well served by transit. Figure I.5-3 shows the trade-off between the operator costs and service level required in the neighborhood region under three different rebalancing costs. The main takeaways are:

- This inspires the potential idea of 'commuting rebalancing' where commuters (instead of the company) rebalance the system by taking e-scooters with them on transit (e.g., buses) while commuting in the morning or the evening. This ensures that e-scooters are present during commutes (thereby improving access to transit) while allowing increasing utilization during the day (once they are in the city center).
- Reducing the cost of rebalancing is key to getting the best trade-off between total trips completed by the system and improving access to public transit (in the neighborhood).

- A good potential metric for measuring service in regions is availability (% of time that an e-scooter with charge is close enough to a perspective user). This can be measured by app openings or estimated by using time-weighted demand and population density estimates.

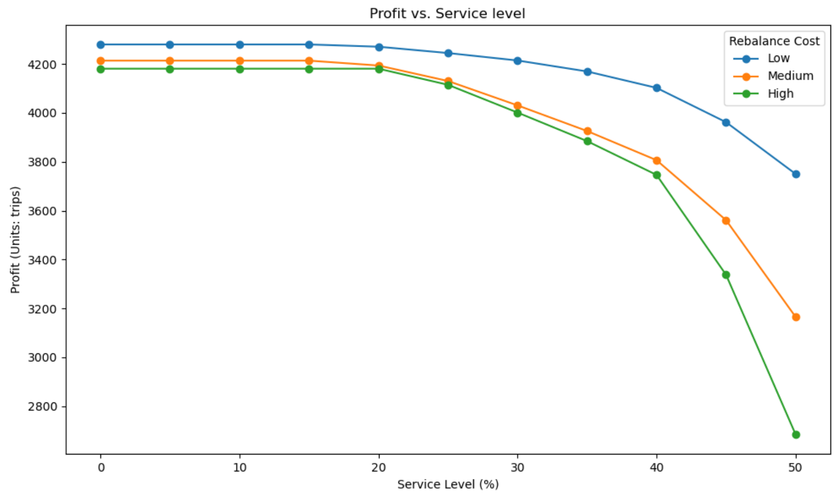

Figure I.5-3. Impact of rebalancing cost on e-scooter profit-service level dynamics

Continuation of Microtransit Pilot - Ride Pingo to Transit, King County Metro

Over summer and fall of 2022, The Cornell team developed a rider evaluation survey and interview protocol for Ride Pingo. The team will pilot the survey in October and will begin fielding the full survey in November.

Launched on September 14, 2021, the Kent Station microtransit pilot continued throughout 2022. Using a software platform provided by TRC branded as "Ride Pingo to Transit," the service connects travelers to buses and trains at Kent Station as well as to key buses at a second hub in the Kent Industrial Valley at an Amazon fulfillment warehouse. Riders can request a connection to fixed-route transit using a feature on the Ride Pingo app that was developed for this project called "Transit Connect." The pilot has continued to operate seven days a week ever since except for severe weather conditions (e.g., snow).

Using the Transit Connect feature, riders can tell the app which bus or train they're trying to connect with from a list of potential transfers, all of which meet a range from not too early that the microtransit cannot effectively deliver the rider to the transfer, to not too late that the service is no longer on-demand.

Initially ridership numbers grew slowly and stabilized at lower levels than originally hoped. The project team monitored the pilot carefully and implemented measures to improve the service and awareness. The pilot management team met weekly to review operational data, and discussed system and app performance and potential service adjustments. Staff from Ford, TRC, KCM, and the local vehicle operator, Hopelink, all participated in these meetings.

KCM implemented driver staging on January 31, 2022, as a service adjustment to improve system efficiency. Previously shuttle drivers were instructed to go to Kent Station if they were idle. Based on analysis and some guidance from KCM about best practices for optimizing the ratio of "passenger miles traveled" to "vehicle miles traveled", i.e., PMT:VMT, drivers were instructed to remain idle in their vehicles if there were no passengers on board, which reduced empty VMT.

The team implemented another major service adjustment on March 12, 2022, whereby the number of vehicles operating on weekends was reduced from two to one due to low demand. After this change, the rate of unfulfilled trips increased because the driver could not serve all trip requests within the maximum wait time constraint of 35 minutes. The maximum wait time parameter was therefore extended to 45 minutes on the weekends to better serve all riders.

Meanwhile TRC continued to improve the app, develop new features, and fine-tune data reporting in response to user reports and requests from KCM. In March, TRC organized a marketing event for St Patrick's Day where "street teams" dressed in costume engaged with riders and helped people install the Ride Pingo app and learn how to use the service.

To further raise awareness, Ford worked with TRC and KCM during Summer of 2022 on a marketing campaign for the pilot. TRC worked with KCM and marketed their joint Ride Pingo to Transit service, operating within the Kent, Washington area. Those activities included social media influencing, social media advertising, radio and television advertisements, outdoor signage, promotional events, and street teaming. The overall impact of these activities was remarkable. In the week prior to the commencement of marketing (week of May 23), there were a total of 60 unique riders completing trips. In the week of September 22, there were 110 riders completing trips, representing an increase of 83% (Figure I.5-4).

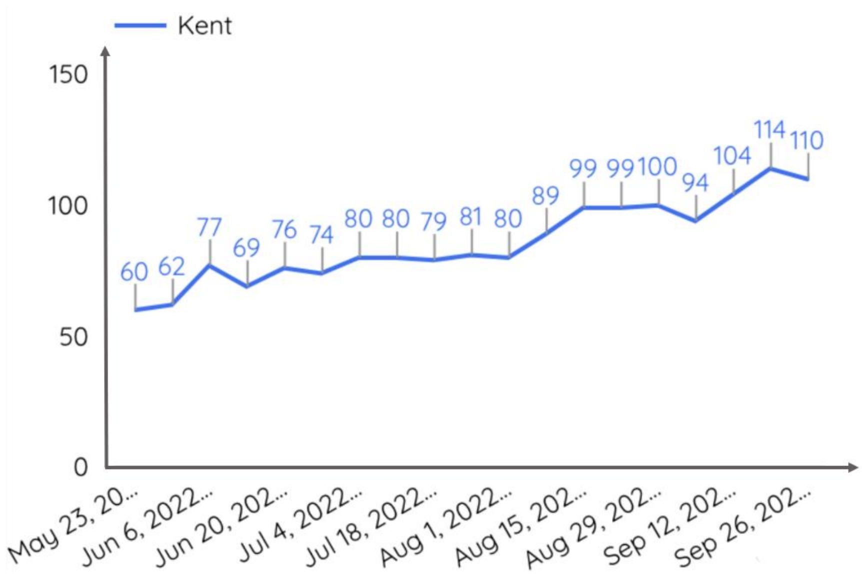

Figure I.5-4. Weekly number of unique riders who completed ride with the Ride Pingo service

The increase in ridership also resulted in an improvement in vehicle utilization, and thereby fleet productivity. For the Ride Pingo to Transit pilot, KCM runs a fleet of three 13-seat shuttle buses to provide riders with the "1st mile" service around the Kent Station. In a typical day, all three buses are in service during the morning and late afternoon peak hours but only two for the rest of the day. As the ridership number grows, so does the productivity measured by "passenger per vehicle online hour." As shown in Figure I.5-5, by the end of September 2022, the average productivity of the fleet has reached 2.44 passenger per vehicle online hour. Also shown in the figure are plots of 95th and 99th percentiles of productivity which have increased to above 5 and 6, respectively. They represent the top 5 and top 1 percent productivity indicative of what peak productivity looks like during highest demand periods.

The Kent Station microtransit pilot is scheduled to end in March 2023. TRC will then share the data collected with the Cornell team for analysis and impact assessment.

Figure I.5-5. Monthly passengers per vehicle online hour, Ride Pingo service.

Launch of Micromobility Pilot – Bike and Scoot to Transit, King County Metro

Ford worked with KCM and Cornell to identify the research objectives for the micromobility pilot including:

- Improving public understanding of which mode, microtransit or micromobility, is more suitable for first/last mile access to public transit and in which type of urban areas.
- Preparing research papers documenting findings about use of micromobility for first/last mile access to transit, overcoming barriers to access, and improving seamless connections between e-scooter and transit operators.
- Evaluating the effectiveness of financial incentives and user responses to discounts.
- Creating a micromobility trip dataset for public access by researchers containing e-scooter trips connecting to public transit with origin/destination (O/D), time, type of connection (bus, train), and type and amount of fare discount.

DOE approved this proposal in March 2022 with modified project tasks that included contracting with a new software vendor to work with micromobility operators and to collect the data. The team selected Bytemark as the software vendor, and the micromobility project was locally named Bike and Scoot to Transit. There are four service providers in the system: Bird, Veo, Lime and Link (i.e., Superpedestrian). Bytemark worked with KCM, Sound Transit (ST), and Seattle DOT (SDOT) to identify mobility hub locations in Seattle for the pilot. Those geo-fenced locations are the *preferred* parking locations within the scope of this pilot. Additionally, ST and SDOT piloted the use of preferred parking locations with physical markings for e-scooters and e-bike-share programs.

A key element of the micromobility pilot is to learn how to effectively deploy financial incentives for improving overall use of the system. In this pilot, riders of the four micromobility service providers can get up to $8 on qualifying trips. A trip becomes “qualifying” if the rider parks the e-scooter or e-bike at one of the preferred locations. Additionally, if a rider completes one qualifying trip every week, he/she will be provided with one set of links to transit tickets for free on the Transit Go Ticket app. Accepting these free tickets unlocks opportunities to earn Transit Go Rewards points on the Transit Go Ticket app, which can be redeemed for transit tickets as well as credits for bike-share and scooter-share services.

The Bike and Scoot to Transit program will be launched in November 2022, and we will review and discuss its operation in our next year's annual report.

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I.6 Understanding and Improving Energy Efficiency of Regional Mobility Systems Leveraging System Level Data (Carnegie Mellon University)

Sean Qian, Principal Investigator
Carnegie Mellon University
5000 Forbes Ave.
Pittsburgh, PA 15213
E-mail: seanqian@cmu.edu

Mark Smith, DOE Program Manager
U.S. Department of Energy
E-mail: mark.smith@ee.doe.gov

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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 ridesharing 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, ridesharing 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 ridesharing 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 ridesharing 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 [1]. 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 traffic modes, heterogeneous travelers route choice and infrastructure modeling (such as parking facilities). The mobility model can be calibrated with multi-source system-level 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 addressed in this modeling process are:

- 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 are proposed, validated, and tested to ensure the network simulation can approximate real-world system-level multi-source data, in all three regional networks.

- 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 can approach all those observations within 24 hours, and one shot of the network simulation can be completed in 30 minutes on a regular personal computer.

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 [2]. 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 several classes: 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 age in 5-year increments. 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 attributed to vehicles in the Pittsburgh region by each road segment, shown in Figure I.6-1. Energy consumption and carbon dioxide (CO2) emissions follow a similar pattern across difference source types of vehicles; passenger cars and passenger trucks contribute the majority of the energy consumption and gas emissions. However, emissions of NOx, carbon monoxide (CO), and hydrocarbons (HC) follow a rather different pattern. NOx, CO, and HC from aging vehicles (older than 15 years) are larger while CO2 emissions and energy consumption are smaller than the other vehicles.

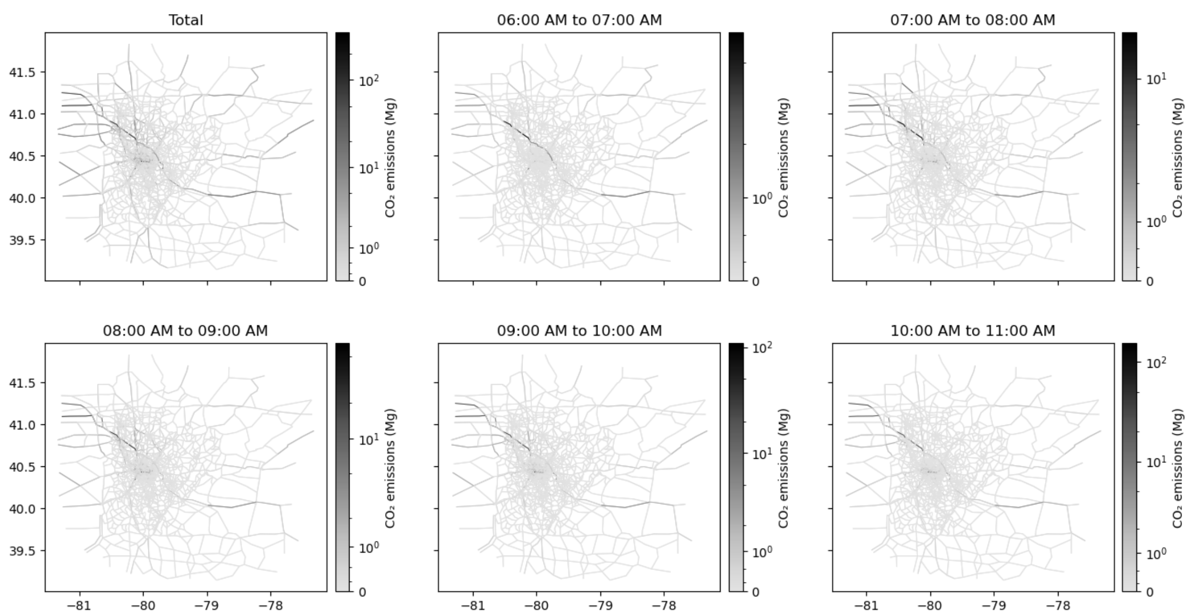

Figure I.6-1. Total energy consumption and CO2 emissions for all vehicle classes in Pittsburgh region

In another example, we estimate the energy consumption and gas emissions of the whole system under three strategies for replacing aging vehicles with new vehicles using the same fuels, namely replacing all vehicles older than 15 years, 20 years, and 25 years, respectively, shown in Figure I.6-2. Even though replacing aging vehicles does not help on improving energy efficiency or reducing CO2 emissions, it has an apparent effect on cutting down the emissions of NOx, CO, and HC; when we replace all vehicles older than 15 years with new vehicles, we can reduce the emissions of those gases by over 60%.

The general modeling framework and computational platform allows 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.

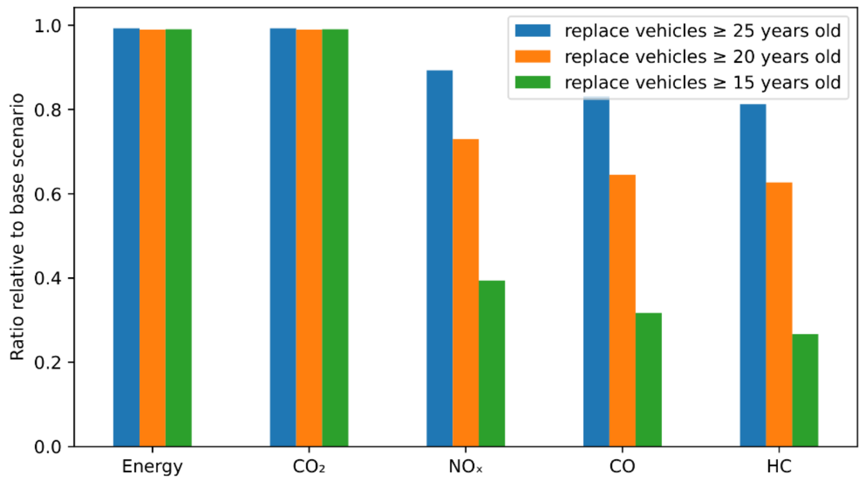

Figure I.6-2. Ratios of energy consumption and gas emissions with respect to the base scenario under different strategies for replacing aging vehicles (Pittsburgh region)

Currently we are preparing the initial release of the software platform (under C++ and Python) by January 31, 2023 and once it is released the development will be fully transferred 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, agile development of transportation-energy models for regional network for system-level measures, 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 demand variation, 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

Qiling Zou, Sean Qian, (2023) Estimating Dynamic Origin-Destination Demand for Multi-modal Transportation Network: A Computational-Graph-based Approach, Transportation Research Board Annual Meeting, No. 23-02212. 2023.

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

Pengji Zhang, Wei Ma, and Sean Qian. Cluster analysis of day-to-day traffic data in networks. Transportation Research Part C, Vol.144, 103882.

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. (2023) Estimating environmental impacts of large-scale transportation systems by leveraging vehicle registration data in integrated network models. Under review, Transportation Research Part D.

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.

References

[1] Xidong Pi, Wei Ma, and Sean Qian. "A general formulation for multi-modal dynamic traffic assignment considering multi-class vehicles, public transit and parking." Transportation Research Part C: Emerging Technologies 104 (2019): 369-389.

[2] 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.7 Multi-Unit Dwelling and Curbside Plug-In Electric Vehicle Charging Innovation Pilots in Multiple Metropolitan Areas (The Center for Sustainable Energy)

Rick Teebay, Principal Investigator
The Center for Sustainable Energy
3980 Sherman Street, Suite 170
San Diego, CA 92110
E-mail: rick.teebay@energycenter.org

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

Start Date: April 8, 2019 End Date: December 31, 2022
Project Funding: $3,000,000 DOE share: $1,500,000 Non-DOE share: $1,500,000

Project Introduction

Because of the Inflation Reduction Act of 2022, Bloomberg New Energy Finance projects that by 2030, electric vehicles (EVs) will be 52% of the new vehicle sales [1]. While EVs were only 2.0% of the nationwide market in 2018 [2], EV sales could be as high as 52% of total light-duty vehicle sales by 2030. In 2020, there were 55 EV models available in one or more states. By 2025, there will be more than 160 models available in the US [3]. With the proliferation of EVs from traditional manufacturers and the shift away from internal combustion engine vehicles, there will be a growing need for charging infrastructure. EV charging occurs primarily at three locations: at home, at work, and other locations (such as destinations). The U.S. Department of Energy indicates that more than 80% of EV charging currently occurs at home [4], making access to home charging critical to widespread EV adoption.

Charging at owner-occupied single-family homes has developed fairly rapidly, but nationally, about 34% of all housing is multiunit dwellings (MUD) or multi-family housing [5]. In 2015, less than 5% of home-based charging occurred at MUDs [6]. In metropolitan areas like Washington DC., Chicago, and San Francisco, more than 70% of the housing is MUDs. There has been some very limited deployment of curbside residential charging stations adjacent to apartments and condominiums, but there are significant barriers to providing charging for residents in multi-unit dwelling (MUDs). Some of the primary barriers that have limited widespread deployment of EV charging at MUDs and curbside residential locations include:

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

This DOE project will transform the MUD charging market and support deployment of EV charging infrastructure in MUDs. This required creating a baseline understanding of the current market conditions, identifying the technical and soft barriers experienced by key stakeholders, and addressing those barriers. Key stakeholders include MUD property owners/managers, Homeowner Associations (HOAs), MUD residents, industry associations/organizations, EV charging technology providers, Clean Cities coalitions, local utilities, state and federal organizations, and property developers. The project demonstrated several innovative charging technologies, created tools that will assist stakeholders overcome the identified barriers, and disseminated the project findings across local, state, regional, and national channels.

Objectives

The project's objective is to develop a *Multi-Unit Dwelling EV Charging Toolkit* that includes all the necessary information on technical considerations and the development of the business case for installing and operating EV charging at MUDs. It also includes sample agreements and policies. The project evaluated and implemented innovative, cost-effective, and flexibly expandable charging technology and software solutions that will enhance the residential MUD and curbside EV charging systems market. The project's results and the *Toolkit* have been 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 those without dedicated parking.

Approach

In year three, the project team created tools and resources specifically focused on best practices at MUDs for EV charging infrastructure installation, operation, and maintenance, and placed them on the newly created vci-mud.org website. The project team shared and disseminated the vci-mud.org website with stakeholders through its Clean Cities partners.

Year three, the final year of the project, focused 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 (HOAs). The *Toolkit* features resources and tools providing educational information for the users and helping them identify potential barriers in their MUD through a self-evaluation survey. The survey results can be used in the technology recommendations tool to search for technologies that may address the barriers identified. In addition to this key feature, the *Toolkit* also features MUD charging roadmaps and best practices for EV charging program design to help users prepare for their respective endeavors.

Results

The project team launched the *Toolkit* at https://vci-mud.org and broadly disseminated it to key stakeholders and to audiences nationally to ensure the project has a meaningful and broad impact on the market.

The project team disseminated project learnings through conferences, webinars, and journal publications such as the Electric Vehicle Symposium (EVS 35 in Oslo, Norway) and Forth's annual Roadmap Conference in Portland, Oregon.

Conclusions

This project assembled a large and diverse dataset that deepens the understanding of MUD and curbside residential charging. The qualitative data has confirmed many of the barriers to deploying charging at MUDs. But it also reinforced that MUDs are not a monolithic sector, and that there can be 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

MUD and Curbside Residential Charging Toolkit, on the Vehicle Charging Innovations for Multi-Unit Dwellings (VCI-MUD.org) website.

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[2] IEA. “Global EV Outlook.” IEA (2021): https://www.iea.org/reports/global-ev-outlook-2021

[3] https://evstatistics.com/2021/03/number-of-ev-models-available-in-the-us-to-triple-by-2025/

[4] Klonsky, M. et al. “Incorporating Residential Smart Electric Vehicle Charging in Home Energy Management Systems” Preprint, National Renewable Energy Laboratory, NREL/CP-5D00-78540 (2021): https://www.nrel.gov/docs/fy21osti/78540.pdf

[5] US Census Bureau “2017 American Community Survey, 1-Year Estimates.” https://www.nmhc.org/research-insight/quick-facts-figures/quick-facts-resident-demographics/#Structures

[6] “NOVA Workforce Development, Electric Vehicle Charging in Apartment-Based Housing”. Accessed April 2015. https://files.novaworks.org/Reports/EV-MUD.pdf

Acknowledgements

The CSE team acknowledges the financial and project support and guidance of DOE staff: Linda Bluestein and Margaret Smith, and National Energy Technology Laboratory staff, Brett Aristegui. The team also recognizes the intellectual and time contributions of our Clean Cities coalitions and other partners and Project Advisory Committee members for advancing the project.

I.8 EVSE Innovation: Streetlight Charging in City Rights of Way (Metropolitan Energy Center)

Miriam Bouallegue, Principal Investigator
Metropolitan Energy Center
300 E 39th St.
Kansas City, MO 64111
Email: miriam@metroenergy.org

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

Start Date: October 1, 2018 End Date: December 31, 2023
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 2023.

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. Thirty ChargePoint CT4013-GW1 Wall Mount Units are planned for delivery in November 2022 and will be held until installation begins in January 2023.

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 points-of-interest or multifamily residents. See Figure I.8-1for a visual of the streetlights selected by the project engineer for further review and approval, overlaid on the six different city council districts.

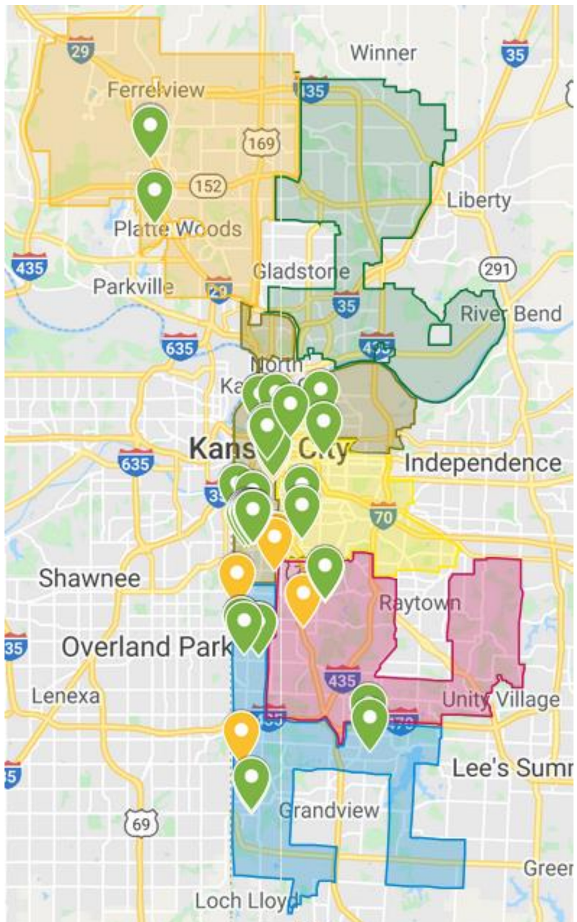

Figure I.8-1. Go/Maybe EVSE sites. MEC

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.

Progress in Q3 of CY22 was slow, due to the site host negotiations between Evergy and the City having to run through the City Council. The first presentation to Council on July 20 resulted in all parties having to re-evaluate sites selected to balance out the number of sites allocated to each council district. Though time consuming, the bigger delay came when trying to reschedule our second presentation to the council, which finally occurred on Sept 14. Council's approval on that date facilitated execution of the site host agreement by Sept 30. At the end of Q3 CY22, parties were finally all cleared to proceed with installation activities.

This latest delay resulted in one more amendment request to DOE for a final No Cost Time Extension to ensure deployment activities are conducted within BP2. Site visits are complete, and the selection committee has selected the top 30 sites. Sites were prioritized by choosing areas that overlap between the MST and NREL models, and sites with high cost-benefit ratios. See Figure I.8-2 for a visual of the top 30 EVSE final sites selected for installation. Note that the Kansas City, Missouri district boundaries were updated with 2023 boundary lines. MEC plans to analyze reasons for non-selection and incorporate this information into the final report.

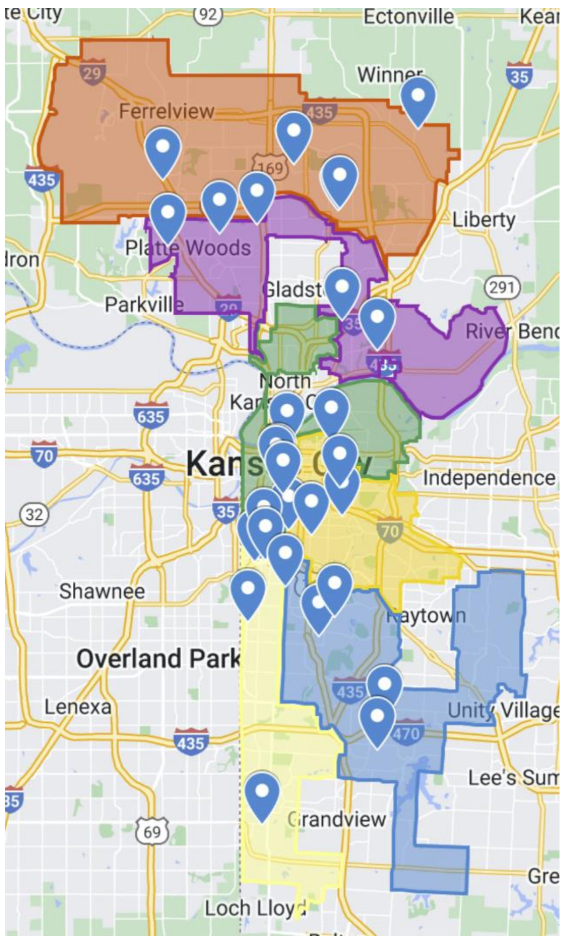

Figure I.8-2. Thirty Go EVSE sites in new 2023 districts

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, EVN, 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 the city enforces this ordinance. 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. Both the Parks and Recreation Department and the Parking Program reviewed and approved the project in the summer of 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 (BOD) 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 continued to explore ownership options until we received a decision from the PSC. Installations were delayed until a viable ownership strategy could be established, in early 2022. Throughout 2021, MEC continued to provide relevant information to the PSC, Evergy, and the Missouri Office of Public Counsel as requested, to aid in decision-making. In early 2022, the PSC issued its decision that Evergy may take on ownership of the chargers and Evergy and the City proceeded to finalize the site agreement with Evergy as the station owner.

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. For example, many, if not most, of the DOE-identified Disadvantaged Communities (DACs) in Kansas City are primarily comprised of owner-occupied detached single-family houses. Sometimes these houses did not have access to off-street parking whereas multifamily units in other areas did. These concerns were specifically expressed to MEC and the City by EV-driving owner-occupants in the DACs without off-street parking access. Community input is imperative in conjunction with data to mitigate any bias or assumptions on the part of researchers.

- 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.

- Equity is a growing concern among policymakers, both at the local and federal levels. Projects like these may be paired with other initiatives in the future to meet the needs of diverse communities more comprehensively on a local level.

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. Installation is now on track to begin in January 2023 with the goal of installing two to three chargers every week until completion by the end of March 2023 at the latest.

References

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I.9 NGV U.P.T.I.M.E. Analysis: Updated Performance Tracking Integrating Maintenance Expenses (Clean Fuels Ohio)

Timothy Cho, Principal Investigator
Clean Fuels Ohio
17 S. High Street, Suite 810
Columbus, OH 43215
E-mail: tim@cleanfuelsohio.org

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

Start Date: October 1, 2019 End Date: December 31, 2022
Project Funding: $950,000 DOE share: $450,000 Non-DOE share: $500,000

Project Introduction

The NGV U.P.T.I.M.E. Analysis project will quantify the difference in maintenance cost between diesel and compressed natural gas (CNG) freight and goods movement vehicles, identify and quantify technology and process improvements between older and newer generation natural gas vehicles (NGVs), and assess individual NGV fleets to identify opportunities to enhance operations using newly generated and legacy NGV and diesel fleet data. The NGV industry currently lacks comprehensive analysis and metrics regarding maintenance costs since users tend to be siloed by various use cases or competing in similar verticals. In addition, vehicle and engine manufacturers have been reticent to make this data widely available. This has led to a paucity of available information for current and prospective NGV users. There is little publicly available data that clearly compares the relative maintenance costs of NGVs and current advanced diesel trucks with modern exhaust aftertreatment systems (post-2010) to effectively capture recent NGV technology advancements, evaluate NGVs' potential to lower operating costs, and investigate claims of NGVs' lower total cost of ownership (ultimately improving cost-effectiveness and national energy security). NGV UPTIME's purpose is to bridge this information gap and facilitate an unbiased analysis drawing on a diverse dataset of national fleets to provide robust, real-world results for the broadest possible group of stakeholders. The project implemented a proven, multi-dataset analysis approach at both the system and component levels to determine the maintenance repair frequencies and cost differences between CNG engines (including previous and current state-of-the-art generations) and advanced clean-diesel engines (including post-2010 and post-2017 generations). The project results provided fleets, NGV industry stakeholders, and other end users with relevant, current, real-world information. The project results showcase the analysis findings (broken down by engine and/or fuel type) at the system, assembly, and component levels to better determine the NGV industry's current status and to identify specific research, development, and outreach needs.

Objectives

The objectives of the project are to quantify the difference in maintenance costs between diesel and 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 natural gas (NG) 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). This requires digital records of fleet operational, maintenance/repair, and fueling data and costs through Vehicle Maintenance Reporting Standards (VMRS) from fleet partners. The VMRS coding system is a way for the project to effectively collect, clean, and analyze common maintenance tracking descriptions and sub-systems across different fleets and to clearly see types of repairs done on the vehicles and the associated cost, labor, and parts for each specific repair. This data collection approach allowed the project to gather multiple similarly structured fleet data sets into a database and sort the maintenance data that are relevant to the analysis of the project.

Results

Clean Fuels Ohio has completed project tasks and deliverables which have led to the successful completion of a series of milestones in the third year of the project. Milestones from Year 3 include:

1. **Data Analysis and Summaries:** Complete individualized fleet data analyses, visualizations, and summaries for the combined dataset.
2. **Fleet-Specific Reports:** Complete and distribute fleet-specific reports from individualized fleet data analyses and data summaries.
3. **Final Report:** Complete and disseminate final report.
4. **Final dataset:** Complete final dataset in a consistent and accurate way that is sufficient for final analysis.

Data Analysis and Summaries – Data Collection Process and Dataset Profile

The project team developed and finalized the project's data analysis and summaries that determined the maintenance cost differences between current generation NG trucks, previous generation NG trucks, and current generation diesel trucks for freight and goods movement applications. The data collection stage of this project proved to be particularly challenging. The project team spent the majority of the first two project years actively trying to recruit fleets. The network of Clean Cities project partners identified and pursued a total of 138 fleets. Project recruitment was somewhat successful in the first ~1.5 years in terms of securing the contract-required number of vehicles despite the COVID-19 pandemic. This included only three fleets, however, one of which is very large. Fleet 1 has an outsized influence on the demographics of the dataset due to its size, has a more aggressive sustainability initiative, and is phasing out its diesel vehicles. Despite having only three fleets willing to provide data at the end of the recruitment period, the data collection resulted in a dataset that included over 1,800 vehicles with at least one repair order (RO). The overall model-year range for all the vehicles in this dataset is relatively small, with almost all the vehicles falling within a 6-year range, from 2015 to 2021. This condensed range made it difficult to make comparisons between different generations of NG and diesel vehicles. Another important note is that the average NG truck is newer than the average diesel truck in this dataset, which can be attributed to Fleet 1's prioritization of purchasing NG-powered trucks starting in 2019. (Figure I.9-1).

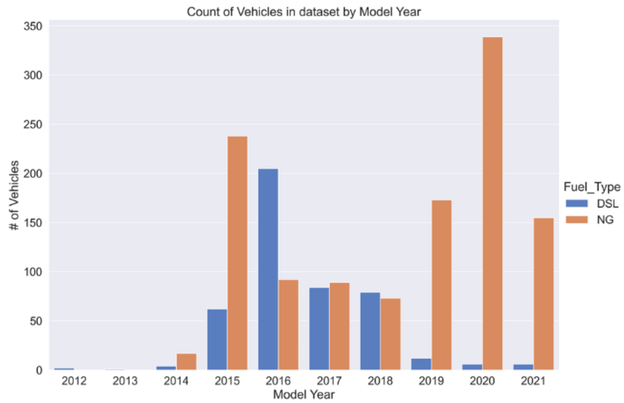

Figure I.9-1. Count of vehicles in dataset by model year

Total vehicle miles traveled for trucks in the dataset was just shy of 780 million miles, and the total number of useable ROs analyzed was approximately 244,500. The project team modified our analysis approach due to the limited number of participating fleets and the various data-quality issues. The distribution of ROs by model year shows that almost 80% of maintenance records in Figure I.9-2). This condensed timeframe of available data made it difficult to make comparisons between different vehicle generations.

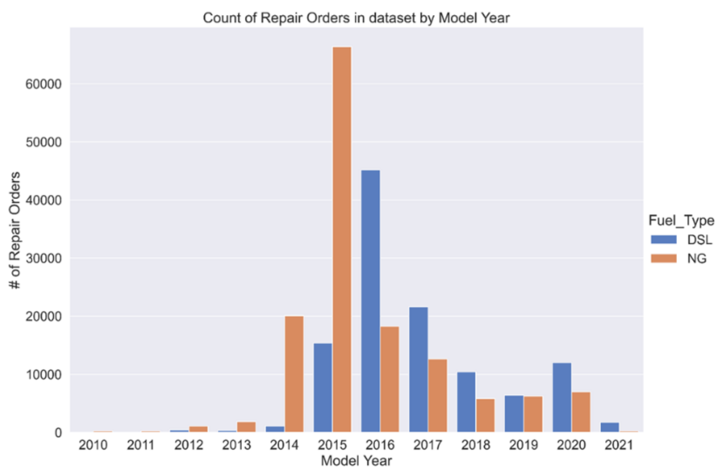

Figure I.9-2. Number of repair orders by vehicle model year and fuel type

Data Analysis and Summaries – Overall Analysis and Findings

In many instances, it was not possible or appropriate to make direct comparisons between the three fleets due to the differences in data completeness. Despite these data issues, the team was still able to make interesting observations from the project's dataset. Our initial expectation was that CNG trucks would require higher amounts of maintenance than diesel earlier in their lifespan. This theory was based on the assumption that NGV engines have shorter oil change intervals and require more routine maintenance for their ignition and fuel systems. Diesel trucks were expected to require more maintenance than NGVs toward the end of their lifespans due to the complicated exhaust aftertreatment systems required for diesel engines, which we thought would become more expensive to maintain (and replace) as the trucks age. NG engines, by comparison, have much simpler three-way catalytic converters for exhaust aftertreatment and are typically maintenance-free for the life of the truck. The results revealed that NG trucks required more maintenance than their diesel counterparts, but the maintenance costs never reached the expected parity between the two fuel types. The NG trucks in this dataset generated more repair orders and required more maintenance expenditures than their diesel counterparts at almost every odometer range. This trend was observed in the maintenance data from all three participating fleets. Further investigation revealed that the powerplant, cooling, ignition, and exhaust systems accounted for most of these observed differences.

Regarding VMRS component-level repair frequency, only Fleet 1 was able to provide data so only their data is used for the specific component-level analysis. This began by identifying differences at the broadest VMRS system level. See Figure I.9-3for the average count of repair orders for each of the fuel type significant VMRS system codes. As expected, the average count of ROs for the ignition and exhaust systems were significantly different between the two fuel types since diesel engines have more complex exhaust systems, and NG engines have more complex ignition systems. The differences seen in the number of ROs for the power plant, fuel, and cooling systems were unanticipated.

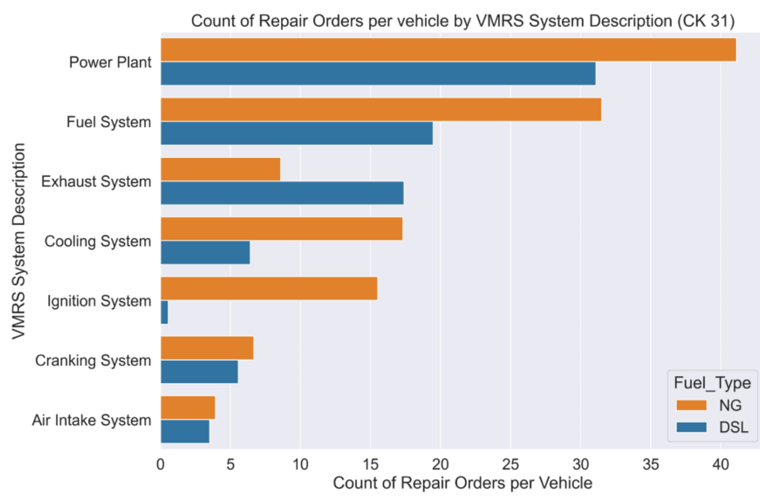

Figure I.9-3. Average count of repair orders by fuel type and VMRS system

Energetics subject matter staff met with Project Advisory Committee member Cummins at the conclusion of the data analysis phase to share the project approach, discuss results, and learn additional insights from Cummins' experience. As detailed earlier, the specific component-level analysis for all these systems revealed some interesting differences between diesel and NG. The powerplant system required the most maintenance for both fuel types, but the NG trucks had significantly more ROs for the cylinder head component than the diesel trucks. Cummins mentioned that the NG engines require more frequent valve adjustments than diesel engines. This could explain some of the differences in cylinder head-related maintenance. The cooling system also had unexpectedly large differences in maintenance frequency and cost between the two fuel types. Radiator-related failures were the leading cause. The NG trucks experienced significantly more cooling system failures than the diesel trucks. Cummins noted that the company provides diesel and NG truck manufacturers with cooling system specifications for its engines but does not provide the cooling system components or review/approve the integrations. We did not collect sufficient data to determine the cause of the higher cooling system failure rates with the NG engines, however.

The NG trucks accumulated three times as many turbocharger-related ROs as the diesel trucks. Cummins mentioned that the turbochargers may be experiencing premature wear due to the higher NG combustion exhaust gas temperatures, causing turbocharger reliability issues. The costs associated with the additional turbocharger maintenance required for NG trucks offset most of the advantages gained from their simpler/less costly exhaust aftertreatment systems. The diesel trucks generated three times as many exhaust system-related ROs, but the average exhaust system-related costs were very similar between the two engine types.

Figure I.9-4 shows the flow of dollars for the exhaust system maintenance expenditures. The emission controls assembly and the catalytic converter component required the most maintenance within this system for both fuel types. The diesel truck costs were 2.5 times the NG truck costs for the emission controls assembly, but the NG trucks required almost 5 times as much spending for the turbocharger assembly maintenance.

We saw that the turbocharger component itself was the cause of most of the repair orders within this assembly. Cummins staff noted that the NGV UPTIME project findings are similar to the findings from their internal analyses, which have been/are being used to guide the development of Cummins' recent and future spark-ignited engine families, with the goal of reducing maintenance costs and improving reliability to be on par with diesel.

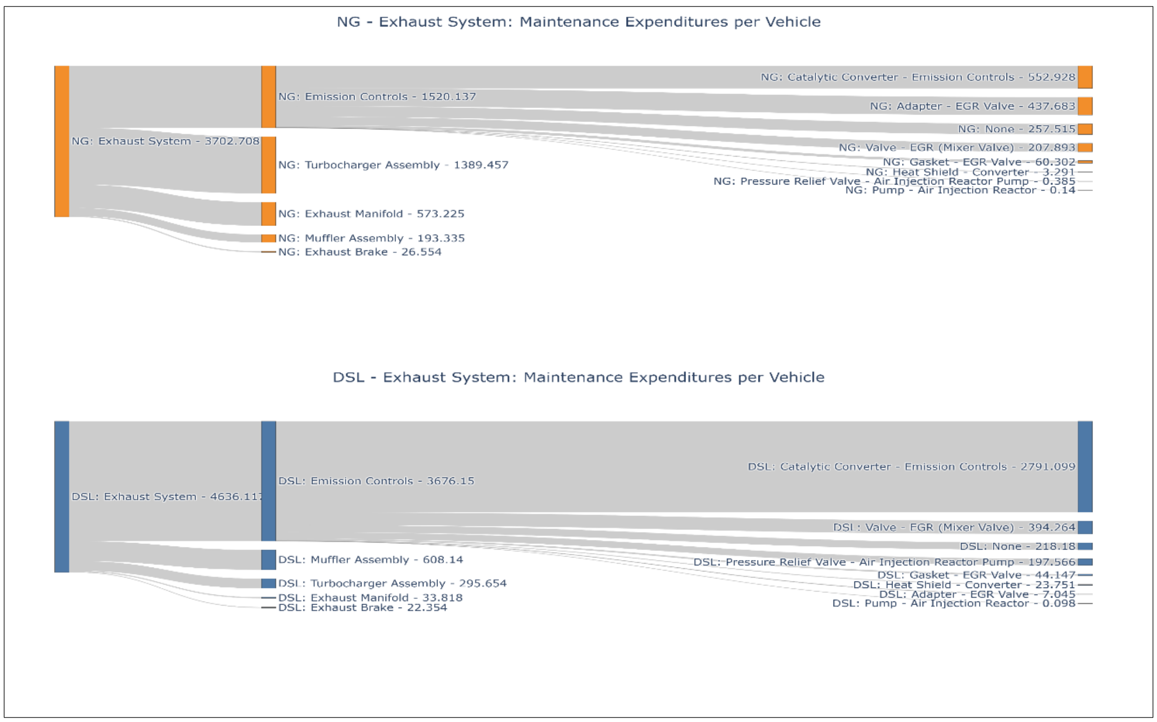

Figure I.9-4. Sankey plots of average maintenance costs per active vehicle for exhaust system components

This study's results quantified the key differences in maintenance frequency and costs between NG and diesel trucks. Data limitations did not allow for performing the planned comprehensive analysis, however. With the established data and analysis framework, gaining access to a larger and broader dataset with more variety and data granularity (i.e., at the component level) would allow for better analysis of the reliability improvements across NG engine generations and make it more feasible to pinpoint areas that would benefit from additional development. This information would allow NG engine Original Equipment Manufacturers to make the improvements necessary to better align the maintenance requirements for diesel and NG engines. Eliminating this maintenance disparity between the two fuel types would remove one of the biggest hurdles and consumer adoption barriers for NGV adoption.

Fleet-Specific Reports

Energetics developed and finalized three (3) fleet-specific reports (See Figure I.9-5) that highlight the most important and specific insightful interpretations for each of the three individual fleet data partners' data sets. Each fleet-specific report includes a summary of the respective data partner's fleet vehicle profile/makeup, the data cleaning process, analysis assumptions, and visuals for dataset profiles (vehicle data and maintenance data), overall repair frequency, component level repair frequency, overall cost analysis, component level cost analysis, and overall impressions and conclusions.

Figure I.9-5. Example of individual fleet data partner maintenance data analysis results summary

Final Report

The project team developed the final report of the NGV UPTIME Analysis project which summarizes in detail the efforts of this NG and diesel counterpart vehicle maintenance study. The final report (Figure I.9-6) captures and evaluates one of the biggest barriers to NG engine adoption: maintenance. Specifically, the project team sought to evaluate the differences in maintenance frequency and costs between various generations of heavy-duty NG engines and current diesel engines in the freight and goods movement sector. A link to the final report can be found in the Key Publications section below.

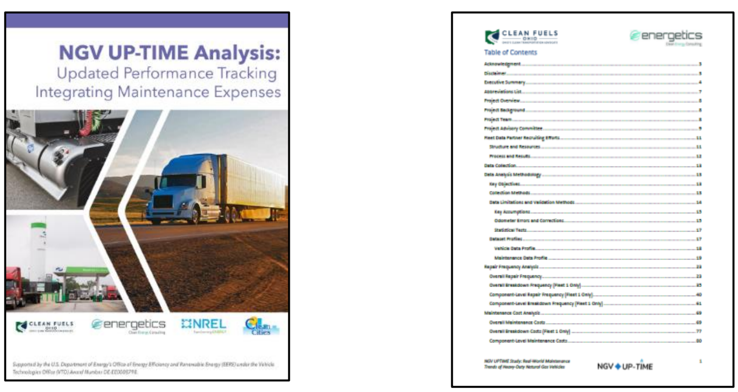

Figure I.9-6. NGV UPTIME Analysis final report cover page and Table of Contents page

Complete final dataset

Clean Fuels Ohio and Energetics finalized assembly of the anonymized dataset of NG and diesel vehicles maintenance costs and data. Clean Fuels Ohio also provided high level meta data information, the project logo, project description, and the dataset description to the NREL Livewire team. The NGV UPTIME project and dataset page became "live" on Livewire in June 2022. The final dataset is available at the weblink: https://livewire.energy.gov/project/ngv-uptime.

Conclusions

Clean Fuels Ohio anticipates wrapping up the NGV UPTIME Analysis project in December 2022 and achieving its four milestones for the third year of the project. Clean Fuels Ohio will successfully accomplish the project's scope of work in the Statement of Project Objectives which states that the project will include data from at least 1,041 total vehicles accumulated across at least 383 vehicle months. Clean Fuels Ohio will have collected maintenance cost data for 1,145 vehicles. The project results will provide fleets, NGV industry stakeholders, and other end users with relevant current real-world information. The project results showcase the analysis findings (broken down by engine and/or fuel type) at the system, assembly, and component levels to better determine the NGV industry's status and to identify specific research, development, and outreach needs.

Key Publications

NGV UPTIME Analysis Final Report

NGV UPTIME Analysis Dataset (Livewire) Note: You must sign into a Livewire account to view the data.

I.10 Smart CNG Station Deployment (Gas Technology Institute)

Jason Stair, Principal Investigator
Gas Technology Institute
1700 S. Mount Prospect Road
Des Plaines, IL 60018
E-mail: JStair@gti.energy

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

Start Date: October 1, 2019 End Date: December 31, 2023
Project Funding: $3,999,781 DOE share: $1,999,789 Non-DOE share: $1,999,992

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 is currently partnered with 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.

GTI is also working closely with ANGI Energy Systems (ANGI). ANGI Energy Systems LLC, is a U.S. based manufacturer of quality engineered gas compression equipment and a leading supplier of compressed natural gas (CNG) refueling equipment and systems. ANGI has a longstanding reputation as a leader and innovator in both the Compression and Natural Gas Vehicle (NGV) Refueling Station industries and has over 30 years of experience providing worldwide clients with high quality products and services.

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 Ozinga fleet vehicles instrumented with data acquisition units collecting mileage, fuel consumption, CNG pressure and temperature, and other relevant data. The team will collect baseline and smart-filling data for at least a year at multiple Ozinga sites. This will ensure the performance of the baseline and smart station systems are fully characterized and quantified over a wide range of operating conditions. The vehicles used in the demonstration will include several models of concrete mixers that operate in and around the Chicago area. By ensuring a 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 outside 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 focused 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. 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 upgraded smart dispensers, 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. 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 data acquisition systems (DAS) using parts from HEM and Campbell Scientific in the first year of the project, Ozinga Brothers 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.10-1. 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.10-1. HEM DAS components mounted in Pelican Case and Pelican Case inside Ozinga Brothers cement truck

All the HEM DAS for Ozinga were delivered and 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. 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). GTI purchased and fabricated four additional HEM DAS. These have been used to lab-test the smart dispenser components by connecting them to CNG cylinders being filled by GTI's CNG station.

All the CAN Bus data monitored by the HEM DAS, including the pressure and temperatures, is being transmitted over Wi-Fi and cellular networks. The cell connection is used to send all recorded data to a cloud server for analysis by GTI engineers. GTI is collecting and analyzing the data to measure and evaluate system performance. The Wi-Fi connection is used to send all relevant data to the station in real time during fueling events and will be used to control the smart dispensers.

GTI also completed development of a smart dispenser module that will communicate with the vehicle data acquisition systems. The smart dispenser module uses an ESP32 microcontroller. This device uses vehicle and dispenser data in real time to accurately select which smart vehicle is connected and then controls 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.10-2. The ESP32 was 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. When a vehicle connects to the dispenser, the measured tank pressure is 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 developed a connection flow chart for the ESP32 and vehicle and programmed 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.10-2. 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 identifies the connected vehicles, calculates how full they are using GTI's filling algorithm, and then provides 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.10-3. The CAN shields each represent a vehicle connected to the HEM streamers being used for Wi-Fi communications. The ESP32 connected to the streamers to read data from the vehicles, analyzed the data, and then provided the analyzed data to the PC that was set up as a Modbus master.

Following bench testing, GTI modified an existing test cell to enable the prototype ESP32 to be tested during controlled CNG fills. GTI used two CNG tanks to represent separate vehicles and connected a HEM DAS to each tank. GTI then programmed standard dispenser logic into LabView to act as a commercial dispenser during test fills. GTI then connected the ESP32 to LabView using a Modbus protocol, the same that would be used for actual dispenser. When the simulated vehicles were connected to the simulated dispenser the commercial filling algorithm was started. However, the ESP32 would also start scanning the two HEM DAS systems to determine if their system was connected to the LabView dispenser. If the ESP32 determined that a vehicle was connected, then it would override the standard dispenser algorithm and take over the fill. This process was tested, and the team was able to identify the connected vehicle and transmit real time filling data from the vehicle to the LabView dispenser. Unfortunately, the LabView Modbus software was buggy and would not reliably let the ESP32 take control of the fill. This is not anticipated to be a problem on actual dispensers because they are designed to used Modbus, whereas LabView does not use it as a native communication protocol.

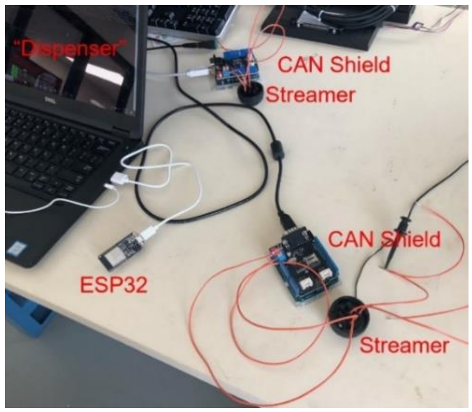

Figure I.10-3. The smart dispenser test bench is shown with HEM streamers sending data to a smart dispenser.

GTI also purchased and received a commercial dispenser from ANGI and worked with their engineers to determine the best way to integrate the smart dispenser hardware into the dispenser. The dispenser recently arrived at GTI and was hooked up to power to start interfacing with the dispenser control system. GTI has verified that the dispenser signals can be read and is working on gaining write privileges from ANGI. This is typically locked but ANGI believes they can provide GTI with a software patch to allow GTI to write specific variables that are needed for controlling a CNG fill. The dispenser is being installed in a new test cell that will enable the ambient and gas temperatures to be controlled to test fills across a wide range of filling conditions.

Preliminary Data Analysis

GTI tested the smart dispenser and vehicle communications in the lab using LabView to represent the dispenser and two CNG cylinders to represent vehicles. Each vehicle was connected to a HEM DAS and then broadcast fueling data to the dispenser in real time. The LabView dispenser was connected to the ESP32 microcontroller that scanned for nearby smart vehicles and then established a secure connection to the vehicle that was determined to be connected to the dispenser. Figure I.10-4 shows the test setup for the preliminary smart dispenser testing.

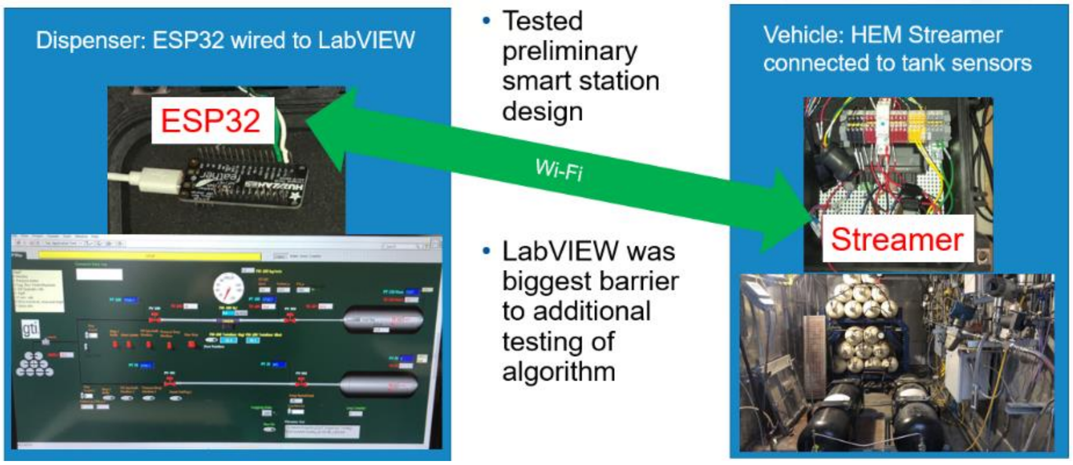

Figure I.10-4. The lab test setup of the smart dispenser is pictured. The vehicle cylinders are in the bottom left and are connected to the HEM DAS and streamer. The dispenser logic was programmed into LabView on the bottom left and the LabView computer is connected to the ESP32 microcontroller. The microcontroller looks for the vehicles and then establishes a secure Wi-Fi connection to receive real time vehicle data during a fill.

GTI conducted several fills to demonstrate that the smart vehicle could be identified and that a secure connection could be established. Real time data was sent from the vehicle to the dispenser; however, limitations within LabView prevented a fill from being fully controlled by the ESP32. Instead of spending further time debugging this system, GTI plans to use the newly purchased dispenser for development moving forward.

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 is working with industry experts to develop vehicle and dispenser hardware that will securely connect when fueling to provide a safer, improved full fill. GTI has demonstrated this equipment on the bench and during preliminary testing. GTI is now working to install and test the smart components within a commercial CNG dispenser provided by ANGI.

I.11 Next Generation NGV Driver Information System (Gas Technology Institute)

Devin Halliday, Principal Investigator
GTI Energy (formerly known as Gas Technology Institute)
1700 S. Mount Prospect Road
Des Plaines, IL 60018
E-mail: dhalliday@gti.energy

Mark Smith, DOE Program Manager
U.S. Department of Energy
E-mail: mark.smith@ee.doe.gov

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 these 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 NGV Driver Information System that includes a prediction of the remaining distance-to-empty (DTE) within 5% or 25 miles (whichever is greater) at any time during vehicle operation. The predictive model will increase the driver's confidence in the remaining vehicle range and allow a reduction of on-board fuel capacity or frequency of fueling stops.

Approach

The calculation of the remaining distance-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. GTI Energy (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 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 mobile app to display a real-time distance-to-empty prediction to the driver. This app will also be used for driver guidance and fleet management. 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 were 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 and improve predictions.

Results

GTI built and tested two different Data Acquisition Systems (DAS) and then installed the system that used parts from HEM Data on 12 trucks owned and operated by Ozinga Brothers, a major concrete provider in the Chicago area. The HEM DAS collects CAN (Controller Area Network; the vehicle's data communication system) 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 before installing similar systems on the other 11 trucks. It sent data over the cellular interface for storage and review as designed. 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.11-1.


Figure I.11-1. HEM data acquisition system in Pelican case (left) and mounted in truck (right)

Data are transferred from the vehicle to a cloud server. GTI then collects and analyzes the data to measure and evaluate system performance. Data are also transferred from the data logger to a mobile device in the cab so that the tanks' fill status and the remaining range are calculated for the driver. Several critical issues have been identified during the past year. First, the Ozinga trucks used in the project represent several different vintages. They have different engines and fuel systems with CAN bus arrangements that vary widely. The newer trucks (2018 and later) have multiple CAN systems and ensuring the data acquisition devices are monitoring the correct CAN bus requires has presented some difficulty. Finding the right data source and transmitting large volumes of data reliably have been on-going problems that affected progress and data analysis efforts. Second, it has become apparent that the Ozinga trucks spend a significant fraction of their operating time idling while the concrete mixer is turning or dispensing product. This increases the uncertainty in Distance-to-Empty (DTE) predictions because the truck is not moving and yet the fuel consumption can be great because of the load represented by the turning drum. ANL and GTI have developed ways of dealing with this uncertainty.

Data Analysis

GTI and ANL have been developing the ability to predict the distance that can be traveled with the remaining fuel in the tank (i.e., DTE). This requires knowing the quantity and properties of the fuel in the tank (through measurement and estimation) and knowing the likely future fuel consumption rate (through knowing recent fuel economy trends and expected future route conditions). To predict the fuel consumption rate, we have been collecting and studying data from multiple trucks that describe their various duty cycles and their rates of fuel consumption on these duty cycles. Some of these data come from cell phones installed in the truck cabs in compartments inaccessible to the driver.

Figure I.11-2 displays the distance traveled per day (typically 8-12 hours of operation) for four trucks from both urban and suburban areas, with the bars representing the density of days ending in each bin, with a bin-width of 10km each. The continuous trace represents the cumulative distribution function on the right. Truck 1416 shows the shortest distances traveled (attributable to its urban location) while truck 1825 covers a median distance more than 2.5 times as much as truck 1416 due to its operation in more rural and suburban areas (which allow for higher average speeds). On average, truck 1416 covers around 55km/day and truck 1825 around 145km/day. The distances traveled by trucks 1331 and 1332, which both operate in the same suburban area, are between those for trucks 1416 and 1825, at 120km/day and 115km/day respectively.

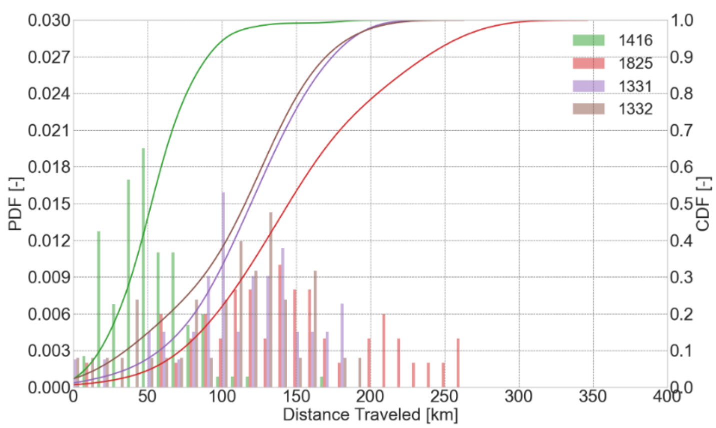

Figure I.11-2. Probability density function (PDF) and Cumulative density function (CDF) across distance traveled for truck 1416 (Chinatown) and 1825 (Mokena) and 1331 and 1332 (Des Plaines).

The influence of these different distances driven by these four trucks, and the effect on fuel consumption, is shown in Figure I.11-3. Operating a vehicle over longer distances (and at higher average speeds) is associated with more fuel consumption. Improved fuel economy at higher engine load conditions is indirectly shown in Figure I.11-3, as the median fuel consumption for truck 1825 is only about 1.6 times higher than truck 1416 (~114kg versus ~70kg) although it typically travels more than 2.6 times as far. While trucks 1331 and 1332 operate in the same area and travel similar distances, Figure I.11-3 shows that truck 1331 operates more efficiently than truck 1332, with an average daily fuel consumption of 81kg versus 91kg.

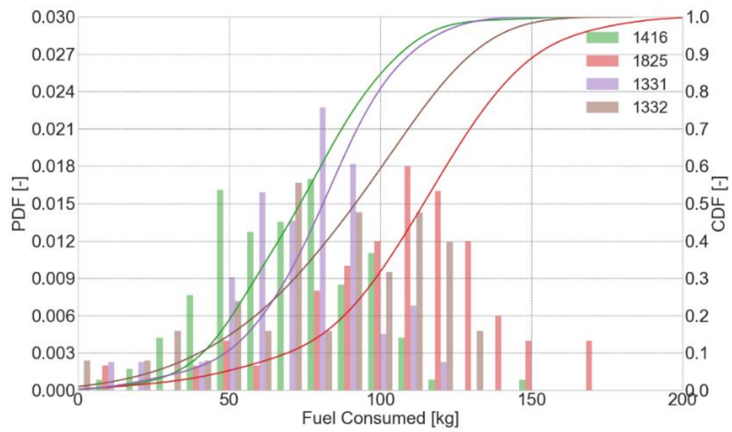

Figure I.11-3. Probability density function (PDF) and Cumulative density function (CDF) across fuel consumed for truck 1416 (Chinatown) and 1825 (Mokena) and 1331 and 1332 (Des Plaines)

The results presented in Figure I.11-4 show fuel economy for these four trucks in miles per diesel gallon equivalent (mpg_{dge}) versus average truck speed, with each marker representing a given day. The trend in Figure I.11-4 clearly indicates that higher average speeds also result in higher mpg_{dge} values and thus higher fuel economy. The highest average speeds were found for truck 1825 at just below 20mph, resulting in mpg_{dge} of 3-3.5, while average speeds of around 4.1mph for truck 1416 result in fuel economies of only around 1.4 mpg_{dge}. The trend of fuel consumption over average speed also shows that the relation starts to top out as the average speed increases. The average speed of any truck could be affected by driving conditions (urban/suburban/rural) and by idling time at a job site. Fuel consumption rate can be affected by engine load, vehicle speed, and driver performance. These factors combine to produce the variability in fuel consumption shown in Figure I.11-4.

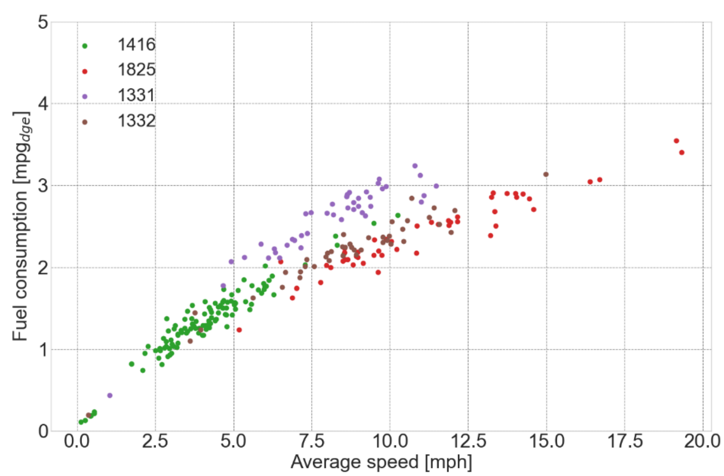

Figure I.11-4. Fuel consumption in diesel gallon equivalent (mpgdge) versus average speed for 1416 (Chinatown) and 1825 (Mokena) as well as 1331 and 1332 (Des Plaines).

To better understand the variability in measured fuel consumption at a given average vehicle speed, the team developed a statistical model based on data from truck #1416 by means of a first-order Markov model. It uses two independent states - vehicle speed (v) and total fuel consumed (m_{fuel}). The random variable related to the first state, v, is acceleration, while the fuel consumption is conditioned on vehicle speed as well as acceleration.

The probability distribution for the random variables (acceleration and instantaneous fuel mass flow) was determined from the data collected by truck #1416. To simulate multiple days of operation for truck 1416, the statistical model was exercised multiple (over 1000) times using sampled variables from distributions in actual trips. The results obtained from this procedure allow for a comprehensive analysis of the relationship between fuel consumption and distance traveled. One parameter was found to consistently predict distance traveled for a given fuel mass: average speed. The relationship between these three parameters is shown in Figure I.11-5. Distance traveled was found to be linearly dependent on fuel mass and non-linearly dependent on average speed, as shown in the equation below and in the top left in Figure I.11-5.

$$\boldsymbol{distance\ traveled = m_{fuel}(c_1 v^{c_2} + c_3 v)} \quad [1]$$

This equation contains three calibration parameters, c_1, c_2, and c_3, with m_{fuel} being the fuel mass and v being the average vehicle speed across the timeframe that a given fuel mass was consumed.

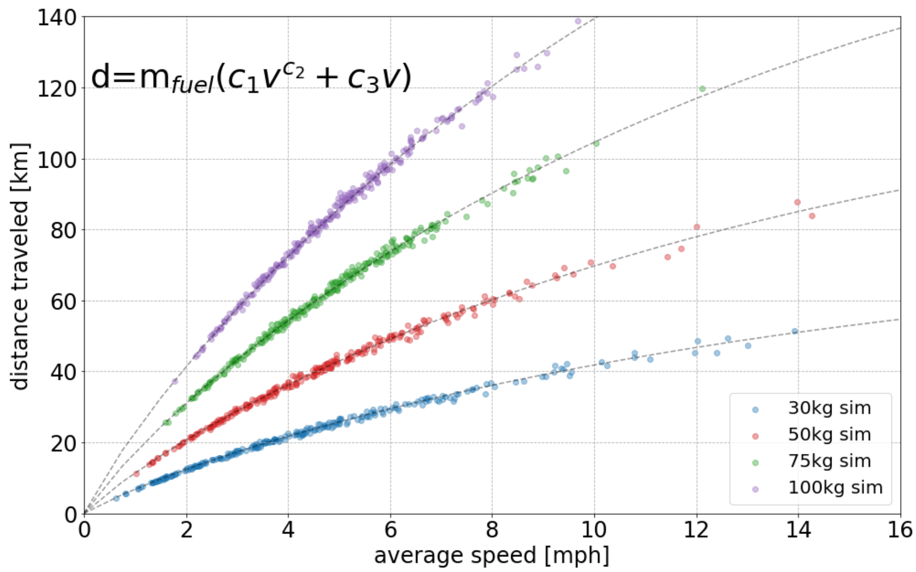

Figure I.11-5. Relationship between fuel mass, average speed and distance traveled. Data based on simulation results.

Figure I.11-5 shows distance traveled as a function of average speed for 30kg, 50kg, 75kg and, 100kg of natural gas. The analysis confirms that distance traveled versus average speed increases non-linearly as the average speed is increased. This is most likely due to the high powertrain losses at low vehicle speeds. However, the gain in distance traveled over average speed tops out at approximately 38mph (outside the bounds of the figure), most likely due to increases in aerodynamic drag.

The GTI/Argonne team intends to use the relationship between average speed, fuel mass, and distance traveled to implement the distance-to-empty prediction algorithm. Deviations from the dashed lines in Figure I.11-5 (i.e., deviations from Equation 1) will be addressed by displaying a range of distance-to-empty rather than a single value. The range of distance-to-empty will then be adjusted based on actual fuel economy values computed as a function of recent driving conditions.

Methods to Display DTE Results and Fleet Interest in DTE Information

GTI and ANL worked with Ozinga Brothers on how to display the remaining range information. After deciding to use the existing phones as displays rather than a separate gauge, this effort focused on designing and fabricating a case that can be mounted on the dashboard for easy viewing and enhanced cooling while still restricting driver access to the phone. Google Pixel 4a and Pixel 4XL phones will be used to process data and track the vehicle and multiple vehicle-specific parameters, such as natural gas consumed, as a function of time.

The factors that needed to be considered when designing the case were heat rejection capability, size, mounting configuration, and restricting driver access. As the phone is processing data, the battery and processor could reach their maximum operating temperature. Therefore, augmented cooling had to be implemented within the case to maintain a lower temperature. Included with the case is a Peltier cooler that contains two semiconductive materials that transfer electrical current between two plates. It creates a temperature gradient between those plates and transfers heat away from the phone. After a meeting with the managers at Ozinga Brothers, it was decided that the front cover would be made a part of the phone case, with a cutout at the bottom showing the distance-to-empty gauge, so that the driver cannot remove or utilize the phone. The redesigned phone case is shown in Figure I.11-6.

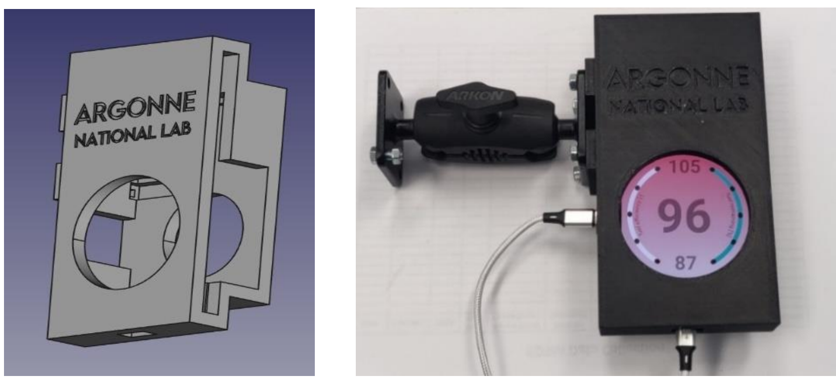

Figure I.11-6. Virtual mockup of the phone case created in FreeCad on the left. 3D printed phone case and phone displaying the fuel gauge on the right. The USB connections supply power to the phone and an integrated fan.

As described above, there are uncertainties in determining the vehicle's average speed and the tank's remaining fuel mass. Therefore, it is desirable to display a range of distance-to-empty values rather than a single value. The range of distance-to-empty can be adjusted based on actual fuel economy computed as a function of recent driving conditions. The values displayed on the fuel gauge (right picture in Figure I.11-6) represent distance-to-empty values based on different driving scenarios. As the truck is being driven, the Android app keeps track of fuel consumed and distance covered. This information is used to calculate the covariance in fuel efficiency. Multiplying the remaining usable fuel mass in the tank with the average fuel efficiency per distance traveled results in the bold number in the middle - 96. The top number, 105, illustrates a driving scenario with the fuel efficiency one standard deviation above the mean, while the bottom number, 87, reflects fuel efficiency one standard deviation below the historic average. Phones with the distance-to-empty prediction algorithm are now being installed in multiple trucks.

In partnership with GTI, Chicago Area Clean Cities (CACC) conducted a survey of NGV fleets/fleet drivers about fueling behaviors and concerns around fueling and predicted range. The survey was created using Microsoft Forms and emailed to 22 contacts representing 16 organizations. Ten responses were received, representing fleets that operate from 2 to 190 vehicles, primarily in the Midwest. Three respondents stated that there is no added information that would be helpful, two wanted generally “better fuel gauges”, three wanted DTE added, and one mentioned that the fuel gauges in their vehicles are worthless. There was a range of answers – from 500 to 1,500 psig – for how close to empty drivers were willing to drive with typical 3600 psig CNG tank systems.

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 calculate fuel economy, estimate remaining fuel on board, estimate DTE, and overcome range anxiety. This will provide value to users and give NGV designers 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.12 Statewide Alternative Fuel Resiliency Workplan (Florida Office of Energy)

Alexander Mack, Principal Investigator
Florida Department of Agriculture & Consumer Services
Office of Energy
600 South Calhoun Street, Suite B04
Tallahassee, Florida 32399-1300
E-mail: alexander.mack@fdacs.gov

Mark Smith, DOE Program Manager
U.S. Department of Energy
E-mail: mark.smith@ee.doe.gov

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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), Tampa Bay Clean Cities Coalition (TBCCC) and University of South Florida (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 (EVSE) 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. The project team will analyze the results from the survey and incorporate them 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 first year for protection of staff. The team was able to schedule site visits for December of 2021 and beyond. The project team performed the following reviews during FY 2020-2021:

- 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 (AHCA) – 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 FY 2021-2022:

From October through December, 2021, USF/TBCCC continued assisting NREL with collecting data on Florida alternative fuel fleets. TBCCC continued surveying fleets regarding their resilience practices and experience with standing water. The online survey distributed to the list of stakeholders around the state identified very few cases in Florida of fleets encountering standing water conditions. Additionally, USF/TBCCC was able to identify few standing water cases outside of Florida. They referred all identified cases of fleets encountering standing water conditions to NREL for the follow-up in-depth interviews. TBCCC worked with the Southeast Florida Clean Cities Coalition (SFCCC) and North Florida Clean Cities Coalition (NFCCC) to identify alternative fuel fleets and schedule site visits. During this quarter, USF and TBCCC researchers performed site visits to the Broward County Transit (BCT) propane paratransit fleet (Fort Lauderdale), City Furniture compressed natural gas (CNG) fueling facility (Tamarac), and Jacksonville Transportation Authority (JTA) CNG/electric transit fleet facility (Jacksonville). During this quarter, the USF team continued working on designing the web-based EVSE tool. The USF team has completed the backend EV evacuation planning algorithm/model providing for efficient EV charging and routing. The team also started testing the web tool.

TBCCC coordinated with the other three Florida Clean Cities coalitions (SFCCC, NFCCC and Central Florida Clean Cities Coalition) to compile a list of alternative fuel vendors in the state. TBCCC will forward the list to

FDACS and NREL. Finally, TBCCC presented (virtually) on the status of the State Resilience Project at the 2021 Florida Energy Summit, held on November 16, 2021.

From January through March 2022, USF and TBCCC continued assisting NREL with collecting data on Florida alternative fuel fleets. TBCCC continued looking for fleets regarding their resilience practices and experience with standing water. TBCCC continued working with the other Florida Clean Cities coalitions and local fleet partners to identify alternative fuel fleets for potential site visits. Identified fleets that may be targeted for a visit include the Florida Power and Light (FPL) facility in Southeast Florida and the City of Ocala. Coordination efforts with FPL and SFCCC to facilitate the visit are still in progress. TBCCC scheduled a site visit to the city of Ocala battery-electric refuse fleet, in August 2022.

During this period, the USF team continued working on designing the web-based EVSE tool. The USF team has completed the evacuation route model illustration providing for efficient EV charging and routing. The team also started working on the integration of the background algorithm and the web tool. TBCCC organized a meeting between USF tool developers and NREL to demonstrate tool functionality and coordinate input data integration with the Alternative Fuels Data Center (AFDC). Once the tool algorithm is finalized, TBCCC will organize a meeting with USF and Florida EVSE networks to address further EVSE data integration and compatibility.

TBCCC identified a potential vendor providing high-water-capable vehicles. Dannar LLC (https://www.dannar.us.com) produces electric off-road mobile power stations/work vehicles. According to the vehicle specifications, the vehicles can operate in up to four feet of water since all electric components and batteries are located high above ground and are sealed. Dannar vehicles also have changeable attachments (for different tasks) and can be operated using a remote control (without a human on board), from up to one mile away (given a direct line of sight). This feature makes Dannar vehicles well-suited for emergency operations to provide recovery after a hurricane. TBCCC met with a Dannar representative to discuss the product and saw the vehicle in person when it was demonstrated at the Sustainable Transportation & Technology Expo in Cocoa, Florida in March and at the Drive Green Fleet Expo in Hollywood, Florida in May.

From April through June 2022, the USF team continued designing the web-based EVSE tool. The team completed the evacuation route model and the development of a webtool prototype.

During this quarter TBCCC/USF continued working on the Alternative Fuel Resilience Plan. TBCCC reviewed sections of the plan prepared by NREL and continued working on the TBCCC/USF sections of the Plan. Additionally, TBCCC finalized the Florida AFV vendor list and provided it to FDACS.

Finally, TBCCC/USF participated in a planning call (in June) with the entire project team to coordinate efforts on the project and discuss project status, challenges, and future steps.

From July through September 2022, the USF team continued working on finalizing the web-based EVSE prototype tool. Both the backend and frontend tool development have been completed. TBCCC organized a meeting with project stakeholders (NREL, FDACS) where the USF development team demonstrated the tool and received feedback on the prototype, required for further EVSE data integration and compatibility.

TBCCC continued working with Florida Clean Cities coalitions and local fleet partners to identify alternative fuel fleets for potential site visits. In August, TBCCC organized a site visit to the city of Ocala battery-electric refuse fleet. While that site visit was implemented as part of another effort, separate from this project, the project team incorporated relevant findings from the site visit in the final draft of the Alternative Fuel Resilience Plan.

TBCCC/USF collaborated and coordinated with NREL, USF, FDACS, and other project stakeholders to finalize the Alternative Fuel Resilience Plan. NREL will publish the Plan in the near future (expected before the end of 2022).

Conclusions

None at this time.

Acknowledgements

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I.13 Integration of Smart Ride-Sharing into an Existing Electric Vehicle Carsharing Service in the San Joaquin Valley (University of California, Davis)

Caroline Rodier, Principal Investigator
Institute of Transportation Studies, University of California, Davis
1605 Tilia Street, Suite 100
Davis, CA 95818
E-mail: cjrodier@ucdavis.edu

Mark Smith, DOE Program Manager
U.S. Department of Energy
E-mail: mark.smith@ee.doe.gov

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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:

- 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.
- Improve mobility in target communities by making it easier for clients to travel to new destinations and for different purposes.
- Demonstrate a path towards cost-effective non-profit operations of volunteer EV ridesharing in low-income rural communities.

- 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 nonprofit 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

Year two focused on pilot implementation, with project partners working to coordinate all aspects of the service. This included recruiting, training, and managing staff, promoting the service, implementing and managing the ridesharing software SNAP to track rides and vehicle activity, and creating and implementing research data collection protocols such as member surveys.

Míoride began providing its first rides in November 2021. The service traveled 394 miles in November by providing a total of 11 rides that served a total of 51 riders (and 49 unique riders) with an average of 4.6 riders per ride. These rides included using vans to transport multiple Míoride clients to destinations such as a community meeting on local air quality issues, a food distribution site, and a medical center. In December 2021, Míoride provided 642 service miles to 30 unique riders. Between January 2022 – May 2022, Míoride provided approximately 40 rides to a variety of destinations including medical appointments, community meetings, shopping locations, and other types of trips.

During this period, UC Davis made efforts to collect self-report data from Míoride riders to understand their reasons for joining the service and how it affected their travel capabilities. A total of 18 Míoride riders completed the initial research survey issued by UC Davis. However, some of these responses were incomplete. Most of these respondents reported that they use Míoride because they do not have access to a car or because they cannot take fixed route transit to where they need to go. All these respondents stated that their household has access to either 1 or 0 personal vehicles. UC Davis also issued a monthly survey for Míoride to assess how the service had affected their transportation experience over the course of a month, and this survey received 13 responses. However, as with the initial survey, many of these responses were incomplete and some responses suggested inconsistencies in the collected data. In both cases, researchers did not have enough information to determine whether the collected survey data were representative of the population of Míoride riders, and due to the frequently incomplete responses, analysis of the collected data is limited.

In 2022, Míoride encountered challenges in maintaining a sufficient base of active drivers and riders, and in coordinating vehicle fleet availability given the limited demand for the service.

Due to continued operational difficulties, the project team was not able to meet its proposed milestones during this most recent reporting period. After concerted efforts to overcome these obstacles, the team determined that the Míoride project would be unlikely to meet its success criteria during this grant period. As a result, the project was closed in October 2022, with Míoride ceasing operations.

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.14 The Clean Rural Shared Electric Mobility Project (Forth)

Kelly Yearick, Principal Investigator
Forth
2035 NW Front Avenue, Suite 101
Portland, OR 97209
E-mail: kellyy@forthmobility.org

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: Michael.laughlin@ee.doe.gov

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 (EVs), 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 EV 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 EV carsharing deployment at five sites in Hood River, to achieve the following targeted improvements:

- Initiate and grow EV 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 EV 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

Budget Period 2 ended on June 30, 2022, and Budget Period 3 began on July 1, 2022. As such, major tasks and milestones to be completed in 2022 were split across two budget periods and fell into the following categories:

- Project Refinement.
  - Implement Spanish-Language Upgrades to Reservation Platform.
  - Begin Data Analysis.
  - Refine Outreach and Promotion Strategies.
- Project Wrap-up and Dissemination.
  - Continue Project Refinement.
  - Develop Tiered Pricing Structure.
  - Provide Technical Assistance to Clean Cities Coalitions.
  - Develop Online Toolkit and Final Case Study.

Progress made toward these major tasks was as follows:

Implement Spanish-Language Upgrades to Reservation Platform

The reservation platform, Envoy, underwent a launch of a new software application in late 2021 to provide improved accessibility and user experience. The Spanish version of this app was implemented for CRuSE in early 2022. In addition, to provide as much accessibility as possible, the project team has ensured that all communications materials are provided in Spanish. Envoy also 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. Pacific Northwest National Laboratory has begun work on a final report summarizing results for the entire project, but those results are not yet available. Table I.14.1 shows the key results for the first three quarters of 2022, the total number of bookings made by members and the revenue received from those bookings.

Table I.14.1. Key Results – January – September 2022

	January – March 2022	April – June 2022	July – September 2022
Number of Bookings	15	27	51
Total Revenue	$57.90	$230.80	$244.33

Additionally, in January 2022, Forth began administering surveys to members via Envoy, the carshare platform provider. The results of these surveys have provided valuable insights into needed program refinements, which are described in another section below. Some of this feedback from six total respondents is summarized by Pacific Northwest National Laboratory below:

- Average rating of the program overall is 4 out of 5.
- 75% of respondents are more likely to consider an EV for a personal vehicle in the future.
- 100% of the respondents would recommend this service to friends and family.
- Trips have been for test drives, leisure/entertainment, grocery shopping/household errands, and for medical appointments.

Refine Outreach and Promotion Strategies

A key outreach strategy throughout the life of this project has been to provide outreach materials and communications in both English and Spanish. This continued with the development of bilingual collateral materials such as flyers and postcards to be used by partners, volunteers, and property management staff to promote the service. Our partner, Envoy, completed new "how-to" videos, including a Spanish version, that describe downloading the Envoy Mobility app and setting up an account.

In July 2022, one of the carshare vehicles was driven in the Hood River 4th of July Parade to raise awareness of the program. For this event, Forth collaborated with local partners to design posters for display on the vehicle and provided postcards to be handed out to the community during the event. A feature in the City of Hood River newsletter (See Car-sharing program news) [1] also accompanied this event.

Additionally, Forth partnered with The Next Door Inc. to plan and coordinate an inclusive, bilingual, in-person event for the residents at Wyeast Vista and Rio Bella Heights, the two affordable housing locations for the project. This event is scheduled to take place in November 2022 to raise awareness of the program that residents could utilize, and also provide an opportunity to conduct surveys with attendees to better understand their transportation needs.

Finally, Forth partnered with local Spanish-language radio station, Radio Tierra to produce bilingual public service announcements to play on air to describe the program to listeners.

Continued Project Refinement

Perhaps the largest and most impactful refinement to take place this year was upgrading the vehicles available on the platform. After receiving ample feedback from users and partners about the real and perceived range limitations of the Honda Clarity EVs, Forth was able to secure additional funding to lease five 2022 Nissan Leaf EVs, nearly doubling the electric range available to users. Those vehicles became available on the platform in early 2022. Coinciding with this shift, the Honda Clarity EVs were removed from the carshare platform and repurposed by local partners for other uses such as administrative vehicles for the City of Hood River.

Based on feedback from project partners, we increased efforts to raise awareness of the program overall. In addition to the strategies mentioned above, we also worked with Envoy to design and implement additional signage and vehicle decals so the carshare vehicles would be more visible and apparent to the general public. These decals were implemented beginning in July 2022. Forth and project partner Columbia Area Transit designed and implemented a series of bus ads to include on local transit buses and at bus stops. These advertisements served to communicate about the program and how this carshare could supplement other public transportation options available in the community.

Develop Tiered Pricing Structure

One of the objectives of this project is to identify a financially sustainable model for carshare in this community, with a key characteristic being that affordability is maintained. As such, it is important to be able to offer varying rates for users such that low-income users have a reduced rate to use the service. This year we have been able to lower the cost of the program overall but also offer different pricing to some users. Rental rates have been lowered from $8/hour to $5/hour for the public and $2/hour for affordable housing residents. The rate was reduced across the board to encourage ongoing utilization as the slower winter season began. Additionally, the very low rate at the affordable housing locations seeks to help the community have better incentives and accessibility – the residents are primarily low-income migrant workers who experience significant financial and technological barriers.

Provide Technical Assistance to Clean Cities Coalitions

One of the objects of this project is to provide technical assistance to Clean Cities Coalitions interested in replicating this project in their communities. Efforts toward meeting this objective are underway through our continued partnership with Columbia-Willamette Clean Cities Coalition. Forth is in conversations with Columbia-Willamette Clean Cities Coalition and together we will be planning a workshop series for other Clean Cities coalitions that will provide more detailed, on-the-ground learnings and technical assistance to inform replication in other rural communities. We will speak to the CRuSE program learnings, and about our experiences launching carshare programs in more rural communities over the past couple of years.

Develop Online Toolkit and Final Case Study

The toolkit development has been delayed with many other competing priorities such as onboarding all new vehicles, launching a new app, and extending our outreach work to increase utilization at a critical time. These activities enhanced the service and increased awareness, both locally about the carshare and with a national audience about this approach. The online toolkit was started in 2022 but, along with the Final Case Study, has not been completed yet. A report (Community Impacts: Accessible Electric Vehicle Carshare) detailing Forth's learnings to date on launching equitable carshare programs was published in early 2022.

Conclusions

As we await the final results of our data analytics efforts, we cannot yet make any final conclusions about this program. However, we have found local partnerships and program refinement to be key components to this program's continued growth in Hood River.

Key Publications

Herman, Connor. June 2022. Community Impacts: Accessible Electric Vehicle Carshare, https://forthmobility.org/storage/app/media/Reports/Community%20Impacts-%20Accessible%20EV%20Carshare%20Programs.pdf

References

[1] Hood River Community Connections Summer 2022 (cityofhoodriver.gov)

Acknowledgements

Forth would like to acknowledge and thank National Energy Technology Laboratory Project Manager Dan Nardozzi and DOE Technology Development Manager Michael Laughlin for their 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, Oregon
- Port of Hood River, Oregon
- Mid-Columbia Economic Development District
- Columbia Cascade Housing Corporation
- Columbia Area Transit
- Ride Connection.

I.15 Holistic and Energy-efficient Rural County Mobility Platform (RAMP) (Carnegie Mellon University)

Sean Qian, Principal Investigator
Carnegie Mellon University
5000 Forbes Ave.
Pittsburgh, PA 15213
E-mail: seanqian@cmu.edu

Mark Smith, DOE Program Manager
U.S. Department of Energy
E-mail: mark.smith@ee.doe.gov

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 per 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 (GC) 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 to offer a comprehensive set of mobility services: trip reservations, on-demand trip request in the rural area, structured fixed-route and on-demand 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, fixed-route, 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. The RAMP system will be developed by May 31, 2023 and piloted in Greene County thereafter.

Approach

As an initial and ongoing activity, the team engaged 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 have collected data from riders, volunteers, and shuttle services, and conducted surveys of local residents and WU students/faculty/staff, with the aim of improving the system design throughout the project. We also reached out nationally in various conferences 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 are designing 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, gas gift cards, vouchers for community shopping, free shuttle rides, Bonner scholar hours (for WU students only), etc. Not everyone in a rural area like Greene County 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 mobility system designed under RAMP is analogous to hub-and-spoke networks, where the fixed-route shuttle service runs between center hubs, but on-demand shuttle services and volunteer service trips meet the demand from the main hubs to scattered origins/destinations, or between scatter origins/destinations. The RAMP system, once piloted in 2023, will collect anonymous data from both volunteers and rider requests. Those data together will be analyzed on a monthly basis to identify system inefficiencies, 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 leverages existing data sources (from public agencies and social media, e.g., PennDOT and Twitter/Waze) to monitor traffic conditions in real-time, and then take them into account when optimizing mobility services and disseminating trip/traffic information to residents.

The performance of the mobility services is measured and optimized in terms of travel time, vehicle-miles traveled, fuel use, emissions, accessibility, affordability, and mobility-energy productivity (MEP). MEP is an emerging energy and user cost weighted accessibility metric under development at the National Renewable Energy Laboratory (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 at 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 was formally distributed and conducted from November 2021 to August 2022. The team received and validated 450 samples from Waynesburg University affiliates and 450 samples from the County general public. Data analytics regarding the survey are being conducted as of fall 2022. This also provides an opportunity to train a team of survey takers from Waynesburg University to assist with studies of rural mobility and data analytics.

The team worked with Greene County Transportation Program to understand what data can be extracted from the current software used by Greene County, *Ecolane*. The team has downloaded all data since 2016 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 all points of interest for trips taken since 2016. Additional points of interest are also acquired from Google Maps. See Figure I.15-1 for all points of interest.

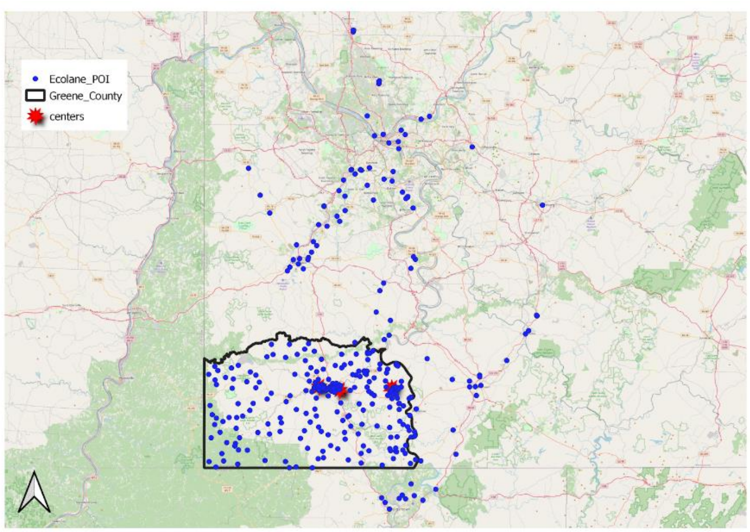


Figure I.15-1. All points of interest of trips in Greene County and three mobility hubs/centers

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 been calibrated using *Ecolane* data and survey data. Two research papers on this model were recently published (Grahn et. al, 2021, Grahn et. Al 2022), and one paper is under review. The model is generally applicable in any rural/suburban area or region with low demand density and has been implemented for the overall Greene County – Allegheny County regional network.

Based on the simulation and optimization model, the team developed a hybrid mobility system for Greene County. The system is designed to be demand responsive point to point. The team has completed designing 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 (also known as points of interest) are selected through interviews, surveys, and data collection, and further mapped along with residential patterns. With community input and using GIS mapping capabilities, we proposed three potential main points of interest, also known as hubs, along with three fixed routes with daily trips scheduled between those hubs extending to outside Greene County (see Figure I.15-2).

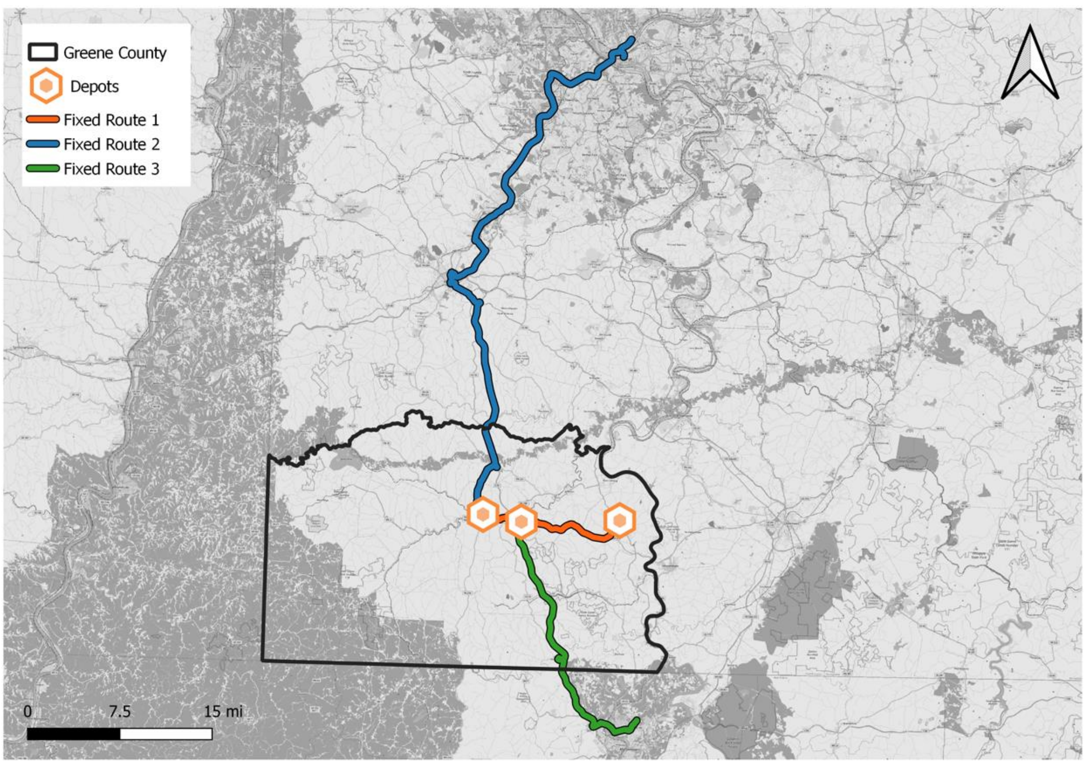


Figure I.15-2. Three mobility hubs in Greene County and three fixed routes

Routes are fixed in terms of schedules and planned routes/hubs but are flexible in terms of making actual stops along the route (also known as flag stops) on a daily basis. Those fixed routes are designed to carry riders for long-distance trips within the County and to/from adjacent cities (Morgantown WV, Washington PA, and Pittsburgh PA). This shuttle service differs 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. In addition, those fixed routes are supplemented with on-demand circulator shuttles. Each hub is equipped with several circulator shuttles which are responsible for taking on-demand or walk-up demand for short-distance trips within the County, from their requested pick-up locations to either the requested destination or the most relevant hub connecting to fixed route transit. During the pilot in spring 2023, the team will install GPS sensors and dashboard cameras on the shuttles to collect service data, ensure passenger/driver safety, and collect information on road conditions.

The team has developed 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 for the mobility services in general. The software provides portals for shuttle drivers, riders, system managers and volunteers, respectively. It is anticipated that the software will be tested in a pilot study in Spring/Summer 2023 for a period of three months in partnerships with the Greene County Transportation Program, Waynesburg University and Greene County Commissioners' Office. Several local non-profit organizations are also engaged and subcontracted under Waynesburg University to assist with this pilot program. It is the team's goal to pilot the RAMP system, including both modeling and service software, in other rural and suburban areas, and ultimately commercialize this system.

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 the 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 RAMP system consists of service optimization models and a set of software that supports this rural mobility service. The system will collect anonymous data from both volunteers and riders, once under pilot. 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 (as well as for suburban areas with low trip densities), 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, the team plans to transfer the technology to further develop and deploy rural mobility systems in other rural regions.

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.

Grahn, Rick, Sean Qian, Chris Hendrickson, (2022) "Optimizing first- and last-mile mobility services using transportation network companies (TNC)", Transportation.

I.16 R.O.A.D.M.A.P: Rural Open Access Development Mobility Action Plan (Rural Action)

Joe Brehm, Principal Investigator
Rural Action
9030 Hocking Hills Drive
The Plains, Ohio 45780
E-mail: sarah@ruralaction.org

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

Start Date: October 1, 2019 End Date: June 30, 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 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 shares progress regularly through a series of events hosted by the Appalachian Clean Transportation (ACT) Forum, a complementary outreach initiative administered by Rural Action and funded by the Joyce Foundation. Rural Action will distribute final summary reports and technology transfer plans to all stakeholders at the conclusion of the project.

Task 6: EVSE Planning and Analysis

An added task for Budget Period 3, Task 6 involves partners doing the following: mapping potential EVSE sites in a 5-county area that are optimal for rural charging; facilitating distribution of the DOT ROUTES EVSE Toolkit; and engaging with rural stakeholders to access funding and incentives to strategically site and install EVSE infrastructure at rural sites. In addition, Rural Action staff will analyze existing rural EVSE and station performance and usage data and upload datasets to NREL’s Livewire platform.

Results

Rural Action disseminated the Rural Electrification Report to stakeholders along with a companion piece in Farm and Dairy magazine entitled “The Crossroads of the Energy Transition and Rural Communities,” profiling the challenges of rural EV ownership. The Rural Electrification Report is available at https://ruralaction.org/our-work/sustainable-energy-solutions/clean-transportation/. The CFO team has presented on this report to a variety of stakeholders, as well as directly sharing with Clean Cities Directors and regional peers during the fourth quarter of 2021 and first quarter of 2022.

CFO and Rural Action worked together to create an online showcase of clean transportation solutions: The Transportation Solutions Showcase. It provides a learn-at-your-own pace set of resources for both individual motorists and fleets, featuring success stories, recorded conversations, webinars, and other multimedia resources. The CFO team has scheduled, recorded, and edited interviews with various rural electrification stakeholders and solutions providers. The Showcase is available at https://cleanfuelsohio.org/transportation-solution-showcase-home/.

Figure I.16-1. R.O.A.D.M.A.P. EV shuttle chassis during powertrain upfitting. Source: Motiv Power Systems.

HAPCAP continued to collect baseline internal combustion engine (ICE) vehicle data throughout the year as the build process for the EV Shuttle progressed (Figure I.16-1).

Rural Action and HAPCAP staff members were present for the shuttle delivery on July 28, 2022; however, it was later ascertained that the vehicle had not received a required undercoating treatment and final inspection. The drivetrain upfitter, Motiv Power Systems (Motiv), arranged to have it transported back to the factory. Work to finalize the vehicle wrap, schedule staff training, and procure and install Level 2 EVSE at the transit garage continued.

Rural Action coordinated with Motiv and HAPCAP to facilitate the final re-delivery of the EV shuttle bus, which took place two months after initial delivery, on September 28, 2022. Staff planned a ribbon-cutting event for late fall 2022.

The TRC concluded their third and final round of deployment and data collection activities for the AV task. The data collection activities were primarily performed on a fixed route located in the Southeast Ohio region around the City of Athens. This route offers a wide range of representative rural roadway conditions characterized by features such as poor quality of lane-markings, grade changes, narrow shoulders, sharp turns, and streets with geometric designs that lead to oblique merges and intersections. These conditions offer an interesting set of challenges to state-of-the-art AVs and offer added insight into their performance under conditions that are representative of rural environments nationwide. At the close of the reporting period, TRC had wrapped up final controlled environment testing, as well as data processing and analysis activities.

As the COVID-19 pandemic waned in 2022, events associated with Tasks 1, 2, 5, and 6 have ramped up. On February 2, 2022, Brandon Jones of CFO delivered a presentation about the Rural Electrification Report and the City of Athens Fleet Analysis to the Athens Environment and Sustainability Commission. The U.S. Department of Transportation (DOT) Volpe Center invited Rural Action to present at a webinar on February 9, 2022, entitled Charging Forward: A Toolkit for Planning and Funding Rural Electric Mobility Infrastructure. There were over 500 attendees (peak 535) at the webinar. Rural Action's segment showcased work on the R.O.A.D.M.A.P. project and beyond as a case study in rural EVSE adoption. Session materials are available at https://www.transportation.gov/rural/ev/toolkit.

On April 7, 2022, Rural Action hosted a ribbon-cutting event for the Level 2 Charging Station at their 8 North Plains Road facility in The Plains, Ohio. State and local officials as well as a variety of organizational partners attended the opening. See Figure I.16-2. On April 18, 2022, Rural Action organized 10 volunteer owners for the Ohio University Earth EV Showcase, which included six cars, three e-bikes, a motorcycle, scooter, and an e-skateboard. On April 28, 2022, Rural Action's Project Investigator Sarah Conley-Ballew was a presenter for NREL's Energy and Environmental Justice Initiative (EEJI) Webinar #5: Rural and Tribal Transportation. The audience was composed of Clean Cities Coalition directors from across the country.

Figure I.16-2. Rural Action charging station ribbon cutting. Source: Rural Action.

Sarah Conley-Ballew and CFO's Brandon Jones moderated a presentation for American Planning Association Ohio membership on June 9, 2022; Lily Ballangee, Transportation Specialist at the DOT, was a guest speaker. It focused on current trends in the EV market, federal/state funding for EV charging infrastructure, and best practices for planners/developers when integrating clean transportation into their communities' planning strategies. The group discussed some of the tools and resources that municipalities can access for EV infrastructure development in their communities. Rural Action organized an EV ride and drive event at Athens County Public Library on June 19, 2022, with coordination from CFO. See Figure I.16-3.

Figure I.16-3. Athens County Public Library Ride and Drive event, June 19, 2022. Source: Rural Action)

To round out events in the reporting year, the Rural Action team planned and successfully carried out the 2022 Ohio Pawpaw Festival EV Showcase, held September 17, 2022. This year's showcase featured the new Ford F-150 Lightning, an e-bike corral, and electrified camper vans, as well as a variety of other EVs. Seventeen owner-volunteers showed their vehicles and reported 320 engagements with festival attendees.

With the start of the third and final project budget period in July 2022, focus has centered on preparing for final analysis and reporting. The Rural Action team worked with NREL to configure a project page within NREL's Livewire data platform, define metadata and begin the process of populating the page with task-specific datasets. R.O.A.D.M.A.P.'s page is available at https://livewire.energy.gov/project/roadmap .

Conclusions

Data analysis, and in some cases collection, is still ongoing. Some important insights have emerged regarding the challenges and opportunities in each R.O.A.D.M.A.P. task area, and many more conclusions will be forthcoming as final analysis takes place.

- Rural motorists are becoming more interested in EVs: while the pandemic depressed participation in local ride and drive events and complicated event planning, it was evident in events scheduled during 2022 that participation was rising rapidly, surpassing pre-pandemic levels in some cases. The strong participant interest in the Ford F-150 Lightning at the 2022 Ohio Pawpaw Festival is an example of this trend.

- Another indicator of rural EV uptake is the data arriving from the longest-monitored EVSE installation in the project – the charging stations at the Athens Public Library – which are showing increasing usage, especially during overnight charging sessions.

- The length of the procurement and build timeline for the EV Shuttle – nearly two years in total from bid to final delivery at the close of the reporting period – suggests that on the procurement front, additional streamlining will be needed prior to widespread EV adoption by rural transit agencies. While the pandemic and supply chain shortages undoubtedly contributed to overall delay, it is worth noting that 180-day lead times are historically typical of ICE shuttle procurements in the industry, around four times faster than the lead time on this pilot.
- R.O.A.D.M.A.P.'s partnership with the DOT ROUTES team in 2022 has been a fruitful addition to the project. As major funding continues to become available through recently passed federal initiatives and cooperation between the U.S. Department of Energy (DOE) and DOT is encouraged, the team believes that this collaboration can be a model for other partnerships and should be replicated if possible.

Installation of EVSE at Rural Action's office provided key insights into the challenges facing rural charging host sites, namely the upfront cost to install a station. Rural Action received a rebate from AEP Ohio, the local utility provider, to offset the cost, but once the utility incentive program was fully subscribed, this option became unavailable to the dozens of interested site hosts in the region. Promising new federal funding that includes the National Electric Vehicle Infrastructure (NEVI) Formula Program could enable more non-corridor chargers to be installed, but until guidance is released on the priority allocations for discretionary grant dollars, most projects are on pause. Our efforts to inform interest groups, councils of government, and economic development corporations through an EV-focused learning opportunity provided successful guidance and tools for proper EVSE planning in rural communities.

Key Publications

"The Crossroads of the Energy Transition and Rural Communities", *Farm and Dairy*, October 21, 2021. https://www.farmanddairy.com/news/the-crossroads-of-the-energy-transition-and-rural-communities/689334.html

Rural Electrification in Ohio: Challenges and Opportunities. Jones, Brandon, and Nikolas Merten, October 2021. https://ruralaction.org/ra-download/6829/?tmstv=1675976677

Transportation Solutions Showcase: https://cleanfuelsohio.org/transportation-solution-showcase-home/. Web resource, Rachel Ellenberger production lead.

Livewire data platform project page: https://livewire.energy.gov/project/roadmap

Acknowledgements

The R.O.A.D.M.A.P. team wishes to thank NETL Technical Project Officer Erin Russell-Story and NREL Livewire contact Lauren Spath Luhring for their continued support as the project completes its deployment phase and enters the final reporting period. In addition, Rob Hyman, Lily Balangee and the rest of the DOT ROUTES team have been an invaluable resource.

I.17 Electric First/Last Mile On-demand Shuttle Service for Rural Communities in Central Texas (Lone Star Clean Fuels Alliance)

Elizabeth Munger, Principal Investigator
Lone Star Clean Fuels Alliance
P.O. Box 30045
Austin, TX 78755
E-mail: elizabeth@lonestarcfa.org

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: Michael.laughlin@ee.doe.gov

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

Project Introduction

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

Objectives

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

Approach

Lone Star Clean Fuels Alliance (LSCFA) oversees the project and facilitates communication among the stakeholders and project partners to ensure 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 provided the vehicles and drivers and managed 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, interpreting traffic and parking counts, survey administration, and data analysis. 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 employers, employees, and business owners 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 fixed route services, the Interurban and Municipal buses which pick up/drop off at indicated times. These routes offer connections to cities and towns in the nine counties throughout the region. Within Bastrop the only other CARTS service when this project was launched was a phone-in demand response Country Bus providing curb-to-curb service for customers scheduling a pickup. Service is a shared ride in mini-bus or van, and reservations must be made in advance. The Country Bus serves the general public, elderly, and disabled riders.

Additional local partners are the City of Bastrop, Visit Bastrop, and the Bastrop Chamber of Commerce. These partners provided input on vehicle use opportunities and promoted the vehicles through community outreach.

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

Operating independently of the CARTS NOW program allowed eCab to adjust hours to operate during nights and weekends outside of the Monday through Friday 7:00 a.m. to 7:00 p.m. service hours of the CARTS NOW shuttle vans. The eCabs operated their own dispatching app and accepted text and street hailing. On February 6, 2022, eCab changed Sunday hours to 10:00 a.m. to 6:00 p.m. from 2:00 p.m. to 10:00 p.m. to better align with customer requests, resulting in increased ridership.

The eCab service segment of this project is anticipated to end on November 30, 2022, with final data collection, analysis and dissemination remaining.

Results

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 the project performance to meet those goals, the operations and research team collected 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

Over 22 months of eCab operation (December 14, 2020, to September 30th, 2022), ridership grew steadily: 9,618 rides were given to 12,892 passengers (Figure I.17-1) Word-of-mouth; City, Chamber, and Visit Bastrop outreach; social media; and general visibility of eCabs around town were key factors in creating awareness. W&W's interviews of local businesses and organizations in the downtown area regarding customer and employee usage of the service also provided service details to those who were not familiar with them. Figure I.17-1 shows an increase in ridership over time and the increase in rider trends at each of the service hour change points, September 2021 and February 2022.

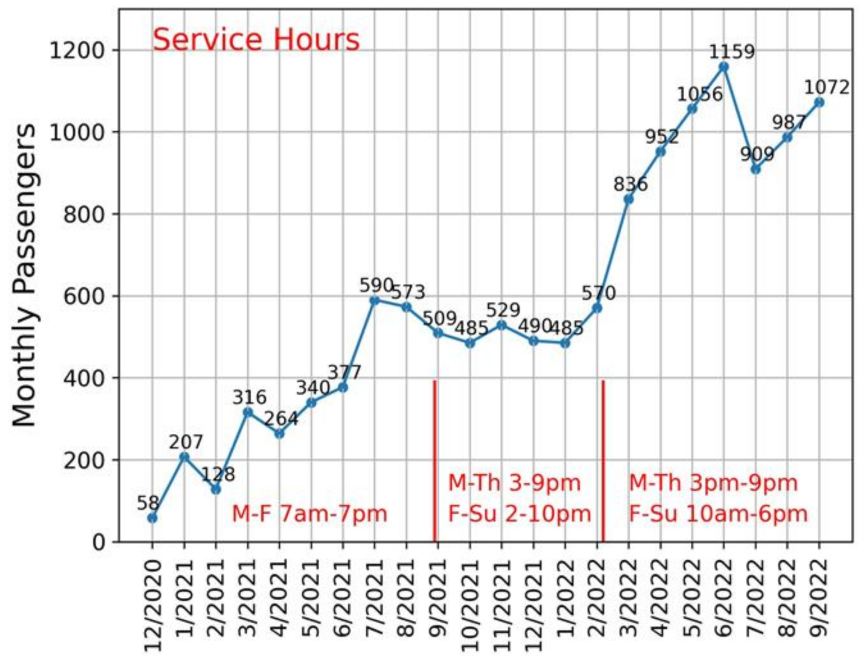


Figure I.17-1. eCab monthly ridership over time. Credit NREL.

Ridership data (Figure I.17-2) shows the highest rates of eCab use, 35.3%, by passengers in the over 55 age group. Usage was roughly equal for the 18-34 age group (26.5%) and 35-55 age group (26%), and understandably lower usage (13.1%) in the under 18 age group which required an adult presence. While the service appeals to a wide range of ages, the group over 55 years, which needs transportation options, is the group served most frequently.

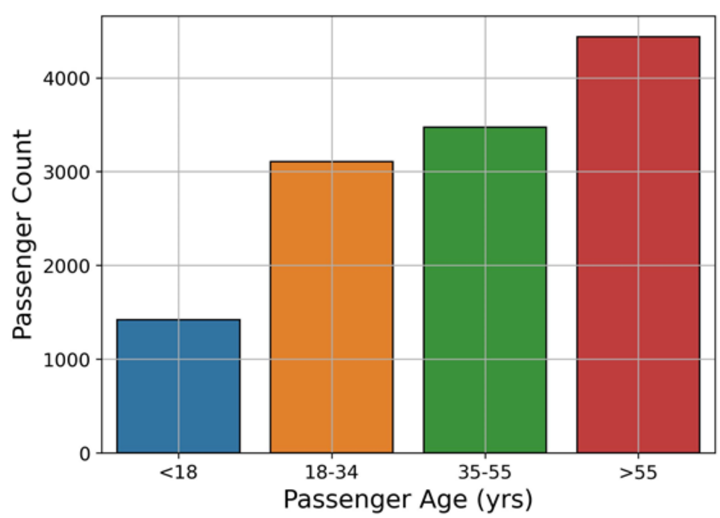


Figure I.17-2. Ridership data by passenger age. Credit NREL.

Figure I.17-3 shows riders are predominantly female, 65.8%, compared to 34.2% male. Interestingly, this ratio is similar in other geographic areas eCabs serves outside of this project.

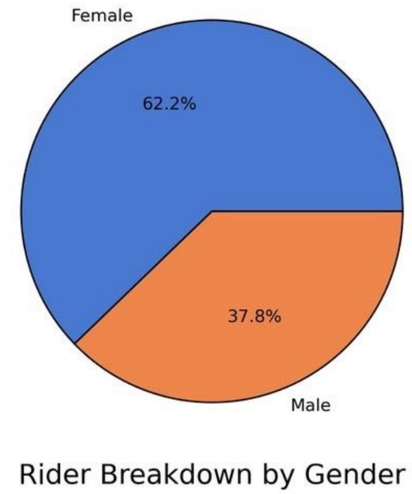
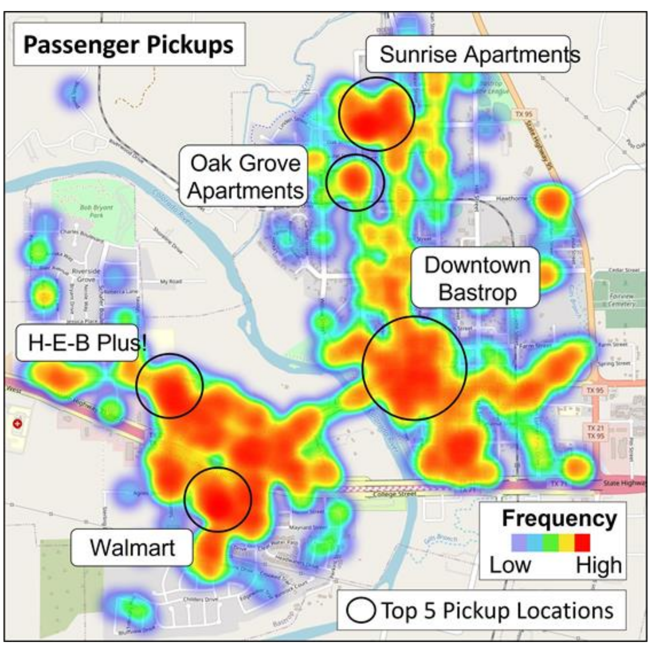


Figure I.17-3. Rider breakdown by gender. Credit NREL

eCab used the Gazoop dispatching software to generate the following heat maps based on data collected. The software uses the latitude and longitude of a vehicle's route, reported approximately every five seconds, for all trips with GPS data from September 27, 2021, to September 30, 2022 (9,618 trips). While the Gazoop software was in use only for the 12 months after the eCabs moved to their independent mode of dispatch, data collected by the eCab drivers over the 22 months of the project included estimated passenger age, gender, destination and pickup, either through discussion with or observation of the passengers, and passenger input in the hailing app. In the heat maps shown in Figure I.17-4 and Figure I.17-5, red indicates the highest number of trips to the same data coordinates, blue indicates the lowest number of trips, and green, yellow, and orange are in-



between.

Figure I.17-4. Top five passenger pickup locations. Credit NREL

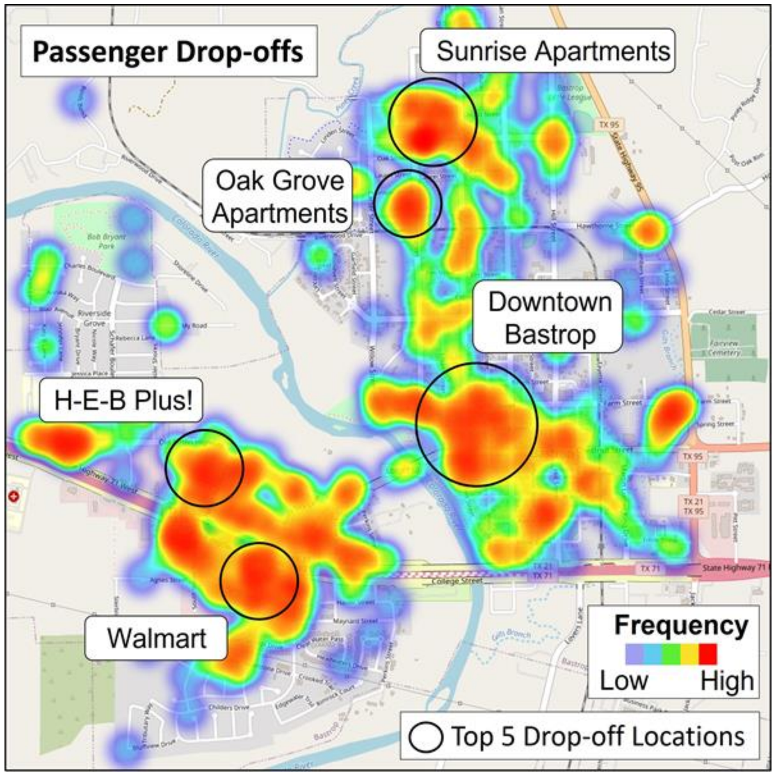


Figure I.17-5. Top five drop-off locations. Credit NREL

eCab Community Integration

Local partner support and outreach has been important for community awareness and acceptance of the eCabs. CARTS, the City of Bastrop, Visit Bastrop, and the Chamber of Commerce have supported and helped to publicize the service. W&W's surveying at community events and interviewing business owners and managers provided an additional means to discuss the details of the service. This summer LSCFA coordinated with MotorWeek for CARTS, the City of Bastrop and LSCFA to appear in a MotorWeek episode highlighting this project which has been shown in various mediums. This fall CARTS successfully nominated the three organizations, CARTS, LSCFA, and the City of Bastrop, for the Capital Area Council of Governments' 2022 Air Central Texas "Outstanding Organization Award." resulting in additional publicity across our region.

Additional factors that have helped community acceptance:

- The eCabs have a fun and friendly look.
- eCabs are a free, fast, and easy quick trip, typically between one and two miles. For comparison, the CARTS NOW on demand red van service services a footprint slightly larger than the eCab demand response area, and charges $2 per ride. These vehicles are larger and will pick up and drop off more passengers during the course of a trip.
- The eCab driver is in close proximity to passengers due to the size of the cab and is encouraged to act as an "ambassador" getting to know the passengers to better serve their needs. The driver interacts with passengers in order to collect data and gets to know them and their routines as well as offering information to riders who do not know the area.

eCab Hailing

In addition to having contact information posted on the eCab, the driver has business cards with hours, phone number and app information and invites passengers to call or text. Some people don't want to download an app; most repeat customers prefer to text.

The app is great for a first-time user or when the pickup location is not near an easily described landmark as both passenger and driver can see each other's progress. No need to explain where one is standing or move to a specific location like a bus stop. Unlike a ride through a Transportation Network Company, the eCab is distinctive and the riders will not mistake a random vehicle for their eCab ride as the app shows their approach and describes the branded vehicle.

Battery Range

A battery charge meter is built into the center of the eCab dashboard. It shows the percentage of battery life as well as an estimated number of miles remaining. Once an eCab's battery drops to 20%, the driver will swap cabs and plug in the low battery cab to charge for the next few hours. Initially all three cabs were using flooded lead-acid batteries with about a 40-mile range per charge. In March 2021 and January 2022, the two 6-seater eCabs (non-Americans with Disabilities Act compliant) and the one 3-seater (Americans with Disabilities Act compliant) were replaced with newer cabs with lithium-ion batteries to support the increases in ridership. This left only the ADA cab, which gets much less use, with a lead-acid battery pack. Cabs with lithium-ion batteries get more range, typically about 50 miles on a full charge, which is roughly three hours of continuous drive time in Bastrop due to the relative flatness of the area. Cold weather reduces lithium-ion battery range 10-15% when operating under 32°F, with flooded lead acid batteries affected slightly less, about 5-10%. A battery pack takes roughly six hours to charge from 20% to 100%. This time is similar in both lithium-ion and lead-acid battery packs.

Conclusions

The ridership and survey data indicate eCabs provide a useful service to the community, evidenced by the steady ridership growth. Initial survey findings suggest that eCabs have replaced car trips in some cases and in others, riders used eCabs instead of walking or riding with others. Both walking and riding with others can have their limitations; walking, in particular, to shop for food or other items can be very limiting. Independence, especially for older age groups is critical to their quality of life. This shows eCab's role in Bastrop has been to both replace some car trips and expand accessibility efficiently within the community.

Project Continuation

A resounding endorsement of the value of the eCab service to Bastrop can be seen in the financial support provided by the City of Bastrop to continue the service (with some modifications) when the project funding ends. The city has agreed to fund the eCab service effective December 1, 2022, the day after the grant support ends.

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; Andrew Duval, Stanley Young and Rick Grahn of NREL for insight, guidance and analysis; the City of Bastrop, the Bastrop Chamber of Commerce, Visit Bastrop and MTM, Inc. for general support and marketing of the eCab service.

I.18 East Zion National Park Electric Vehicle Shuttle System Plan (EVZion) (Utah Clean Cities Coalition)

Tammie Bostick, Principal Investigator
Utah Clean Cities Coalition
451 South State Street
Salt Lake City, UT, 84111
E-mail: tammie.bostick@utahcleancities.org

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

Start Date: October 1, 2019 End Date: August 31, 2023
Project Funding: $1,436,568 DOE share: $655,000 Non-DOE share: $781,568

Project Introduction

EVZion will demonstrate a small-scale, environmentally sound, zero-emission, electric vehicle (EV) shuttle system deployed from a small gateway community service district near the east entrance of Zion National Park. This high-tech, electric shuttle pilot demonstration project will involve data collection by the National Renewable Energy Laboratory (NREL), and road testing the electric shuttles in an environment with extreme climate fluctuation, steep grades, hairpin turns, and other challenging conditions. Key to the project's success is effectively working with local and rural community leaders to meet project milestones, with the support of the National Park Service. This nationally recognized project is intended to support the mission of resilience and sustainability in Zion National Park along with the economic and environmental sustainability objectives of rural gateway communities. Unique to the project is working with a newly formed limited-service district, Zion Mountain Local Service District (ZMLSD) which is an independent, special-purpose governmental unit that exists separately from local governments such as county, municipal, and township governments, with substantial administrative and fiscal independence. ZMLSD was specially formed in 2022 to support the emerging Zion National Park Discovery visitor center and residents in the county.

This pilot highlights the challenges and complexities involved in addressing transportation issues in Zion National Park, which are exacerbated by high traffic volumes, record numbers of visitors, and the remote location of the park. It also emphasizes the need for advanced technology shuttle systems and transit logistics to address scalability, which could be applied to similar transportation systems.

Furthermore, it acknowledges the pressing goals for the preservation of the environmentally sensitive areas inherent to national and state parks, recreation areas, and monuments throughout the United States. These goals will require careful planning and implementation of sustainable transportation solutions that prioritize the protection of the natural environment.

Overall, the EVZion project has made positive strides in its mission to address these complex issues, but there is still much work to be done to develop and implement effective transportation solutions that balance the needs of visitors with the need to preserve the natural beauty and resources of Zion National Park and other similar areas.

Objectives

The objective of this project is to conduct a small-scale proof-of-concept EV shuttle demonstration that connects the gateway communities and neighboring counties in rural Utah to Zion National Park. The project aims to collect and share usage data with a Department of Energy (DOE) Federally Funded Research and

Development Center for further analysis, develop lessons learned and best practices, and conduct outreach with other fleets to assist with technology adoption decisions.

One unique aspect of this project is the requirement that the shuttle be able to pass through the historic narrow Mt. Carmel Tunnel in Zion National Park. This tunnel is open to free-flowing traffic for less than 15 minutes a day due to oversized vehicles, buses, and RVs, making it a significant challenge for any shuttle system.

At the conclusion of the pilot, the project aims to propose positive strategies and smart mobility solutions through the design of an electrified and resilient park touring transportation system. This will involve evaluating the usage data, lessons learned, and best practices developed during the pilot, and using this information to inform the design of a sustainable and efficient transportation system that meets the needs of visitors to the park while minimizing the impact on the natural environment.

Approach

To achieve its objectives, the project will undertake several initiatives across all budget periods with varying levels of effort. These initiatives include an Assessment of the Electric Vehicle Supply Equipment (EVSE) Shuttle System Planning phase, which builds on the successful milestones achieved in the first budget period.

During this phase, the project collected input from stakeholders, identified key transportation strategies, mapped the shuttle system, and issued a Request for Proposals (RFP) to potential EV and EVSE vendors to meet project requirements. The first milestones were accomplished at the original contracted site in Kanab City, Utah, with the support of matching funds for the charging infrastructure from Utah's Volkswagen Settlement funding and Utah Department of Transportation (UDOT) assistance.

The third budget period required an adjustment to fast track a new location closer to Zion National Park in collaboration with the newly formed ZMLSD, with the contract requirements and ownership of the shuttles. This move allowed for the shuttle to deploy base operations effectively and in closer proximity to the park, and necessitated upgrades to support the three-phase power build-out and the right type of EVSE to operate the shuttle in the park and gateway communities.

The project team is currently working on building capacity for the developed and built site at Zion Mountain Ranch to ensure the success of the pilot and the effective deployment of the shuttle system. These efforts will help the project achieve its objectives and create positive strategies and smart mobility solutions for a sustainable park touring transportation system.

EVSE and Shuttle Stop Development with the East Zion Initiative: The third budget period continued to include the selection of vendors for Shuttle #2, the purchase and installation of EVSE infrastructure near the park entrance on Zion Mountain Ranch Property, and the study of how the park will manage shuttle stops and touring with the new East Zion Visitor Center. 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 updates, expands, and carefully curates them. The EV shuttle demonstration is an integral part of the East Zion Initiative and key to the park experience and new visitor center.

UCC has entered into a collaborative study and review of the National Park EV Development Smart Mobility Concept Plan – Mobility Outdoors Visitor Experience (MOVE), which addresses logistics for effectively moving millions of visitors in the park system and the greater Zion National Park area. It focuses on the park, visitor's centers (existing and to be built in 2024), transit systems, transportation hubs, gateway communities in proximity to both sides of Zion National Park, and nearby metropolitan areas. The project’s focus has grown in breadth and depth and is intended to address the transportation needs of the whole area, including the large workforce related to the operation of Zion National Park, visitor and tourism services, and congestion mitigation related to all the services associated with the park and surrounding area. Deploying the new generation of electric and fuel cell transit vehicles will be challenging, while creating, curating, and maintaining the integrity of the visitor experience for the third most visited park in the nation.

Phase II Shuttle, Deployment, EVSE, and Logistics: The third budget period required some adjustments to meet the new parameters of the project. The goals of the final budget period include purchasing and deploying the second shuttle, installing Type II and DC Fast Charging, and completing electric shuttle performance data logging.

UCC is involved in the Zion Regional Collaborative **(ZRC)** and its efforts to improve the quality of life for residents and visitors in the Zion Canyon area. The ZRC is a group of municipalities, public land management agencies, state agencies, and other interested parties that provides regional planning and coordination in the Zion Canyon area. The ZRC is focused on smart mobility planning and deployment, as well as exploring innovative solutions such as electric shuttle systems for the park and nearby communities. It is important to address the issue of congestion and overcrowding not only within the park but also on the state roadways leading into it. Overall, there is considerable collaborative effort and a focus on finding sustainable solutions for transportation in the region.

The pilot study has put into motion the ongoing collaborative work of key stakeholders including Zion National Park, ZRC, and a dozen key partners in the creation of MOVE, as discussed above. This logistical analysis aims to demonstrate new and integrated National Park Service transportation systems that involve the whole visitor experience from start to finish.

NREL is leading the data analysis, which is 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. NREL will collect, test, and assess data for the EVZion project, including infrastructure development, vehicle deployment, maintenance, and demonstration, deployment of advanced mechanical, networked systems and electrical innovations, and driver performance.

State funding through the Department of Environmental Quality (DEQ) for workplace charging will support infrastructure for the ZMLSD, where EVSE will be installed at Zion Mountain Ranch adjacent to the visitor center. UCC is looking to find a meaningful partnership to use the shuttle as a park employee support vehicle on both sides of the park, possibly serving ZMLSD and the west side main entrance.

Results

UCC continued to meet with key Zion National Park transportation leadership to establish logistical routing, EVSE placement planning, and overall deployment of the electric shuttles. The state DEQ has approved the EVSE and has helped fund the ZMLSD by providing funding for workplace charging.

UCC has been working with the East Zion Initiative to explore options for charging, energy efficiency, energy storage, and utility work. UCC joined the ZRC board in September and has begun supporting the larger collaborative efforts to ensure coordination and technical support. The ZRC sponsors a number of studies, plans, projects, and other strategies to improve the quality of life for residents and visitors to Zion Canyon.

UCC has been promoting the EVZion project through local, statewide, and national media opportunities, and hosted several statewide press events to promote the electric shuttle in the park and nearby communities. The EVZion shuttle was a featured EV in St. George, Utah, during National Drive Electric Week in September 2022 with many EV enthusiasts learning more about medium duty electrification, the future of the Zion National Park shuttle system, and the exciting world of powerful, zero-emission vehicles emerging in rural areas.

UCC is playing a critical role in the Zion National Park community, not only with the deployment of the EVZion shuttle but also in expanding working partnerships and participating in visitor use planning. The shuttle system is being considered as a solution to remote rural transportation needs and could potentially transport tribal interpreters and other community members from Pipe Spring and rural areas to the East Zion Visitor Center as part of the MOVE workforce initiative. UCC is dedicated to ensuring that all visitors, employees, and community members have access to transportation options that are efficient, sustainable, and inclusive.

The EVZion shuttle will assist in transporting members of the Paiute tribe, local government leaders, and important project partners to the park for the second Zion Forever Founders Gathering, to be held in November 2022. The gathering is intended to better curate indigenous peoples' and pioneer settlers' perspectives and stories.

Additionally, the shuttle will provide a VIP shuttle service for the gateway community of Springdale City which hosts the 2022 5K Butch Cassidy marathon which is held annually on Veterans Day. The shuttle has become an iconic symbol in the park and surrounding communities as a harbinger of clean transportation and EV technologies.

The EV Zion shuttle is not only serving as a means of transportation for visitors to Zion National Park but also playing an important role in connecting rural area gateway communities and supporting local events. The media piece, EV Zion Shuttle Video, is an initiative to educate the public on the shuttle's technical specifications and capabilities. Overall, the EVZion shuttle project is making a positive impact on the Zion region and setting an example for sustainable transportation. By promoting clean transportation, the shuttle is contributing to the reduction of greenhouse gas emissions and helping to create a more sustainable future.

Data Logging

The UCC team has been proactive in collecting data on the shuttle's performance and efficiency. NREL has analyzed the data and provided recommendations based on their findings. It is important to continue monitoring and collecting data to ensure that the shuttle is operating as efficiently and effectively as possible. The upcoming phase will look at the impacts of passenger loading and winter season weather on the shuttle's performance.

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, NREL defined the shuttle parameters and specifications in a detailed report. The first shuttle has been collecting data that has been reviewed by NREL with favorable results with batch data included from late 2021 to 2022. The data collection includes informative geographical coordinates gathered mostly through an intensive drive cycle in June and July 2022. NREL identified and mapped key destinations, and logged and provided logistical data on operation, performance, and efficiency. Data collection included key routes in and around Zion National Park, including Springdale (Visitor Center), East Entrance, Zion Mountain Ranch (near the future site of the East Zion Visitor Center), Hurricane (a gateway community) and Highway 9, which runs into and through the park.

The second phase of the project involves acquiring a new shuttle, Shuttle #2, which is designed as a sprinter van and can accommodate 14-16 passengers. It is also designed to fit the tunnel requirements with a height of less than 94 inches. The shuttle is expected to be delivered in Spring 2023, but there may be delays due to supply and demand issues. Once delivered, Shuttle #2 will be able to demonstrate side-by-side passage in the Mt. Carmel Tunnel. The project team will focus on comparing the use of air conditioning, heat, fans, and other features that require electricity, as the climate in the area can vary greatly, with temperatures ranging from freezing to triple digits.

EVSE at East Zion

The East Zion EVSE will be operational by Winter-Spring 2023, subject to availability of a transformer and other equipment, which may be delayed due to supply chain issues. UCC is assisting with state DEQ funding, which will cover most of the cost for the EVSE unit with battery storage. The new DC Fast Charger, once installed, will support the two shuttles in their operation in and around the park.

When the second shuttle arrives in 2023, it will also be tunnel-approved before data logging begins. The data collected from Shuttle #2 will be compared with data from Shuttle #1. The shuttles are from two different manufacturers, Lightning eMotors and GreenPower, and are different sizes and configurations. The second shuttle is narrower and able to travel through the Mt. Carmel Tunnel with two-way traffic. The project team will compare the two shuttle designs, along with performance metrics and overall operational observations and data.

Conclusions

The EVZion project team and its partners are working to assess transportation needs and opportunities for Zion National Park and the surrounding gateway communities. This includes evaluating options for workforce transportation, tourism, congestion mitigation, and the use of electric and fuel cell transit vehicles. The project is focused on maintaining the visitor experience while also promoting resiliency efforts for the natural and built environments and addressing serious congestion issues and poor air quality.

The project team is working with a variety of stakeholders, including Zion National Park, ZMLSD, Kane County, Zion Forever, Zion Regional Collaborative, UDOT, five county governments, the Utah Office of the Governor, Utah Tourism, academic institutions, private and public entities, and Tribal communities. This network is ensuring that the East Zion Initiatives are coordinated and that all parties are engaged in the conversation and resultant work.

Zion National Park has the largest transit system of any national park, and the project team is evaluating opportunities to improve transportation infrastructure and systems in the park and surrounding areas. This includes assessing the needs of visitor centers, transit systems, transportation hubs, gateway communities, and nearby metropolitan areas.

Key Publications

- EVZION- East Zion Electric Vehicle Shuttle System Project, UCC Website
- EVZion BP 2 Year Review Presentation
- East Zion Initiative
- MOVE: Mobility Outdoors Visitor Experience
- EV Zion @ Scale – Cost Analysis
- EVZion One-page Summary
- EVZion Road Map
- EV Zion DOE VTO Merit Review
- 2021 Zion Founders Circle: The Right People, The Right Time
- EV Zion Shuttle Video

Acknowledgements

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

I.19 Developing an EV Demonstration Testbed in the Upper Cumberland Region of Tennessee, an Economy Distressed Rural Region (Tennessee Technological University)

Pingen Chen, Principal Investigator
Tennessee Technological University
115 West, 10th Street
Cookeville, TN, 38505
E-mail: pchen@tntech.edu

Mark Smith, DOE Program Manager
U.S. Department of Energy
E-mail: mark.smith@ee.doe.gov

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 infrastructure, 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, 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?
- 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 third and last year of the project (FY 2022), the project team has had the following accomplishments:

As of September 30, 2022, TTU and the project partner, Seven States Power Corporation, have been able to smoothly operate and maintain all 9 public charging stations including eight Level-2 dual-port charging stations and one DCFC station in the UC region, as displayed in Figure I.19-1. 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 EV communities have frequently utilized the DCFC station in this project. As of September 30, 2022, the established charging station network has supported 931 EV charging events (561 charging events recorded from October 1, 2021 to September 30, 2022). From October 1, 2019 to September 30, 2022, the established public EV charging stations have supplied a total energy of 14,837 kWh to EVs. The public EV charging stations have contributed to saving 1,862 gallons of gasoline fuel. In addition, they have reduced greenhouse gas emissions by 10,158 kg in total.

In addition to three Nissan Leaf EVs and the plug-in hybrid pickup truck delivered in the first year (FY 2020) and the second year (FY 2021), the project team anticipated that an all-electric shuttle bus would be delivered to the rural transit agency, UCHRA in December, 2022, to provide various transit services to rural communities in the UC region. The ADA-compliant vehicle provides 12+2 seats for passengers and can offer up to 130 electric miles per full charge with a 125-kWh battery pack. In addition, the vehicle is equipped with a 13-kW AC J1772 on-board charging system which can fully charge the vehicle within 10 hours, as well as a DC fast charging port which can fully charge the vehicle within 2-3 hours. This vehicle will be recognized as the first electric shuttle bus in a rural transit agency in Tennessee. The photo of the all-electric shuttle bus is shown in Figure I.19-2.

Figure I.19-1. Eight Level-2 Dual-port and one DCFC Charging Stations Installed in the Rural UC Region

Figure I.19-2. Electric shuttle bus ordered by UCHRA

The project team created a signature two-week EV test drive program for the rural communities in the UC region to test drive the project EVs. It has been in effect since August 10, 2020. All 14 counties in the Upper Cumberland region have been exposed to the recruitment information. A majority of them are rural areas with limited or no EV exposure. As of September 30, 2022, the project team has achieved the following accomplishments:

- **859** rural residents from the 14 counties in the UC region have been exposed to the EV test drive opportunity.
- **537** residents have provided complete contact information to allow the project team to follow up with them and provide additional application materials.
- **175** participants have been approved for the two-week EV demonstration.
- The project EVs have been demonstrated to **141** approved participants (7 in FY 2020 and 64 in FY 2021, and 70 in FY 2022) with each participant driving an EV for two weeks as daily commute vehicles (occasionally for intercity trips) to learn EV operation, EV charging, benefits, operating issues, and best practices.
- The recruitment and demonstration efforts have reached diverse communities including rural communities, low-income communities, women, the elderly, and minority groups. The EV demonstration has reached 11 Counties: Putnam, DeKalb, Jackson, White, Cumberland, Macon, Smith, Overton, Fentress, Warren, and White in the Upper Cumberland region. The EV fleet has accumulated **78,000** miles in the Upper Cumberland region through the EV test drive program. For the remaining three counties without two-week EV test-drive experience, the team provided EV outreach events therein for EV education.

As part of 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:

- 116 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 a two-week operation window.
- 130 sets of pre-demonstration survey data, 102 sets of post-demonstration survey data, and 70 sets of post-demonstration interview data.
- 28 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).

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

- When provided with two EV options (150 miles vs 215 miles), 84% residents in the UC rural areas who participated in the pre-demonstration survey, prefer to test drive the longer-range EV, while the remaining 16% of the participants in the pre-demonstration survey would like to test drive the shorter-range EV. This is mainly due to range anxiety and the limited availabilities of EV charging stations in rural areas.
- Plug-in hybrid-electric pickup trucks (PHEVs) are of strong interest in the rural UC region. According to the pre-demonstration survey results, about 45% of the participants are interested in a test drive of a PHEV pickup truck, while the remaining 55% of the participants are interested in all-electric passenger EVs.
- Through the EV demonstration to 141 rural residents in diverse applications, the current EV technologies have proven to be feasible solutions to meet the transportation needs for rural communities from an EV range perspective. 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.

- The top three compelling reasons for the test-drive participants to purchase or lease EVs are fuel cost, environmental impact, and maintenance cost, respectively. Tax incentive and the vehicle performance are the next two reasons.

- The top three compelling reasons that may prevent the rural communities from purchasing or leasing EVs are driving range, availabilities of charging stations, and up-front purchase cost.

- 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. 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 85% of the participants are more likely to adopt EVs as their next vehicles. The participants in the EV test program can help accelerate EV adoption in the community, as about 88% of the participants are likely to recommend EVs to others.

- 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.

- 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:

- Eight EV "Ride-and-Drive/Show-and-Tell/Education and Recruitment" events during National Drive Electric Week, and Drive Electric Earth Day. The key numbers of the EV outreach events are summarized in Table I.19.1. Key Numbers of EV Outreach Events (October 1, 2021 – September 30, 2022).. In total, the project team has directly engaged with more than 665 rural residents and exposed various EVs to 1025 rural residents. Five additional EV outreach events are planned from October 1, 2022 – September 30, 2023, as summarized in Table I.19.2.

- The project team, led by TTU and TCFC, co-organized an EV charging planning workshop on June 7, 2022, in Cookeville, Tennessee. The highlights of the workshop include engagement of 40 various EV stakeholders such as state agencies, a regional transportation planning group, rural transit agencies, university and community colleges, Middle-West Tennessee Clean Fuels Coalition and ETCFC, local power companies, Seven States Power Corporation, an electric aviation company, and others.

- TTU helped the U.S. Department of Transportation (DOT) organize the first workshop on the Toolkit for Planning and Funding Rural Electric Mobility Infrastructure on Thursday, March 10, 2022. Professor Chen helped DOT identify the key EV stakeholders in Cumberland County to participate in the workshop. Professor Chen presented the latest progress of this project as the regional highlight. In addition, the DOT team and the regional stakeholders discussed various key topics including workforce development, access to federal funding for EV infrastructure development, partnership development, ways to pursue an equitable EV infrastructure planning process, goals for EV infrastructure in different communities, and others. The informative discussion will help DOT further improve their toolkit and better serve rural community in planning EV infrastructure.

- TTU has exchanged the project findings with various stakeholders through panel discussions at the Tennessee Smart Mobility Expo on August 4-6, 2022, which is a major electric mobility-related forum in Tennessee.

Table I.19.1. Key Numbers of EV Outreach Events (October 1, 2021 – September 30, 2022).

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, Cookeville, TN	Oct. 2, 2021	113	113	9	24
EV Ride-and-Drive Event, McMinnville, TN	Oct. 16, 2021	75	75	3	20
EV Education and Recruitment Event, Cookeville, TN	Feb. 26, 2022	150	150	3	0
EV Education and Recruitment Event, Cookeville, TN	March 5, 2022	150	150	3	0
EV Ride-and-Drive Event, Cookeville, TN	May 7, 2022	27	27	6	17
EV Ride-and-Drive Event, Jamestown, TN	June 7, 2022	40	40	2	8
EV Show-and-Tell Event, Carthage, TN	Sep. 10, 2022	40	400	3	1
EV Show-and-Tell Event, Knoxville, TN	Sep. 24, 2022	70	70	2	0
Total		665	1025	31	70

Table I.19.2. Key Numbers of Planned EV Outreach Events (October 1, 2022 – September 30, 2023).

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 Education and Recruitment Event, Cookeville, TN	Oct. 1, 2022	70	TBA	TBA	TBA
EV Ride-and-Drive Event, Cookeville, TN	Oct. 2, 2022	40	TBA	TBA	TBA
EV Ride-and-Drive Event, Byrdstown, TN	Dec. 3, 2022	20	TBA	TBA	TBA
EV Ride-and-Drive Event, Woodbury, TN	Dec. 10, 2022	10	TBA	TBA	TBA
EV Ride-and-Drive Event, Spencer, TN	Dec. 17, 2022	10	TBA	TBA	TBA
Total		147	TBA	TBA	TBA

Conclusions

Through the demonstration of a small EV fleet in the proof-of-concept rural EV testbed in the UC region, the project team identified strong interest and concerns from the rural communities in the UC region in adopting EVs. The successful EV demonstrations to 141 participants in total 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

Shen, H., Wang, Z., Zhou, X., Lamantia, M., Yang, K., Chen, P. and Wang, J., 2022. Electric Vehicle Velocity and Energy Consumption Predictions Using Transformer and Markov-Chain Monte Carlo. IEEE Transactions on Transportation Electrification, 8(3), pp.3836-3847.

Shen, H., Zhou, X., Wang, Z., Ahn, H., Lamantia, M., Chen, P. and Wang, J., 2022. Electric Vehicle Energy Consumption Estimation with Consideration of Longitudinal Slip Ratio and Machine-Learning-Based Powertrain Efficiency. IFAC-PapersOnLine, 55(37), pp.158-163.

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I.20 Heavy Duty EV Demonstrations for Freight & Mobility Solutions (Clean Fuels Ohio)

Timothy Cho, Principal Investigator
Clean Fuels Ohio
17 S. High Street, Suite 810
Columbus, OH 43215
E-mail: tim@cleanfuelsohio.org

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

Start Date: October 1, 2019 End Date: December 31, 2022
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 can 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 (CFO) 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. CFO will partner with Orange EV, SEA Electric, and Lightning Systems to operate three demonstration projects of MD and HD EVs with three fleets in Ohio: DHL Supply Chain, Two Men and a Truck, and Columbus Yellow Cab. The project team also includes Sawatch Labs and four Clean Cities coalition partners (Wisconsin Clean Cities, Utah Clean Cities, New Jersey Clean Cities, Minnesota Clean Cities) that will perform individualized analysis and identify key prospect fleets with similar applications for EV adoption, to demonstrate how these specific MD/HD EVs can be adopted by more fleets. 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: DHL Supply Chain, Two Men and a Truck, and Columbus Yellow Cab.

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:

- **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.
- **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.

- **Operational & financial performance analysis tools informed by OEM end-user data** on real world vehicle deployments.
- **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 pilot vehicles can be adopted by additional fleets to improve economic and environmental performance.

Results

CFO, in conjunction with project partners, made progress on the following milestones in the third year of the project:

- **Real-world Deployments of Medium-Heavy Duty EVs by highly visible fleets:** Two Men and a Truck Columbus deployed their Class 6 SEA Electric Freightliner M2 EV moving truck in May 2022 as shown in Figure I.20-1. Two Men and A Truck Class 6 SEA Electric Freightliner M2 EV moving truck in Columbus, OH. The other two vehicles were deployed in 2021 and are shown in Figure I.20-2. Columbus Yellow Cab Class 4 Lightning eMotors EV passenger van in Columbus, OH and Figure I.20-3. DHL supply chain Class 8 Orange EV yard hosteler/terminal truck in Dayton, OH.
- **Key Prospect Fleets Engaged and Analyzed:** Clean Cities partners identify, engage, analyze key prospect fleets, and connect fleets to resources.
- **Replication Resources and Tools Assembled:** Create outline, complete, and assemble replication resources and seek feedback.
- **Disseminate Replication Resources for Scale:** Revise, finalize, and disseminate final replication resources, complete and document final project deliverables.

Figure I.20-1. Two Men and A Truck Class 6 SEA Electric Freightliner M2 EV moving truck in Columbus, OH

Figure I.20-2. Columbus Yellow Cab Class 4 Lightning eMotors EV passenger van in Columbus, OH

Figure I.20-3. DHL supply chain Class 8 Orange EV yard hosteler/terminal truck in Dayton, OH

Figure I.20-4. Heavy Duty EV Demonstrations for Freight & Mobility Solutions Clean Cities coalition partners

The project team, which includes CFO and four Clean Cities coalition partners (Wisconsin Clean Cities, Utah Clean Cities, New Jersey Clean Cities, Minnesota Clean Cities) as shown in Figure I.20-4. Heavy Duty EV Demonstrations for Freight & Mobility Solutions Clean Cities coalition partners, continued to engage and secure key prospect fleets in their regions with vehicle operations similar to the three MD-HD EV demonstrations in this project. CFO continued to hold individual check-ins with the coalitions on status of potential partners and provided them with resources to secure agreements and available vehicle telemetry, operations, and performance data from potential fleets.

Key Prospect Fleets Engaged and Analyzed

The Clean Cities partners provided an updated and finalized list of fleet partners, vehicle types/vehicle applications, and potential pathways to receive data from the fleet partners, which included delivery, freight, and refuse vehicles, and passenger transportation/mobility. CFO continued to support and equip the four Clean Cities coalition partners with requirements around data collection, coordinating data transfers from fleet partners to Sawatch Labs for analysis and input gathering, and setting up follow-up conversations with fleets and Sawatch Labs to address questions and concerns. CFO continued to engage with Sawatch Labs on sharing available vehicle operations and financial data from fleet partners, as part of the replication resources and tools development portion of the project.

Replication Resources and Tools Assembled

Clean Fuels Ohio and Sawatch Labs finalized a general outline and completion plan for replication resources and tools that will be developed through the results of this analysis and fleet case studies from this project. The general outline and completion include the following components: Project Background, Project Purpose, Project Results (1. MD/HD EV Analysis of Ohio fleet deployments from this project for the 3 key vehicle applications [Class 8 Yard Hostler/Terminal Truck, Class 6 Moving/Delivery Truck, Class 4 Passenger Van], 2. National Fleet Case Studies from key regions with Clean Cities partnerships, 3. MD/HD EV Analysis & Modeling Tool developed by Sawatch Labs, Project Insights for Fleets & Decision Makers, Conclusion). CFO plans to complete assembly of replication resources with Sawatch Labs, seek feedback from Project Advisory Committee members, fleet partners, and other key stakeholders, and make progress toward this subtask once key final data collection, analysis, and development of models and tools are complete.

Disseminate Replication Resources for Scale

CFO began initial planning for development of project final replication resources to demonstrate the viability of MD and HD EVs in new fleets and communities and plans to finalize all replication resources and make progress toward this milestone once key data collection, analysis, and finalization of models and tools are complete.

Conclusions

CFO's goal was to achieve successful completion for all milestones by the end of calendar year 2022. CFO formally requested a six month, no-cost time extension, as additional time is needed to accomplish these milestones. The core reasons for this extension include a delay in securing key prospect fleets and corresponding vehicle telemetry, operations, and performance data (due to shifts in fleet priorities post-pandemic out of the project team's control) from Clean Cities replication partners; a lack of sufficient vehicle data to input into Sawatch Labs MD/HD EV analysis and modeling tool to create final EV analysis models; and a delay in developing final project case studies and replication resources/tools to be disseminated by Clean Cities replication partners.

Sawatch Labs continued to identify data needs and make good progress on development of their EV analysis and modeling tools with their own existing national dataset of vehicle data. They are expected to wrap-up development when the project gathers final remaining and available vehicle data.

I.21 Electric Vehicle Widescale Analysis for Tomorrow's Transportation Solutions (EVWATTS) (Energetics, a Division of Akimeka, LLC)

Bryan Roy, Principal Investigator
Energetics, a Division of Akimeka, LLC
7075 Samuel Morse Drive, Suite 100
Columbia, MD 21046
E-mail: broy@energetics.com

Michael Laughlin, DOE Technology Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

Start Date: October 1, 2019 End Date: March 31, 2023
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. Personally Identifiable Information (PII) will not be distributed or released to the National Laboratories or the public. The critical success factors for achieving these objectives are:

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

state energy offices, utilities, telematics providers, academia, and vehicle Original Equipment Manufacturers; state and local organizations; and industry partners.

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

- Provide anonymized PEV and EVSE data that augments existing National Laboratory datasets. This data, formatted to leverage National Laboratory capabilities, will be representative of nationwide PEV and EVSE operation.
- Develop and regularly share high-level data summaries and interactive dashboards 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 PEVs and 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.

- 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.
- 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 and interactive dashboards published by the project.
- 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 engaged numerous potential data partners to discuss project participation. At the end of September 2022, EV WATTS had secured data sharing agreements from 68 entities and consent for participation from 86 individuals. The current quantity of data from these data partners is approximately 45,000 EVSE charging ports and 900 PEVs.

Energetics published an online interactive dashboard summarizing the EVSE data collected in 2021 and continues to update the dashboard quarterly. through Figure I.21-3 are screenshots from the dashboard that showcase the content of the EVSE database at the end of September 2022 as well as some analysis and results that come from this large nationwide collection of real-world station operations.

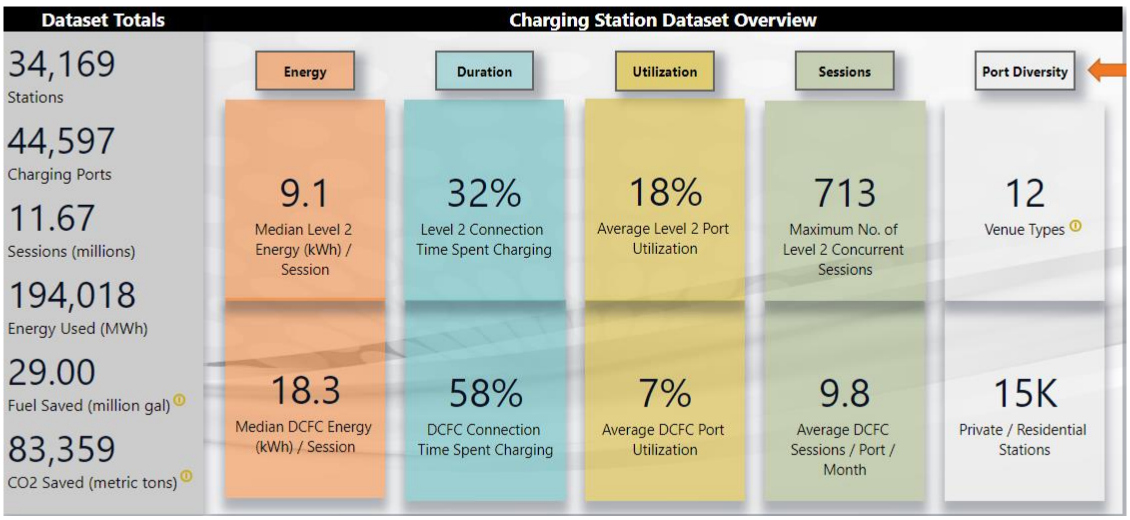

Figure I.21-1. EV WATTS EVSE Database Dashboard – Summary

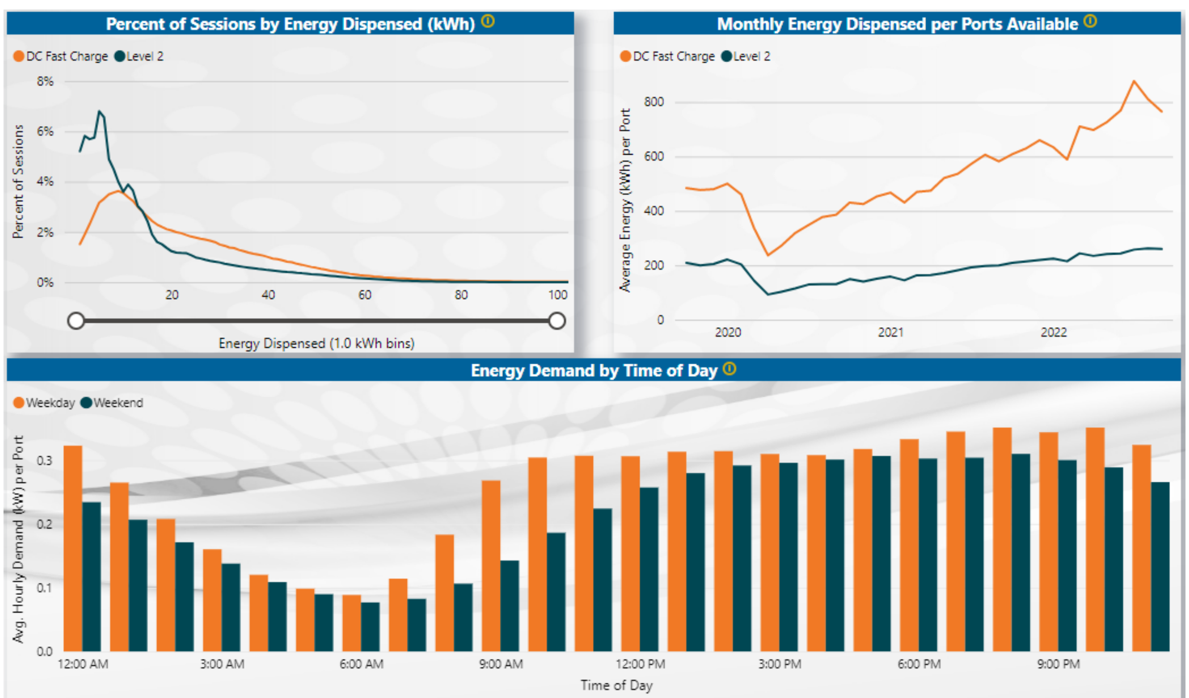

Figure I.21-2. EV WATTS EVSE Database Dashboard – Energy Analysis Results

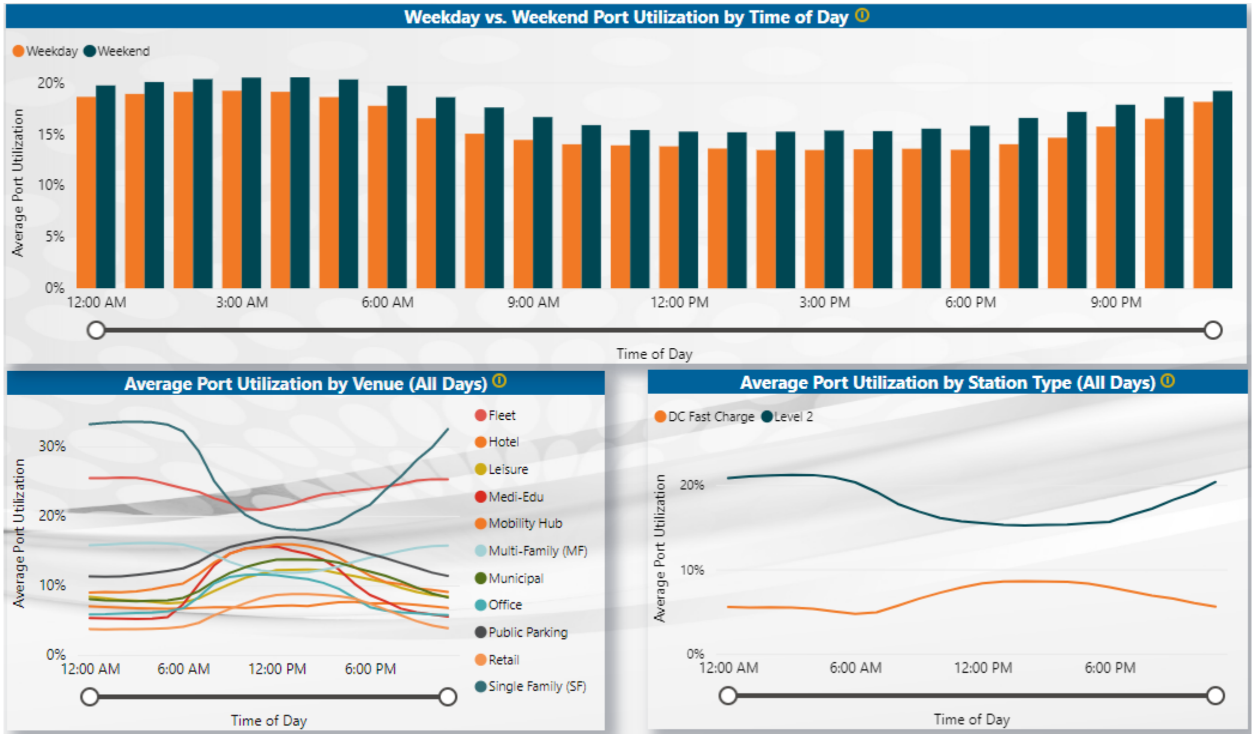

Figure I.21-3. EV WATTS EVSE Database Dashboard – Utilization Analysis Results

In 2022, Energetics published another online interactive dashboard summarizing the light-duty PEV data collected that is also updated quarterly. Figure I.21-4 through Figure I.21-6 are screenshots from the dashboard that showcase the content of the light-duty PEV database at the end of September 2022 as well as some analysis and results.

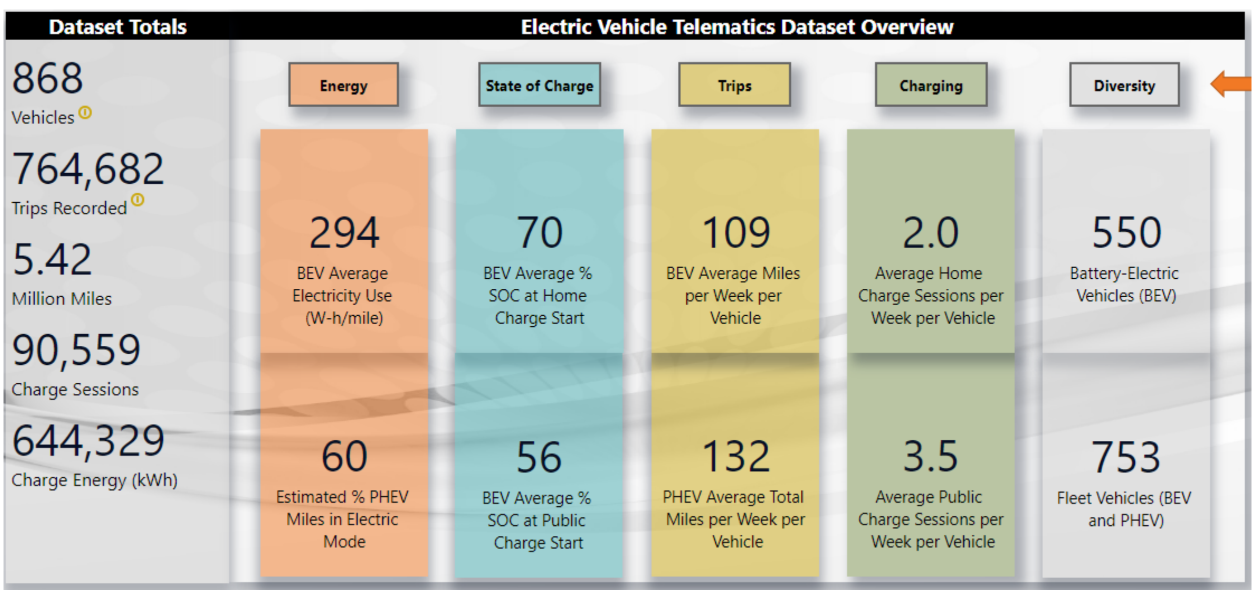

Figure I.21-4. EV WATTS Light-duty PEV Database Dashboard – Summary

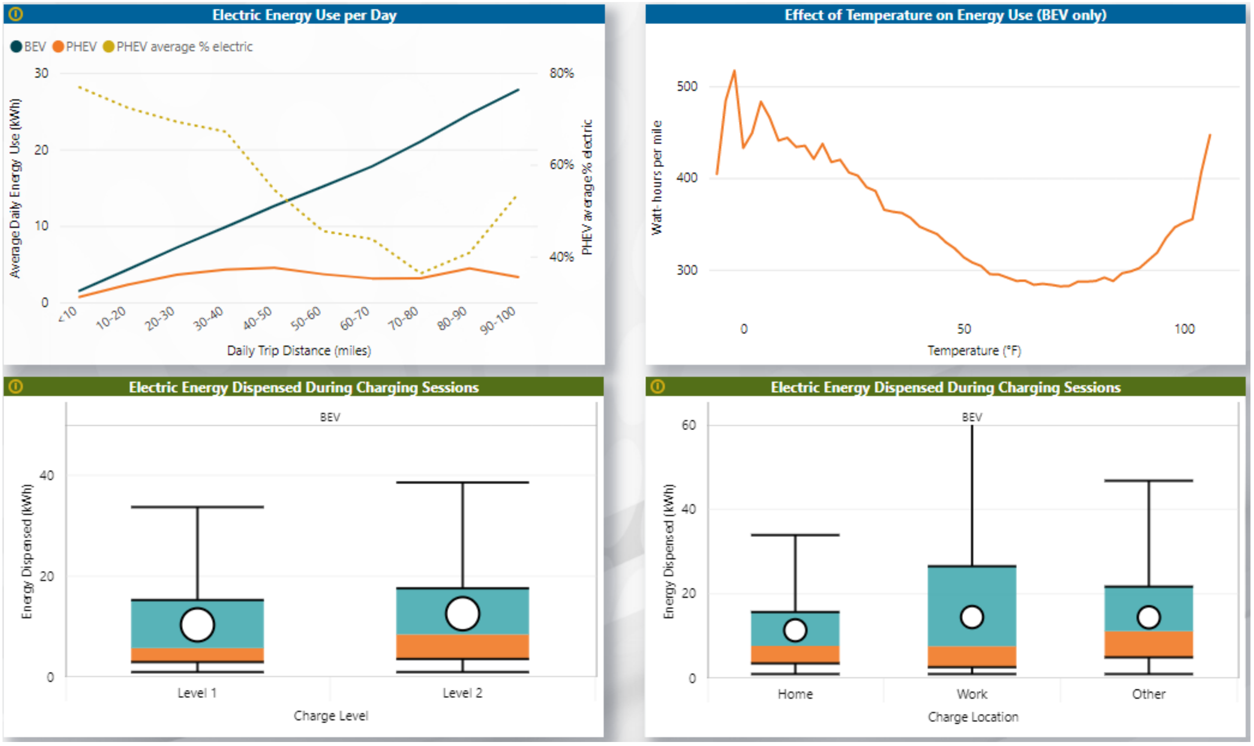

Figure I.21-5. EV WATTS Light-duty PEV Database Dashboard – Energy Analysis Results

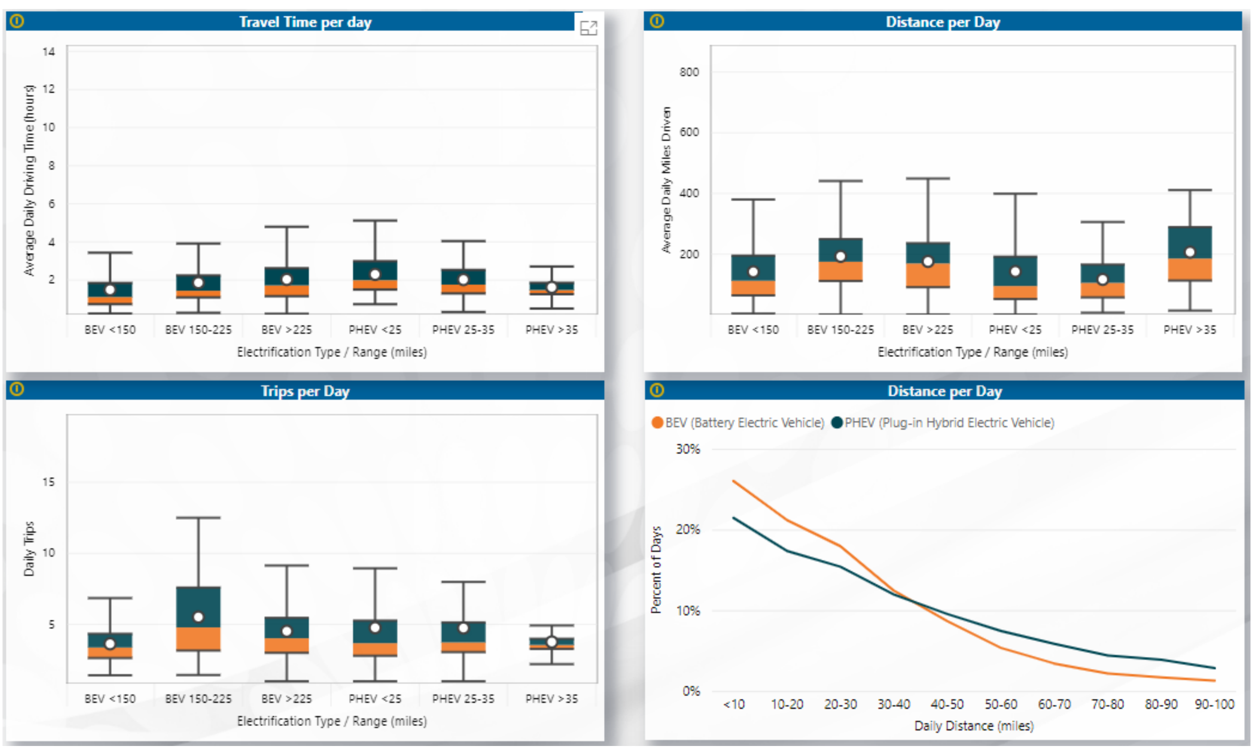

Figure I.21-6. EV WATTS Light-duty PEV Database Dashboard – Trip Analysis Results

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 has shown the following interesting results. Further analyses by Energetics and the DOE National Laboratories continues to provide additional insights.

- 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 between October 2021 and September 2022 was 5-10% for fast chargers and 15-22% for Level 2 chargers.

The PEV dataset has shown the following interesting results.

- PEV energy use while driving averages 280-300 watt-hours per mile when the outside temperature is between 56- and 88-degrees Fahrenheit (F) but is much less efficient in colder or warmer temperatures (averages over 400 watt-hours per mile when it is less than 26 F).
- Plug-in hybrid electric vehicles are driven 20% more than battery electric vehicles (132 miles per week on average as compared to 109).
- The average state of charge when battery electric vehicles begin charging is 62%.

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

- 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).
- The resulting summary data published on the EV WATTS interactive dashboards has gained attention recently and several organizations have let us know that it has been very valuable to understanding the EV market as they plan charging station deployments. There have also been several requests from researchers to access the anonymized dataset, so we know there is interest in that when it becomes publicly available in early 2023.

Key Publications

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

I.22 Medium and Heavy-Duty Electric Vehicle Deployment – Data Collection (CALSTART)

Jasna Tomic, Principal Investigator
CALSTART
48 S. Chester Ave
Pasadena, CA 91106
E-mail: jtomic@calstart.org

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

Start Date: October 1, 2019 End Date: September 30, 2023
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) electric vehicles (EVs) 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 EV 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 the 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. The team will provide project data to the Department of Energy (DOE) and will make it publicly accessible on DOE's LiveWire Data Platform, a data resource created and maintained by the National Renewable Energy Laboratory. The overall goal is for Livewire to be the central repository for all transportation and mobility data, allowing for streamlined research that will prove more efficient and enable research of broader questions.

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 loggers are 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 EV performance data. This includes a wide variety of parameters describing the operation of the vehicle. For example, parameters like distance traveled, 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.

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 most of the 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.22.1.

Table I.22.1. 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
Vocational Use	Utility Rate Structure	
Gross Vehicle Weight Rating (GVWR)	Demand Charges	
Vehicle Model Year	Electricity Consumption	

Maintenance Data

The maintenance data will include all EV-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 third year, the project team moved from Phase 2 into Phase 3 of the project. In this phase, data collection continued with focus shifting to the analysis of collected data to understand vehicle performance trends and the diversity of different use cases. The project team collected, cleaned, and uploaded data from 47 new MD and HD EVs. Through further recruitment efforts, the team also established several new agreements for Category B and new Category C projects where data collection would continue through the extended project period. Table I.22.2 through Table I.22.5 show, by vehicle group, the number of vehicles that are confirmed by signed data sharing agreements and notes their data collection status. The team uploaded the first set of data from Category A projects, comprising 25 vehicles, at the end of 2020. In support of the project's outreach component, the team has continued collaboration with the Clean Cities Coalition partners to deliver four (4) recorded webinar events and anticipates an additional five (5) to be scheduled during the final year of the project.

Table I.22.2. Status of Vehicles within Category A

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

Table I.22.3. Status of Vehicles within Category B

	Confirmed Vehicles			Pending Vehicles
	Vehicles with Agreements	Completed Vehicles	Active Vehicles	Not Started
HD	106	53	43	10
MD	24	16	-	8
Off Road	18	8	-	10
School	50	16	14	20
Category B Total	198	93	57	48

Table I.22.4. Status of Vehicles within Category C

	Confirmed Vehicles			Pending Vehicles
	Vehicles with Agreements	Completed Vehicles	Active Vehicles	Not Started
HD	19	2	17	-
MD	2	-	2	-
Off Road	12	6	6	-
School	-	-	-	-
Category C Total	33	8	25	-

Table I.22.5. Summary Counts of Vehicles within All Categories

	Confirmed Vehicles			Pending Vehicles
	Vehicles with Agreements	Completed Vehicles	Active Vehicles	Not Started
HD	150	80	60	10
MD	26	16	2	8
Off Road	30	14	6	10
School	50	16	14	20
Total	256	126	82	48

Conclusions

This project seeks to collect, aggregate, clean, analyze, and publish data from MD and HD vehicle deployments across the United States. As of writing, in its third year of implementation, the project has uploaded a total of 126 vehicle datasets across all MD and HD vehicle categories through the end of 2022.

Over the course of the project, we have faced several logistical challenges partly due to the rebound of the COVID-19 pandemic. Moreover, fleet participation has been the greatest challenge as an executed data sharing agreement did not guarantee data collection. Several confirmed fleets anticipating the delivery and deployment of EVs ran into delays or other challenges that have resulted in the need for them to drop out. 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 which caused delays in the data collection process. This issue is more prevalent when working with commercial fleets versus public fleets. Despite this difficult challenge, based on our current uploads including active data collection, we are still on track to exceed the project objective of uploading 200 MD and HD EVs to DOE's LiveWire platform.

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 has usually required an individualized approach for each fleet, leading to longer processing times.

We have also encountered issues with fleets needing dataloggers, with delays occurring during a secondary contractual process that 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.

During 2022, the project team delivered a public facing dashboard that allows users to interact and visualize the collected vehicle data in different analytical formats. The MHD EV Data Visualization Dashboard, shown in

Figure I.22-1, includes insights on vehicle performance, vehicle attributes, duty cycle characteristics, and energy efficiency and temperature impacts. The dashboard serves as a publicly accessible tool to explore and share insights on the growing volume of data collected through the project with the goal of informing research efforts and decision making on public policies, fleet operations, and industry development.

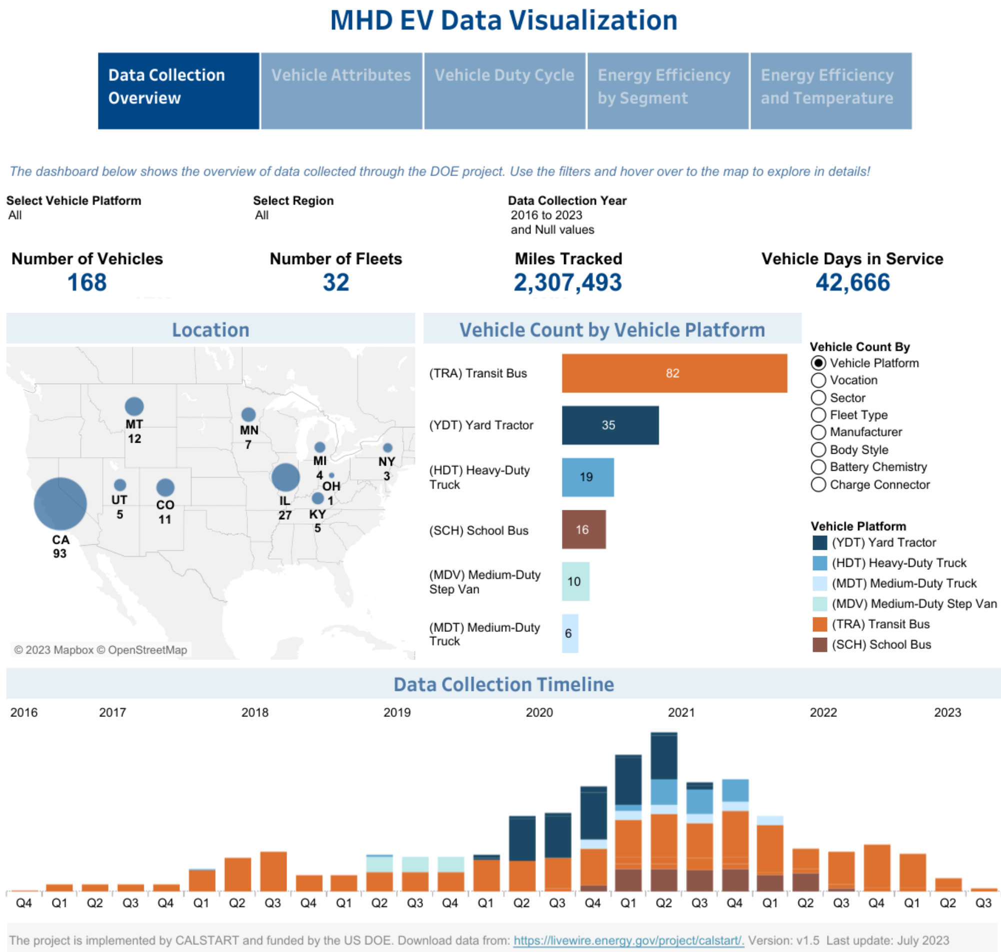

Figure I.22-1. MHD EV Data Visualization dashboard

In addition to the dashboard, the project team has started to deliver fleet report cards to participating fleets that have completed their twelve (12) months of data collection. The [Fleet Report Card] is a customized and standalone webpage (HTML file) shared with each participating fleet to present key metrics from the data collection while also providing actionable insights.

Next steps for the project involve completing data collection on the remaining vehicles in the project pipeline, producing technical publications and presentations that highlight key learnings and insights from this program, and ultimately making all collected data publicly available. The project team will continue efforts to work with our Clean Cities Coalition partners to develop and implement webinars to expand the dissemination of program learnings at the national level. The team will develop a Final Report to capture the comprehensive results of the project, including the data collected, analysis conducted, publications produced, and key results, learnings, and recommendations.

Key Publications

Project Dashboard: Medium- and Heavy-Duty EV Deployment: Data Collection - CALSTART

Fleet Report Card Webpage: Fleet Report Card
DOE M/HD Webinar: Kentucky Clean Fuels Coalition (February 23, 2022)
DOE M/HD Webinar: Drive Clean Colorado (June 22, 2022)
DOE M/HD Podcast: Empire Clean Cities, Part 1 (August 30, 2022)
DOE M/HD Podcast: Empire Clean Cities, Part 2 (September 30, 2022)

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 Energetics.

I.23 Mid-Atlantic Electric School Bus Experience Project (Virginia Clean Cities at James Madison University)

Alleyn Harned, Principal Investigator
Virginia Clean Cities at James Madison University
1401 Technology Drive
MSC 4115
Harrisonburg, VA 22807
E-mail: aharned@vacleancities.org

Sarah Stalcup-Jones, Principal Investigator
Virginia Clean Cities at James Madison University
1401 Technology Drive
MSC 4115
Harrisonburg, VA 22807
E-mail: sstalcupjones@vacleancities.org

Michael Laughlin, DOE Technology Program Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

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.23-1. 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) (Figure I.23-1) is working with school bus manufacturers, Clean Cities coalitions and other partners to support existing electric school bus (ESB) deployments and provide electric school buses for free short-term demonstrations in selected school fleets in Virginia, Maryland, Washington D.C., Pennsylvania, and New Jersey. Electric school buses are an exciting tool for school districts to reduce operating costs; improve local air quality; achieve sustainability goals; and protect the health of children.

These demonstrations are a fantastic opportunity for school administrators, mechanics, drivers, faculty, and the public 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 objectives of MEEP are to provide local school districts with experience operating electric school buses in their fleets, and to generate 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; 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 receiving short-term demonstrations of electric school bus technology in the multi-state project region, as well as school districts and pupil transportation contractors to work with the project as data partners.

In this second budget period (BP2), encompassing the 2022 calendar year, the MEEP project team worked with school districts and pupil transportation contractors to support short-term electric school bus demonstrations in the multi-state project region. In addition to short-term vehicle demonstrations, the project team also worked to support pupil transportation fleets interested in the first round of the U.S. Environmental Protection Agency's (EPA's) Clean School Bus Program funding. This support was provided through hosting multiple clean school bus webinars, connecting fleets with technology providers, Original Equipment Manufacturers (OEMs) and information, and connecting school districts with their peers who already have experience with the technology.

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.

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

In this second budget year of the project, the MEEP project pivoted to fully support many more short-term demonstrations, lasting a half day to three days, rather than 6 to 8-week demonstrations. The MEEP project is underway and experiencing some market specific challenges related to ongoing logistics issues, as well as the increased demand for electric school bus technology.

The supply chain difficulties that have arisen since the start of the COVID-19 pandemic have exacerbated electric school bus manufacturing and deployment delays. These supply chain issues, in addition to the increased demand for electric school buses across the country, have increased delivery timelines. This has created delays in data collection and analysis publication as many of the project buses on the road in the region are tied up in data agreements by bus deployment and infrastructure funders such as Dominion Energy's utility led programs. For example, in a Virginia deployment case, the schools operating the buses provided by the utility entered into an isolated data agreement that allows the utility and school fleets to collect operational data, but that data is not yet publicly accessible. While the project team expects to gain access to this data, as Dominion is a project partner, it will likely be delayed until the third budget period. In FY 2022, project partners developed data collection plans and established relationships with school districts and contractors who are onboarding electric school buses and expecting deliveries before project close.

Over the past few years, we have seen increased funding for electric school buses from public and private sources. In the Spring of 2022, EPA launched the largest opportunity when it announced its first round of the Clean School Bus Program. While the funding and hype around electric school buses made it more challenging to secure electric school buses for long-term demonstrations, it has provided the project team the ability to uplift and support school districts, especially disadvantaged school districts, in their electric school bus journeys.

The MEEP project allowed our partners to use the information, contacts, and resources available through the program to connect with and provide one-on-one support to these school districts even before the program was announced. Project team members were able to connect with school systems to present actionable information on the EPA program and facilitate technology budgeting and planning. A barrier that often arises with large funding opportunities is the limited time that applicants are given to submit applications. This especially becomes a barrier to disadvantaged communities that may not have designated grant writing staffers. In rural and disadvantaged communities, school district staff often wear multiple hats leaving little time and resources to sort through funding and new technology. Team members facilitated state and national outreach explaining technology, hosted demonstrations, and collaborated with a wide range of environmental and technology outreach partners (Figure I.23-2). Simple solutions like key messages and material for visual learners allowed this information to connect with school fleet audiences across the project region.

Figure I.23-2. Virginia Clean Cities and Thomas Built Dealer Sonny Merryman display a demonstration electric school bus at the entrance to the Virginia State Fair. Photo courtesy of Virginia Clean Cities.

Activities this period:

- Initiated project bi-weekly calls.
- Published and distributed training videos.
- Created project data collection plan.
- Supported school districts interested in the EPA Clean School Bus Program.
- Created 2 Electric School Bus webpages.
- Engaged school bus and additional manufacturers (Blue Bird, IC, Thomas Built, Micro Bird, Motiv, and Green Power).
- Engaged a financing company (Highland Electric Fleets).
- Held 8 short-term demonstrations across the project region (Table I.23.1).
- Hosted 6 virtual events and workshops (Table I.23.2).
- Invited project members to speak about the project at ten conferences, meetings, and events (Table I.23.3).
- Deployed project electric school buses in Bedford and Augusta Counties in Virginia.

Table I.23.1.Short-Term Demonstrations

MEEP Partner	Date	School Districts/ Location
Virginia Clean Cities	1/7/2022-1/9/2022	Hampton Roads International Auto Show, Norfolk, Virginia
Virginia Clean Cities and VEIC	3/14/2022	Vienna, Virginia
Virginia Clean Cities	4/7/2022	Salem, Virginia
Greater Washington Region Clean Cities Coalition	5/17/2022	Washington D.C.
New Jersery Clean Cities Coalition	6/8/2022	Somerset, New Jersey
New Jersey Clean Cities Coalition	7/20/2022	Newark, New Jersey
Eastern Pennsylvania Alliance for Clean Transportation	8/31/2022	Philadelphia, PA
Virginia Clean Cities	9/27/2022	Virginia State Fair

Table I.23.2. Virtual Events and Workshops

MEEP Partner	Date	Event Name
Eastern Pennsylvania Alliance for Clean Transporation, New Jersey Clean Cities Coalition, and VEIC	5/20/2022	Electric School Bus Workshop with PECO, EPA Region 3, and DVRPC
Virginia Clean Cities, VEIC, and New Jersey Clean Cities Coalition	6/14/2022	Planning for Clean Pupil Transportation: what to consider when preparing for electric school buses
Greater Washington Region Clean Cities Coalition	6/16/2022	Equity Listening Session
Virginia Clean Cities	6/21/2022	National Electric School Bus webinar, Clean School Buses Success Stories & EPA Clean School Bus Rebate Program
Greater Washington Region Clean Cities Coalition	8/2/2022	Benefits of Electric School Buses
Greater Washingon Region Clean Cities Coalition	12/13/2022	Electric School Bus Listening Session

Table I.23.3. Speaking Events

Meep Partner	Date	Conference/ Event
Greater Washington Region Clean Cities Coalition	1/20/2022	Washington D.C. Auto Show
Greater Washingtion Region Clean Cities Coalition	6/15/2022	GreenPower Visit to the Capitol
Greater Washington Region Clean Cities Coalition	6/25/2022	Virginia ALL IN Festival
Eastern Pennsyslvania Alliance for Clean Transportation	8/1/2022-12/31/2022	7 National Electric Vehicle Infrastructure (NEVI) Formula Program Events and meetings

Conclusions

Electric school bus adoption is up and federal, state, and utility resource allocations shows no sign of slowing down. School districts are excited about this technology, and school districts are increasingly receptive to the technology as they hear positive feedback from their peers. With funding opportunities making electric school buses more accessible across the nation, the project team has been able to leverage the project to work with federal agencies, national laboratories, and fleets on education, procurement, and deployment. Through these experiences, we have found that these fleet continue to need education and support, particularly for infrastructure decisions and planning. Funding programs, such as the first enhanced Infrastructure Investment and Jobs Act (IIJA) round of the EPA's Clean School Bus Program, have gotten money for ESBs out quickly, but in some cases have left school districts with the overpromised false idea that this early-stage technology requires little planning. The project is showing success through utility, school, and technical support experiences. In the final year of the project, the team will share lessons learned with national laboratories and peers nationwide.

Key Publications

"Electric School Bus Success in Rural Virginia: Louisa County Public Schools." September 28, 2022. *Virginia Clean Cities* (blog). Accessed January 13, 2023. https://vacleancities.org/electric-school-bus-success-in-rural-virginia-louisa-county-public-schools/.

"EPA Clean School Bus Awards Double to $1 Billion – Virginia Clean Cities." September 30,2022. Accessed January 13, 2023. https://vacleancities.org/epa-clean-school-bus-awards-double-to-1-billion/.

"GET READY: Clean School Bus Funding Community Guidance." May 3, 2022. *Virginia Clean Cities* (blog). Accessed January 13, 2023. https://vacleancities.org/get-ready-clean-school-bus-community-guidance/.

"GreenPower Progression on Electric School Buses in D.C -." June 17, 2022. Greater Washing Region Clean Cities (blog). Accessed January 13, 2023. https://gwrccc.org/news/greenpower-progression-on-electric-school-buss-in-d-c/.

"Looking Back on School Bus Electrification Efforts in 2022." December 17, 2022. New Jersey Clean Cities (blog). Accessed January 13, 2023. https://njcleancities.org/blog/id/6.

"Message from Our Executive Director – 'The U.S. Needs More Electric School Buses' -." August 28, 2022. Greater Washing Region Clean Cities (blog). Accessed January 13, 2023. https://gwrccc.org/news/message-from-our-executive-director-the-u-s-needs-more-electric-school-buses/.

"MORE THAN $14 MILLION AWARDED FOR CLEAN SCHOOL BUSES." May 4, 2022. *Virginia Clean Cities* (blog). Accessed January 13, 2023. https://vacleancities.org/more-than-14-million-awarded-for-clean-school-buses/.

"Planning for Clean Pupil Transportation Webinar Recording." June 18, 2022. *Virginia Clean Cities* (blog). Accessed January 13, 2023. https://vacleancities.org/planning-for-clean-pupil-transportation-webinar-recording/.

"School Bus Rebates: Clean School Bus Program." May 25, 2022. *Virginia Clean Cities* (blog). Accessed January 13, 2023. https://vacleancities.org/school-bus-rebates-clean-school-bus-program/.

"Technology Happy Hour: Highland." August 8, 2022. *Virginia Clean Cities* (blog). Accessed January 13, 2023. https://vacleancities.org/technology-happy-hour-highland/.

Acknowledgements

This work is a collaborative effort and progress has been due to the collective effort of Virginia Clean Cities, Vermont Energy Investment Corporation (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 the manufacturers, dealers, and school districts that have shown interest in this project and have done work to support these demonstrations.

Finally, we would like to acknowledge the support and hard work contributed to the project by National Energy Technology Laboratory (NETL) Program Manager Erin Russell-Story.

I.24 CORWest – Supporting Electric Vehicle Infrastructure Deployment along Rural Corridors in the Intermountain West (Utah Clean Cities Coalition)

Tammie Bostick, Principal Investigator
Utah Clean Cities Coalition
451 South State Street
Salt Lake City, UT, 84111
E-mail: tammie.bostick@utahcleancities.org

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

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.24-1.
- 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.24-1. 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.

Needs Assessment, Tool Aggregation, and Strategy Development

Utah Clean Cities (UCC) will assemble and engage stakeholders through an Advisory Committee. UCC will identify key barriers inhibiting EV market development, and specific needs for the region. UCC will also aggregate existing tools, such as those within the Alternative Fuels 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 to maintain the online repository and will update the website with new station openings, tools and resources created, such as the Needs Assessment and Demand Charge Assessment. UCC will develop and implement the branding and marketing strategies. UCC will also begin outreach to dealerships and used vehicle exchanges to ensure EV options are available.

Infrastructure Deployment, Public and Private Partnerships, and Corridor Expansion

UCC will review and report on all current and pending station investments; prepare and submit to the team the recommendations for enhancing EVSE and EVs in underserved markers; and further develop educational outreach to foster awareness and meet generated demand for EVs. Finally, UCC will ensure the public facing tool website portal is updated with the most current tools and that the project partners, stakeholders, and future information seekers find user-friendly access to the tool suite.

Results

CORWest was officially rebranded and launched as ChargeWest: West Electric Highway during Q3, 2022. The project will be referred to as ChargeWest throughout this report. UCC hosted the first of the launch events in June 2022, followed by individual state events planned throughout the fall, based on timelines and availability of groups to host events. UCC supported states in hosting these events (more details below). States also worked closely with the communications and marketing group, Element Pro, to continue building out the ChargeWest website. UCC also began actively seeking funding and continuation opportunities to support the ChargeWest brand and project moving forward, with goals to have funding ready by early 2023.

During Budget Period 3, the project team continued with monthly and quarterly meetings with the assigned ChargeWest Advisory Committee, as shown in Table I.24.1, Advisory Committee Members, 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.24.1. 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

Organization	Category
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

In 2021-2022, the project team accomplished the first part of the Needs Assessment, dissemination of the questionnaire on EV readiness. The purpose of the questionnaire was to assess barriers to, and opportunities for, EV adoption in rural and underserved areas of the Intermountain West. The project team developed a questionnaire 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 and included unique questions 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 AFDC 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 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.

The 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 report on demand charges. In April, NASEO reached out to four external organizations – the Electric Edison Institute, the Regulatory Assistance Project, MJ Bradley and Associates, and the National Association of Regulatory Utility Commissioners – to provide a review of the report, to ensure our assumptions and methodology were correct. 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.

NASEO provided the final draft to UCC. All the ChargeWest Advisory Committee members, Western Interstate Energy Board, and NASEO reviewed this completed report, which 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 ChargeWest 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).

The final version was shared in Q3 2021 with the committee and shared throughout the UCC network in Q3 and Q4 2021. UCC and NASEO provided an in-depth webinar on the report, which can be found on the UCC website and is publicly available.

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 ChargeWest 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).

Off-Grid Charging Assessment

This report is scheduled to be released publicly as of Q4, 2022. The project team submitted a revised research proposal to address an adjusted scope, as well as case study examples for three types of low/off-grid stations. This report will assess the needs for low/off-grid charging infrastructure. Goals of this report include identifying challenges faced in connecting corridors through rural highways, as well as examining the role that on-site renewables and storage can play, by reviewing several case studies and examining not only extra costs, but also new capabilities. Case studies within the final report will cover topics in a) Storage b) Renewables and c) Fuel generation. The technologies outlined in this report can help state governments and other stakeholders assess the need and support the future installation of fast charging even in remote regions.

Webinars/Education

UCC continued to host regular monthly meetings with the team Advisory Committee. Meetings have focused heavily on brand launch events and plans for closing out the project in December 2022, including discussing funding and next steps for the project. The team shared updates on the ChargeWest website and provided project requests to states and organizations for final updates to the website with state specific information. (See website section below for more details). NASEO provided updates and announced movement on NASEO's review of Off the Grid charging assessment. Partner states then provided updates and UCC provided details on upcoming events, timelines, and webinars relevant to the ChargeWest project.

Branding

UCC, NASEO, and other assigned branding members from the Advisory Committee completed the branding workshops in Q3 of 2021. Moving into 2022, UCC and partner agencies collaborated on branding efforts. UCC submitted the trademark for the logo and name in March of 2022 and it is currently in the process of being finalized. UCC and the branding team developed the branding guideline during Q2. They were finalized during Q3 and have been used in support of ChargeWest materials.

ChargeWest Website

With the updated branding efforts, the new website can be viewed at https://chargewestev.org and reflects the updated ChargeWest name**.** UCC began collecting individual state information as of the January 2022 quarterly Advisory Committee meeting. UCC worked closely with the website developers to continue building out the website for the estimated launch in Q2 2022. UCC worked closely with this development team to build a successful and useful platform for digital marketing moving forward. The goals of the site continue as follows: to provide users with a space to learn more about EV corridors, trip planning, and EV incentives, and to provide state based informational pages for residents.

Each state worked closely with the developers to build individual state resources and highlights that can be seen by viewing the main page of the site. Updates will continue into the end of Q4 with updates being completed before December 2022. Partners are actively discussing management of the website and resources over the long term with a plan to be created before the completion of this grant.

Brand Awareness Events and Outreach

UCC held the official launch event for the new ChargeWest brand on June 21, 2022, in partnership with our partner, Packsize, and its CEO Hanko Kiessner and his team. He is a longtime supporter and partner of UCC, member of the UCC Board of Trustees, and Co-Founder and Chairman of Leaders for Clean Air. The launch was held at the Packsize office in Salt Lake City and brought together over 75 attendees including state and local government officials, industry leaders and community partners. The event showcased the culmination of over five years of planning with state governors, departments of transportation, departments of environmental quality, and Clean Cities coalitions.

The launch began with a brief introduction to the initiative by Tammie Bostick, Executive Director of Utah Clean Cities. It was followed by a recording of Governor Spencer Cox's special keynote speech regarding ChargeWest™.[7] Following this, the distinguished event speakers gave speeches, covering the importance of this initiative, what its long-term impacts will be, and how this collaborative effort came to be. Speakers for the launch included Mayor Erin Mendenhall, Salt Lake City Mayor; Kim Frost Executive, Director Utah Clean Air Partnership; Hanko Kiessner; Flint Timmins, Destination Development Specialist Utah Office of Tourism; and Tammie Bostick. The official launch and event wrapped up with an exciting EV and workplace charging showcase, with ride-n-drives featuring the latest in EVs available from Rivian, Tesla, Chevrolet, BMW, and Arcimoto. Event details and video highlights can be viewed on the UCC website, as well as the ChargeWest website.

Each Clean Cities and state representative was asked to host similar events throughout the remainder of Budget Period 3 to highlight the EV work in participating states. Clean Cities and state representatives held three press events, including a standalone joint event with Idaho, Montana, and Wyoming, and highlight events in Colorado, Nevada, New Mexico, and Arizona. All events were completed as of September 2022.

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 U.S. Department of Transportation's (DOT) policy director, Rob Hymen, requested a meeting with UCC. DOT chose the ChargeWest 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 DOT, which asked for a second meeting where we reviewed several of our projects and our work in general with the Clean Cities program and highlighted the work at NREL and the AFDC. NREL presented on some of the key tools for DOT. 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 ChargeWest. UCC has steadily delved into the world of hydrogen and renewables and continues to participate in several forums both locally and with Argonne National Laboratory. UCC has met

[7] ChargeWest - West Electric Highway Program Launch - Message from Gov. Cox - YouTube

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. UCC 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 continues to be assessed and updated based on annual reviews. The most recent version is available via the Utah Governors website.
    - 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 through its Workplace Electric Vehicle Charging Funding Assistance Program.
- National Electric Vehicle Infrastructure (NEVI) Program and State Plans
    - Partners within ChargeWest shared monthly updates on state plans and processes, shared resources, and asked questions, and ensured that NEVI was promoted and highlighted in relation to ChargeWest. Outreach and events included highlights and details on NEVI, as well as connecting closely with state departments of transportations and energy offices. Resources and news related to NEVI will continue to be shared within the ChargeWest website, as well.

Conclusions

During the third year of the ChargeWest, project, the project partners successfully developed the core branding image and goals, (soft) launched the ChargeWest 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 ChargeWest and EV Corridors.

Key Publications

CORWest Electric Vehicle Charging Needs Assessment. 2021. Published on NASEO and on the UCC websites: https://www.naseo.org/data/sites/1/documents/publications/EVWest_NeedsAssessment_Final.pdf

Demand Charges & Electric Vehicle Fast-Charging. 2021. Published on the Utah Clean Cities website, https://utahcleancities.org/wp-content/uploads/2021/10/Demand-Charges-and-EV-Charging-Final-1.pdf

Branding and Logo workshop materials. 2022. Available via the Utah Clean Cities website, https://utahcleancities.org/wp-content/uploads/2022/01/Copy-of-CORWest-Brand-Identity-Workshop-Summary.docx.pdf

Acknowledgements

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

I.25 Decentralized Mobility Ecosystem: Market Solutions for 21st Century Electrified Mobility (Clean Fuels Ohio)

Timothy Cho, Principal Investigator
Clean Fuels Ohio
17 S. High Street, Suite 810
Columbus, OH 43215
E-mail: tim@cleanfuelsohio.org

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

Start Date: October 1, 2019 End Date: June 30, 2023
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 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, in conjunction with project partners, made progress on the following milestones in the third year of the project:

- **Deployment of Mobility Hubs:** Deploy EVs and EVSE at Southside, Short North, and Westside mobility hub locations.
- **Marketing for Electric Vehicle Mobility Hubs Completed:** Market and operate EV mobility hubs to relevant user audiences.
- **Replication Playbook Completed and Feedback Requested:** Finalized replication playbook and distributed for comment.
- **Replication Playbook Revised, Completed, and Disseminated:** Completed replication playbook and disseminated to the public.

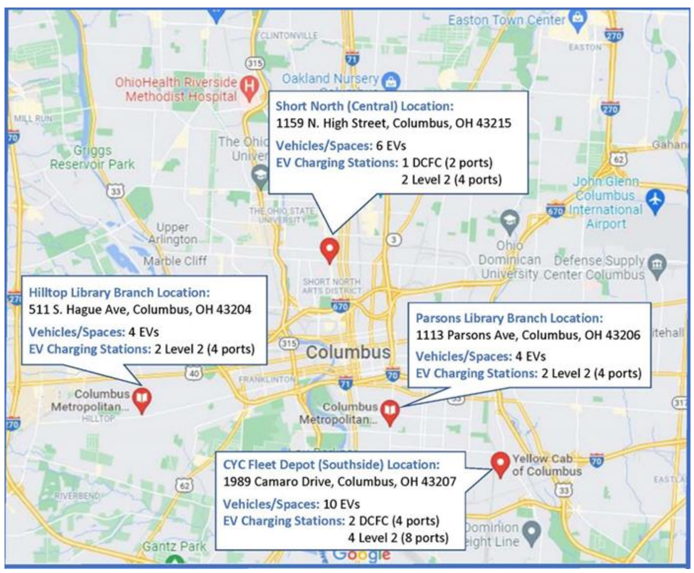

Figure I.25-1. Map and location of four Columbus Yellow Cab EV mobility hubs

Mobility Hubs Deployed

Clean Fuels Ohio continued to work with Columbus Yellow Cab to deploy EVs and utilize EVSE at the four project EV charging mobility hub locations (See Figure I.25-1):

<u>Southside Mobility Hub:</u> Leveraging funding and incentives available through the utility (AEP) and the Smart Columbus program, Columbus Yellow Cab 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 Columbus Yellow Cab's fleet. The public facing access will be launched in early 2023 when all the other mobility hubs are completed and constructed. (See Figure I.25-2.)

Figure I.25-2. Southside Columbus Yellow Cab Mobility Hub

Short North Mobility Hub: Columbus Yellow Cab worked with the City of Columbus, HNTB and the EV charging installers to finalize the deployment of this mobility hub. Overall, due to delays in the construction timeline and processes regarding final approvals with the City of Columbus on things such as conduits, electrical wiring, power cables, and Americans with Disabilities Act (ADA) compliance, this hub is now expected to be completed in January 2023. The charging station installation process will take about 4 weeks and about 1-2 weeks downtime until the panel gets delivered as long as there are no more delays. The project team will meet with the City of Columbus regarding Pre-Inspection in early October to discuss issues surrounding design plans for the fiber optic wires, conduits, and power cables that will be submitted to the Department of Power. (See Figure I.25-3).

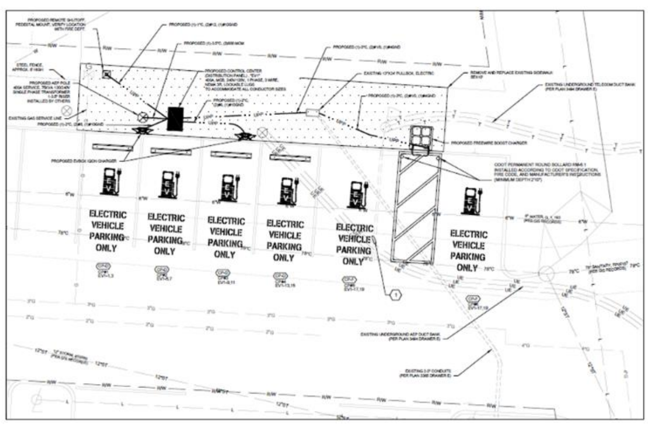

Figure I.25-3. Design Plans for Short North Columbus Yellow Cab Mobility Hub

Eastside (now Westside and Central) Mobility Hub: Columbus Yellow Cab worked with the Columbus Metropolitan Library System to offer and construct mobility hubs at two specific library branches (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 two library branches are in underserved and disadvantaged neighborhoods that have been historically redlined. The selection of these new locations would place EVSE ports where there are currently no chargers available. Clean Fuels Ohio and the project team are moving forward with these 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 library branches and anticipates finalizing plans with the library in November 2022. (See Figure I.25-4 and Figure I.25-5).

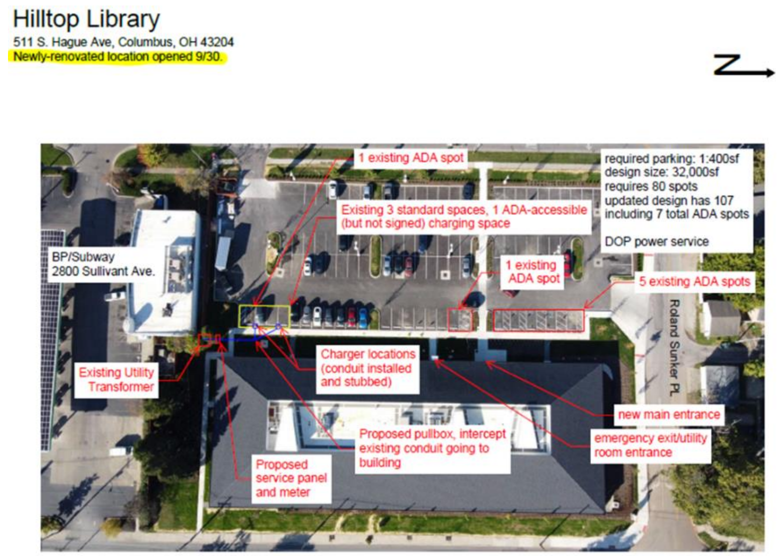

Figure I.25-4. Design Plans for Westside Columbus Yellow Cab Mobility Hub

Figure I.25-5. Design Plans for Central Columbus Yellow Cab Mobility Hub

EV Mobility Hub Reservation App

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 that 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 vehicle use cases. Columbus Yellow Cab continued to work with Greenlots, a charging station and network provider, to configure plans for integrating the Greenlots platform with the existing Columbus Yellow Cab reservation 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 the mobile EV reservation platform once it is launched and receives feedback from users.

The Columbus Yellow Cab mobility hub EV reservation platform continues to go through final stages of development through the partnership with Greenlots. The Columbus Yellow Cab mobility hub reservation platform includes core charging functions such as charger management, billing, and payment, charging reports, cellular data, and driver support. It also includes SKY Enterprise charging functions for the mobility hub owner (Columbus Yellow Cab) such as detailed site layout and charging equipment data, integrated view of charging equipment issue ticketing, view of firmware testing process and scheduled updates, independent configuration for charging network and segmented data access, and advanced analytics and reporting. Once all four mobility hubs are deployed, the final version of the Columbus Yellow Cab mobility hub EV reservation platform will be available. Greenlots and Columbus Yellow Cab are working towards finalizing the reservation platform at the same time as the completion of the mobility hubs construction. See Figure I.25-6.

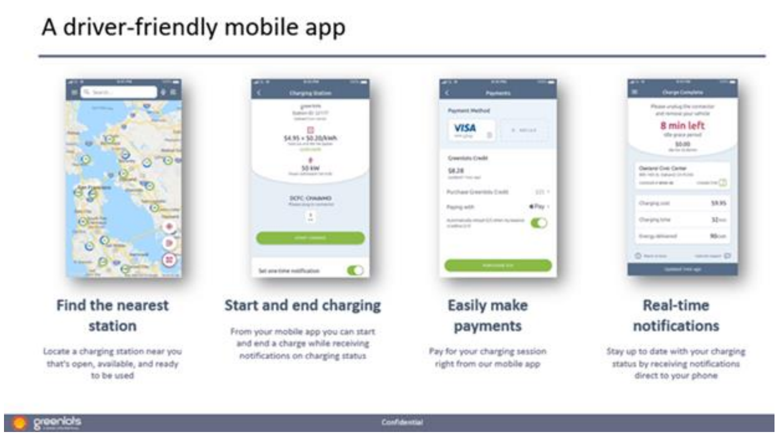

Figure I.25-6. Columbus Yellow Cab mobility hub EV reservation app via Greenlots

Marketing for Electric Vehicle Mobility Hubs Completed

Clean Fuels Ohio worked with the City of Columbus Sustainable Columbus team and four community-based organization partners to execute a marketing and community engagement plan for the EV mobility hubs. Clean Fuels Ohio, Columbus Yellow Cab, and Sustainable Columbus are committed to a collaborative approach with community-based organization partners and members of central Ohio local communities. The project team identified and selected community-based partners for each EV mobility hub location to receive grant funding that will support local community-facing outreach, marketing, and education efforts to promote the hubs. The role of the community partners will be to help enable community residents to access the EV mobility hubs through existing individual and community services, and to support the project team with the key activities:

- Training, marketing, and outreach regarding EV mobility hubs.
- Promoting, attending, and supporting EV mobility hub events (expos, showcases, trainings).
- Assisting with community education, awareness, and engagement.

The community partners include IMPACT Community Action (Southside), Zora's House (Short North), Community Development for All People (Central), and Greater Hilltop Area Shalom Zone (Westside).

Clean Fuels Ohio will provide the community partners with knowledge and resources to facilitate engagement within their local communities, to promote broad awareness of the EV mobility hubs, and to enable the local communities to access and utilize them. Resources will include information on EV and charging availability, uses, and service models; vehicle and charging station reservation platform/process; trainings for mobility hub users; and community support resources. Clean Fuels Ohio and the community partners agreed to leverage relationships to engage with and build/establish clean transportation/mobility access-centered relationships with their community members through outreach, marketing, and education activities. The project team will rely on the community-based partners to be trusted sources of broad and general education, and facilitation support. Clean Fuels Ohio finalized and shared a Marketing and Community Engagement Plan with the rest of the project team and the community partners. The plan’s scope of work includes tasks such as conducting surveys, outreach, marketing, education, training, and events about EV mobility hub availability, access, and utilization, and began in May 2022. Phase 1a: Survey Communities & Refine Workplan was completed in June 2022. Phase 1b: Work to Secure Community Partners began in August 2022 and we anticipate completion in December 2022. Clean Fuels Ohio and the project team will begin initial steps for Phase 3: Host EV Mobility Hub Expos, Showcases, and User Specific Trainings, with a goal for completion in April 2023. The rest of the phases in the workplan will be completed during 2023.

Replication Playbook Completed and Feedback Requested

Clean Fuels Ohio finalized 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. Project partner HNTB was assigned to develop the draft of the replication playbook in Year 3 and provided Clean Fuels Ohio with a draft outline which includes sections on existing and future conditions analysis (focusing on transit routes, taxi/TNC routes, routes in charging, etc.); community and stakeholder engagement (focusing on feedback from community areas/zones that were determined to inform and refine the final locations, general validation and support of the mobility hub concept, etc.); design (focusing on design practices, ADA compliance, curbs, grading, site specific design, transformer location, emergency shutoff, equipment, local jurisdiction zoning and building codes, site constraints, etc.); and implementation (focusing on permitting and management best practices). The outline also highlights lessons learned, issues/challenges, risk matrix, and resources/tools.

Replication Playbook Revised, Completed, and Disseminated

Clean Fuels Ohio continued to receive guidance and feedback from project partners on the initial draft of the replication playbook and will receive further input from these partners and the Project Advisory Committee throughout the rest of Year 3 (which ends on June 30, 2023), to develop a final draft of the playbook. Clean Fuels Ohio will work with HNTB to finalize the replication playbook outline, content, visuals, and design. The final draft of the replication playbook with all forms of input and feedback will be available in Q2 2023. Clean Fuels Ohio will then revise, complete, and disseminate it.

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 due to the EVSE hardware delivery delay. Challenges around rezoning for the final Eastside Mobility Hub location have resulted in the addition of two new mobility hub locations at the Parsons and Hilltop Libraries 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 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 3 timelines and milestones.

Key Publications

Decentralized Mobility Ecosystem Website

I.26 Integrated Fuel Cell Electric Powertrain Demonstration (Cummins Inc.)

Patrick Kaufman, Principal Investigator
Cummins Inc.
3300 Industrial Blvd., Suite 600
West Sacramento, CA 95691
E-mail: patrick.kaufman@cummins.com

Mark Smith, DOE Program Manager
U.S. Department of Energy
E-mail: mark.smith@ee.doe.gov

Start Date: October 1, 2020 End Date: December 31, 2023
Project Funding: $7,208,624 DOE share: $3,44,063 Non-DOE share: $3,765,624

Project Introduction

Heavy-duty fuel cell electric vehicles are not new to the truck and bus market; however, fuel cell and hydrogen technologies have not gained widespread market adoption 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 resulting 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 (H2) technologies. In particular, the integration and packaging of the different components that make up a fuel cell electric powertrain are complex and remain costly. In addition, H2 fuel prices remain high, the cost of fuel cell stacks and H2 fuel storage solutions is still high, and there is a need to increase H2 storage energy density.

Cummins Inc. (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 H2 vehicles. In addition to meeting the goal of the area of interest of the solicitation, the proposed fuel cell powertrain technology offers the following benefits:

- Vertically integrated.
- Modular and scalable.
- Highly integrated and manufacturable.
- Increased driving range.
- Increased fuel economy.
- Rapid refueling.
- 1:1 replacement of conventional vehicles.
- Total Cost of Ownership (TCO) reduction.

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, with the capabilities shown in Table I.26.1.

Table I.26.1. Project Target Metrics

Parameter	Measure
Range (Component Level)	≥ 300 miles
Fuel Economy (Component Level)	≥8 miles per kg H2 (truck) / ≥10 miles per kg H2 (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 H2 at high volumes

Approach

Cummins 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; build, commission and test the prototype fuel cell vehicles; provide service and support during the field demonstration at Spark Area Regional Transit Authority (SARTA) in Ohio and Werner Enterprises in Los Angeles; assist CALSTART with the data collection and analysis; develop the product development and manufacturing plan; and work 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 H2 economy and the commercialization of fuel cell and H2 technologies.

Budget Period 1 - Integrated Fuel Cell Electric Powertrain Design and Assembly: Cummins will design a modular and scalable integrated fuel cell electric powertrain by leveraging existing fuel cell powertrains and design and integrate the powertrain and its components, ensuring a high level of commonality in components between the truck and bus versions of the powertrain. Cummins will also refine the powertrain layouts and integration processes to make them highly manufacturable and will construct and commission a prototype fuel cell Class 8 truck and a prototype fuel cell transit bus.

Budget Period 2 - Vehicle Testing, Demonstration and Evaluation: Cummins will test the prototype vehicles for performance, safety, durability, and reliability in operation closely simulating the drive cycles typically taken by the end-user fleets. Cummins will deliver prototype vehicles to the end-user fleets (Werner Enterprises in Los Angeles for the trucks and SARTA in Ohio for the transit bus) which will operate them in real-world conditions covering both hot and cold climate. The end-user fleets will thoroughly evaluate the performance of each vehicle and report on it throughout the demonstration period.

Budget Period 3 - Technology Commercialization: Public outreach activities will help establish strong relationships throughout the H2 ecosystem to support future commercialization efforts. Cummins, in collaboration with the Original Equipment Manufacturer (OEM) partners, will create an actionable technology deployment plan to complete the introduction to market of the Integrated Fuel Cell Electric Powertrain, achieve high production volumes at reduced costs, and identify a viable pathway for commercialization to achieve near-term, rapid, and substantial penetration of the truck and bus market.

The expected outcome of the project is a market-ready fuel cell electric powertrain with operational performance and total cost of ownership that will support near-term, rapid, and substantial penetration of the truck and bus market.

Results

Task 0.0 Project Management and Planning activities were underway in 2022. The project schedule and budget require adjustment to recognize the delayed start and shifting of all milestone dates accordingly. It is anticipated that in December 2022, Cummins will submit a proposal for modification of Cooperative Agreement DE-EE0009214. The modification may include changes to the Scope of Work, to implement the newest technology currently available, and a proposal to complete the work on this program through September 30, 2025. In this submittal, Cummins may submit an updated Project Management plan (PMP) in accordance with which the project will be managed and implemented.

The following was or will be accomplished by end of 2022:

Fuel Cell Truck (Anticipated):

- Began Task 1.1 Integrated Fuel Cell Electric Powertrain Design activities.
  - In October 2022, the Cummins team will begin discussions with OEM partner on Powertrain Architecture.
- Update and finalize Roles and Responsibilities agreement, in RASIC (Responsible, Approving, Supporting, Informed, and Consulting) format, with OEM partner, anticipated November 2022.
- Execute Amendment 1 to Navistar subcontract agreement, anticipated December 2022.

Fuel Cell Bus:

- Began Task 1.1 Integrated Fuel Cell Electric Powertrain Design activities.
  - Received vehicle information, including computer-aided design (CAD) models of stock bus.
  - Completed component layout in CAD.
  - Held a workshop to finalize the project plan and architecture.
    - Ninety percent of the architecture has been finalized except for the H2 Storage System which we anticipate will be completed in February 2023.

The project has experienced delays over the course of the year due to incremental technological advancements, staffing changes, and delays in the rehire process. The project team noted changes from HD90 Gen 3 to Gen 4 fuel cell engine, new high-power battery packs, eAxle traction system for Class 8 application, direct drive traction improvement for Transit Bus application, and 700bar H2 storage system with more H2 capacity for Class 8 applications.

Conclusions

None to date.

I.27 Field Demonstration of a Near-Zero, Tier 5 Compliant, Natural Gas Hybrid Line-Haul Locomotive (GTI Energy)

Ted Barnes, Principal Investigator
GTI Energy
1700 S. Mount Prospect Road
Des Plaines, IL
E-mail: tbarnes@gti.energy

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

Start Date: October 1, 2020 End Date: December 31, 2024
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 GTI Energy, 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.27.1 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.27.1. 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
CA Air Resources Board (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 Energy 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 U.S.

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 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 Railserve in Longview, TX. 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. Following that, the locomotive will be moved to the Association of American Railroads' (AAR) Transportation Technology Center (TTC) 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 TTC testing facility the locomotive will operate on the 50-mile test loop in real-world conditions. The operation at TTC 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 testing at TTC, the team is planning to perform three months of in-service field-testing in a practical application with Patriot Rail in Utah or California.

Results

The project was delayed in 2021 due to the COVID-19 outbreak, labor market challenges, supply chain disruptions and design shift to CNG/RNG-only design. The team requested a 12-month no-cost extension which was granted in Q1 2022.

The project team has conducted multiple design review meetings in addition to weekly administrative updates. Throughout the course of the year, the team has completed the functional objectives and the design has undergone several iterations. The baseline platform has been selected as the EMD SD70M-2, a 74-foot-long locomotive with two triple-axle trucks that will enable the objectives of this project to be demonstrated.

The powerplant has iterated from the original assumption of using four 400hp Cummins ISX12N natural gas engines and one diesel-fueled 2,700hp QSK60 engine, to using 10 ISX12N transversely mounted engines, to the current plan of 8 ISX12N engines axially mounted onto the platform. The latest concept layout is shown in Figure I.27-1.

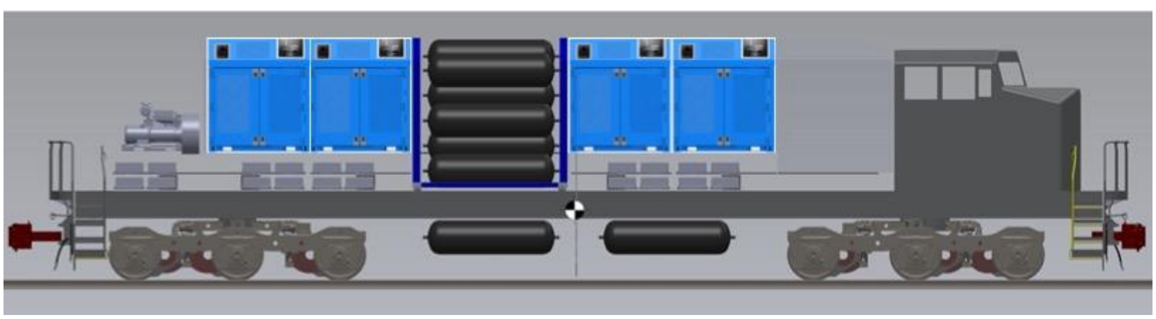

Figure I.27-1. CNG/RNG locomotive concept layout

Evolution of the design has been driven by design reviews with engine manufacturer and serviceability reviews. The resulting architecture offered improved cooling airflow, improved accessibility for service and increased space for fuel storage.

To ensure the performance of the locomotive, the team modeled the Duty Cycle and Power Required at each Notch Level using the EPA line haul duty cycle and the EPA percentage power notch schedule. The calculations are based on 5,091 locomotive operating hours annually and the power of 3,200hp from the eight 400 hp RNG engine pods and 1,000hp (750 kW) from four 313 kW-hr battery packs.

Modeling results indicate that the batteries are used only at notch 7 and 8, which represents 22.63% of the time or 1,152 hours. The maximum load on the batteries is 747 kW at notch 8 for up to an hour. Each of the engine pods operates 44% of the annual time or 2,217 hours. The load factors for each of the 400 hp engines is 34% or 135 hp.

The CNG Hybrid Locomotive technology consists of 3 types of modules, the Engine Modules with Alternator, the Battery Module, and the Fuel Storage Module. The space claims for each are shown based on the new engine module design. See Figure I.27-2.

42,00 or 5,500 hp RNG hybrid (4000 hp 8 ISX12N or X15N), Line Haul Loco (3 axles Truck)		
Coupler to Coupler	890	74.17
	in	**Ft**
Coupler and railing	25	2.08
Partial Steps (30" total)	12.0	1.00
SD70 Cab	159.0	13.25
Medha Control Module & DB module	108.00	9.00
Two X15N Pods (83" L x 46.5" W x 72.5 to 85 T)	83	6.92
Two X15N Pods (83" L x 46.5" W x 72.5 to 85 T)	83	6.92
CNG Storage System - 132" x 123" x 119.5" - abt 1,250 DGE	132	11.00
Two X15N Pods (83" L x 46.5" W x 72.5 to 85 T)	83	6.92
Two X15N Pods (83" L x 46.5" W x 72.5 to 85 T)	83	6.92
END Module	97.00	8.08
Platform, Steps and coupler	25.00	2.08
	0	0.00
Total (Coupler to Coupler)	**890.00**	**74.17**

Figure I.27-2. Module Space Claim

Each module is designed to have a high degree of commonality and modularity. The modules are connected to each other using ISO corner locks, allowing for the installation and removal of any module on the locomotive deck, and interlock with each other for stability and crash survival.

As the design progressed and the team conducted applications reviews with the component suppliers, the configuration of the transverse mounted modules, which included insufficient airflow within the module and cooling system issues with radiator placement, became a concern. To reconcile these concerns, the team redesigned the engine modules as shown in Figure I.27-3. This layout allows for additional width of the module to address airflow and opens space on the vertical wall of the module for the engine coolant radiator. Axially mounting the modules in this way creates a center walkway along the locomotive that provides multiple benefits including improved manufacturability and serviceability of the engines / components within.

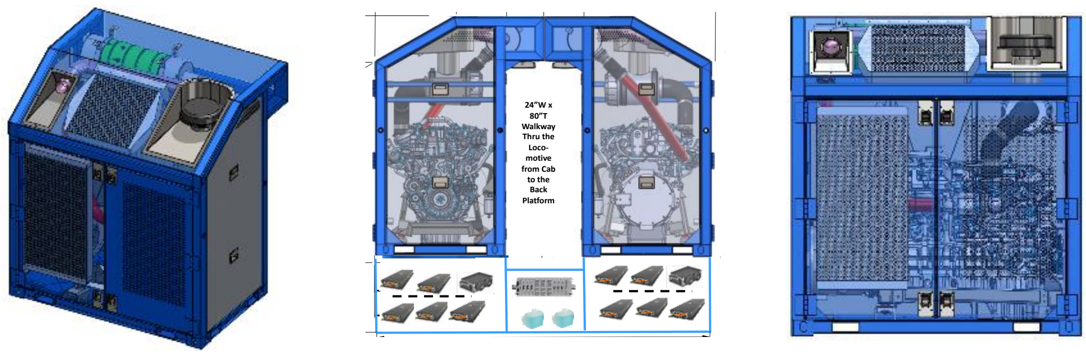

Figure I.27-3. Engine module

Each of the four battery modules contains 313 kWh of Lithium Iron Phosphate (LFP) batteries, one BAE Modular Power Control System (MPCS), and two chillers. The battery solution consists of ten off-the-shelf packs for a nominal voltage of 686V and 312 kWh capacity at 1-C discharge rating for each of the four battery bays. (Figure I.27-4). The battery cells are rated for 4000 cycles, which is adequate for the anticipated 10-year useful life of the powertrain.

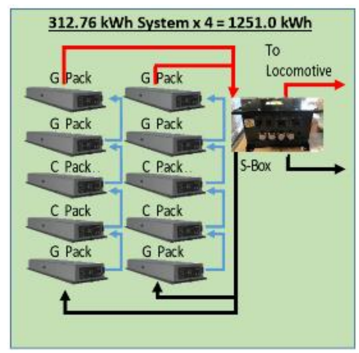

Figure I.27-4. Battery module architecture

Overall, the battery modules provide continuous power of 1,251 kW at 1-C discharge; 750 kW at 0.6-C discharge; and peak power of 2,502 kW for 60 seconds.

The CNG/RNG on-deck storage module shown in Figure I.27-5 is 134” wide x 123” deep x 119.5” tall. It offers a 24” x 80” walkway in the middle of the unit to allow the personnel to go from the front to the back of the locomotive. The new locomotive layout allowed for additional length to be added to the on-deck storage cylinders, boosting the on-deck storage capacity to 1,300 diesel gallon equivalent (DGE). Under-deck storage is comprised of 8 tanks, bringing the combined fuel storage capacity to 2,100 DGE

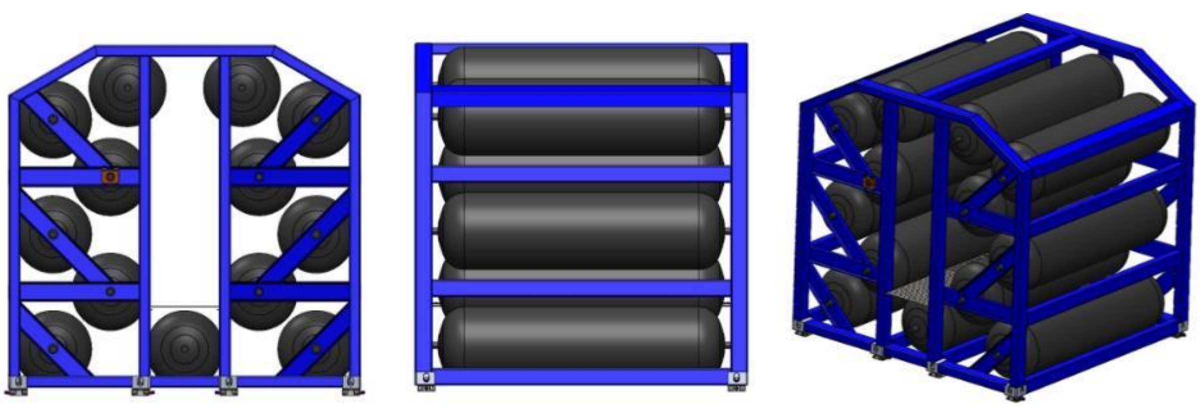

Figure I.27-5. Fuel storage module

OptiFuel has identified all the major component suppliers and has been working with Railserve on the assembly plan for the locomotive at their site in Longview, TX. OptiFuel and Railserve have also been planning an acquisition of a used SD70M-2 locomotive in Budget Period 2 along with ordering of the long-lead items, such as pressure vessels, engines, generators, batteries, and control system. The locomotive receipt is expected by June 2023 and start of assembly in October 2023.

The technical testing will occur at the FRA's Transportation Technology Center (TTC) prior to going into service. The locomotive is expected to be shipped to TTC in April of 2024. Technical testing will occur for 4 months and will be followed by operational testing, either at TTC or with Patriot Rail at one of two of their railroads in Sacramento, California or Salt Lake City, Utah.

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 to maintain progress in Budget Period 2 and recover a significant portion of the schedule.

Acknowledgements

The project team would like to acknowledge the support of its DOE Project Manager, Mr. Daniel Nardozzi.

I.28 Delivering Clean Air in Denver: Propane Trucks and Infrastructure in Mail Delivery Application (Drive Clean Colorado)

Bonnie Trowbridge, Principal Investigator
Executive Director
Drive Clean Colorado
12650 W 64th Avenue, Unit E#216
Arvada, CO 80004-3887
E-mail: bonnie@drivecleanco.org

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

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Project Funding (FY 2022): $1,000,010 DOE share: $500,005 Non-DOE share: $500,005

Project Introduction

This project will partially fund, 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 were 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.

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 installed.

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

BP1: 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 affected by the global COVID-19 pandemic; high demand has also led to prolonged build-times. The five propane Autogas trucks have been delivered as of August 1, 2022.

BP1: Fuel Infrastructure

Project partners AmeriGas and Hi Pro, Inc. have signed agreements for fuel purchase and installation of the propane Autogas fueling infrastructure, installed at Hi Pro, Inc.'s location in Commerce City, CO. Permitting and installation of the fueling infrastructure was complete as of August 1, 2022. Fueling infrastructure is operational as of September 1, 2022.

BP1: Education and Outreach

DCC and PERC developed and disseminated a press release in April 2021. PERC 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 announced the project to stakeholders in a monthly newsletter in May 2021 and published a project overview on the organizational website.

BP2: Truck Operation

All trucks are delivered and will be operating on reduced routes beginning in November 2022. Trucks are meeting operational reliability within initial piloting phase, to be fully deployed in January 2023. A photo of trucks with Hi Pro, Inc. logo is displayed in Figure I.28-1.

Figure I.28-1. Hi Pro, Inc. propane Autogas truck

BP2: Data Collection

Data collection devices collected summer operational data on diesel trucks from August-September 2022. NREL will collect data on propane trucks for comparable winter data in January/February 2023 and comparable summer data in July/August 2023.

BP2: Education and Outreach

DCC and PERC disseminated a press release upon truck delivery in August 2022. Hi-Pro, Inc. hosted a ribbon cutting on August 2, 2022. See Figure I.28-2. Two webinars were planned – one in Budget Year 1 and another in Budget Year 2. These webinars are to be combined and will be presented in summer of 2023 (Budget Year 3). The decision to delay and combine the webinars was prompted by the long delays in truck delivery and data collection. We feel that the webinar will have greater impact once we have findings to report on for both the process of ordering and integrating the new trucks into the fleet, as well as the performance metrics and operational features of the trucks running on routes.

A short list of attendees at Hi Pro, Inc. ribbon cutting is as follows:

- Jennifer Beiro-Reveille, Senior Director, Environmental Affairs and Corporate Sustainability at USPS.
- Greg Reed, Executive Director of the National Star Route Mail Contractors Association.
- Josh Stoneback, Owner and CEO at Hi Pro, Inc.
- Chris Ransom, National Account Manager at AmeriGas.
- John Gonzales, Senior Engineer, Center for Integrated Mobility Sciences at NREL.
- Derek Whaley, Business Development at Roush CleanTech.
- Steve Whaley, Director of Autogas Business Development at PERC.

- Bobby Stanley, Rush Enterprises.
- Bonnie Trowbridge, Executive Director, Drive Clean Colorado.

Figure I.28-2. Ribbon cutting ceremony at Hi Pro, Inc. for propane Autogas fueling infrastructure and propane Autogas truck delivery.

BP2: Trade Show Participation

Due to the project delays DCC was unable to attend Work Truck Week in Indianapolis in March of 2022 but plans to attend a major industry trade show in 2023 when project conclusions can be presented. DCC plans to provide a project overview and highlights at the Drive Clean Summit & Expo in October 2022 in Golden, CO and to present the same information at the Clean Cities Training in Golden, CO from Nov 15-17, 2022.

BP2: Outreach

PERC attended and ROUSH presented at the National Star Route Mail Contractors Association Convention with Hi Pro, Inc. in August 2022. Approximately 470 were in attendance including several dozen Postal Officials. It was a huge success in getting the Hi Pro story out in front of many other contractors, and many of them committed to getting vehicle quotes and site visits for fueling infrastructure.

Conclusions

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

Key Publications

DCC Ribbon Cutting at Hi Pro, Inc. Event Page:

Drive Clean Colorado Staff, "Propane Fleet Demonstration Project Event," Drive Clean Colorado, July 15, 2022, https://drivecleancolorado.org/event/propane-ribbon-cutting/.

DCC Press Release published in American Journal of Transportation (AJOT):

AJOT Staff, "Delivering clean air in Denver: USPS contractor adds ultra-low NOx propane Autogas vehicles to fleet," AJOT News, August 3, 2022, https://ajot.com/news/delivering-clean-air-in-denver-usps-contractor-adds-ultra-low-nox-propane-autogas-vehicles-to-fleet.

DCC Press Release published in LP Gas Magazine:
Carly Bemer, "USPS Contractor Adds Propane Autogas Vehicles to Fleet," LPS Gas Magazine, August 4, 2022, https://www.lpgasmagazine.com/usps-contractor-adds-propane-autogas-vehicles-to-fleet/.

DCC Press Release published in Butane-Propane News:
BP News, "USPS Contractor Adds Ultra-Low NOx Propane Vehicles to Fleet," August 3, 2022, https://bpnews.com/news/usps-contractor-adds-ultra-low-nox-propane-autogas-vehicles-fleet.

DCC Feature on Denver7 News:
Denver7 Staff, "Hi Pro, Inc. adding propane mail transport trucks," Denver7 News, August 2, 2022, YouTube, https://www.youtube.com/watch?v=DhY657xWxnw

DCC Press Release published in Work Truck Online:
Government Fleet Staff, "USPS Contractor Adds Propane Autogas Vehicles to Fleet," Work Truck Online, August 3, 2022, https://www.worktruckonline.com/10178285/usps-contractor-adds-propane-autogas-vehicles-to-fleet.

Propane Education and Research Council Feature:
Steve Whaley, "Growth Trends in the Propane Autogas Market," ACTNews, August 18, 2022, https://www.act-news.com/news/growth-trends-in-the-propane-autogas-market/.

Acknowledgements

We want to thank and acknowledge the Propane Education and Research Council (PERC) for their assistance with public relations and event and media support.

We also want to thank our project manager, Sonja Meintsma, Drive Clean Colorado, and Steve Trowbridge, Fleet Advisor with Drive Clean Colorado, for their work in maintaining project cohesion and meeting DOE requirements for reporting.

I.29 St. Louis Vehicle Electrification Rides for Seniors (Forth)

Connor Herman, Principal Investigator
Forth
2035 NW Front St. Portland OR 972109
Portland OR 97209
E-mail: connorh@forthmobility.org

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

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Project Introduction

St. Louis, Missouri is a diverse Midwestern city that has encountered a half-century of economic downturn, 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. Missouri has about 6,740 registered EVs, compared to Oregon, which has more than 36,000.

The goals of the St. Louis Vehicle Electrification Rides for Seniors (SiLVERS) project are to increase EV adoption and to reduce transportation-related operating expenses for social service agencies in low-income communities. The project seeks to increase EV adoption by (1) validating that EV fleets can save social service agencies money on transportation operation costs while improving service delivery, (2) providing access to electric vehicle supply equipment (EVSE) for employees and community members, and (3) 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 the benefits they provide.

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 been fully explored as an opportunity to decrease transportation emissions and increase EV adoption.

Objectives

This pilot of five EVs and five chargers has the following objectives:

- Measure the extent to which EV fleets can save CBOs or social service agencies money and improve service delivery.
- Create a model for deploying EVSE that can serve CBO or agency fleets and can also serve CBO or agency employees and other community members.
- Showcase that pilots like this can accelerate regional EV adoption.
- Create tools and best practices so this model can be replicated by CBOs and agencies nationwide.

These objectives aim to create the following outcomes:

- Additional social service agencies adopt the model for their own fleets.
- Improved skills and capacity of agencies to manage their EV fleets; optimized charger usage; and reduced operating costs.
- Increased EV adoption in the St. Louis market.

Approach

Budget Period 1

First, Forth assembled the project partners. As an equity-focused project, this included identifying two CBOs that provide services to elderly residents that require the use of vehicles. Forth established a partnership with the St. Louis Area Agency on Aging (SLAAA), a government entity that provides funding to private CBOs to service the St. Louis elderly population. Forth selected Northside Youth and Senior Service Center (NYSSC) and City Seniors, Inc. (CSI) as the two participating CBOs, due to their geographic locations (both CBOs service traditionally low-income areas, and North St. Louis, where NYSSC is located, 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. Charging network 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 into the ampUp network.

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, was a critical partner as there were necessary transformer upgrades for the charging stations. Additionally, Ameren provided a grant that 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 internal combustion engine (ICE) fleets of the selected agencies, to determine which vehicles should be replaced with EVs for the highest overall impact. In addition, Forth will capture baseline metrics for current vehicle selection. 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 provided $75,000 in matching funds to support the project.

Forth provided a virtual training to CBO staff and volunteers on EVs, how to charge them, 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 another 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 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.

Budget Period 2

Throughout the second year of the grant, Forth continued to host quarterly and monthly meetings with project partners. In May, Forth, staff visited St. Louis and collaborated with NYSSC, CSI, SLAAA, and North Newstead Association to host an event in coordination with Older Americans Month. Held at CSI, the event had several objectives: (1) raise awareness around the utilization of EVs for the CBOs' needs; (2) conduct test rides with local seniors; and (3) showcase the program to other local CBOs. CBO partners continued to utilize the vehicles for services.

Information dissemination and tool creation were focus areas of Budget Period 2. Forth recently released its first series of publicly available tools, which can be found on the SiLVERS webpage. [1] Additionally, Forth shared information on SiLVERS at two major conferences, as detailed in Table I.29.1.

Table I.29.1. Table highlighting conference showcasing of project

Conference/Event	Description
International Electric Vehicle Symposium & Exhibition (EVS 35) Oslo, Norway – *June 2022*	A paper and poster presentation on SiLVERS were completed as part of EVS35, which was considered the largest EV event of 2022 with 11,000 attendees from over 70 countries. In the paper, SiLVERS was one of the primary projects discussed on innovative, equitable, models for carsharing. View the link to the paper in Key Publications.
Forth's Roadmap Conference Portland OR – *June 2022*	The Roadmap Conference is held annually in Portland, Oregon. This year saw nearly 1,000 attendees from across the transportation electrification industry, including policy makers, municipal staff, nonprofit workers, and private industry, meet to discuss topics. The SiLVERS project was detailed during two plenary sessions: • Cities Electrifying Transportation: Reflections from the American Cities Climate Challenge. Maurice Muia of the City of St. Louis presented on the SiLVERS program. • Carsharing Creativity, Ensuring Access to All. Connor Herman, Forth, participated on a panel related to carsharing and detailed the SiLVERS framework.

Results

The SiLVERS Older Americans Month event had over 30 attendees, including seniors (most of whom had been served by the SiLVERS program), staff of CBOs similar to NSSYC, municipal staff, and three St. Louis Alderpeople. Forth, SLAAA, CSI, and Alderpeople all gave remarks on the program and the benefits of vehicle electrification.

Figure I.29-1. Photo from the Older Americans Month event

SLRCC has relayed information about SiLVERS to many stakeholders thus far in the Budget Period. SLRCC has spoken to dealerships and board members and has shared information at Air Quality Advisory Committee meetings, monthly regional calls, car club meetings, and conferences. Audiences ranged from 8 to 350 attendees, with an average audience size of 25. For the 39 meetings, it is estimated that 650 people were engaged in person and another 10,000 through media.

Program vehicles continued to be used heavily for program services. A summary of utilization data from January 2022 through September 2022 is provided in Table I.29.2.

Table I.29.2.Table of utilization metrics, January 2022 – September 2022

	Q1	Q2	Q3
Number of Meals Delivered	2,656	2,831	646
Number of Rides Provided to Seniors	366	382	194
Number of Charging Sessions	186	187	301
Number of kWh recorded for vehicle charging	4,302	3,855	5326
Estimated lbs of CO_2 avoided (per AMP Up's admin dashboard)	6,884	6,168	8,521

Forth also collected qualitative data through survey interviews with vehicle drivers. Thus far Forth has received 11 individual responses from staff at CSI, NSSYC, and North Newstead Association. Selected survey results are displayed in Figure I.29-2, Figure I.29-3, and Figure I.29-4.

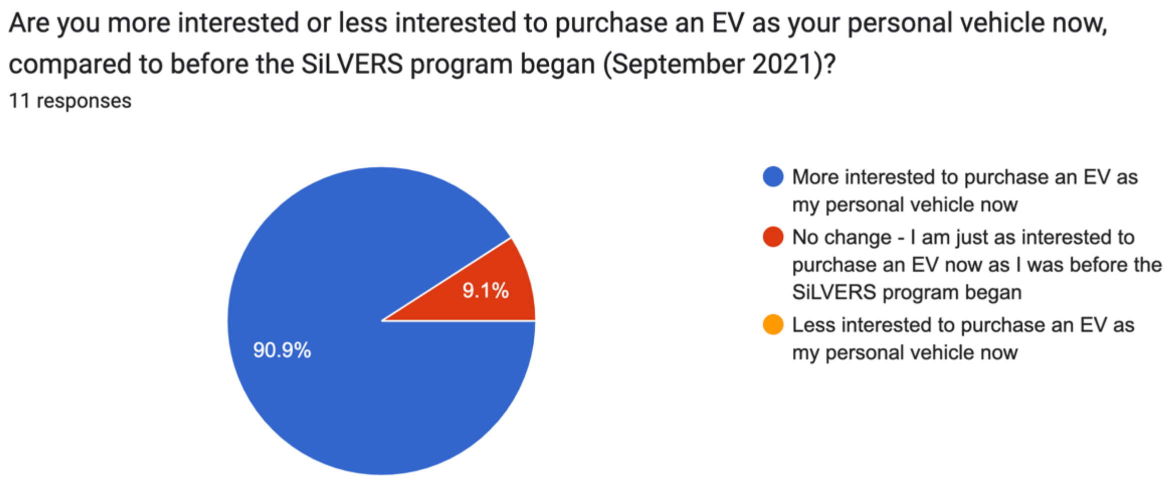

Figure I.29-2. Change in driver interest in their own EV purchase, after program implementation

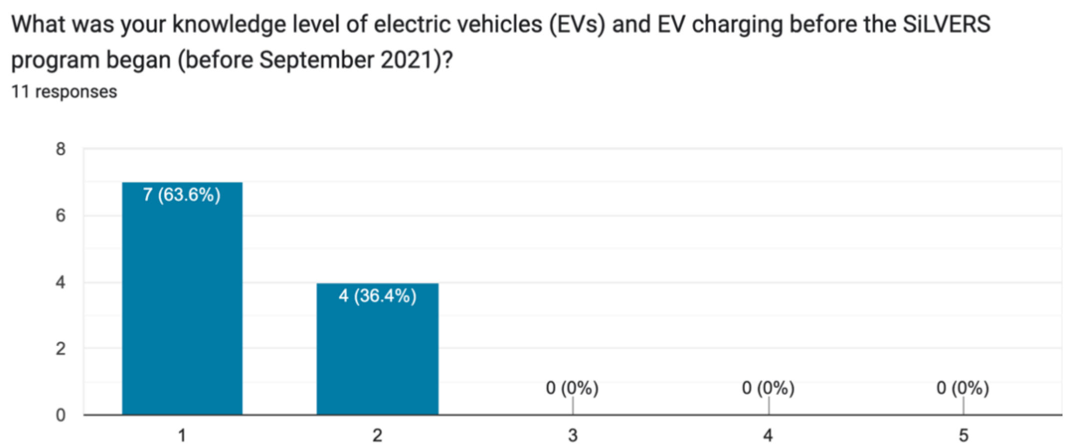

Figure I.29-3. Chart of driver EV knowledge, before program vehicle utilization

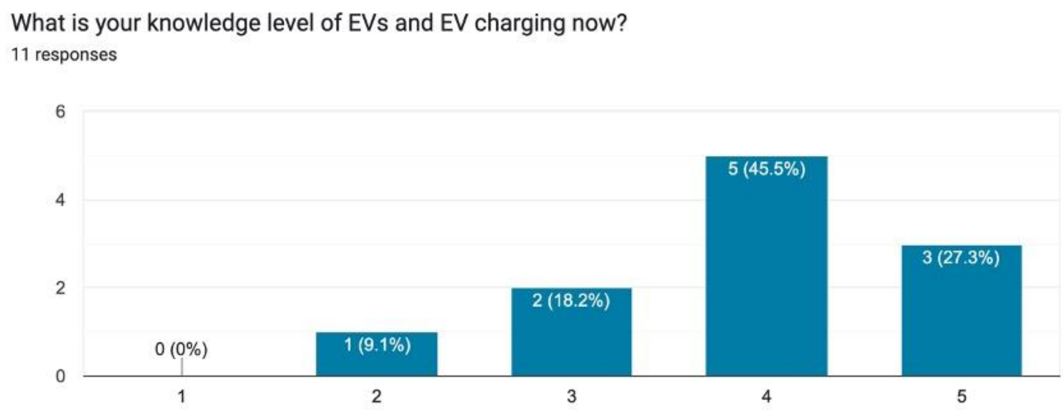

Figure I.29-4. Chart of driver EV knowledge, after program vehicle utilization

Conclusions

After a year of project implementation and data gathering, the project is going according to plan. While there have been some challenges with vehicle recalls, down charging networks, and staffing shortages for CBO drivers, the vehicles have been used effectively. Results to date show behavior changes on both the individual and business levels for CBO staff and volunteers in utilizing program vehicles. There have been several opportunities to share program learnings and project development throughout the last year.

The information dissemination and tool creation that began in Budget Period 2 will continue and expand in Budget Period 3. This will conclude with a final case study in 2023.

Key Publications

Herman, Connor. 2022. Accessible Electric Vehicle Carsharing Programs. https://forthmobility.org/storage/app/media/Reports/Community%20Impacts-%20Accessible%20EV%20Carshare%20Programs.pdf

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Shana Watson – Northside Youth and Senior Service Center

Jennifer Bess – City Seniors, Inc.

Kevin Herdler – St. Louis Regional Clean Cities

Jennifer Zavon – Forth

I.30 Pilot Heavy-Duty Electric Vehicle (EV) Demonstration for Municipal Solid Waste Collection (Municipality of Anchorage)

Kelli Toth, Principal Investigator
Municipality of Anchorage, Solid Waste Services
1111 E. 56th Avenue
Anchorage, AK 99518
E-mail: kelli.toth@anchorageak.gov

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

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Project Funding: $1,978,568 DOE share: $689,659 Non-DOE share: $1,288,909

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 communities in 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.

- Provide project data to local and statewide fleet managers.
- Compare performance to manufacturer claims and document in quarterly reports.
- 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 220EV and two 520EVs. The Peterbilt 520EV is a product of a partnership between Peterbilt and Meritor, Inc, while Peterbilt partnered with Dana, Inc. to manufacture the 220EV. All 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 520EVs. 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 220EV overnight. A charge takes 7-9 hours based on the truck's daily duty-cycle. See Figure I.30-1.

SWS drivers have put the truck into operation. There was a change in the Principal Investigator (PI) and the team implemented a new effort to streamline communication between the mechanics, driver, and PI. The new PI created a driving log that is stored in the 220EV to document activity, issues, and resolutions. Drivers identified some specific issues that are possibly specific to cold weather states:

- Regenerative brakes must be disabled during winter months due to the inability to control braking, particularly on icy roads. Abrupt braking is not safe.
- When easing off the gas pedal, truck performance is affected, as it causes the truck to slow down, there is some speculation that there are safety sensors that are causing the truck to "jump" maybe it is sensing bumps in the road caused by snow accumulation. Drivers must get used to this feature prior to driving in icy, inclement conditions.
- The push button shifter cannot shift quickly between gears and must go into neutral gear before proceeding. This can cause a pause in reaction time, which is a concern.

Figure I.30-1. SWS's ChargePoint station for the 220EV box truck located at the Central Transfer Station in Anchorage, Alaska. ChargePoint provides data used in analysis of performance and efficiencies performed by PI and Alaska Center for Energy and Power milestone 1.3.2. Dividing this (calculation) evenly by the 7105.6 kWh of charging, would effectively add $0.37 per kWh, for a total effective rate of $0.48/kWh. Photo Credit: Kelli Toth

Our team is currently troubleshooting the following issues during winter months. Several times warning messages appeared; however, most were resolved. The following points are not an exhaustive list of issues, but indicate some of the most concerning:

- In colder winter months, the driver must put the heater in recirculate mode because the truck does not react well to pulling cold air into the intake system. The team is conducting a thermal test on the heater.
- The team is investigating the battery charging and performance. The percentage of battery life that is displayed on the main monitor is not consistent with what is displayed on the gauge. For example, the monitoring screen shows 60-70%, however the gauge shows 100% full. This discrepancy causes driver hesitation because they do not want to end up with a dead battery in the field. A few times the truck has come back in the red zone.
- There are questions as to how much energy is restored to the battery when using the regenerative brakes. During the winter months the regenerative brakes are disabled, and the team is investigating whether that is the reason the truck comes back in the red zone.

The team regularly monitors and evaluates the performance of the 220EV for issues and efficiency. See Figure I.30-2. The 220EV was in the mechanical shop nine different times for various issues, including the following:

- The alternator had high voltage issues.
- The shop replaced a DC battery.
- High voltage wires were rubbing, and the shop put shielding in place.

- The shop replaced a clock spring, did several software updates, installed a reverse camera, installed a resistor and shock absorber kit, and added shims to the driveline due to surging while driving.

Figure I.30-2. SWS's Peterbilt 220EV box truck momentarily parked outside in the falling snow. Photo Credit: Kelli Toth

Average efficiency of the Municipality of Anchorage's 220EV box truck for the year from September 30, 2021, to September 30, 2022, was 1.13 kWh/mile. The effective rate for this charging is between $0.11 and $0.48/kWh depending on the coincidence of charging with facility peak demand. As charging is currently managed to minimize this coincidence, the rate should be closer to the lower end, leading to a fueling cost of approximately $0.12/mile. In the first part of this period, some coincident peak charging did occur, leading to an actual effective rate which was slightly higher. If some of the charging happens each month coincident to the facility's non-charging peak, $2,640 may be added to yearly electricity costs due to demand charges ($22 x 10kW x 12 months). Dividing this evenly by the 7105.6 kWh of charging, this would effectively add $0.37 per kWh, for a total effective rate of $0.48/kWh. The data is an example of what is generated from the analyses performed by the Alaska Center for Energy and Power, milestone 1.3.2. See Figure I.30-3.

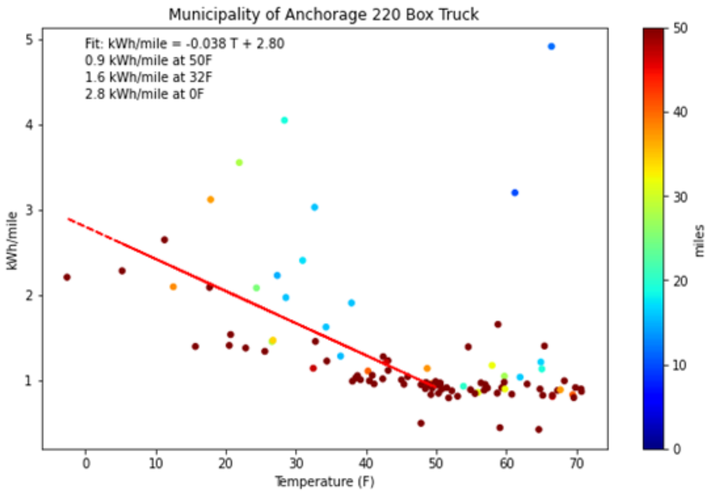


Figure I.30-3. Plot of the energy use per mile of the 220EV vs ambient temperature, with a linear fit for temperatures below 50F. Temperature data for Merrill Field, Anchorage from www.NOAA.gov. Charging data used to find energy use downloaded from ChargePoint MOA account. Trip data used to find miles traveled from Dana. Data range from 6/18/2021 – 9/30/2022. Color of data points corresponds to the total miles driven between charges. Milestone 1.3.2 and 1.3.3 collection of data and analysis.

The global COVID-19 pandemic, along with the accompanying border and factory closures, has made for long equipment lead times. Peterbilt reports that the two 520EVs should be delivered in 2023.

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. The eCamion station will be installed by a local contractor in November 2022. The cabinet will be installed outside of the warm storage and two ports will be installed inside where the two 520EV trucks will be parked when they arrive. Testing will begin when the two 520EVs have arrived. eCamion has offered to return for training, if necessary, although most of the operations can be monitored and conducted remotely from their headquarters in Canada.

Conclusion

While portions of the pilot project are now delayed into 2023, 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. Extensive efforts to monitor and analyze the performance of the 220EV truck have proven to aid in gleaning insights to the truck's performance and capabilities.

While the Peterbilt 220EV has come with its challenges, we continue to learn more about EV operations and will continue tracking progress and anxiously await the 520EVs. SWS remains excited about incorporating the two Peterbilt 520EVs into its fleet in 2023.

I.31 Zero Emission Freight Future (Clean Fuels Ohio)

Timothy Cho, Principal Investigator
Clean Fuels Ohio
17 S. High Street, Suite 810
Columbus, OH 43215
E-mail: tim@cleanfuelsohio.org

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

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

Clean Fuels Ohio (CFO) is partnering with Original Equipment Manufacturers (OEMs) and electric vehicle supply equipment (EVSE) providers to operate three demonstration projects of medium-duty (MD) and heavy-duty (HD) electric vehicles (EVs) in Ohio with a goal of spurring Class 4-8 EV adoption in fleet applications nationwide. MD and HD EVs are just beginning to see mass market introduction by the traditional commercial truck 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. The scope of the Zero Emission Freight Future project is to conduct small, targeted proof-of-concept demonstrations of MD/HD EVs and EVSE that can give fleets the experience needed to make technology adoption decisions, helping them understand cost, operational issues, and performance attributes before making a significant investment.

Objectives

The Zero Emission Freight Future (ZEFF) project is designed to demonstrate the viability of MD/HD EVs in new fleets, communities, or areas that have little or no experience with these technologies. The fleet and OEM project partners include highly visible fleets in freight/goods movement and refuse services, including Bimbo Bakery and Motiv Power Systems (Class 6 EV in bakery delivery operations); PITT OHIO and Volvo (Class 7 HD EV Straight Truck in Midwest logistics operations); and City of Columbus and an EV refuse truck manufacturer (Class 8 electric refuse truck in city refuse operations). The project data modeling and analysis partner is Sawatch Labs. 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:

- Conduct MD/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 Department.
- Update MD/HD EV operational and economic analysis models and integrate MD/HD EVs in Sawatch Labs' EZ EV analysis platform with data input and detailed feedback from EV OEMs.

- Utilize operational and financial MD/HD EV performance analysis tools informed by OEM end-user data on real world vehicle deployments.
- Distribute Replication Playbook to fleet stakeholders with similar vehicle operations, share case studies, and perform individualized analyses. The project team will use these results to demonstrate how pilot vehicles can be adopted by additional fleets to improve economic and environmental performance.

Results

CFO, in conjunction with project partners, made progress on the following milestones in the second year of the project:

- Medium-/Heavy-Duty EV Deployments.
- Data Gaps Identified.
- Telematics Data Analysis Improved.
- Data Gathering.
- Analysis Needs Identified.
- Analysis Data Gathered.

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

Medium-/Heavy-Duty EV Deployments

In Q1 2022, CFO formally updated the U.S. Department of Energy (DOE) that delivery of MD/HD EVs for two out of the three fleet demonstration partners would be further delayed. These delays included the Class 6 EV delivery truck/step van from Motiv Power Systems (EPIC 6 vehicle model) for Bimbo Bakery and the Class 8 EV refuse truck for the City of Columbus. The city is currently finalizing a bidding process for a new OEM partner, after the former OEM, Lion Electric, rescinded their participation. The delay of the two fleet demonstration partners' EVs prevented the project from collecting sufficient EV operational and performance data for FY 2022. CFO requested and received a no-cost 6-month extension to allow time to collect sufficient data on the project's fleet demonstration partners' EV deployments and operations. Doing so would allow the project to collect around 3-4 months of EV performance and operational data from the two fleet demonstration partners by the end of June 2023 to ensure successful progress and completion of all milestones for BP2.

The PITT OHIO Volvo EV straight truck (Figure I.31-1) deployed in May 2022 gives the project sufficient data (~8 months) by the end of BP2. The City of Columbus Class 8 refuse truck (Figure I.31-2) is now expected to be delivered/deployed in Q4 2023. The Bimbo Bakery Motiv Systems EV delivery step van (Figure I.31-3) is now expected to be delivered and deployed in Q1 2023.

Figure I.31-1. PITT OHIO Class 7 Volvo EV Straight Truck in Cleveland, OH

Figure I.31-2. City of Columbus Class 8 EV Refuse Truck to be deployed in Columbus, OH

Figure I.31-3. Bimbo Bakeries Class 6 Motiv Power Systems EV Delivery Van to be deployed in Dayton, OH

Data Gaps Identified

Sawatch Labs developed an initial list of data points and targeted areas of interest for MD/HD EV applications specific to the project (straight truck, refuse truck, delivery step van) to inform the data analysis on the Sawatch MD/HD "ezEV" telematics analysis platform. As part of Sawatch Labs' deliverables to create new models in their candidates table for the new MD/HD EVs and create comparable internal combustion engine (ICE) models for the project's EV applications, Sawatch provided CFO the following list of preliminary data points they would need from OEMs. Sawatch realizes that some data is proprietary and may be more difficult to retrieve. The full vehicle model data requirements requested by Sawatch include:

- Gross Vehicle Weight Rating (GVWR).
- Curb Weight.
- Battery Capacity.
- Estimated Range (Optional).
- Estimated Manufacturer's Suggested Retail Price (MSRP).
- Motor Count.
- Motor kW Draw.
- Accessory Equipment Draw.

Once the remaining two vehicles are deployed, CFO will work with the fleet and OEM demonstration partners and Sawatch Labs to collect and assess the telemetry data from the three different vehicles and determine where the gaps are in the datasets to ensure alignment with Sawatch Labs' list of target data points. Sawatch Labs will utilize their existing "ezEV" suitability tool for light-duty vehicles to develop a beta version of a MD/HD EV modeling and analysis tool with the project's MD/HD EV applications.

Telematics Data Analysis Improved

From the first 60-90 days of collected data, Sawatch Labs will be able to provide telematics data analysis improvements from their experience with conducting analysis of EV data and providing insights/dashboards of the analysis. Since PITT OHIO did receive their Class 8 EV straight truck from Volvo and deployed the unit in May 2022, this gave the project some data to work with to conduct preliminary analysis of the vehicle operations and performance.

PITT OHIO's VP of Vehicle Maintenance and Fleet Services, Taki Darakos, provided insight and data on the vehicle performance and operations via a summary report over a 2-week period from May 28 to June 11, 2022, the first month the truck was in service (see Figure I.31-4). The truck is averaging 1.12 kWh/mile with a 28-mpg efficiency using a 264-kWh battery pack (approximately a 200-mile range).

PITT OHIO is operating two Volvo Class 7 VNR Electric Straight Trucks out of their Parma, OH facility, one in partnership with Clean Fuels Ohio through this project and the other in partnership with Drive Clean Indiana through 2021 Diesel Emissions Reduction Act (DERA) funding. The data and quotes shared by PITT OHIO below represent insights from both trucks, which have been running similar delivery routes, generating similar charging patterns, and demonstrating similar performance and efficiency results.

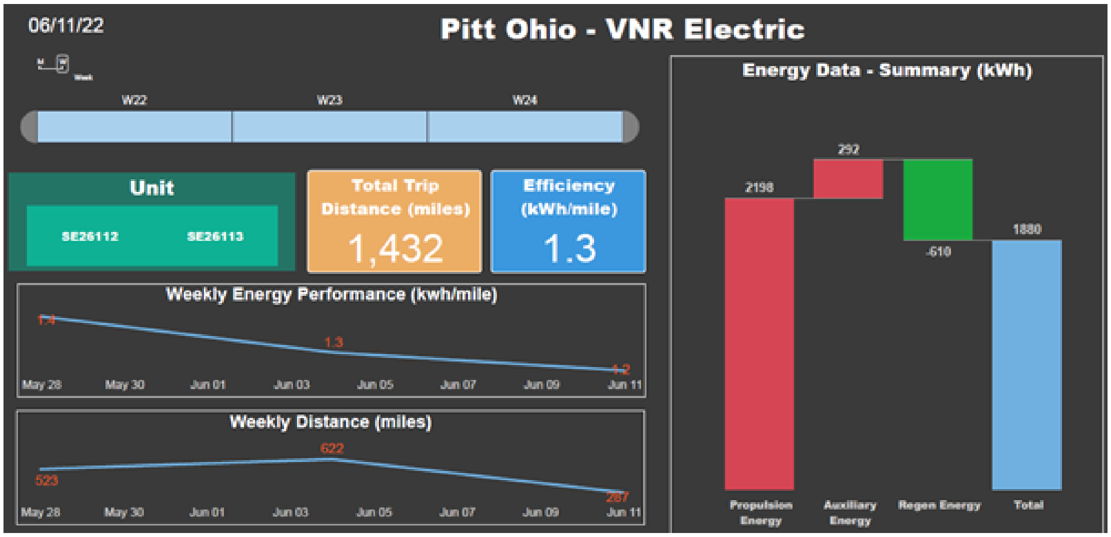


Figure I.31-4. PITT OHIO Performance Report of Class 7 Volvo EV Straight Truck

- "We believe that in wintertime there will be a degradation of fuel economy due to cold temperatures (maybe up to 15%), but so far, we have gotten off to a good start. Approximately 25% of the energy being used is being offset by regenerative energy being captured throughout the course of the driver's day-to-day routes/stops. Drivers have been learning the trucks and adjusting their driving behaviors, so the most recent data shows an even better number than what you see on the attached. For the month of June, the trucks were at 1.09 and 1.16 kWh/mile respectively. There is an algorithm that calculates a mpg equivalent. It's showing almost 29 and 27 mpg respectively."
- "The truck is topped out at 8,800 lbs. of payload (which is significantly less than the 15,000 lbs. that we could haul in a conventional unit). The truck is equipped with a 26-foot body with liftgates. There is rooftop solar providing power (300 watts) to the liftgate. To this point we had one liftgate issue that was corrected and some high cooling fan usage on one of the units."
- "The drivers have been extremely complimentary of the trucks. One of the drivers commented that he could possibly get 200 miles of range on the batteries. The battery packs on these trucks amount to 264 kWh of batteries. Knowing that we are not depleting the batteries down below 20% should be good for battery life over time. The longest trip to date was approximately 105 miles of travel in a day. They are operating in Cleveland (primarily in the city) and are doing what the drivers did with their conventional units in terms of pick-ups and deliveries.
- The Cleveland team has put together a good process to get the units unloaded upon arriving back at the terminal, on the chargers and back on the dock to be loaded for the next day's work. It's something that if additional units were added into the mix could be replicated. Looking at the charge cycles the units are taking approximately a couple of hours to charge up. We are still working on validating the charger reporting. It shows an average of 50 minutes, but I don't believe that is accurate. I think that it's normally about two hours from where they come in (state of charge) to 100%. As we get more comfortable with the integrity of the data and get more of it, this should help us understand power consumption rates and the ratio of vehicles that can be supported by each charger and how best to grow the EV fleet."

Data gathering

Clean Fuels Ohio's collection of vehicle telemetry, operations, and performance data will consist of the following:

- EV data from the project's three vehicle demonstrations, PITT OHIO Class 8 EV straight truck, City of Columbus Class 8 EV refuse truck, and Bimbo Bakeries Class 6 EV delivery step van.
- Additional EV and non-EV (typically gasoline or diesel) data from other national MD/HD OEM data partners comprising Clean Fuels Ohio stakeholders, members, industry peers, and project fleet partners.

Sawatch Labs developed 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. OEM and fleet project partners provided additional data throughout the remainder of the budget period to identify data gaps and design improvements.

CFO has asked the project's vehicle demonstration OEM partners to provide letters of commitment citing how much data (number of vehicles and number of historic data months) they will provide. These data sharing commitments entail high-level telemetry data with vehicle operational performance as well as the OEM partners' experience on their respective vehicle deployments to date, to spur the development of the Sawatch Labs MD/HD EV analysis tool. CFO plans to engage with the three OEMs, three fleet partners, and Sawatch Labs throughout Budget Period 2 to capture sufficient data. CFO facilitated communication between Sawatch Labs and several EV OEMs throughout 2022 and has provided relevant Geotab Passenger Identifications (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.

Analysis Needs Identified and Data Gathered

The project team seeks to capture sufficient and complete project demonstration vehicle telemetry data once all three vehicles are deployed (in late Q1 2023). These vehicles will come with built-in telematics hardware from the OEM vehicle provider when delivered to the fleet demonstration partner. Due to delayed delivery for the EV refuse truck and EV delivery step van, CFO anticipates identifying analysis needs during the 3-4 months (March – June 2023) after the two remaining vehicles are delivered and deployed. Complete sufficient data collection and data gap identification should occur by June 30, 2023.

Conclusions

The project's goal was to achieve successful completion for all milestones by the end of BP2 (Dec 31, 2022). Clean Fuels Ohio expects to make significant progress and achieve satisfactory completion for the milestones by the end of June 2023.

The remaining fleet demonstration partner vehicle deployments, the City of Columbus Class 8 EV refuse truck from Lion Electric and the Bimbo Bakeries Class 6 EV delivery step van from Motiv Power Systems, are both expected to deploy in late Q1 2023 which should give the project ~3 months of data by the end of June 2023. Sawatch Labs has informed CFO that 60-90 months of vehicle telemetry, operations, and performance data would be sufficient to inform the MD/HD EV analysis and modeling tool.

The project team is largely proceeding as planned with project plans and deliverables for the rest of Budget Period 2 and anticipates continuing into Budget Period 3. Industry supply chain delays remain the biggest factor affecting the project to date. PITT OHIO was able to move forward and has been the "success" so far for the project.

I.32 Demonstrating Electric Shuttles for the New Orleans Region (Tulane University)

Jordan Stewart, Principal Investigator
Tulane University
6823 St. Charles Avenue
New Orleans, LA 70118
E-mail: jstewar6@tulane.edu

Shelley Meaux, Principal Investigator
Tulane University
6823 St. Charles Avenue
New Orleans, LA 70118
E-mail: smeaux@tulane.edu

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

Start Date: October 1, 2020 End Date: December 31, 2023
Project Funding: $1,566,510 DOE share: $737,555 Non-DOE share: $828,955

Project Introduction

Accelerating the adoption of electric vehicles (EVs) in the New Orleans 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.

This project proposed to replace five diesel buses near the end of their service life with five new all-electric shuttles designed for the medium-sized bus market. Tulane has operated diesel vehicles on shuttle routes between the university's Uptown, Downtown, Elmwood and University Square campuses, and other destinations around the Greater New Orleans metropolitan area.

The proposal was developed with the Grande West Vicinity LT-E electric shuttle bus as the replacement vehicle for retired diesel buses. The project pivoted to four electric conversion models when the Grande West Vicinity LT-E was found to be unavailable at the price points and timelines initially understood.

At the close of FY 2022, the updated project scope replaces five diesel buses in the current fleet with four electric conversion models and develops an EV Charging Station area in a university-owned parking lot to serve the electric shuttles. Selected shuttles are anticipated to arrive in 2023.

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 two years have 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

Creative Bus Sales (formerly The Alliance Bus Group), 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; however, that EV product was not available at the price and timeline understood when preparing the project. The project team has re-evaluated the market, costs, and timelines to move forward with four new Lightning eMotors E-450 shuttle buses.

This product is an electric conversion vehicle using the Ford E-450 Cutaway produced as a combustion model by Starcraft that is converted to electric operation by Lightning eMotors. The evaluation process included several steps.

- Evaluating available vehicles meeting Tulane's operations needs
- Speaking to a fleet manager using the prospective model
- Testing a diesel version of the vehicle in New Orleans
- Visiting the Lightning eMotors conversion facility

Tulane ordered the Lightning eMotors E-450s during the summer of 2022 and are anticipated to arrive in New Orleans for aftermarket additions and Tulane branding between March and April of 2023. Shuttle wrap designs have been updated to suit the new models.

EV Infrastructure Development

During the first 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 construction documents. Tulane advertised the project for construction bids in June 2021. The construction contract was 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 was lifted and the selected site relieved of use for staging building repairs to campus, construction began. Installation of the charging stations and identifying striping were put on hold to align more closely with the delivery of the shuttles and are anticipated to be completed within 2022. Commissioning and training remain to be completed.

Though the team moved forward with four EV shuttle vehicles rather than five, the team installed all five charging stations as originally planned. The site design was re-evaluated to support the EV shuttles selected in the second round. Adaptations needed were modest. The new vehicles charge on the opposite side of the vehicle from the Grande West Vicinity LT-E shuttles, requiring reassessment of the best approach and orientation of the charging units. The result was rotating the chargers to face the opposite direction and adapting the surface striping according to the new preferred approach for each shuttle. Reviewing the approaches is part of confirming that the shuttles can travel through the parking lot without obvious or hidden obstacles as well as supporting the best flow of traffic through the lot.

The key steps in the EV Infrastructure design development were:

- Initial Charging Station Plan Project Layout: A team, including members from Tulane Shuttles & Transportation and the Office of Sustainability, developed a schematic plan to locate all five 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 shuttle schedules, 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.

- Electrical Service and Site Plan Development: 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 scope for electrical service improvements and charging station area layout during this site visit.

- 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.32-1. Tulane University staff use existing buses to test fit the space between prospective charging station islands.) 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, ADA 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. See Figure I.32-1 and Figure I.32-2 showing Tulane University staff testing proposed charging station locations and sizes with the current buses, tape, and cones.

- 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 the team checked both insurance requirements and the location of the electrical systems within the chargers themselves. Synergy ultimately included a 6" concrete pad in the design, placing the chargers about 1 foot above the surface of the parking lot.

Figure I.32-1. Tulane University staff use existing buses to test fit the space between prospective charging station islands.

Figure I.32-2 Tulane University staff use cones to assess the size and clearances of a prospective island for charging equipment between two parked buses.

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, changes in vehicles, and emergency conditions, in addition to bringing electrical service to the site. 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.

Site design lessons stemming from the second year of this project point to adaptability. While the shuttles and the design of corresponding charging infrastructure were customized to the vehicles, charging equipment, and location of our project, those designs have already proven to have been sufficiently flexible to adapt for a change in electric vehicle model. We are pleased our infrastructural plans were not so tightly designed that adjusting for different vehicle models presented a significant obstacle.

Acknowledgements

We wish to thank our DOE Project Manager Neil Kirschner for his helpful guidance and encouragement.

The Tulane Electric Shuttles Project Team includes Tulane staff members Brian Lowe and Laura Persich. Scott Barrios of the Electric Mobility unit of KeyString Labs by Entergy remains a key team member. The Project Team also includes Kevin Grubbs from Creative Bus Sales (formerly Alliance Bus Group). Aspen Nero has taken leadership of the Southeast Louisiana Clean Fuels Partnership, member of the Clean Cities Coalition Network, formerly led by Courtney Young. Her work is central to our regional outreach efforts. Mark Bacques, Lead Sr. Engineering Associate, Entergy New Orleans, handled the provision of electrical service.

Amanda Rivera, University Architect, Amber Beezley, Director of Feasibility, Planning and Programming, and Mark LeBlanc, Construction Project Manager, continued to provide key assistance with the design and construction of the EV Charging Station area. Melinda Viles, Creative Director, created the bus wrap design. Customer service and communications colleagues Kelly Venable Caroll, Kate Simon, and Jaime Dunkle are integral to outreach initiatives on campus and beyond. We also extend our appreciation to Viet Tran, the university's customer service contact for Entergy New Orleans who has an increasingly visible role with outreach initiatives.

I.33 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)

Leigh Huffman, Principal Investigator
Memphis & Shelby County Division of Planning and Development
125 N. Main St, Ste. 468
Memphis, TN 38103
E-mail: leigh.huffman@memphistn.gov

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

Start Date: October 1, 2020 | End Date: March 31, 2025
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 39% 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

This project experienced several delays during the first year of the project and the first quarters of 2022. An on-the-job injury caused one RBE staff member working on vehicle procurement to step away from his role entirely during recovery. Additionally, the project team has encountered supply chain and manufacturing delays due to the COVID-19 pandemic, which has slowed the procurement of vehicles. Despite these challenges, the project team problem-solved and made quick decisions, pivoting the project in a direction that still accomplishes its goals. As a result of these delays, the project team submitted and received approval for a no-cost time extension for the grant.

During the second year, the project team accomplished the following tasks:

- Partnered with Tennessee Clean Fuels to host electric vehicle test drives for RBE staff.
- Worked with RBE and Shelby County Support Services to assess the most suitable sites for charging infrastructure on Shelby County property and the appropriate electric vehicle supply equipment (EVSE) products to meet the charging specifications of selected vehicles.
- Researched and chose appropriate vehicles to satisfy purchase requirements and demands.
- Issued purchase orders to procure four Ford F-150 Lightnings, one medium-duty Lion Electric Lion6 truck, and a Blink DC fast charger.
- Began installing a DC fast charger at the Shelby County Codes Enforcement building in September 2022. The project team expects the installation to be complete in the 4th quarter of 2022.

In addition to the vehicle and equipment procurement activities listed above, the project team began to identify the appropriate data points to collect. Staff held discussions with vehicle telematics vendors to determine whether networked charging stations or OBD2 data loggers would best meet our data collection needs. Staff anticipates the delivery of the Lion Electric Lion6 truck in November 2022. After delivery, RBE is expected to begin driving the vehicle on work routes in late 2022.

Conclusions

Despite the delays and extensive internal procedural steps to purchase vehicles, this project is underway with momentum and leadership support. The project team accomplished several essential tasks this year including issuing purchase orders for all 5 electric vehicles, accepting the delivery of the medium-duty truck, and installing the first charging station. The team continues to work with internal and external partners to install additional charging stations at identified locations and is looking forward to beginning the data collection and analysis on the on the truck.

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 in applying for the grant and conducting initial research.

I.34 Medium-duty Electric Truck (eTruck): Pilot Electrified Fleets in Urban and Regional Applications (University of Texas at Austin)

Junmin Wang, Principal Investigator
University of Texas at Austin
204 E. Dean Keeton St.
Austin, Texas 78712
E-mail: jwang@austin.utexas.edu

Michael Laughlin, DOE Program Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

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 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 (UT 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 (TTU) 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. Lightning eMotors (LEM) and SEA Electric each provided an eTruck, and the third one is being built by Phoenix Motorcars. UT Austin sends Oak Ridge National Laboratory (ORNL) and National Renewable Energy Laboratory (NREL) the eTruck 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: Develop MD eTruck demonstration and charging infrastructure in various fleets to help fleets with limited or no eTruck experience make informed decisions on eTruck adoptions.
- Approach 2: Collect first-hand 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: Share information and conduct outreach to promote eTruck public awareness and educate next-generation electric vehicle engineers.

Results

The Foreign National approvals of several project team members have delayed the progress. DOE has approved a 12-month extension for budget period 1. Additionally, vehicle and equipment delays from vehicle suppliers have impacted the project progress.

The main results accomplished this year are summarized as follows:

Electric MD trucks

UT Austin has purchased and received two eTrucks; a Class-4 eTruck made by LEM and a Class-5 eTruck by SEA Electric (Figure I.34-1) and set up data acquisition systems to collect various operational data for both trucks. In addition to the default dataloggers provided by the manufacturers, UT Austin installed a secondary data logger for the SEA truck to meet the required data resolution. A virtual machine server is used for the logger's data transfer process. The list of available signals is matched between the trucks and the team has verified the collected data.

Figure I.34-1. Class-4 electric truck from Lightning eMotors (left), Class-5 electric truck from SEA Electric (right)

The truck delivery to Tennessee has been delayed due to supply chain issues and a COVID outbreak in the production factory.

Fleet recruitment and demonstration

All documentation processes necessary for the fleet recruitment and demonstration in Texas and Tennessee are completed. The Institutional Review Board (IRB) approved the applications for the eTruck demonstration for both UT Austin and TTU, and the vehicle loan agreements and study consent forms are finalized. UT Austin has prepared recruitment materials, including an information flyer and public websites, and passed them on to Lone Star Clean Fuels Alliance, which has reached out to fleets in Texas to encourage participation from public, private and government-owned fleets with varying fleet sizes and daily mileage. UT Austin has evaluated the applications received and notified the approved fleets of their expected loan periods and relevant project details. For Tennessee, East Tennessee Clean Fuels Coalition (ETCF) has compiled an informal list of interested fleets.

In Texas, UT Austin loaned the LEM and SEA trucks to three different fleets in Austin, and the paperwork for the next fleets is in progress. UT Austin has collected data and shared it with NREL and ORNL. For each fleet, Smart Charge America conducted site inspection and installation of a Level-2 charging station.

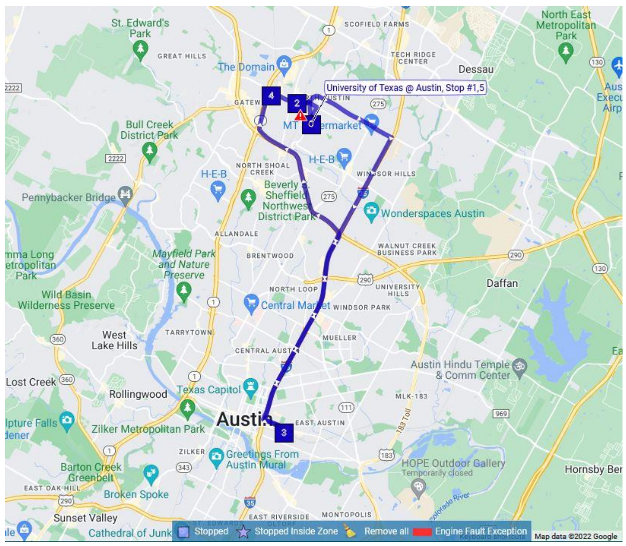


Figure I.34-2. Example of GPS coordinate of data collected from the SEA electric truck

In Tennessee, Seven States Power Corporation has donated 16 Level-2 chargers to this project. These charging stations will be installed at the bases of potential fleet partners in the project to support electric truck charging overnight. As the first potential participating fleet, TTU has identified a charging station site and a parking space on the TTU campus and completed the installation as of September 2022.

Data analysis and Modeling

Before the collected data can be used for modeling, analysis or simulation, the data needs to be preprocessed. UT Austin differentiates and labels the data collected from both trucks based on the driving/idling/charging operations, with unnecessary data removed. UT Austin then consolidates all data types from multiple sources including the payload information logged manually by the drivers and a secondary datalogger for the SEA truck, into a single file.

Truck modeling using the processed data is in progress. With the truck specifications provided by the manufacturers, UT Austin and TTU are creating simulation models for both trucks using vehicle simulation tools such as Autonomie (by Argonne National Lab) and FASTsim.

Post study surveys on the user experiences of the fleet managers and drivers were collected. The survey is set up to be able to compare not only the participant's perception of the electric trucks before and after the study in various fields such as range satisfaction, charging and environmental impact, but also to compare experiences in fleet applications. The team is conducting additional fleet manager interviews to better understand the collected data, including information on repeated destinations, additional passengers or charging patterns.

The team has published six peer-reviewed papers from this project.

Education and Outreach

Several efforts were made to promote eTruck public awareness in Texas and Tennessee:

- The UT Austin team participated in the SAE Austin meeting and demonstrated the LEM electric truck.
- ETCF took on the responsibility to build a website specific to the project with plans to clearly display the truck's capabilities with fleet managers in mind as the individuals most likely to traffic the site. The project website can be found via the following link: https://mdetruck.com/
- Prof. Pingen Chen (The PI at TTU) was invited to speak about the challenges and opportunities of rural electrification at the inaugural Tennessee Smart Mobility Expo in the Smart Academia session, Aug 4-6, 2022, Nashville TN. More information can be accessed via https://www.tnsmartmobilityexpo.com/. Prof. Chen introduced this project to EV stakeholders in Tennessee, including but not limited to, truck fleet companies like FedEx, Tennessee Department of Transportation, Tennessee State Energy Office, Nissan, ChargePoint, and others.

Conclusions

This year, the project team has made satisfactory progress, finishing most of the project milestones for this period despite the unforeseen delays. On the Texas side, the truck demonstration has begun, with the data acquisition for both trucks fully set up and the necessary paperwork completed. Additional fleet recruitment for both trucks is continuing.

UT Austin has loaned the two trucks to three different fleets in Austin and have collected operational data of the trucking fleets including the vehicle maneuver, GPS, payload, and charging. The team then used the processed data to create truck models in vehicle simulation tools to be used in further studies. In addition, post-study surveys on fleet managers and drivers are conducted to collect practical user experiences with the eTrucks.

Despite the truck delivery in Tennessee having been delayed significantly, the TTU team has made progress especially in the Education and Outreach area, promoting electric trucks in Tennessee by attending regional conferences and Expos.

Key Publications

Ahn, H., Wang, Z., Shen, H., Zhou, X., & Wang, J. (2022). A Two-Stage Genetic Algorithm for Battery Sizing and Route Optimization of Medium-Duty Electric Delivery Fleets. *IFAC-PapersOnLine*, 55(37), 50-55.

Innis, C., & Chen, P. (2022). A Fast Macroscopic Speed Planner for Electric Vehicle Platooning. *IFAC-PapersOnLine*, *55*(24), 72-77.

Innis, C., & Chen, P. (2022). Dynamic Programming-based Macroscopic Speed Planner for Electric Vehicle Platooning. *IFAC-PapersOnLine*, 55(37), 31-36.

Su, Z., & Chen, P. (2022). Cooperative Eco-driving Controller for Battery Electric Vehicle Platooning. *IFAC-PapersOnLine*, *55*(37), 205-210.

Su, Z., & Chen, P. (2022). Eco-driving for Battery Electric Vehicles Using Traffic-aware Computationally Efficient Model Predictive Control. *IFAC-PapersOnLine*, *55*(37), 700-705.

Su, Z., & Chen, P. (2022). Extremum Seeking Control-based Control Framework for Electric Vehicle Platooning. *IFAC-PapersOnLine*, 55(24), 123-128.

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.35 WestSmartEV@Scale: Western Smart Plug-in Electric Vehicle Community Partnership (PacifiCorp)

James Campbell, Principal Investigator
PacifiCorp
825 NE Multnomah St. Suite 1900
Portland, OR 97232
E-mail: james.campbell@pacificorp.com

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

Start Date: October 1, 2020 End Date: December 31, 2023
Project Funding: $17,066,146 DOE share: $6,040,647 Non-DOE share: $11,025,499

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. 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.35-1.

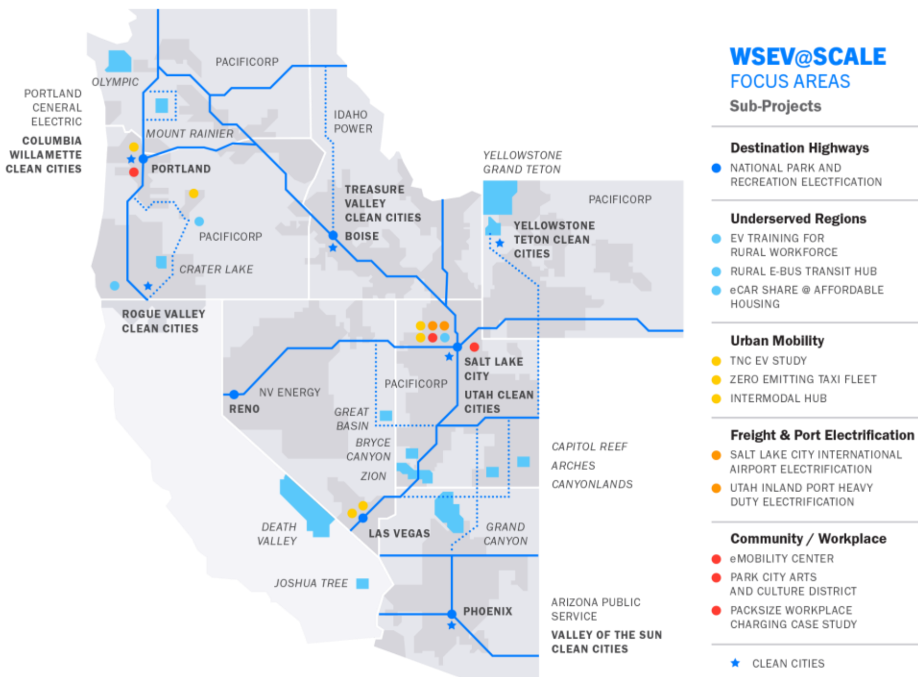


Figure I.35-1. WestSmartEV@Scale region, utility territories, and sub-project locations

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 Area 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 Underserved Workforce:** Evaluate EV workforce development initiatives with communities.
- **Rural eBus Transit Hub:** Develop rural transit bus hub and study effectiveness of electric buses (eBuses) in rural communities.
- **eCar Share @ affordable housing:** Develop electric car (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 and 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 (eMobility) 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 FY 2022:

- Received approval from the Institutional Review Board (IRB) to conduct surveys for travelers to National Parks and Recreation Areas, and surveys for drivers with transportation network companies.
- Hosted community forum with the largest newspaper in Utah, during National Drive Electric week; held public car show highlighting different EVs. Also, held discussion on EV workforce training opportunities with local trade school that was livestreamed.

- Selected vendor for public Direct Current Fast Charger (DCFC) construction and operation. Due to supply chain constraints fast charger locations will be constructed in 2023. Each site will have 1 Megawatt capacity.

Focus Area 1 – Destination Highway Analysis: National Park and Recreation Area Electrification

- Estimated charging station network required to enable electrified road trips to/from/between/through National Parks. See Figure I.35-2.

- Received approval from IRB and begun conducting surveys of travelers to National Parks. Survey respondents were from all over the country with a broad demographic profile.

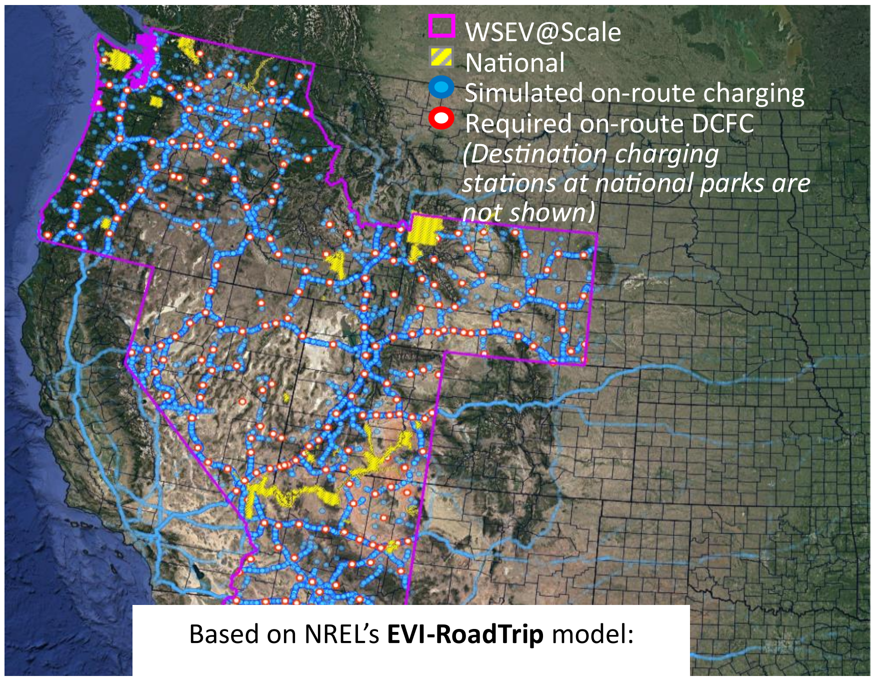


Figure I.35-2. Analysis of charging station needs for National Parks

Focus Area 2 – Underserved Regions: eCar Share @ Affordable Housing and Workforce Development

- Launched eCar share program at affordable multi-family housing.

Figure I.35-3. Photo of eCar Share vehicles. (Photo courtesy of Giv Group)

- Collected telematics data on the participating vehicles (two Chevy Bolts):
  - Average drive distance is 32 miles per day (longest distance was 81 miles in a day), average driving time was 1 hour and 11 minutes per day, and most charging occurred at housing complex.
- Engaged with Salt Lake City community councils representing underserved neighborhoods about developing pre-apprenticeship programs for K-12 to support EV workforce development.
- Engaged with the College of Eastern Idaho about developing a rural EV training program.

Focus Area 3 – Urban Mobility: Transportation Network Company (TNC) Driver Study

This study will evaluate factors that influence behavior from TNC drivers for the purchase and operation of an EV. The study looks at both current internal combustion engine drivers and EV drivers. The team developed a bilingual survey focused on EV perceptions, charging habits and gig work in general. Team members include Forth Mobility, Utah State University, FlexCharging, and Rocky Mountain Institute. See Figure I.35-4.

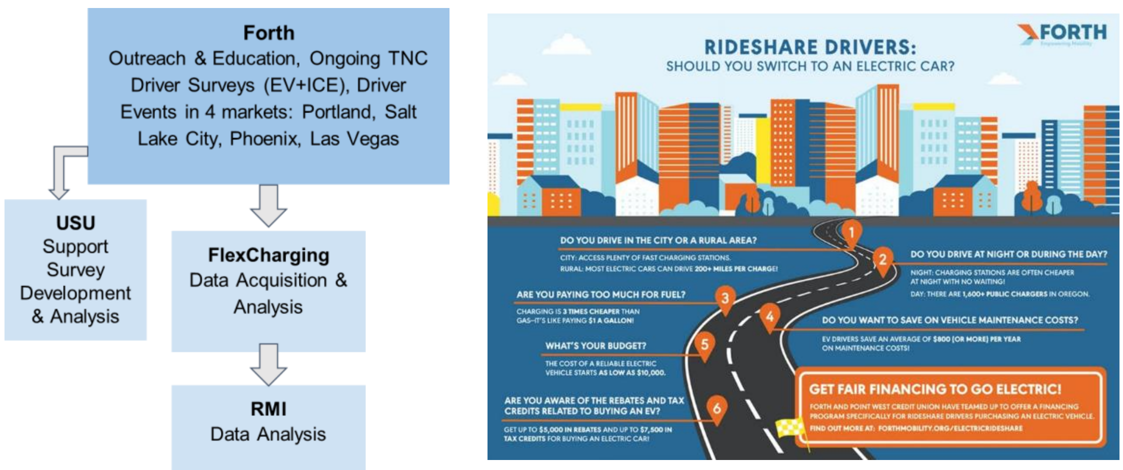
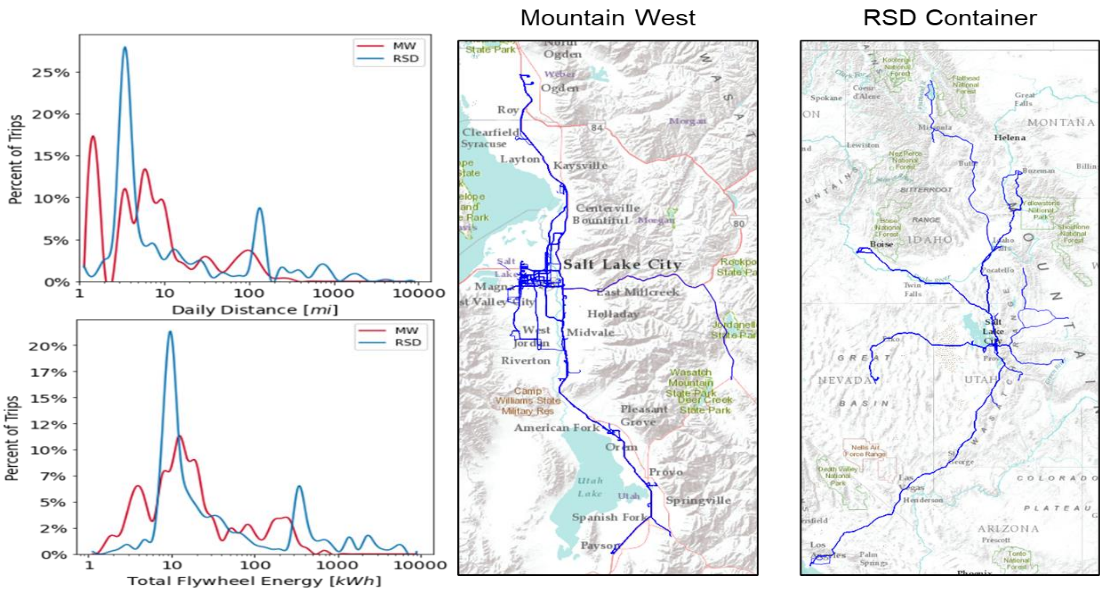


Figure I.35-4. Overview of the TNC Driver Study

Focus Area 4 – Port and Freight Electrification: Utah Inland Port Heavy Duty Electrification

- The National Renewable Energy Laboratory (NREL) conducted analysis of two drayage operators within the Utah Inland Port, and installed telematic monitors to evaluate the operation and the potential for electrification. See Figure I.35-5.
- Data Collection Activities:
  - Mountain West Container Services- 1Hz logger data collection (GPS and CANBUS).
  - RSD Container Yard Services– 1Hz logger data collection, 1 year telematics data, 1 year truck scale data.
  - Access to GEOTAB Altitude data for Utah.
  - NREL also has other applicable trucking data from other sources in the region that may be overlayed with data collected during the project.
- Data Analysis Activities:

- Completed for each individual fleet using 1hz data:
  - Vehicle statistics package (day based, trip based).



  - Basic geofencing.
  - Electrification.
  - Dwell analysis.

Figure I.35-5. Telematics data for drayage trucks at the Inland Port

Focus Area 5 – Community: eMobility Hub

The project is developing an eMobility hub in Ogden, Utah that will implement multi-modal electric transportation solutions including ebuses, e-ride sharing, ebikes and scooters. The team benchmarked Austin, Texas (Figure I.35-6) by meeting with Austin Energy and CapMetro (Austin Transit Authority) to identify strategies to promote multi-modal electric solutions.

Figure I.35-6. eBike location in Austin, TX (Photo courtesy of PacifiCorp)

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 identified specific electric infrastructure needs at National Parks and Recreation Areas in the region. The team identified potential programs for underserved communities to promote EV workforce development. The team successfully launched eCar Share program at an affordable housing complex. The team has developed surveys to evaluate experiences from TNC drivers across four major cities (Portland, Salt Lake City, Las Vegas, and Phoenix. Lastly, the team is collecting telematics data from the eCar Share, TNC drivers and heavy-duty trucking operators.

I.36 Mid-Atlantic Electrification Partnership (Virginia Department of Energy)

Al Christopher, Principal Investigator
Director, Energy Division, Virginia Department of Energy
1100 Bank Street
Richmond, VA 23219
E-mail: al.christopher@energy.virginia.gov

Alleyn Harned, Co-Principal Investigator
Director, Virginia Clean Cities at James Madison University
1401 Technology Drive, MSC 4115
Harrisonburg, VA 22807
E-mail: aharned@vacleancities.org

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

Start Date: October 1, 2020 End Date: December 31, 2024
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 (D.C.), Maryland, and West Virginia, allowing all sizes of EV use for fleets, Transportation Network Companies (TNCs), 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, 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 project enables a regional EV ecosystem in Virginia, the District of Columbia, Maryland, and West Virginia, allowing all sizes of EV use for fleets, TNCs, and consumers through the creation of analysis tools, the deployment of educational activities, and the deployment and demonstration of vehicles and infrastructure.

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. Partners focus on continuing outreach 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. The team established subcommittee meetings on infrastructure, vehicle deployment and deployment site analysis and meets on a regular basis.

Educational Series Launch

Per local facility host rules and regulations during the height of the pandemic, some ride and drive events were 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. More in-person events were able to be executed as restrictions lifted.

Outreach partner EV Noire set a program stretch goal of 10 total executed events for the project year. Table I.36.1 details outreach events to disadvantaged communities, Historically Black Colleges and Universities, and communities.

Table I.36.1. Outreach Events

Project Year	Virtual Events	In-Person Events	Total
2021	7	2	9
2022	3	8	11
Overall	10	10	20

One such example was the National Summer Transportation Institute (NSTI) held in the summer of 2022 at Morgan State University. The NSTI is a free program designed to encourage middle and high school students to pursue careers in transportation.

Other Outreach Activities

In January 2022, members of the project team spoke at the Transportation Research Board Annual Meeting held in Washington, D.C. They spoke about the project's outreach to disadvantaged communities as well as progress on analysis and EV infrastructure deployment in the Mid-Atlantic Region.

In April 2022, the project was honored at the Virginia Green Star Awards in Richmond, Virginia. Co-sponsored by two Virginia state agencies and the Virginia Green Travel Alliance, the MAEP project received the "Most Innovative Green Project" recognition award.

Site Analysis

Argonne National Laboratory's enhancement of the Energy Zones Mapping Tool (EZMT) mapping layers and suitability modeling have facilitated EV charging station planning. The EZMT is a free public national tool for energy-related planning.

It includes nationwide data sets which are downloadable. The team utilized the JOBS EVSE tool to determine the job creation potential of installing EV charging stations at homes, workplaces, and public spaces using data from project partners. Argonne National Laboratory also created an EVSE Siting Analysis and Modeling Data Plan and in 2022 prepared the case study titled, "Modeling EV Charging Station Siting Suitability with a Focus on Equity," which is based on this project. The report is accessible at https://www.osti.gov/biblio/1887567/.

Additionally, there are new suitability models for EVSE planning with an equity emphasis established by the tool for this project and for use by project team. These models allow communities and EZMT users to generate "heat maps" showing areas that may be 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.

Infrastructure Study, Development, and Ecosystem Launch

The project team developed a successful EV charging station intake process and tracking system for potential host sites. The team held initial virtual meetings with dozens of different host sites, which was necessary for helping communities understand the scope of their interest in charging stations, relative to the variations in technology, then with the charging partners and host sites together. The team tracked progress through final deployment and invoicing.

Figure I.36-1. E-mobility hub in Ashland, Virginia

This past year the project team submitted 25 environmental questionnaires for sites through the U.S. Department of Energy's Project Management Center. Charging station deployment and installation is underway at approved sites.

Ecosystem Mobility Hubs

The project team has held more than 50 meetings with municipalities on EV charging deployment in the three project states and Washington, D.C. Project partner Greenspot deployed e-mobility hubs at two locations in the Town of Ashland, VA. See Figure I.36-1. The City of Martinsville, VA has established a workplan for deployment in 2023.

Solar Charger Demonstrations

James Madison University deployed technology for solar EV chargers at its campus in Harrisonburg, VA, as did the Eastern West Virginia Regional Airport in Martinsburg, WV. Both locations hosted public events to educate members of the public about the off-the-grid charging technology in 2022. See Figure I.36-2.

Figure I.36-2. Ribbon cutting ceremony for solar EV charger at James Madison University

School Bus Chargers

Project partner Sonny Merryman ordered equipment and started site preparation work for school bus chargers. Deployment is to take place in early 2023.

DCFC Corridor

Greater Washington Region Clean Cities Coalition and other project partners identified a site in Maryland for the DCFC corridor installation. DCFC corridor planning work is underway in West Virginia in alignment with the state's National Electric Vehicle Infrastructure (NEVI) Plan.

Vehicle and Port Study and Deployment Launch

Project staff attended the local launch of electric heavy-duty vehicles (semis) at the Volvo Trucks factory in Dublin, Virginia in early 2022.

Rideshare Vehicles

The initial order for 25 Kia Niro EVs for the rideshare program arrived in Q3 2022. The vehicles have been deployed in Maryland and have proved to be a popular option among rideshare drivers. The EVs provide a safe and emission-free option for rideshare in the region.

Electric School Buses

The project team launched electric school bus efforts with the selection of Frederick County, Maryland, school fleets and initiated planning for the scheduled deployment of school buses.

Ports Data

There are monthly standing meetings with the project partners Port of Virginia, Maryland Port Administration, and project partner Tradepoint Atlantic (a 3,300 square foot logistics center in Maryland). The port partners have established themselves as electrification sounding boards for equipment and fleet vehicles.

Geospatial Data

Significant data analysis is underway with multiple visioning sessions and publication of data and resources through Argonne National Laboratory.

Conclusions

The project team continued to implement key activities associated with all primary objectives of the project's first budget period and is achieving milestones in the task areas of EV infrastructure deployment, educational outreach, and analysis. Project partners are collaborating through meetings, task completion, and mutual assistance. EVSE deployments have received positive media attention and many localities in the region are interested in participating. Given this positive progress, the project is ready to move to the next phase.

Key Publications

Kuiper, James A., Xinyi Wu, Yan Zhou, Marcy A. Rood, Marcy. 2022. *Modeling Electric Vehicle Charging Station Siting Suitability with a Focus on Equity*. Argonne National Laboratory, ANL-22/33 176173. https://www.osti.gov/biblio/1887567/.

Acknowledgements

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I.37 VoICE-MR: Vocation Integrated Cost Estimation for Maintenance and Repair of Alternative Fuel Vehicles (AFV) (West Virginia University Research Corporation)

Arvind Thiruvengadam, Principal Investigator
Associate Professor
Department of Mechanical and Aerospace Engineering
West Virginia University
Morgantown, WV 26505
E-mail: arvind.thiruvengadam@mail.wvu.edu

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

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Project Introduction

West Virginia University's (WVU) Center for Alternative Fuels, Engines and Emissions (CAFEE); State of West Virginia Clean Cities; Clean Fuels Ohio; the Western Riverside County Clean Cities Coalition; and Wale Associates Inc. jointly proposed a study to develop a tool to estimate the vocation dependent variations in maintenance cost (MC) of heavy- and medium-duty vehicles fueled by alternative fuels that include natural gas, propane, and electric. South Coast Air Quality Management District (SCAQMD) and Southern California Gas Company (SoCal Gas) have jointly provided a cash contribution towards this proposed study and are key partners in this study.

As of July 2022, the project has progressed to activities related to budget period 2 that involve data classification and analysis. In budget period 1, the project team successfully completed all milestones and continuing efforts to recruit more fleet partners to increase the diversity in the data. In budget period 2 (progress until September 30,2022), the project team has made significant progress towards achieving the milestone related to data categorization and analysis of maintenance cost data from different fleets and alternative fuel vehicle (AFV) platforms. Activities involved sanitizing the data, identifying anomalies, and identifying and addressing deficiencies in the quantity of data. The project employed analysis using Microsoft Power Bi for data categorization and analysis. The project team has been successful in collecting historical data from various fleets to assess the trends in maintenance cost as a function of vehicle age and/or miles traveled. The team has developed a website, www.voice-afv.org, for project updates and dissemination of results.

Objectives

The objectives of the study are aimed at providing a detailed estimate of the cost of maintenance of AFVs in comparison to their modern diesel technology counterparts. The global objectives of this study can be summarized as:

1) The dependency of maintenance cost incurred by various fleets as a function of the duty-cycle and the seasonal temperature changes in various regions of the country has seldom been documented. The outcome of this proposed 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 AFV pathway.

2) This study aims to provide feedback to the fleet to adopt best practices that will lower MC for an AFV operating a specific duty cycle. This important outcome will help fleets evaluate their current practices that may not be suitable to the harshness of their vehicle duty-cycle and therefore may be experiencing higher MC.

Approach

Budget period 2 has four main tasks, namely:

1) Extract data stored in the database and begin categorization based on technology type, type of maintenance, fleet, vocation, and vehicle sub-system.

2) Analyze telemetry data collected from a previous SCAQMD funded study as well as data collected from this project.

3) Assess the historical maintenance record from fleets and study the impact of vehicle aging on the maintenance cost.

4) Analyze changes to maintenance cost with seasonal temperature changes.

To accomplish the four main tasks, the project team employed the Microsoft PowerBi tool for data categorization and analysis and employed Amazon Web Server (AWS) based Dynamo DB as the primary storage of the maintenance cost data. The team queried data for the different fuel types (diesel, propane, natural gas, and electric) and imported the exported queried data into PowerBi. PowerBi is powerful in data classification and performing custom analysis to visualize various trends in the data. Analysis through PowerBi was also instrumental in identifying errors associated with manual data entry into the Dynamo DB. Many fleets shared paper records and manual entry of the data was necessary. Sanitation of the data included the exclusion of information associated with chassis related repair activities and maintenance activities that are not related to the vehicle technology. The team assigned maintenance activities associated with warranty claims a $0 charge with a category designation of “warranty repair.” This categorization would help understand any reported warranty repairs for the different AFV technologies.

Results

Results of the analysis are presented as MC trends for the different AFV technologies operating in delivery, goods movement, school bus, transit bus, and vocational truck categories. Results are presented as averages of all vehicles across different fleets in a specific vocation, with variation bars indicating the maximum and minimum cost per mile.

Figure I.37-1 shows the maintenance cost trend from year 2012 to 2021 for diesel trucks operating as delivery vehicles. The results show 4.5 times increase in maintenance cost from an average of $0.14/mile in 2013 to $0.63/mile in 2020. Figure I.37-2 shows the maintenance cost trends for natural gas delivery trucks from 2013 to 2021. Natural gas vehicles (NGVs) exhibited lower maintenance cost per mile compared to diesel trucks. Natural gas delivery vehicles also exhibit an increase in maintenance cost with age. The 2021 average cost per mile is 16 times higher than the cost per mile in 2013. However, the cost of maintenance of an 8-year-old natural gas delivery truck is 50% lower than a diesel vehicle at the same operational age. This can be expected due to the complexity in the exhaust aftertreatment system employed by the diesel vehicles which can lead to higher corrective maintenance procedures. The data from the analysis also suggests that a large fraction of the maintenance cost of diesel vehicles is associated with corrective procedures, while periodic and preventive procedures account for the major fraction of the maintenance cost of NGVs. shows the maintenance cost trends for propane delivery trucks, which are typically in a lower weight class compared to diesel and natural gas trucks. Results show that aged propane delivery vehicles have maintenance cost slightly higher than natural gas and comparable to diesel vehicles. The volume of data for propane delivery trucks is low compared to diesel and NGVs. The maintenance cost observed in could be linked to a maintenance procedure of a specific fleet and may not be representative of the overall maintenance cost trends for propane trucks across the United States. The study is seeking more data for propane delivery vehicles.

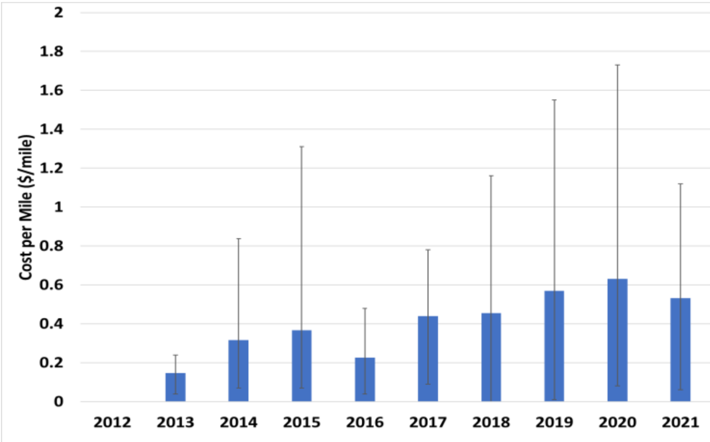

Figure I.37-1. Trends in maintenance cost of diesel delivery trucks

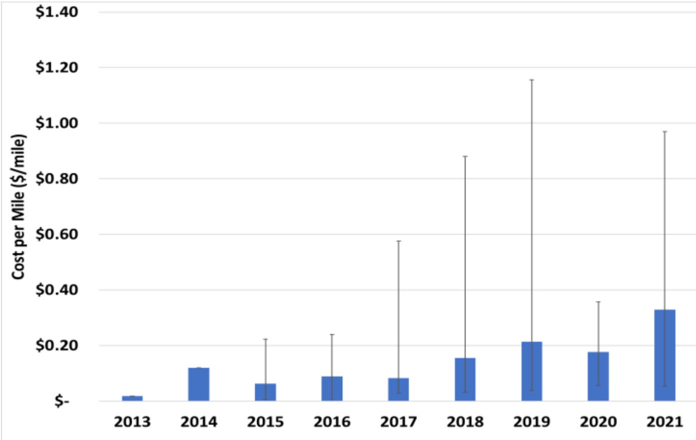

Figure I.37-2. Trends in maintenance cost of natural gas delivery trucks

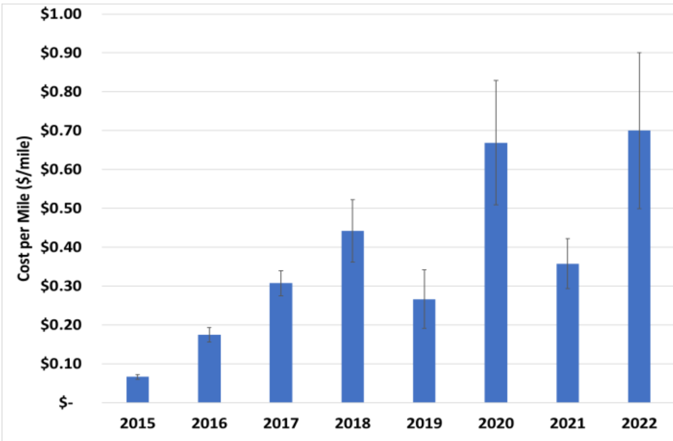

Figure I.37-3. Trends in maintenance cost of propane delivery trucks

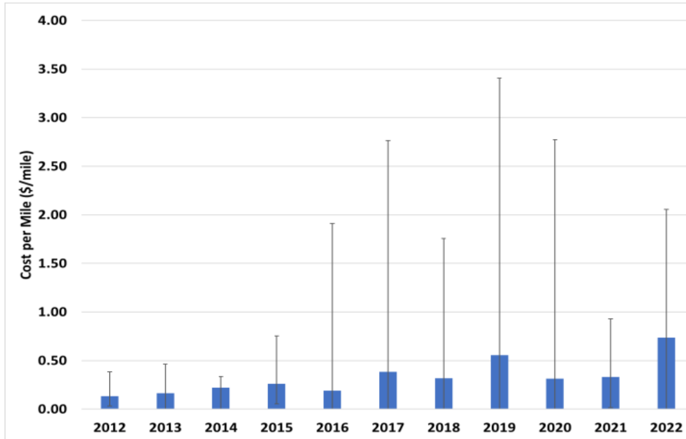

Figure I.37-4. Trends in maintenance cost of diesel school bus

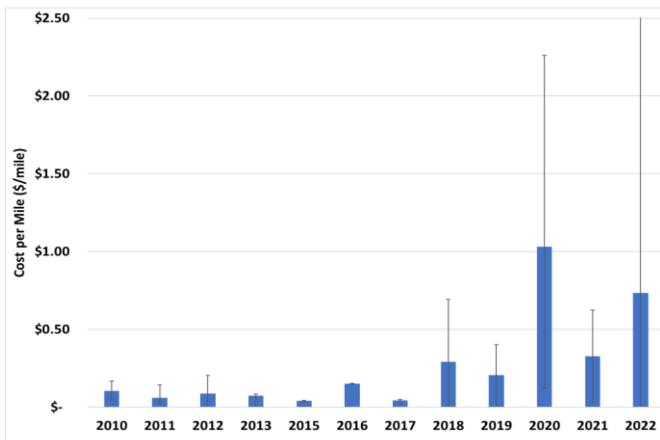

Figure I.37-5. Trends in maintenance cost of NGV school bus

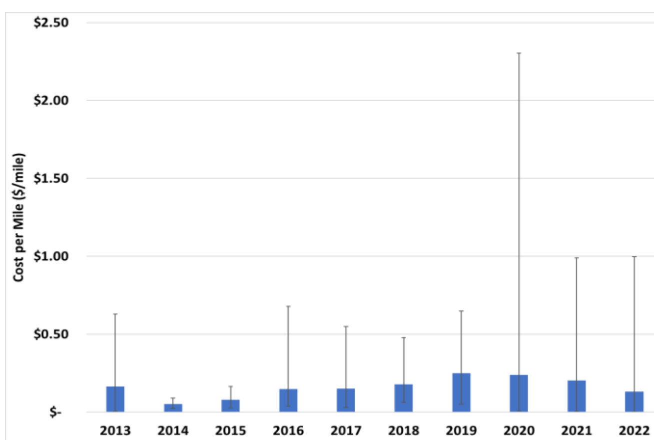

Figure I.37-6. Trends in maintenance cost of propane school bus

Figure I.37-4, Figure I.37-5 and Figure I.37-6 show the trends in maintenance costs for school bus vocation for diesel, natural gas, and propane vehicles, respectively. For the school bus vocation, no clear trend is observed for diesel, natural gas and propane fueled vehicles. Both the diesel and NGV school bus show a slight increase in maintenance cost with age, while the propane vehicles do not exhibit any significant increase in maintenance cost during the 10 years of operation. Overall, propane school buses show lower maintenance cost compared to diesel and NGVs.

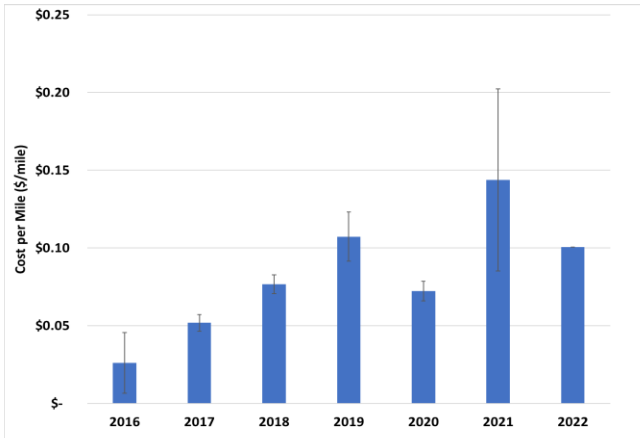

Figure I.37-7. Trends in maintenance cost of natural gas transit bus

Figure I.37-7 shows the trends in maintenance cost of a natural gas transit bus with years of operation. Since a majority of the natural gas transit bus data was collected from California, comparison to diesel vehicles is not available. Most city transit agencies have completely phased out diesel buses in California. Recently secured data sharing partnerships in the Midwest and Mid-Atlantic regions will provide maintenance cost data for diesel and electric transit buses. The results show that overall natural gas transit buses have a maintenance cost of less than $0.15 per mile. A slight increase in maintenance cost is observed with years of vehicle operation.

Conclusions

The team is completing activities linked to budget period 2 and the project is on schedule for meeting the milestones of budget period 2. In the period between July 2022 and September 2022, the team completed milestones linked to data categorization for the different fuels. The project has generated results that show the maintenance costs trends for different vocations as a function of years of operation as well as the contribution of different types of maintenance to the total costs observed; identified deficiencies in the data; and expanded the fleet recruitment activity to securing more data from newer fleets that could potentially add geographical as well as technological diversity to the data.

Natural gas delivery trucks show lower maintenance cost compared to diesel vehicles and propane school buses show the lost maintenance cost compared to both diesel and NGVs. The team has performed preliminary data analysis only as a function of vehicle operational years. The team is conducting further analysis considering miles of operation, duty cycle and region of operation, and performing quality checks of electric vehicle (EV) data following which we will also incorporate EV data analysis.

Acknowledgements

We thank the project manager for his assistance and direction in keeping this exciting research work moving forward. We thank all 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 that 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.38 Developing Replicable, Innovative Variants for Engagement for EVs in the USA (DRIVE Electric USA) (East Tennessee Clean Fuels Coalition)

Jonathan G. Overly, Principal Investigator
East Tennessee Clean Fuels Coalition
311 Conference Center Building
Knoxville, TN 37996-4134
E-mail: jonathan@etcleanfuels.org

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

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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

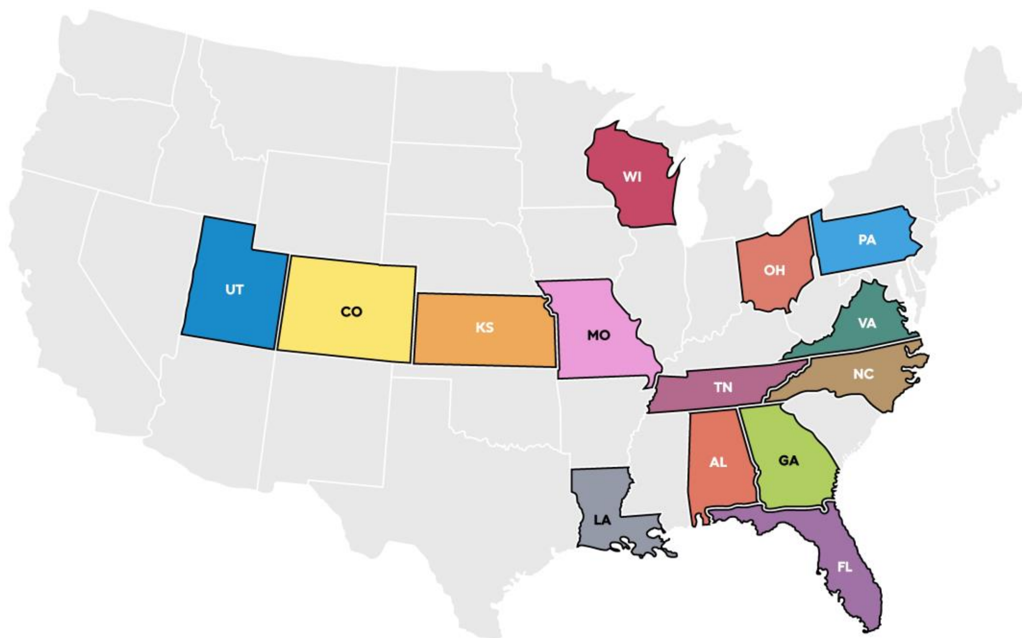

Figure I.38-1. Map of participating states

The project runs from October 2020 through December 2023 (39 months) and comprises a group of diverse stakeholders, including Clean Cities Coalitions (coalitions) from fourteen states, many transportation electrification-related nongovernmental organizations (NGOs), utilities, 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 overcome common EV adoption barriers and drive the purchase and use of EVs of all sizes and by general citizens and fleets and has made great progress during our first two years. See Figure I.38-1 for 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 begun both at the project-wide level and within each state partnership. Additionally, a 35-company Project Advisory Committee (PAC) spent Year 1 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:

- Create and strengthen statewide, branded EV initiatives.
- Educate at least 14,000 consumers through grassroots education initiatives across all states and develop "chapters" of active participants in every state.
- Build relationships with dozens of utilities of all types and utility regulators and build incentives and investment opportunities.
- Conduct EV infrastructure planning sessions for corridors and urban and rural areas, including a focus on disadvantaged and limited-income communities.
- Educate state and local government officials.
- Create "Certified EV Dealer" programs in every state.
- Facilitate EV deployments in fleets.

Approach

The project team includes ETCF as the Principal Investigator while CFO serves as a "super sub" overseeing the administrative management of the 12 other coalitions that are involved in the project. Both coalitions have significant experience working in various collaboratives and groups towards cleaner transportation initiatives.

ETCF and CFO 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 team developed specific tasks and subtasks under each Priority Area 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 Priority Areas to address specific EV-adoption barriers in their states. This project has a total of 57 deliverables/subtasks for each state/coalition, for a total of 798 deliverables.

The project team holds monthly, internal meetings to discuss deliverables and documentation and to aid coalitions in a group format. Additionally, both CFO and ETCF have communicated directly with coalitions to help them overcome issues 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

Some occurrences that have played a role in slowing project progress are noted below. Overall, we are overcoming these obstacles and delays, but we appreciate DOE and other project oversight personnel understanding their impact.

- COVID-19 in the initial year plus reduced the ability of some coalitions/state partners to plan in-person events. Project subtasks like a) holding "convenings" with stakeholders, utilities, government officials and b) setting up events where citizens could directly see and ride in or drive EVs were delayed. In some cases, coalitions set up virtual meetings via tools like Teams or Zoom to hold those meetings, but those cannot compete with in-person meetings to really forge strong relationships, and many coalitions understand that it set back their efforts to build those new or stronger connections and relations.

- Major project leader Sam Spofforth, the Chief Executive Officer of CFO – who helped devise the project – departed CFO at the end of 2021. He was the main partner with ETCF's Executive Director Jonathan Overly in managing not just administrative but some programmatic planning and specifics for the overall project. He was significantly involved in providing guidance to coalitions, but perhaps more importantly in the search for funding to turn this project into a more robust program. For those that never heard of Spofforth, he was one of the most active, proactive, and learned Clean Cities coalition directors and was inducted into the Clean Cities Hall of Fame when it was first developed in 2011. He was so good at what he did that he was hired by the National Renewable Energy Laboratory to provide guidance to coalitions and is in that position now. His departure was like adding speed humps to an interstate – it considerably delayed the work he and Overly were doing to develop long-term, top-level funding for the coalition. While Overly continues this role alone and is making progress in multiple funding opportunities, Spofforth's departure absolutely impacted the project.

- The primary project fiscal oversight staff at CFO changed four times in 2022. Megan Stein, another excellent CFO staff person, left in early 2022, and it has taken CFO some time to find its bearings. In addition to Stein and Spofforth leaving within two months of one another, one of their excellent federal funding managers, Andrew Conley, left as well. ETCF had to work through the multiple personnel changes, and it did delay the process of CFO receiving, reviewing, and handling invoices as needed (e.g., responding to coalition questions, processing payments, and updating the records system for the completion of coalition subtasks).

Coalition work in the project has been going well in Years 1 and 2 despite the above noted issues. Here is a list of project outputs:

Some items from Year 1 worth mentioning include a) developing online but protected project management and accomplishment tracking systems; b) creating templates and a system for coalitions to submit up to monthly completed work and invoices; c) designing and building a project website and four project/program social media channels; and d) holding 37 PAC meetings in 2021.

Year 2

- Coalitions created their own multi-faceted initiative funding plans that are tailored to their best opportunities.

- Social media and engagement efforts have ramped up.

  - Each state was to develop at least 200 social media engagements and 40,000 media impressions in Year 2 for their initiatives. For 14 initiatives, we needed to develop a project-wide a total of 560,000 (40,000 x 14) media impressions. Three states partnered on super-sized, Drive Electric-specific media outreach campaigns in the last year, and that elevated the total numbers. Even with a few states' numbers missing at this point, we anticipate roughly **25 million impressions** for CY22.
  - Additionally, *project-wide* social media work (under the "DEUSA" banner) has increased, and posts from two rounds of efforts that included all states can be found for easy viewing on the DEUSA website: https://www.driveelectricusa.org/success-stories/. Click on any story to open it in a Lightbox and read the full post, and then use the left and right arrows to move between posts.
- Chapter development work continued; 38 chapters developed across the 14 states with event planning efforts growing (a national chapter map is in production).
  - Identify and create at least two consumer grassroots Drive Electric chapters in each state. The goal for this subtask was for each state to create two new chapters. Some states had no chapters of any kind while others already had one or more chapters of the Electric Vehicle Association (the organization formerly known as the Electric Auto Association that has been forming chapters for over 30 years). Our total goal was 28 chapters, and we have a total of 38 in formation right now. The task of bringing together volunteers to commit time/effort and resources is no small undertaking – this is essentially coalition-building work. Some have had an easier time of this than others, and the important facet of this related to Year 2 is that in most cases these chapters require continued communications, support, and assistance, so work is likely ongoing for the foreseeable future with Drive Electric initiatives providing that aid. We are currently producing a nationwide map that will show all the chapter development work, so it is easy to visually understand what has taken place in this work.
  - Host EV consumer outreach and education activities and document at least 200 consumers directly engaged per state. Last year we had a goal of 2,800 direct engagements with local citizens across all states – be that a short discussion or a long EV drive – and created just under 16,000 in-person discussions and interactions. Based on early 2022 results (with a few states still reporting their final numbers), and with a goal for the year across all states of 5,600 direct engagements, we have already **exceeded 25,000 direct consumer engagements** – more than quadrupling our goal.
- Held 28 convenings with electric utilities of various types (Investor-Owned Utilities, municipal, cooperative). The team will produce reports on utility and local/state government engagements and educational sessions held from the Year 2 meetings. Most participating states already had good relationships with their electric utility partners, but they are furthering the *working relationships* now to build out more collaborative outreach to magnify their collective efforts.
- Held 14 convenings with community members to advance community EVSE planning; all states now have a statewide corridor infrastructure plan.
- Held 28 convenings with state and local government officials. Similar to 5) above, many coalitions had decent or good relationships with various local and state entities, but they are furthering those relationships (and making some new ones) to expand on EV/EVSE discussions as well as community engagement for future planning and larger future community discussions.
- Developed State-level "Certified EV" dealership platforms with ongoing work to add more dealerships to their included platforms. (Most of the platforms are web-based interactive maps.) With web-based systems sometimes being more complicated than simple HTML additions, 10 out of 12 states had their systems developed and online as of late 2022.

Developed and released a survey to fleets in each state to solicit feedback on their readiness and willingness to grow EVs in their fleet; held discussions with fleets on their thinking/plans for growing EV use and EVSE planning, and started the process to develop 10 fact sheets, success stories, or reports on those fleet plans in each state (a total of 140 fact sheets will be developed). Fleet surveying has been completed, most states have fully compiled their results (as of late 2022), and all fleets have been provided additional information (and those discussions will continue).

During FY 2021, ETCF's Overly and CFO's Spofforth began the process of reaching out to other states to join in the efforts to develop statewide, branded "Drive Electric" initiatives, including getting them to sign an MOU about interest and future involvement. Also in 2021, many additional states started joining our monthly Zoom meetings to better understand the work we are doing, and we added these states to our email list to receive the invitation to join any monthly virtual meeting. This work continued in 2022 as Overly spoke with even more states to bring the total number of states reached about potentially joining a DEUSA project or program to 20. Table I.38.1 shows the original 14 states in the project and those states contacted during project Years 1 and 2. If we were going to invite additional states to join the effort, we needed to find funding for them to do so (at least to get started). We began efforts to find additional funding and found two sources: one proposal has already been developed and submitted; the other is still in the works, with an expectation of being submitted in the first quarter of calendar year 2023. Table I.38.1 also shows the 12 states that were included in a proposal for funding submitted last fall, and the other states that we attempted to include, but that could not get past hurdles to doing so. Some coalitions are hosted by a state or local government agency and/or only serve localized regions in a state and ran into real or perceived issues with building statewide collaboratives. Other coalitions were hamstrung by capacity issues and an inability to bring on new staff (or lack of experience with doing so), either due to their leadership's worries or lack of vision, or coalition director worries. The good news is that we are continuing discussions with them to help them hopefully surmount those worries or inabilities in the coming years.

Figure I.38-2 highlights the new proposal states.

Table I.38.1 Original States, Proposal-included States, and Additional Interested States

Original 14 States		Proposal-inclusive Additional States	
1 - Alablama	8 - North Carolina	1 – Arizona	7 - Michigan
2 - Colorado	9 - Ohio	2 – Connecticut	8 – New York
3 - Florida	10 - Pennsylvania	3 – District of Columbia	9 – Oklahoma
4 - Georgia	11 - Tennessee	4 – Indiana	10 – South Dakota
5 - Kansas	12 - Utah	5 – Kentucky	11 – Washington
6 - Louisiana	13 - Virginia	6 – Maine	12 – Wyoming
7 - Missouri	14 - Wisconsin		
Additional, DEUSA-Interested States			
Arkansas	Massachusetts	New Hampshire	South Carolina

Texas	Vermont	West Virginia	Montana

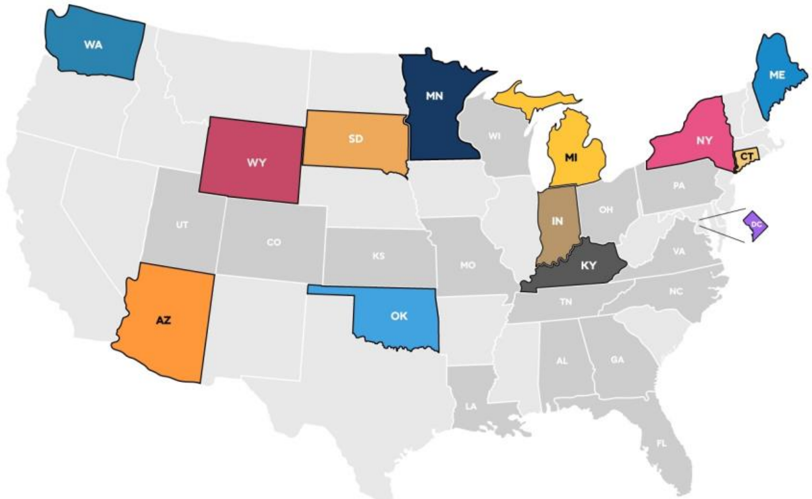

Figure I.38-2. Map of current effort states (brightly colored) plus the new proposal inclusive states (darker gray)

We anticipate having all the 2022 accomplishment numbers, reports, etc., catalogued by March 2023. Approximately 70% of all the Year 2 subtasks have been completed, and eight states have completed and invoiced for 85-100% of their subtask deliverables in Year 2 (excluding some coalition subtask completions that are still being reviewed by CFO).

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. Based on a) the number of partners in this project, b) the number of different subtasks that are integrated which include a wide variety of work by the coalitions (978 total subtasks), c) the difficulty of some of the subtasks (e.g., building a statewide partnership with the intent of it operating into the foreseeable future), and d) issues/occurrences as noted previously, we believe the project team is doing well.

As for outcomes, the project team is still getting full data from Year 2 from coalitions and is not yet ready to show some of the project's more numeric goals. Also, "outcomes" tend more to the actual impact made versus a number, and the primary deliverable for outcomes will be the project **Replication Playbook.** The team started Playbook development work in late 2021 and it continues today. Within each Priority Area there will be at least four specific stories from different states that showcase the state EV and EVSE plans; state initiative longer-term funding plans; utilities, state government discussions and plans; community EVSE plans; web-based platforms that allow state citizens to find Certified EV Dealers; and fleet-engagement and EV-adoption success stories.

Key Publications

Drive Electric USA website, www.driveelectricusa.org

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 also to all the coalitions that have been involved to help us all bring about these valued and helpful statewide "Drive

Electric" programs. We also appreciate the suggestions and guidance of our DOE Project Officer Trev Hall for his contributions to the success of the project.

I.39 Helping Rural Counties Transition to Cleaner Fuels and Vehicles (Transportation Energy Partners)

Ken Brown, Principal Investigator
Transportation Energy Partners
4713 Trent Court
Chevy Chase, MD, 20815-5516
E-mail: ken@akbstrategies.com

Michael Laughlin, DOE Project Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

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Project Funding: $2,160,562 DOE share: $1,078,581 Non-DOE share: $1,081.981

Project Introduction

This project provides 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 workforces. 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 is coordinating and supporting 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 conducted 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 is providing 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

The project team has completed all the remaining Budget Year 1 milestones:

- Milestone: Completed three national webinars.
- Milestone: Completed 24 total outreach events (e.g., state webinars, statewide or regional meetings, presentations at state or regional workshops), with three or more performed in each project state.
- Milestone: Secured at least eight demonstration vehicles contracted for and made available for use in the target states. (See Table I.39.1.)
- Milestone: Identified in-depth technical assistance for 24 target counties with at least three in each project state. (See Table I.39.2.)

Table I.39.1 Project Demonstration Vehicles (Official Cost Share Partners)

Vehicle Provider	Demo Vehicle Description
Altec	(2) Medium/heavy duty bucket trucks that include the JEMS plug-in alternative fuel solution
Alliance Autogas	(1) 2020 Ford F-150 XLT propane powered crew cab
Ingevity	(1) ANG-powered Ford F-150 pickup truck and (1) Ingevity ANG Fueling Appliance
Landi Renzo	(2) Ford F-250 CNG powered pickup trucks
Toyota	(3) Mirai hydrogen fuel cell vehicles

Table I.39.2. Communities Receiving Technical Assistance

Technical Assistance Community	Project State
Perry County / City of Marion	Alabama
Clarke County / City of Thomasville	Alabama

Technical Assistance Community	Project State
Montgomery and Lauderdale Counties / Alabama State Parks	Alabama
Spencer County	Indiana
Warrick County	Indiana
Brown County	Indiana
Erie County / City of Sandusky	Ohio
Scioto County / City of Portsmouth	Ohio
Tuscarawas County / Muskingum Watershed District	Ohio
Deschuttes County	Oregon
Umatilla County / Umatilla Electric Cooperative	Oregon
Lane County	Oregon
Springdale County	Utah
Iron County / Five County Association of Governments	Utah
Grand County / Moab	Utah
Duchesne County	Utah
Cumberland County / Virginia State Parks	Virginia
Pittsylvania County	Virginia
Spotsylvania County / City of Fredericksburg	Virginia
Douglas County / Public Utility District	Washington
Benton County / Port of Benton	Washington
Franklin County	Washington
Eau Claire County / City of Eau Claire	Wisconsin
St. Croix County	Wisconsin
Bayfield County	Wisconsin

The technical assistance phase of the project is at the halfway point, and the project team is making good progress toward meeting the goals and objectives for this phase.

Clean Cities Coalitions are gathering fleet data and conducting fleet analyses in most of the identified target communities. In a few instances, staffing changes in the local communities are delaying the process and coalitions are either working with new staff or with alternative community partners to get data for the analyses.

Clean Cities Coalitions have conducted five clean fuels and vehicles workshops or meetings and have many scheduled for the first quarter of 2023. Coalitions are finding that in some communities, virtual meetings will work better than in-person events because of the time required for fleets to travel to a central location in rural communities.

Vehicle partners and Clean Cities coalitions have completed eight vehicle demonstrations, and others are being scheduled to coordinate with workshops and meetings in the first half of 2023. Communities have expressed a lot of interest in electric vehicle demonstrations and the project team has conducted significant outreach and secured interest from EV companies to participate in the project. Much of that outreach started when the project team attended the NTEA Green Truck Summit and Work Truck Week show in March 2022. The team networked with vehicle providers and held an event to showcase the project to fleets and vehicle providers attending the show. Table I.39.3 shows new vehicle companies participating in the project. These companies are working with the project team to identify opportunities to bring demo vehicles to ride-and-drive events, provide demo vehicles for fleets to test, and/or participate in workshops and meetings with rural fleets.

Table I.39.3. New Project Demonstration Vehicles (Non-Official Partners)

Vehicle Provider	Demo Vehicle Description
Arcimoto	EV utility vehicles
Battle Motors	EV and CNG heavy duty trucks, refuse trucks
Creative Bus Sales	Electric school buses
Lightning eMotors	Electric transit vehicles
ROUSH	Propane transit vans and school buses
Sonny Merryman	Electric school buses
STAG USA	CNG and Propoane pickup trucks

Conclusions

The Helping Rural Counties Transition to Cleaner Fuels and Vehicles project accomplished all its Budget Year 1 planning phase goals and objectives and is on track to accomplish the technical assistance phase goals and objectives with the planned budget. The project is in the middle of the technical assistance phase and the project team's work with the target communities is progressing on pace. The project team is learning and adapting to meet the unique needs of small and rural communities that are interested in exploring clean fuels and vehicles.

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.40 NFPA Spurs the Safe Adoption of Electric Vehicles through Education and Outreach (National Fire Protection Association)

Andrew Klock, Principal Investigator
National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02169
E-mail: aklock@nfpa.org

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

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, and emergency responder risks associated with damaged lithium-ion batteries. 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:

- 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.

- Develop a U.S. Clean Cities Coalitions (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).
- 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 45-month project, NFPA detailed 15 tasks that support successful completion of the established project objectives. See Table I.40.1, Project Approach.

Table I.40.1. 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.
Hire Subject Matter Experts (SMEs) Knowledgeable in EV & EVSE Technology	Hire experienced EV safety SMEs to research and collect content.
Hire a Training Development Team	Locate & contract with an experienced web training developer.
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.
Collect Existing EV Content, Research, and Testing	Collect and refine existing EV content including research, testing, codes & standards, and other pertinent literature.
Develop EV Workshop Toolkit	Conceptualize and build a comprehensive and highly engaging Electric Vehicle Community Preparedness Assessment Workshops curriculum and toolkit
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.
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.

Project Tasks	Description
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.
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.
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.
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).
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.
Compile Feedback	Collect participant and host feedback & evaluations from each coalition host and incorporate into a milestone report.
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.
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 second budget year of this project, NFPA completed the final phase of the course development efforts initiated during 2021. NFPA worked with Allen Communications—an award-winning eLearning design and development firm—to conceptualize, film, and produce a total of 12 new video segments, incorporating animation, narration, and sound effects, which were then incorporated into the 10 previously developed online EV training modules and the EV preparedness workshop materials. These trainings are for the audiences of charging station (EVSE) installers, code officials, utilities, dealerships, fleet owners, garages/maintenance facilities, insurance companies, tow and salvage operators, crash reconstruction teams, and vehicle owners.

NFPA worked closely with East Tennessee Clean Fuels (ETCF) to design and develop the EV Community Preparedness Workshop toolkit. Once drafted, the toolkit underwent several rounds of curriculum review before being finalized and prepared for distribution to Clean Cities Coalition partners for delivery. The toolkit includes the Facilitators Guide (22 Pages), Participant Journal (23 Pages), Trainer's Guide (12 Pages), and a PowerPoint Presentation (33 Slides).

Once the toolkit was finalized, ETCF notified all 30 EV workshop coalition hosts to begin preparations for their participation in the project. As part of this communication, ETCF disseminated key event-related logistics to coalition partners, including information about "train-the-facilitator" virtual sessions that provide an overview of the 'Electric Vehicle Community Preparedness Assessment Workshop' curriculum to each of the host coalitions.

All 10 courses are in production and reside in NFPA's learning management system (LMS), which allows learners to access the training from NFPA.com, as well as the newly created ReadyForEVs.com website. NFPA's LMS provides NFPA and its project partners access to the course completion data and allows reports to be generated on who has participated in these workshops.

As mentioned above, ETCF completed development of www.ReadyForEVs.com this year, which serves as a centralized hub for EV preparedness workshop-related information, including links to NFPA's online EV training modules, event participant registrations, and participant communications. As event details were finalized with host coalitions, they were included on this site for registration and registrant tracking.

During the third quarter of 2022, ETCF successfully scheduled and planned a total of four (4) EV Community Preparedness workshops. To support these efforts, NFPA held weekly team meetings with ETCF, Virginia Clean Cities, and Central Florida Clean Cities. The focus of these meetings was to identify, assign, and complete all planning and logistics activities to ensure the successful delivery of scheduled workshops.

Host coalitions that participated in the workshops included ETFC, Granite State Clean Cities, Northern Colorado Clean Cities Coalition, and Middle-West Tennessee Clean Fuels Coalition. ETCF and NFPA developed a post-event survey, and then deployed it to those participating in the Workshops, providing valuable insights to the project team. This survey and other feedback received helped NFPA decide to rework the curriculum, to shorten the workshop and make it more relevant for participants. NFPA then deployed the revised workshop curriculum to those coalitions hosting the remaining workshops, resulting in even greater success. For instance, in the case of the New Hampshire event, participants indicated that they would continue their productive EV planning conversations after the workshop while adding additional community stakeholders to the discussion. Those involved in the development of the program saw this as a victory of engaging the stakeholders and piquing their interest enough to see additional planning take place outside of the project's planned events.

NFPA has identified, planned, and contacted the following CCCs to hold workshops during the remaining grant performance period. See Table I.40.2, Additional Planned Workshop Locations.

Table I.40.2. Additional Planned 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 Fuels Ohio

Coalition/Host
Dallas-Fort Worth Clean Cities
Delaware Clean Cities Coalition
Drive Clean Colorado
Drive Clean Indiana
East Bay Clean Cities (CA)
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)
Michigan Clean Cities
North Dakota Clean Cities
Pittsburgh Region Clean Cities
Southeast Louisiana Clean Cities
Triangle Clean Cities (NC)
Tulsa Area Clean Cities
Utah Clean Cities

Conclusions

During the second year, NFPA has accomplished the following toward this project's goals:

- Successfully developed and implemented 10 EV community preparedness online training tracks and implemented the ReadyForEVs.com website as a landing page and repository for all workshop materials, trainings, registrations, and communications.
- Successfully developed, revised, and implemented the EV Community Preparedness Workshop, including table-top exercises and curricula, that the Clean Cities Coalitions can use for their surrounding communities nationwide.
- Through our partner Clean Cities Coalitions, NFPA has conducted targeted outreach to identify 30+ suitable EV Community Preparedness virtual workshop hosts and locations.
- Successfully ran four EV Community Preparedness workshops by ETCFC, Granite State Clean Cities, Northern Colorado Clean Cities Coalition, and the Middle-West Tennessee Clean Fuels Coalition.

I.41 Creating the NFPA Distributed Energy Resources Safety Training (DERST) Program (National Fire Protection Association)

Andrew Klock, Principal Investigator
National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02169
E-mail: aklock@nfpa.org

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

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 (DER) are small geographically dispersed electricity generators that are connected to a local distribution system. DERs can include solar panels, energy storage systems (ESS), 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, 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 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 objectives of this project are 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:

- Gathering the latest DER safety research and studies.
- Conducting field testing and collecting data and best practices using the latest DER equipment and vehicles in controlled emergency fires and incidents.
- Updating and modularizing our existing train-the-trainer programs for the fire service and emergency medical service (EMS) on ESS, PV, and EV/EVSE with both NFPA and Underwriters Laboratory's (UL) research, test results, and data, and then distributing them across the country.
- Creating a multi-user and role, scenario-based serious gaming platform for fire departments, based on the collected test result data, to train together on interactive, real-world, multiple DERs in the same structures (think flight simulator-style training for a team of firefighters).
- 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 11 tasks that supported successful completion of the established project objectives. See Table I.41.1, Project Approach.

Table I.41.1. 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.
Hold Partners Kickoff Meeting	Assemble partners and stakeholders for a kickoff meeting, determining issues, risks, responsibilities, rules, project schedule and milestones.
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). Uncover hazards and best practices for extinguishing the structure and DERs effectively and safety.
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.

Project Tasks	Description
Revise and Update Existing Train-The-Trainer Classroom Courses	Modularize and enhance the classroom training with the latest DER tactics.
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.
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.
Onboarding of Serious Gaming Development Vendors	Issue a request for proposals for a qualified eLearning/instructional design and development vendor.
Development of Serious Gaming DER Safety Simulator	Conceptualize and develop a multi-player, multi-role, multi-venue, multi-interconnected-DER incident gamified training tool.
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.
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.
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 second year of this project, NFPA continued to hold bi-monthly meetings with our subrecipient partners University of Texas, Austin (UT-Austin), the North American Fire Training Directors (NAFTD), and Argonne National Laboratory (Argonne), to provide channels of collaboration and continue to make progress toward our goals and objectives. NFPA had UT-Austin worked with local fire departments to identify a residential structure for burn testing DER systems, located a property slated for demolition, and contracted for a burn test with the local authorities (Figure I.41-1). The team worked with Underwriters Laboratories (UL), involved because of a parallel DOE Empowered grant project, to construct a final test plan detailing the DER burn test to be conducted. The purpose of the test was to gather gas sensor and flame path data. Ultraviolet (UV) and color videos were recorded as input to construct a realistic simulation during development of a serious game DERST incident simulation for the fire service.

Figure I.41-1. Residential structure identified for burn test

UT-Austin and NFPA chose a residential property within the city of Austin, Texas, as the test site. The single-family residential structure had an attached garage. A solar panel system was already installed on the roof. NFPA purchased and installed an ESS (a new LINIOTECH 10 KWH LIFEPO4). The team also purchased an electric vehicle stripped of its insignia markings, parked it in the garage, and wired it to many sensor arrays (Figure I.41-2). Argonne donated a Level 2 charging station and installed it in the garage.

Figure I.41-2. EV inside garage

On April 18, 2022, UT-Austin and the Austin Fire Department successfully conducted a residential structure burn test at 4709 Pinehurst, Austin, Texas, with DERs connected throughout the structure (Figure I.41-3).

Figure I.41-3. Structure burn test

Loud explosions and a raging fire enveloped the garage for approximately 45 minutes, before the fire department deemed the fire unsafe for the surrounding environment and extinguished the structure. After the fire was out and deemed safe, the fire department attached chains to the EV and the ESS and, after multiple attempts, pulled both out of the garage and onto the adjacent driveway for inspection. Both devices appeared completely burned up, with only the metal casing and skeletal structure remaining (Figure I.41-4).

Figure I.41-4. Remains of EV and ESS

Preliminary findings showed that the ESS had arc flashed several times, as evidenced by the burn marks and welded holes in the case, and the ESS continued to burn long after the garage was extinguished. Further hose water needed to be applied to cool the ESS and keep it from reigniting, as determined from a thermal imaging camera. When it was cool enough to test, the Austin Fire Department determined that the ESS had completely burned up its batteries and had no state of charge remaining. Most of the EV was also consumed in the blaze, and all that remained was the metal shell of the vehicle and the battery case, bolted to the underneath of the frame.

The first unexpected outcome of this test was that the metal garage door melted and burned down during the fire, allowing a steady stream of air to continue to fuel the blaze during the test. Another unexpected finding was that after inspecting the vehicle's Li-Ion battery, subject matter experts (SMEs) determined that the fire had not intruded through the battery case, and all battery cells were intact and had their initial state of charge.

UT-Austin analyzed, documented, and presented the DER Fire Test Findings to the project's SME panel. NFPA's SMEs took this information and discussed, deconstructed, analyzed, and absorbed the findings to identify best practices and methodologies for the fire service to respond to DER incidents more effectively. UT-Austin and NFPA's SMEs conveyed the preliminary information to NFPA's game developer (GHD Digital) to begin development of the serious game's learning points.

During this period, NFPA and Argonne also collected the latest DER literature from Argonne and NFPA's resources, and UL shared with NFPA some of their energy storage tests, results from those tests, and their preliminary recommendations for the fire service's handling of ESS incidents.

Following the test, NFPA initiated a Request for Proposal (RFP) process and contracted with Emergency Training Solutions to update NFPA's existing Energy Storage, Solar, and Electric Vehicle Safety Classroom Training with the latest safety information, modularizing it for the Fire Service to use it more effectively.

Emergency Training Solutions is in the process of updating and modularized NFPA's courses into smaller chunks, allowing the fire service to incorporate them more efficiently and effectively into onboarding efforts and/or regularly scheduled training classes.

This past year, NFPA also conducted an RFP process to identify a gamification developer and sent the RFP to five software development companies. NFPA chose the gamification vendor that had the most experience with serious gaming, multiple players, the fire service, and interactive exercises, as well as the best graphical experience at the lowest price point. GHD Digital, with experience creating fire service gamification for multiple player interaction in a realistic setting, had constructed a prior serious game for the fire service with railroad train wreckage hazmat scenario. They use the Unreal engine for their virtual environments and will recreate the Austin, Texas, residential structure for NFPA's incident setting. Game play will be free form and involve an incident commander and multiple fire departments responding to a DER incident. New animations are currently being developed by GHD Digital to support this effort.

As suggested and agreed upon by DOE, UL will work with NFPA and provide their latest research findings on their ESS burn tests, which are part of a parallel DOE Energy Storage Safety grant provided by UL. The results from UL's tests will inform the program updates, resulting in safer, more useful fire service training and simulations. NFPA is waiting for finalized data from UL's energy storage burn tests before completing these fire service training modules, to offer the most up-to-date safety information for the fire service.

During the third quarter, NFPA provided GHD Digital with draft specifications for development of the serious game. These included the following:

- Gamification of real-world environments utilizing 3D modeling or other similar high-engagement, high resolution platforms.
- Simulation of emergency incidents including smoke, fire, explosions, and other events fire fighters may encounter during a structure fire.
- A nonlinear instructional design approach that uses real-time game branching to challenge the user's comprehension, thus allowing for many possible performance outcomes during serious game play.
- A multi-user interface allowing for up to 5 simultaneous users filling individual roles to tackle the challenges as a team.
- In-program leaderboard and performance metrics for real-time assessment and feedback on performance.
- A multi-user interface that provides a desktop and mobile-friendly platform with detailed progress tracking.

GHD Digital is in the process of reviewing the provided course materials (e.g., classroom course materials, online training modules, videos, & images) and DER research (e.g., research reports, fire test data, computer simulations, & fire testing footage) and providing instructional analysis, audience profiles, and a strategy for developing an engaging, gamified learning experience. GHD Digital will then identify learning objectives, design challenges, stakeholder requirements, and specifics regarding recommended instructional formats/methodologies for program components, to include scenario-based learning, gamified interactions, immersive experiences, user feedback, and other methods to ensure learner engagement and comprehension.

GHD Digital is developing detailed curriculum outlines, storyboards (Figure I.41-5), and scripts for gamified content, addressing the learning needs of the identified audience through the use of 3D animations, simulations, and other advanced graphic design elements.

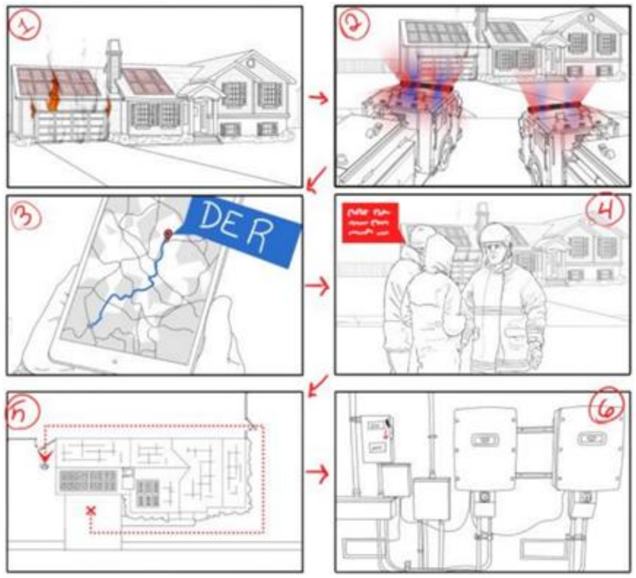

Figure I.41-5. Serious game storyboard

Conclusions

During the second year, NFPA has accomplished the following toward this project's goals:

- NFPA worked with UT-Austin and the Austin Fire Department to identify and set up a residential structure with attached garage to perform this project's burn testing of DER systems.
- NFPA purchased an EV, a 10 kWh Energy Storage System, installed an EV charger (EVSE), and connected the Solar Array on the roof together to form a DER residential structure ready for testing.
- The team worked with Underwriters Laboratories to construct a final test plan detailing the DER burn test to be conducted, with wired gas sensors and UV cameras.
- UT-Austin and the Austin Fire Department initiated a burn test, with the entire garage structure enveloped in flames for 45 minutes. The team collected a large amount of gas and flame path data, and UV and color video from the installed sensors and 3 drones flying over the structure.
- NFPA contracted with and is working with GHD Digital to recreate the residential structure burn test in a fully immersive simulation environment (serious game) to instruct fire departments how to respond more effectively to DER incidents.
- NFPA is working with Emergency Training Solutions to update and modularize NFPA's existing Energy Storage, Solar, and Electric Vehicle Safety Classroom Training with the latest safety information, modularizing it for the Fire Service to use it more effectively.

I.42 Electric Vehicle Market Stimulation in Divested Economies (Metropolitan Energy Center)

Miriam Bouallegue, Principal Investigator
Metropolitan Energy Center
300 E 39th St.
Kansas City, MO 64111
Email: miriam@metroenergy.org

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

Start Date: March 1, 2022 End Date: May 31, 2023
Project Funding: $10,455,288 DOE share: 5,222,326 Non-DOE share: $5,232,962

Project Introduction

Electric Vehicles in Underserved Markets

Eight businesses and municipalities are managing cost-shared projects that operate within Kansas and Missouri environmental justice areas, opportunity zones, and other underserved areas to deploy electric vehicles (EVs) and charging stations. In addition to sedans, they are replacing small and heavy trucks with electric models. Thanks to generous 15% overmatch contributions from these eight funding recipients, this program will also fund a small grants program for underserved communities.

Small grant recipients will define for themselves what project features would be locally most beneficial, such as projects to install public EV charging stations in parking lots and at curbsides near multi-unit residential complexes and retail businesses. The success of the program depends upon placing EV charging stations within underserved or rural areas that feel the effects of environmental justice issues. Diesel emissions from heavy vehicles and off-road machinery contribute to early deaths, asthma rates and family illness, keeping people away from jobs and school. Those are just some of the health and social impacts from diesel fumes that affect the community members Metropolitan Energy Center (MEC) serves.

Objectives

The objective of this project is to expand the availability of EVs and charging at low cost in underserved urban and rural settings, with an emphasis on curbside and multifamily charging installations. Projects will reduce diesel fumes by supporting EV purchases, charging station installations, and outreach efforts to notify communities of these resources. The funds will also help small businesses and rural cities in Missouri and Kansas accelerate their transition to EVs.

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. 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. [1] Between 2006 and 2014, the percentage of Americans who rent rather than own rose from 36.1% to 41.1%. [2] With more people becoming renters, and residential electric vehicle supply equipment (EVSE) less attainable for renters, multifamily and curbside charging presents a more equitable solution.

Approach

Eight proposed subrecipients in the EV Market Stimulation in Divested Economies (EVMS-DE) project will deploy 38 EVs and install 40+ EVSE, directly impacting air quality in the identified Environmental Justice areas and Opportunity Zones. In addition, we will use the data generated to spotlight the project's impact on local residents, placing importance on their lived experience, including available local data that corroborates their anecdotes, coaching larger organizations through this increasingly popular innovative approach, namely businesses and municipalities that have historically looked past the lived experience of those without socio-political voice. This will involve contracting with local community-based organizations (CBOs) that will conduct outreach and engagement to local residents to understand lived experiences and gather data on preferences and needs, then working through the CBOs to identify landowners to host the charging stations. The data collected will inform target landowners and the final locations of the community charging stations under the small grants program. Additionally, our municipal subrecipients such as the City of Osawatomie will follow a similar approach. Post-deployment, we will collect data on usage and locations and compare to the data collected during the outreach process and analyze its relationship to lived experiences voiced by community members. In MEC's experience, when an organization first tries out new technologies, initial projects tend to be much smaller in scope and cost than the projects of experienced project partners. The project's intent is to lower the barrier to entry for businesses and municipalities serving underserved communities, and to offset the historic exclusion of resources to the same communities. MEC requested a higher than customary cost share from initial project partner applicants (now our proposed subrecipients) and plans to utilize these cost-share overages to subsidize smaller projects generated from targeted engagement efforts in underserved communities, to restore healthy living environments through vehicle technology adoption.

Results

The City of Osawatomie, Kansas plans to deploy two EV Ford F-150s, two Ranger EV off-road utility task vehicles, and 16 public Level 2 EVSE at various locations throughout the city. The city held a ribbon cutting event on August 11, 2022, to celebrate the dedication of the location of their first (of ten planned) EV charging stations. See Figure I.42-1. The event was led by Osawatomie's Mayor and City Manager, with remarks by MEC and the State of Kansas Department of Wildlife and Parks. The event was covered by local media, including The Miami County Republic. The event is part of a larger effort by the City to go green and implement sustainability projects funded through this and other grants including an EV hub, bike racks, and walking trails.

Figure I.42-1. City of Osawatomie City Manager, City of Osawatomie Mayor, and MEC staff (left to right) present the project to community members at ribbon-cutting ceremony.

The city plans to hold four public forums in the fourth quarter of 2022, and to release a Request for Proposals (RFP) for charging stations early in Q4. Osawatomie has identified ten charging locations to MEC, and a National Environmental Policy Act (NEPA) Environmental Questionnaire has been submitted and approved by DOE. Their utility task vehicle (UTV) acquisitions are on track, but their Ford Lightning purchases are still up in the air. Their Enterprise representative for Ford has requested a meeting with them to clarify their intention for purchase of these trucks.

Johnson County Community College (JCCC) plans to deploy eight EV and PHEV vehicles including one cargo van, one minivan, three sports utility vehicles (SUVs) and three pickup trucks in budget period 2. JCCC convened a committee to procure EV charging stations by July of 2023. Due to the supply chain issues other subrecipients have experienced in budget period 1 JCCC is reconsidering which fleet vehicles to replace.

Hirschbach Motor Lines plans to deploy a total of six EV terminal tractors and four charging stations in Olathe, Kansas, Edwardsville, Kansas, and Milan, Missouri. Hirschbach is ordering the trucks from Orange EV. Orange EV is at the front end of the design build project and anticipates a timeline from November 2022 to February 2023 on the build phase for their trucks, with planned deployments in first quarter of 2023.

Kansas City Aviation Department (KCI) plans to deploy four EV shuttle buses at the airport. The buses will be used for transporting passengers from parking lots to the airport entrance. The buses are planned to use inductive charging pads while loading and unloading passengers. The inductive charging pads will be paid for from a different grant but will serve the vehicles under this grant. KCI's contract was delayed during initial internal legal review but has now been signed by the deputy aviation director and is in final review. After a price spike in quotes provided by BYD in May raised concerns, KCI negotiated acceptable pricing during a visit to BYD during November and will proceed with the four-bus plan. Since the airport will be purchasing an additional three units outside the grant, BYD cut the prices quoted in May and the original goals of the project remain in place. However, higher bus purchase costs mean that plans to refit EV units already in service with inductive charging systems have been scrapped.

WaterOne is deploying nine EV Ford Lightning pickup trucks as maintenance vehicles. WaterOne has signed their contract with MEC, and it is now under review for possible minor changes. WaterOne submitted a purchase order for three F-150 Lightnings to Shawnee Mission Ford in August. Given higher pricing for EVs in general, the trim line for one of the three units has been changed to the base model to cut costs. Delivery time is currently unknown though Spring 2023 is possible. Two Level 2 chargers will be installed on-site, and additional charging stations will be installed in a new garage building, set for completion in late 2023 or early 2024. The charging stations are part of a different grant but will serve the trucks under this grant.

City of Lee's Summit, Missouri plans to deploy one Ford F-150 Lightning in the Public Works fleet. The city submitted a purchase order to Shawnee Mission Ford in August for acquisition of one Ford F-150 Lightning. The city notes that the original estimate of $39,974 has increased to $43,641, a difference of $3,667. The cost of the original estimate will be coming out of the Water Department's Vehicle Equipment Replacement Program (VERP) fund and the remaining balance will come from Water Operations general operating fund. The city has had contractors conduct site evaluations at the Water Department building to get bids on the cost of the install of the planned charging station.

Lazer Logistics manages yard operations, logistics and safety programs for the warehouse and distribution centers. Lazer Logistics originally planned to deploy 10 EV terminal tractors across three locations; however, they have since determined that two of their originally planned locations will not work out due to local regulations and plans. Lazer Logistics' deployments are underway in Sikeston, Missouri for one fast charger and two trucks. Electricians have broken ground for infrastructure to support chargers. The Kansas City, Kansas site locations have changed and are currently undetermined. Lazer Spot is trying to identify replacement locations within disadvantaged communities (DACs). Lazer Spot is currently working on obtaining clearance to deploy the remaining four trucks at alternative sites and will propose these alternative sites to MEC once they are known. MEC was informed in Q2 that the change in deployment sites was due to a closure at one location and unforeseen local regulations for on road speed requirements at another location. Lazer Spot is evaluating new locations based on the project scope and guidelines for identifying underserved communities issued by MEC and DOE. All proposed locations will be reviewed and approved by MEC and DOE prior to final selection.

City of Ottawa, Kansas originally planned to deploy eight Level 2 EVSE and one DC Fast Charger (DCFC) at seven locations throughout the City; however, their contract is at risk due to concerns about their ability to execute. In Q3 they sent a quarterly report stating that they were still negotiating the contract. They had been unresponsive to calls and emails since July. Recently, MEC met with the City of Ottawa to discuss a path forward and the city plans to make a final decision by the end of the year whether they want to proceed with the grant project. Previously, the city was conducting final site reviews on their planned EVSE locations. Due to new National Electric Vehicle Infrastructure (NEVI) Formula Program requirements that the city was unaware of during the application phase, the city wants to ensure that their planned DCFC location will be aligned with the NEVI plans and requirements. The Kansas Department of Transportation (KDOT) will be informed of Ottawa's DCFC plans as part of our coordination efforts on the State's EV corridor planning.

Small Grants Program

MEC has started outreach to CBOs to conduct Community Listening Sessions in DACs as part of this program. Kansas City, Missouri has a strong neighborhood organization structure, so MEC has identified groups within the DOE Environmental Justice DACs and has contacted a subset of those groups. Response from neighborhoods so far has been low. In response to this, MEC modified the approach to identify CBOs that were expected to have greater capacity for participation in the project. MEC issued an RFP and broadcasted it to eligible CBOs serving underserved areas in the project's geographic scope.

Lessons Learned

- Due to supply chain shortages associated with the COVID-19 pandemic, many subrecipients have received uncertain information from suppliers and it is possible that some equipment may be delayed and/or that subrecipients may incur increased costs because of inflation.

- Through this project we learned the importance of being willing to adapt. This year we experienced a delay with a sub-recipient signing the contract we had agreed on. After multiple months of attempts to contact the sub-recipient, we finally met with them. During the meeting, the sub-recipient informed us that they were still determining if this opportunity was right for their city. After an open discussion, we mutually agreed to discontinue the partnership and plan to reallocate the money to a different sub-recipient. We learned that every city has diverse needs and must prioritize projects accordingly which may not always align with our priorities. In the future, we will continue to have a solid line of communication with our sub-recipients and remain adaptable to changing conditions.

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.

References

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[2] https://www.citylab.com/equity/2016/02/the-rise-of-renting-in-the-us/462948/

I.43 Upper Midwest Inter-Tribal Electric Vehicle Charging Community Network (Native Sun Community Power Development)

Robert Blake, Principal Investigator
Native Sun Community Power Development
4407 E. Lake St.
Minneapolis, MN 55406-2339
E-mail: robert@nativesun.org

Joseph McNeil, Co-Principal Investigator
Standing Rock ("SAGE") Renewable Energy Power Authority
9299 Hwy. 24, Suite 126, P.O. Box 298
Fort Yates, ND 58538-0298
E-mail: jmcneil@sagerst.com

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

Start Date: March 1, 2022 End Date: May 31, 2025
Project Funding: $13,868,484 DOE share: $6,666,667 Non-DOE share: $7,201,817

Project Introduction

The Upper Midwest Inter-Tribal Electric Vehicle (EV) Charging Community Network, a Native-led public-private partnership addressing plug-in EV barriers for Tribal members, is working to provide equitable access to clean, affordable transportation in multi-family housing and rural, underserved Tribal communities. A core goal is to clearly establish for decision makers across public and private sectors that EV-based transportation will effectively lead to a green future; and investments in EV-related infrastructure are not only necessary, but also make good sense. To increase public familiarity with clean transportation options and establish EV corridors from rural Reservations to key medical, educational, and retail destinations, the project is launching "Electric Nation" to:

- Deploy commercial, passenger, and transit EVs plus related equipment to test and demonstrate their potential.
- Catalyze energy self-determination and new job opportunities.
- Expand access to benefits of electrified transportation to more Tribal members.

The Minnesota Pollution Control Agency, Minnesota Power, Otter Tail Power, and Xcel Energy are providing support to electrify highways serving the region's Tribal communities. The project is adding EV chargers on frequently traveled routes from Standing Rock and Red Lake to critical destinations and along the Native American Scenic Byway.

Electric Nation is working to create a sustainable ecosystem to expand EV access by:

- Installing 59 DC fast charging units on Reservations and vital travel routes and installing 63 Level 2 electric vehicle supply equipment (EVSE) at community gathering spots, Tribal colleges, collocated with direct current fast chargers (DCFC), and other destinations.

- Deploying 16 light-duty EVs, an electric shuttle, and two electric school buses.
- Documenting energy savings, emissions reductions, and the impact on Tribal members created by this project and developing a pathway forward to a system free of fossil fuels.
- Developing two new workforce training programs for Red Lake and Standing Rock.
- Engaging in 52 events to engage and educate Tribal members, auto dealership sales staff, and first responders.

Objectives

The objectives of this Native-led public-private partnership project are to address plug-in EV barriers for Tribal members in the Upper Midwest and demonstrate EVs in Tribal communities providing equitable access to clean, affordable transportation in multi-family housing and rural, underserved Tribal communities facing harsh winters. Through the installation of public and curbside charging infrastructure, this project will "connect" Standing Rock Sioux Tribe, Red Lake Nation, and other Reservations with vital medical, retail, and government services in Minnesota, North Dakota, and South Dakota.

The project will deploy 19 commercial, residential, and transit EVs and related equipment (including 2 solar trailers for educational events and 3 freezer cubes for transporting Red Lake fish to markets) to test and demonstrate their potential on rural, cold-climate Reservations; catalyze energy self-determination and new job opportunities; and expand access to the benefits of electrified transportation to more Tribal members.

Leveraging public and private funds, this partnership will install or upgrade 59 public EV charging hubs with DCFC infrastructure and 63 Level 2 EVSE, ensuring all 23 Native Nations in the three states have at least one Level 2 station. The partners will engage at 52 events over the project's three budget periods reaching more than 10,000 attendees, lower the burden of transportation costs, and provide access to advanced clean vehicles and infrastructure to community members disproportionately affected by transportation inequities. A core goal of this project demonstration is to clearly establish for those across the public and private sectors who make infrastructure-related decisions that: (i) EV-based transportation is an effective pathway to a green future; and that, (ii) investments in EV-related infrastructure are not only necessary, but also make good sense.

Approach

Electric Nation founding partners working to catalyze energy self-determination and expand benefits of electrified transportation include Native Sun Community Power Development, SAGE Renewable Energy Power Authority, American Lung Association (ALA), Center for Energy and Environment, Connexus Capital, eFormative Options, and Minnesota and North Dakota Clean Cities coalitions. This project will build on these and other long-standing relationships and establish regional partnerships to create an enduring local ecosystem increasing Tribal EV use across the Upper Midwest.

The Inter-Tribal EV Charging Community Network will demonstrate various EV applications in underserved Tribal communities by focusing on multiple sub-projects in the target three-state geographic area to determine suitable EV routes and strategies. The project will expand the availability of EVSE, including innovative charging approaches for various settings, such as multi-family housing, school and public transit, and highway travel corridors. The project will also deploy light-, medium-, and heavy-duty EVs to test and demonstrate the different vehicle types in settings that may challenge currently available ranges and capabilities. Robust dissemination of experiences from this project will enable other Tribes and communities to benefit from what will be developed.

Results

Some project outcomes have been slowed due to the COVID-19 pandemic and related supply chain delays, including charging station equipment shipping more slowly than previously expected. The project team is working to connect Tribal nations with vital regional services and the clean energy economy as shown in Table

I.43.1 through procuring and planning installations of new EV charging infrastructure; collecting telematics, usage information, and other baseline data on fossil fuel-powered vehicles that will be replaced by or are used similarly to EVs to be deployed; outlining key performance indicators for new EVs; developing messaging and promotional materials; and conducting education, outreach, and engagement. With most EV orders requiring more than a year lead time, the team is evaluating which waiting lists will be optimal for the project.

Table I.43.1 Budget Period 1 Milestone Progress

Milestone	Description	Details
Level 2 Site Locations Finalized	All locations for public available Level 2 EVSE installations on Red Lake and Standing Rock Reservations determined	Red Lake Trading Post, Red Lake Oshkiimaajitahdah Workforce Center, and Ponemah Trading Post in MN; Sitting Bull College in ND; Grand River Casino and McLaughlin High School in SD
Vehicle Needs Assessment	All fleet participation confirmed	Native Sun, Red Lake Immersion School, Red Lake Fisheries, Red Lake Agricultural Department, Red Lake Family & Children Services, SAGE, Sitting Bull College Prairie Knights Casino, Grand River Casino and Resort, Standing Rock Sioux Tribe (SRST) Transit
Fast Charging Locations	All site locations for Red Lake & Standing Rock DCFC evaluated for suitability	Minneapolis, Seven Clans Casino and Hotel, MN; Sitting Bull College Transit Office, SRST Government Center, and Prairie Knights Casino, ND; Grand River Casino and Native American Scenic Byway (2), SD

The project team has printed spiral notebooks with bright covers and printed log sheets, shown in Figure I.43-1, delivered to each fleet manager for use in tracking baseline and test vehicle use. The team's graphic design partner developed and incorporated input from the project team on the artwork for charging stations exterior, shown in Figure I.43-2. The team agreed to omit individual partner logos in the design and utilize the Electric Nation logo only, creating a sense of unity. A QR code was established for access to project information.

Date	$/gallon or $/kWh	# persons in vehicle (incl. driver)	Trip purpose

Figure I.43-1. Electric Nation vehicle logbooks (Source: CEE/eFormative Options)

The project team created a poster display about the project, shown in Figure I.43-3, and conducted outreach at several events in FY 2022, including:

- August 25 - September 5: Native Sun's Lisa Daniels, ALA's Lisa Thurstin, and several other partners tabled at a project-specific exhibit at the 2022 Minnesota State Fair in St. Paul, Minnesota.
- September 7-8: ALA staff attended the United Tribes Technical College Tribal Leaders Summit in Bismarck, North Dakota, to talk about the project specifics, Level 2 charging, and workforce development programs.
- September 23: ALA staffed an exhibit at the League of North Dakota Cities Conference where they talked about the project and signed up about 25 people to receive information.
- September 27-28: Native Sun's Bob Blake attended and spoke at the Xcel Energy (formerly Northern States Power – Minnesota) EV Workshop for Stakeholders, to discuss the August 2022 Public Utility Commission filing in Minneapolis, Minnesota.

Figure I.43-2. Electric Nation EV charging station artwork (Source: Rusty Gillette/Connexus)

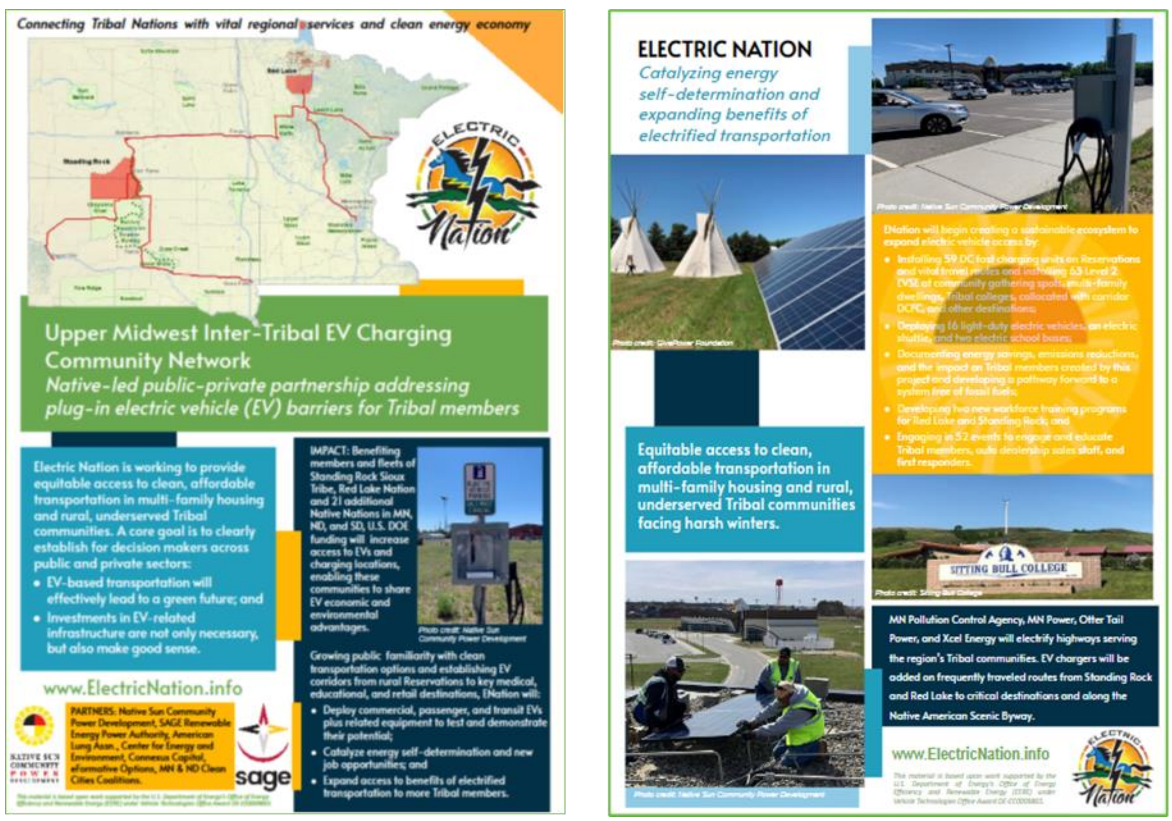

Figure I.43-3. Electric Nation event posters (Source: Native Sun/eFormative Options)

Conclusions

Benefiting members and fleets of Standing Rock Sioux Tribe, Red Lake Nation and 21 additional Native Nations in Minnesota, North Dakota, and South Dakota, DOE funding is demystifying and increasing access to EVs and charging locations, enabling these communities to share EV economic and environmental advantages, reducing hesitancy for their use in cold climates.

Tribal communities continue to be receptive to the placement and use of EV charging stations. Many Tribal departments have been quick to communicate and be active participants in planning EV purchases and have gained knowledge on EV and EVSE capabilities for fleet operations and impacts of cold weather on EVs and charging infrastructure. The team has confirmed viable EV options that can operate for the desired ranges in cold climates. Installing data loggers in vehicles has represented a professional development opportunity for the project team as well as fleet participants. The project team is also advancing workforce development opportunities for Tribal members in renewable energy infrastructure maintenance, including EV fleet maintenance and management.

Key Publications

The team recognizes the importance of documenting its challenges and solutions so that future renewable energy and climate projects can look to this project as a guide. Publicity and media coverage of the project has included:

https://yaleclimateconnections.org/2022/04/two-native-tribes-are-helping-create-an-electric-vehicle-pipeline/

https://www.canarymedia.com/articles/fun-stuff/need-some-earth-day-inspiration-check-out-these-climate-heroes

https://electricenergyonline.com/article/energy/category/climate-change/82/962824/doe-awards-3-6-million-to-promote-equity-and-diversity-in-clean-energy-innovation.html

https://www.roadmapforth.org/RM22/speaker/450810/robert-blake

https://fresh-energy.org/event/powering-up-minnesota

https://www.stevenspointjournal.com/story/entertainment/events/2022/06/14/midwest-renewable-energy-association-energy-fair-returns-custer-june-24-26-after-two-year-hiatus/7543632001/

Acknowledgements

Additional report authors and project administrators include Jon Hunter, American Lung Association/Clean Cities coalitions; Lisa Daniels, Windustry; and Heather Rhoads, eFormative Options LLC.

I.44 Equitable Mobility Powering Opportunities for Workplace Electrification Readiness (EMPOWER) (Columbia-Willamette Clean Cities Coalition)

Michael Graham, Principal Investigator
Columbia-Willamette Clean Cities Coalition (CWCC)
P.O. Box 721
Tualatin, OR 97062
E-mail: michael@cwcleancities.onmicrosoft.com

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

Start Date: April 1, 2022 End Date: June 30, 2025
Project Funding: $5,018,141 DOE share: $3,970,539 Non-DOE share: $1,047,602

Project Introduction

Reliable access to electric vehicle (EV) charging stations at home remains a barrier that prevents many drivers from owning a plug-in vehicle. Workplace charging can provide a pathway for plug-in ownership for those considering an EV and living in apartments, condominiums, or rented single-family homes, where access is severely limited for reliable, onsite, overnight charging stations. Workplace charging helps fill this gap and provides notable benefits to employers in the process by aiding workplaces in employee recruitment, retention, and elevating an organization's sustainability credibility.

The EMPOWER project is providing nationwide consistency for workplace charging resources, conducting valuable research to underscore the importance of these programs, creating a long-term communications framework, and supporting U.S. Department of Energy (DOE) Clean Cities coalitions, utilities, and employers. The project addresses equity issues by increasing workplace charging access and benefits to minority communities, developing career pathways to the EV industry, and incorporating perspectives from diverse underserved communities at every level of project organization.

The EMPOWER team is led by Columbia-Willamette Clean Cities Coalition in partnership with East Tennessee Clean Fuels (ETCF). The project team is comprised of Cadeo, leading data collection/sharing and market barriers report development; University of Tennessee, analyzing collected data; Shift2Electric, developing workplace charging resources and website; Geaux Green, creating the project statement of equity, inclusion, and diversity, along with equity training toolkit/webinars; Innovative Graphics, for printing project outreach supplies; ICF International (ICF), conducting literature and resources review; Center for Sustainable Energy, consulting on data collection/intake, project evaluation, knowledge sharing, and final project report.

The project seeks to accelerate interest and support for workplace charging nationwide by leveraging Clean Cities coalitions, that will refer workplaces to a central resource website housing workplace charging tools, resources, and information, while providing consistent messaging, tactics, and coordination with national data and utility partners. The project has a primary goal of advancing employer commitments for workplace charging programs and installations. Secondary goals include collecting and advancing electric vehicle charging research and increasing career pathways in the EV charging industry for underrepresented communities.

Objectives

The project proposed tasks for Budget Period 1 feature a mix of planning and preparation for future outreach work slated to begin as early as Month 9 of the project. The tasks in Budget Period 1 represent the initiation and planning processes of the EMPOWER project. The project team reviewed existing workplace charging program materials, developed detailed program delivery plans, and established channels of project communications that will last the life of the program.

Success during Budget Period 1 will include developing the necessary resources to arm 30 Clean Cities coalitions as Implementation Partners during the outreach phase of the project, standing up project advisory teams including the Strategic Advisory Team, finalizing project plans, kicking off outreach to workplaces with Implementation Partners, and developing a final Outreach & Dissemination Plan. A more detailed summary of Objectives for Budget Period 1 includes the following:

- Project Management Plan completed.
- Communications and Reporting Plan completed.
- Contracts finalized.
- In-person meeting held.
- Regional Captain kick-off call held.
- Employer interest evaluation plan completed.
- First meeting of Strategic Advisory Team (SAT) held.
- Project schedule finalized.
- Energy and Environmental Justice (EEJ) metrics defined.
- Literature review completed (Cadeo).
- Marketing plan completed.
- Project partner equity toolkit completed.
- Data intake template completed.
- Workplace Charging Resource Center (WCRC), an online platform, launched and available to the public.
- Health and environmental benefits information released on website.
- Final list of employer organizations completed.
- Outreach plan for broadly disseminating the project approach and learnings such that other communities can replicate project successes completed.

Approach

The project will provide resources and support to workplaces in overcoming barriers to installation of workplace charging. Our team will provide data-informed marketing materials, ease of resource sharing, employer engagement, training classes, and recognition for commitments to install workplace charging. The project goal is to engage 2,000 workplaces, and realize 3,500 charger ports installed, with 40% of commitments coming from historically disinvested communities. CWCC together with ETCF will meet the goals by leveraging the project resources with the existing community relationships of 30 Clean Cities coalitions, as Implementation Partners. The project team has started implementation on time and will continue with the Project Management Plan.

The project's Implementation Partners in the form of US DOE Clean Cities coalitions are a core facet of the program to engage with these communities nationwide. These local partners have established relationships with over 30 years of experience in their respective communities. They are the local experts in helping their stakeholders address fundamental barriers to adopting cleaner fuels and technologies, including workplace charging. Clean Cities coalitions will leverage resources, materials, and guidance from the EMPOWER team to foster relationships with local workplaces and help these stakeholders throughout the entire process to successfully install workplace chargers under the EMPOWER project.

Clean Cities Implementation Partners will provide their final lists of workplaces to engage during the Implementation Phase of the project by conducting outreach to workplaces. Coalitions will also provide the project team with individual Outreach Plans to be shared with ICF and compiled into a single project-wide Outreach & Dissemination Plan.

Cadeo will produce a Market Barriers Report literature review summarizing barriers to workplace charging, while ICF will develop a literature review summarizing best practices for recognition, which will directly inform the project's workplace recognition plans. Recognition will take place during Budget Period II.

Regarding internal and external outreach, the project will host a virtual utility workplace charging workshop with the Smart Electric Power Alliance (SEPA) and will similarly host a virtual equity training with project partner Geaux Green.

The project will finalize outreach resources to provide to Clean Cities Implementation Partners. Remaining resources include a one-pager describing the EMPOWER Project and a Workplace Charging one-pager. These resources will be included in updates to the project web-based landing page, housed on workplacecharging.com. Project partner American Lung Association will provide Health & Environmental Benefits of workplace charging, also housed on the website.

Results

The project has made strong progress on the milestones and deliverables outlined in the Statement of Project Objectives (SOPO) and the original Technical Volume (TV).

- The project team finalized the Energy and Environmental Justice (EEJ) Action Plan, Metrics and Toolkit package, aligning with the White House Justice40 Initiative and a major component of the EMPOWER project. The EEJ Action Plan was developed under the EEJ Team's direction with input from key equity experts working on the project, including representatives from Geaux Green and City of Seattle. The EEJ Team met with Geaux Green to determine best practices for the equity component of EMPOWER, create language for EMPOWER's EEJ statement and goals, and create guidance on finalizing the EEJ Action Plan. The EEJ Action Plan is designed to guide the project's implementation work to ensure the EMPOWER project is engaging communities intentionally with equity, the project's EEJ metrics for communities are meeting the project's goal of investing at least 40% of all project work in historically disinvested communities, and the Justice40 Initiative goals are front-of-mind during this engagement. Developing the EMPOWER EEJ Action Plan, Metrics and Toolkit included defining the metrics and variables to accomplish the EEJ portion of the project. This includes the internal EEJ variables for the project team, as well as external EEJ variables for the workplaces and communities served through the EMPOWER project.

- CWCC is one of three concurrent DOE-funded workplaces charging projects. CWCC attended regular weekly planning meetings with the other two DOE-funded workplace charging projects led by Forth Mobility and CALSTART. These meetings were facilitated by ICF, which is funded by the

EMPOWER project for this coordination work. The meetings have been focused primarily on coordinating efforts to reduce duplication or redundancy in workplace outreach. Discussions also centered on data management, website development, and coordinating the unique outreach focuses of each project. EMPOWER and Charge@Work have agreed to use separate websites and branding for the overall initiative to capture multiple audiences and appeal to a wide variety of stakeholders. Tri-project planning meetings have changed from weekly to monthly with the implementation of EMPOWER.

CWCC developed a monthly progress report template for subrecipients to complete when submitting invoices as a tracking and feedback mechanism. A complete summary of project accomplishments and remaining work can be found in Table I.44.1, Project Milestones Log.

Table I.44.1. Project Milestones Log

Date	Result	Source	Description	Status
July 30, 2022	Deliverable	TV*	Project Management Plan completed	Complete
Rescheduled from July 30, 2022 to Feb 28, 2023	Output	TV	Communications and Reporting Plan completed	In-Progress
Rescheduled from August 1, 2022 to Jan 25, 2023	Output	TV	Contracts finalized	In-Progress
August 17, 2022	Output	TV	In-person meeting held	Complete
September 15, 2022	Output	TV	Regional Captain Kick-off Call held	Complete
September 20, 2022	Output	SOPO**	Employer interest evaluation plan completed	Complete
September 15, 2022	Technical	TV	First meeting of Strategic Advisory Team (SAT)	Complete
September 30, 2022	Output	TV	Project Schedule finalized	Complete
November 1, 2022	Output	Other	EEJ Metrics defined	In-Progress
Rescheduled from November 30, 2022 to March 15, 2023	Deliverable	TV	Literature Review completed (Cadeo)	In-Progress
Rescheduled from December 1, 2022 to March 30, 2023	Deliverable	TV	Marketing Plan completed	In-Progress
Jan 1, 2023	Deliverable	TV	Project Partner Equity Toolkit completed	In-Progress
Jan 30, 2023	Output	TV	Data Intake Template completed	In-Progress
Feb 28, 2023	Deliverable	SOPO	Workplace Charging Resource Center (WCRC, an online platform) launched and available to the public	In-Progress
Rescheduled from March 15, 2023 to May 15, 2023	Output	SOPO	Health and environmental benefits information released on website	In-Progress

Date	Result	Source	Description	Status
March 30, 2023	Deliverable	SOPO	Final list of employer organizations completed	In-Progress
June 1, 2023	Go/No-go	SOPO	Outreach plan for broadly disseminating the project approach and learnings such that other communities can replicate project successes completed	In-Progress

*Technical Volume

**Statement of Project Objectives

Conclusions

Overall, the project is moving forward well, and CWCC is in the process of hiring a new Project Manager as of September 30, 2022. Project objectives are on track for completion by the end of Budget Period I, including the Go/No-Go Milestone of an Outreach Plan for broadly disseminating the project approach and learnings such that other communities can replicate successful projects. The project is in good financial standing, and we expect to complete the work on schedule.

I.45 Charge to Work USA (CALSTART)

Benjamin Mandel, Principal Investigator
CALSTART
67 35th Street, Suite B508
Brooklyn, NY 11232
E-mail: bmandel@calstart.org

Michael Laughlin, DOE Technology Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

Start Date: April 1, 2022 End Date: June 30, 2025
Project Funding: $5,040,747 DOE share: $3,999,994 Non-DOE share: $1,040,753

Project Introduction

As electric vehicle (EV) options expand to meet more drivers' transportation needs, access to reliable, convenient, and affordable charging is a paramount determinant of EV adoption. With EVs recently surpassing 5% of new car sales nationwide [1], more charging facilities will be necessary to support mass market levels of EV adoption by 2030. In much of the country, workplaces centrally host vehicles for eight or more hours on working days, which presents immense opportunity to support large-scale EV adoption through the addition of charging stations to office parking lots.

However, the effort, time, cost, and challenge of installing EV charging makes workplace charging (WPC) an uncertain proposition for employers. WPC does not always present employers with a business case in terms of revenue generation, employee satisfaction and retention, or sales growth. Many employers are also not well informed on the options for and benefits of implementing a workplace charging program and will need education and some degree of consulting before they are ready to make a commitment to a WPC program. This may require customization and analysis of third-party service options, based on the workforce, facility, and owner preferences and constraints.

Charge to Work USA aims to create a self-sustaining national market for WPC, spur greater EV adoption by enhancing driver confidence in charger availability, and expand access to electric mobility in disadvantaged communities. A national EV workplace charging program can provide the awareness, education and technical assistance needed to help employers understand the technology and its benefits. There are multiple tiers of beneficiaries, including the business, employees, the environment, and our economy. Charge to Work USA galvanizes greater interest among electric vehicle supply equipment (EVSE) vendors, who until now have perceived WPC projects as low-return undertakings. These vendors thus welcome a means to funnel employers of all types into an intuitive, streamlined and highly automated platform that reduces soft and hard costs, including consulting, planning, and implementation time and effort. Charge to Work USA will significantly reduce costs for all stakeholders in the process (including customer acquisition costs for vendors), spur installation of convenient EVSE at places of business, and ultimately animate greater EV adoption.

Objectives

The objective of Charge to Work USA is to develop and execute a nationwide workplace charging program comprised of education, outreach and technical assistance activities that enables a large-scale increase in WPC. Working in close coordination with companion DOE-funded WPC campaigns under the Charge@Work and EMPOWER brands, the project will gain more than 1,000 employer commitments (100 of which will be from large employers) to adopt WPC programs and install charging ports at their workplaces, with the end goal of catalyzing more than 100,000 EVSE port installations in total.

Approach

Charge to Work USA will reshape workplaces nationwide into charging hubs for electric commutes through a multipronged strategy based upon the following pillars:

- Launching a public influence and recognition campaign in partnership with supportive public officials.
- Conducting outreach and education to employers throughout the country, focusing on large national employers to lead high-volume WPC implementation.
- Providing technical implementation assistance for private and public sector employers to help identify and select EVSE and support installation with complimentary site assessments.
- Developing and disseminating resources to assist employees in advocating for WPC.

Influence and Recognition Campaign: In partnership with the Climate Group's Under2 Coalition and additional sustainability networks of elected leaders across the United States, CALSTART aims to secure endorsements of the Charge@Work program from at least 200 public/elected officials. Charge to Work USA is developing and implementing a national campaign to engage public officials who are committed to transportation electrification, and to support them by working with EVNoire and Clean Cities coalitions in strategic locations of the country to host workplace charging rallies and showcase events. Project partner Northeast States for Coordinated Air Use Management (NESCAUM) will compile case studies for at least eight exemplary WPC programs spanning a diverse range of employer types.

Employer Recruitment: Working in coordination with the other Charge@Work campaigns, Charge to Work USA aims to recruit a total of 1,000 employers to commit to WPC by signing the Charge@Work pledge. Our team will generate social and earned media to recruit diverse employers to participate in the campaign. Participants that sign the Charge@Work employer pledge will qualify for tailored technical assistance with implementing a WPC program. The project team will emphasize enterprise-wide commitments from large employers (>500 employees) by leveraging major corporate sustainability networks such as the EV100 campaign convened by the Climate Group. In total, Charge to Work USA will recruit a minimum of 100 large employers to account for the bulk of the 100,000 EVSE port commitment target, supplemented by smaller port commitments from 900 small (≤50) and midsize (51-500) employers (see Table I.45.1).

Table I.45.1. Annual Program Targets for Employer Recruitment

Employer Size (# Employees)	Large (>500)	Medium (51-500)	Small (1-50)
Budget Period 1	10	25	75
Budget Period 2	40	75	225
Budget Period 3	50	125	375
Total	100	225	675

Technical Implementation Assistance: Our team will design, develop, operate, and maintain an online Workplace Charging Resource Center (WCRC) to function as a centralized resource hub for workplace charging information and implementation nationally. This platform will provide customized WPC resources for employers, employees, municipalities, and industry, and enable WCRC visitors to request ride-and-drive events. The WCRC will include a dedicated Implementation Portal to walk employers through EVSE implementation, including EVSE comparison, site assessment and planning, and financial projections. The web platform will also host an employer certification module developed in collaboration with Forth's EVAL program.

Data Collection and Analysis: The Charge to Work USA team will collect and analyze data to measure the internal and external performance of the Charge@Work program, and to understand how best to educate and motivate employers and assist them as they commit to and implement WPC programs. The team will undertake data collection and analysis to monitor internal performance including efforts to effectively lead, control and continuously improve WPC campaign efforts. Further, the team will empirically observe external performance and market conditions, such as the evolution of EV consumer perception and knowledge, the change in EVSE equipment, installation, and customer acquisition costs over time, and the effectiveness of WPC efforts in catalyzing EV adoption and EVSE utilization. Data collection and reporting will cover multiple aspects of program performance including technical and cost data from installations, geographic progress in implementing WPC programs, behavioral and planning data about employers and employees, data about WPC program decisions by employers, and data from EV charger operations.

The project will be conducted across three budget periods:

Lay the Foundation for Workplace Charging Nationwide (Budget Period 1):

During the first budget period, we are prioritizing coordination with fellow WPC grantees to develop a unified Charge@Work brand and associated collateral. We will build and launch the Workplace Charging Resource Center (WCRC), a program website that will contain WPC resources such as best practices guides, case studies, and employee advocacy materials, as well as an Implementation Portal where employers can receive tailored technical assistance to streamline WPC selection, planning, and execution. We are developing initial versions of the Employer Recruitment Strategy, Data Collection Plan, and Outreach/Dissemination Plan, and beginning to work with partners to obtain commitments and endorsements from large employers and public officials alike. We will hold multiple influence campaign events featuring supportive officials and businesses, some of which will feature ride-and-drives to promote EV awareness among employees and the general public.

Gain Momentum in Workplace Charging Implementation (Budget Period 2):

In the second budget period, our team will emphasize large-scale employer recruitment and provision of extensive technical assistance through the online Implementation Portal. We will continue to convene workplace charging rallies and other public events with public officials to promote WPC, showcase leading employers, and prepare written case studies to profile exemplary employers. We will present on program progress and preliminary/interim results at the Vehicle Technologies Office's Annual Merit Review. We will begin developing a white paper describing best practices for utility programs to support workplace charging. We will update the Employer Recruitment Strategy, Data Collection Plan, and Outreach/Dissemination Plans.

Create a Self-Sustaining Market for Workplace Charging (Budget Period 3):

In the third budget period, our team will continue to conduct employer recruitment and to provide technical assistance through the online Implementation Portal, with emphasis on completing as many EVSE installations as possible before the project period expires. We will develop a funding model to sustain the operation and maintenance of the WCRC following the conclusion of the grant. We will continue to convene workplace charging rallies and other public events with public officials to promote WPC and showcase leading employers and prepare additional written case studies to profile exemplary employers. We will present on program progress and preliminary/interim results at the Vehicle Technologies Office's Annual Merit Review. We will finalize and publish the white paper describing best practices for utility programs to support workplace charging. We will make final updates to the Employer Recruitment Strategy, Data Collection Plan, and Outreach/Dissemination Plans and complete a final report for the program.

Key Publications

Project landing page: https://chargetoworkusa.org/

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Acknowledgements

CALSTART acknowledges the partnership of the full Charge to Work USA team, which includes EVNoire, the Climate Group, NESCAUM, ZappyRide, Qmerit, National Grid, EVgo, Edison Electric Institute, Empire Clean Cities, Eastern Pennsylvania Alliance for Clean Transportation, Pittsburgh Region Clean Cities, Drive Clean Colorado, and Northern Colorado Clean Cities Coalition. We would like to express gratitude for the support and guidance we have received for this grant from our NETL program manager, Brett Aristegui, and contract administrator, Maureen Davison. We also acknowledge the productive collaboration and coordination we have enjoyed with companion teams, LEEP (led by Forth) and EMPOWER (led by Columbia-Willamette Clean Cities), which were funded in parallel by DOE from the same area of interest.

I.46 Project Sila: An Arctic CNG Pilot Test Program

Hans Hoffman, Project Manager
ASRC Consulting & Environmental Services, LLC
3900 C. St., Suite 701
Anchorage, AK 99516
hahoffman@asrcenergy.com

Keith Patterson, Principal Investigator
ASRC Energy Services Equipment
3900 C. St., Suite 701
Anchorage, AK 99516
kpatterson@asrcenergy.com

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

Start Date: March 11, 2022 End Date: May 31, 2025
Project Funding: $2,128,154 DOE share: $1,064,076 Non-DOE share: $1,064,078

Project Introduction

The overall objective of this project is to successfully demonstrate how compressed natural gas (CNG) vehicles can reduce greenhouse gas emissions and be adopted at a larger scale across the Prudhoe Bay oilfield. ASRC Consulting & Environmental Services, LLC (ACES) will purchase two CNG heavy-duty (Class 8) trucks fitted to serve the Deadhorse, Alaska area in water and liquid waste hauling. To support these trucks, a CNG compressor and a fueling station will be engineered and installed at the ASRC Energy Services (AES) fleet and maintenance facility in Deadhorse. AES will operate and maintain the vehicles and the refueling station. AES will collect data from these activities on performance, costs, and emissions to demonstrate the advantages of CNG operations in remote, arctic locations. This project commenced in March 2022 with an anticipated completion in June of 2025. If successful, this may result in a nearly 40% reduction in greenhouse gas emissions and lower operating costs for the Deadhorse and Prudhoe Bay area.

The goals for Budget Period 1 are to purchase two CNG heavy-duty trucks and modify them for arctic operation as well as install a CNG compressor and fueling station at AES facilities in Deadhorse. ACES has ordered the trucks and truck procurement is on track with the project schedule. Discussions with CNG compressor and fill station vendors have been delayed due to lack of familiarity with Prudhoe Bay gas. The gas contains elevated levels of CO_2 and H_2S, and the primary concern from vendors is the CO_2. When compressed, the CO_2 will be highly corrosive to engine components both at the compressor and in the truck. ACES is currently working to resolve these issues by evaluating the practicality of proceeding with this inherent risk and by researching CO_2 and H_2S treatment options. ACES plans to order the CNG compressors and fill station in Budget Period 1 but does not intend to receive them until Budget Period 2.

Objectives

The primary objective of this study is to prove CNG trucks can operate in the arctic using a readily available fuel source that is more economical and reduces greenhouse gas emissions. After the initial pilot study is complete ACES believes CNG will be adopted at a greater scale across the North Slope utilizing an expanded fleet of CNG powered vehicles.

To achieve these objectives ACES will select and procure the necessary equipment in year one; install, implement, and monitor the CNG compressors, fill station, and trucks in year two; and continue implementation and monitoring in year three.

Approach

AES will introduce two vocational CNG trucks into its existing fleet of equipment in 2023. AES will train operators and adjust schedules to accommodate the inherent nature of CNG use. Fueling the CNG trucks will utilize the time-fill method, which will require operators to connect to the fill station at the end of the shift to ensure trucks are full at the start of the next work shift. AES will monitor emissions and record metrics to prove the efficiency and reliability of the system.

Accomplishments

ACES has placed orders for two Kenworth T880 CNG trucks, one equipped with a Westmark 90bbl vac unit and one equipped with a Westmark potable water unit. ACES has also selected a CNG compressor and fill station provider. After talking in detail with six potential providers, ACES has chosen Onboard Dynamics to provide up to 2 50-horsepower (80 SCFM) compressors with one time-fill dispenser. Onboard Dynamics has been made aware of our decision to proceed with their configuration, and ACES anticipates finalizing the purchase agreement in Q1 2023.

ACES is currently awaiting build dates for the trucks. In the interim, ACES is evaluating the feasibility of upgrading the 90bbl vac unit to a 150bbl unit which it believes will provide increased efficiency.

During the next reporting period, ACES will place orders for the CNG compressor(s) and fueling station and continue engineering and design. There are potential concerns about the gas composition's effects on the truck engines and compressors. ACES will monitor these effects and modify maintenance schedules accordingly.

Results

There have been no results to report on to date.

I.47 Solutions for Curbside Charging Electric Vehicles for Planned Urban Growth (UNC Charlotte)

Robert Cox, Principal Investigator
Energy Production and Infrastructure Center (EPIC) at The University of North Carolina at Charlotte
9201 University City Boulevard
Charlotte, NC 28223
E-mail: Robert.cox@uncc.edu

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

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 University of North Carolina at Charlotte (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.

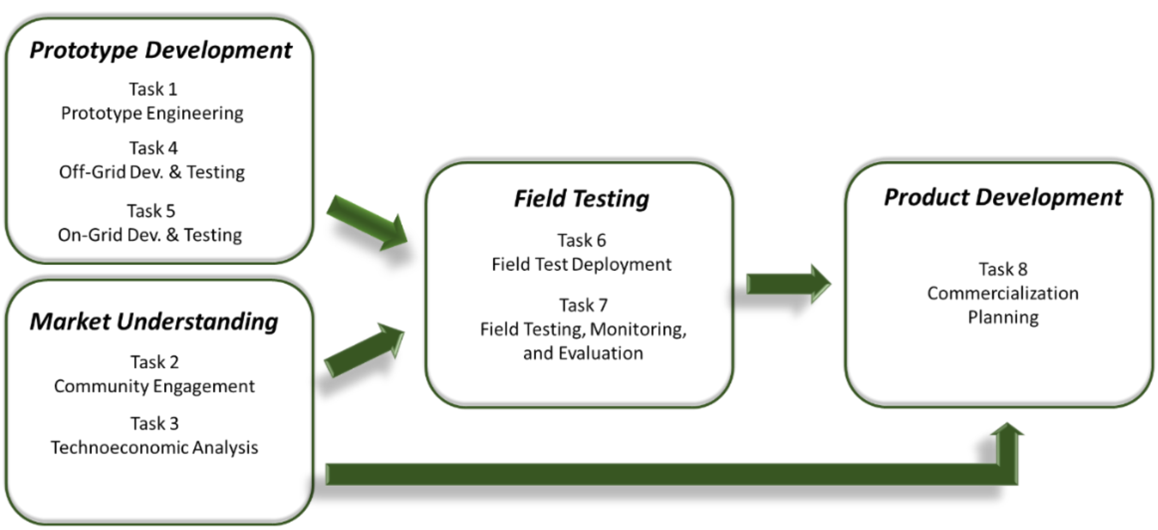

Figure I.47-1. Prototype charging station deployed on the campus of UNC Charlotte

Figure I.47-1 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.

Results

The first two budget periods focused on the two leftmost boxes shown in Figure I.47-1. 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. The team developed this platform using a cloud infrastructure that can be scaled to include thousands of charging stations.

Throughout 2021, the team leveraged its learnings from the initial stations deployed at UNC Charlotte to develop a commercial prototype. Figure I.47-2 shows the first on-street station deployed in the City of Charlotte. This unit, which is known as PoleVolt™, was opened to the public on February 24, 2022. The unit is installed on a streetlight pole fed from an overhead electric distribution circuit. 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.

Figure I.47-2. The first on-street station deployed in the City of Charlotte, known as PoleVolt™.

Figure I.47-3 shows the grand opening of the first station. The system was continuously operational throughout its first year of deployment and has been used approximately once every four days.

Figure I.47-3. UNC Charlotte student demonstrating the PoleVolt™ to North Carolina Governor Roy Cooper.

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 challenge 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

The project team would like to thank Duke Energy, Eaton Corporation, and the City of Charlotte for their support. The team also would like to recognize the efforts of Trevelyn Hall, the project's NETL manager.

I.48 Electrifying Terminal Trucks in Un-Incentivized Markets (Metropolitan Energy Center)

Kelly Gilbert, Principal Investigator
Metropolitan Energy Center
300 E 39th St.
Kansas City, MO 64111
E-mail: kelly@metroenergy.org

Margaret Smith, DOE Technology Development Manager
U.S. Department of Energy
E-mail: Margaret.smith@ee.doe.gov

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 40-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 25 years of experience working with alternative fuel vehicles of all types. This project, Electrifying Terminal Trucks in Un-Incentivized Markets, simultaneously fulfills aspects of MEC's energy transformation strategy and meets 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 demonstrates 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 metropolitan area, 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 U.S. and Canada for manufacturers and retailers. Lazer Spot, which acquired Firefly Transportation, deployed two trucks in the Chicago metropolitan area. One of their deployments is Orange EV's all new T-Series Tandem terminal truck. First deployed under this project, the customer-driven tandem axel model spreads weight over an additional axel and is designed to legally transport loads up to 81,000 pounds on public roads.

- Johnson County Wastewater Department deployed one truck running trailers for solids at their new wastewater treatment facility located in Leawood, KS. Johnson County is one of fourteen counties in the Kansas City metropolitan area. Figure I.48-1 shows the truck at its deployment location, during an interview for production of an informational video.

Figure I.48-1 Blue Symphony, a Kansas City-based marketing agency, interviews a vehicle operator at Johnson County's wastewater treatment facility.

- Hirschbach Motor Lines, a private long-haul carrier with emphasis on refrigerated and other specialized services, deployed one truck at a client site in Wyandotte County, KS, located in the Kansas City metropolitan area.

- Orange EV manufactured a demonstration truck that is available for use by interested fleets across the U.S. at no cost except for a shipping fee of $500. The truck has been to more than 20 demonstration sites since 2020.

Approach

In addition to telematics and data collection, the project team held 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 was 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. The team also generated an informational video under the production of local contractor Blue Symphony, which shot footage and conducted interviews at each deployment location. Successful workshops with follow-up surveys and meetings will generate new strategic deployment opportunities.

In year three of the project, MEC worked with Orange EV and the pilot fleets to present the project at a national conference. Analysis of all project data is also underway, with a research report intended to provide a reliable basis for replication, as well as 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, the pilot fleets deployed four trucks, and Orange EV built and deployed the demonstration vehicle. In 2021 MEC focused on data collection and community outreach, which continued into 2022. In 2022 Penn State University began analysis of qualitative and quantitative data collected from the deployments, roundtables, questionnaires, and interviews.

- 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 questionnaires to the pilot fleets. The questions focused on the following topics: pre-deployment, charging infrastructure, telematics, and vehicle operation and maintenance.
- More than 20 fleets across the U.S. have utilized the demonstration vehicle. MEC continues to work with Orange EV to ensure the demonstration fleet questionnaires are completed and to connect the users to additional resources when requested.
- In October 2021, MEC hosted a virtual community workshop, *Electrifying Terminal Trucks: Best practices and lessons learned from deployments in the Kansas City region and beyond*. The pilot fleets, Orange EV, the project researcher from Penn State, and Kansas City's electric utility each shared their real-world experiences with zero-emission freight handling in a roundtable format. Its recording is available on our project web page and YouTube channel and has been viewed 62 times.
- Produced in late 2021 by MEC contractor Blue Symphony, DRIVING THE FUTURE with Electric Terminal Trucks is an informational video that has been viewed nearly 400 times. It demonstrates 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. The video is available on our project website and at our YouTube channel.
- Orange EV has sold and/or leased 27 trucks thanks to the demonstration vehicle funded through the project.
- In April 2022, MEC staff, Orange EV, PennState, and pilot fleet participant Lazer Spot participated in a fleet electrification panel at Green Transportation Summit and Expo in Tacoma, WA. The session was titled, Zero-Emission Freight Handling: Making the Case with Electric Yard Trucks, and the moderator was Karl Pepple, West Coast Collaborative Lead, EPA Region 10. He presented on the project to a full room and then opened the floor for questions. Questions were mostly related to infrastructure requirements, vehicle technology, and barriers to implementation. The engagement from the audience, training received via conference sessions, and relationship building throughout the conference made the trip a success.

Upcoming Activities

With our researcher moving from one university to another in early 2022, the analysis work was delayed by several months. MEC has requested an extension into 2023, during which time the wrap-up work of drafting and delivering reports and fleet resources will conclude.

Conclusions

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

Key Publications

Video: Driving the Future with Electric Terminal Trucks.
Webinar video: Electrifying Terminal Trucks: Best practices and lessons learned from deployments in the Kansas City region and beyond

Acknowledgements

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

II National Laboratory Projects

II.1 AFLEET Tool (Argonne National Laboratory)

Andrew Burnham, Principal Investigator
Argonne National Laboratory
9700 S. Cass Ave.
Argonne, IL 60439
Email: aburnham@anl.gov

Margaret Smith, Technology Development Manager
U.S. Department of Energy
E-mail: margaret.smith@ee.doe.gov

Start Date: October 1, 2021 End Date: September 30, 2022
Project Funding (FY 2022): $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), heavy-duty vehicles (HDVs), and off-road equipment, 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.

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 11,000 individuals for the spreadsheet and 11,200 for the online version. The primary audiences for this tool are Clean Cities directors, 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 FY 2022, the AFLEET Tool had several factors that needed updating. 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 [5].

In FY 2022, Argonne began developing a calculation method to estimate emissions from Infrastructure Investment and Jobs Act (also known as the Bipartisan Infrastructure Law, or BIL) proposals for the discretionary funding for alternative fuel refueling infrastructure. In addition, Argonne began developing a calculation methodology to examine the costs of charging electric vehicles.

Approach

Argonne used the GREET 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. GREET 2021 added the capability to examine the environmental impacts of vehicle production for three (3) HDV types. AFLEET has seven (7) HDV types based on EPA MOVES categories, and therefore needed to expand upon GREET's modeling capabilities. Argonne collected data on component level weights from Argonne's Autonomie model simulations and modified GREET to estimate the vehicle production emission impacts for the remaining types [6]. 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 to account for the latest data.

Argonne developed a public electric vehicle charging emissions calculator for AFLEET 2019 to support actions under the Volkswagen Settlement. Building on this methodology, Argonne expanded its capabilities to examine the emission impacts of refueling infrastructure projects to include hydrogen, propane, and natural gas. The calculator allows users to examine emission reductions from a baseline fuel (i.e., gasoline or diesel) based on fueling infrastructure utilization, vehicle mix, and feedstock type.

In addition to emission analysis of electric vehicle charging infrastructure, Argonne began developing a utility rate calculator to estimate the cost of residential, public, and fleet electric vehicle charging based on site charging characteristics including utility rate design, charger power, charger period of use, and charging strategy. The underlying rate data used in the calculator is from the Utility Rate Database [7]. Argonne built the calculator to handle a wide range of rate design, including time-of-use structures for both energy and demand charges. The calculator estimates the total electricity dispensed and maximum electricity demand on an hourly basis for both summer and winter periods. From the utility rate design, the calculator outputs energy charges, demand charges, and fixed charges to estimate a total annual electricity bill, as well as an amortized cost per kilowatt-hour.

Results

During FY 2022, users downloaded the AFLEET Tool about 900 times, and the accompanying AFLEET user manual about 2,300 times. To date, 11,000 individual users have downloaded the tool. The user-friendly AFLEET online tool released in FY 2019 had more than 11,200 new users.

Conclusions

In FY 2022, 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 and charging costs. In addition, Argonne developed a calculator to help stakeholders estimate the cost impacts of alternative fuel off-road equipment.

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[6] Argonne National Laboratory, 2022. Autonomie, https://vms.taps.anl.gov/tools/autonomie/.

[7] National Renewable Energy Laboratory, 2022. Utility Rate Database, https://openei.org/wiki/Utility_Rate_Database.

Acknowledgements

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II.2 EcoCAR Advanced Vehicle Technology Competition (Argonne National Laboratory)

Kristen Wahl, Principal Investigator
Argonne National Laboratory
9700 South Cass Avenue, Bldg. 362
Lemont, IL 60439
E-mail: kwahl@anl.gov

Jesse Alley, Principal Investigator
Argonne National Laboratory
9700 South Cass Avenue, Bldg. 362
Lemont, IL 60439
E-mail: ralley@anl.gov

Connie Bezanson, DOE Education and Outreach Manager
U.S. Department of Energy
E-mail: connie.bezanson@ee.doe.gov

Start Date: October 1, 2021	End Date: September 30, 2022	
Project Funding (FY 2022): $4,400,000	DOE share: $3,000,000	Non-DOE share: $1,400,000

Project Introduction

The U.S. Department of Energy (DOE), 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 consumer acceptability, safety, and cost considerations. EcoCAR teams are following General Motors' (GM) 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 fourth and final year, culminating with a battery of vehicle evaluations and technical presentations at Year 4 Final Competition in May of 2022.

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.2.1 lists the universities participating in the EcoCAR Mobility Challenge along with the abbreviations used in this report.

Table II.2.1. Teams Participating in the EcoCAR Mobility Challenge Year

University	Abbreviation	University	Abbreviation
Embry-Riddle Aeronautical University	ERAU	University of Tennessee	UT
Georgia Institute of Technology	GT	University of Washington	UW
McMaster University	MAC	University of Waterloo	UWAFT
Mississippi State University	MSU	Virginia Tech	VT
The Ohio State University	OSU	West Virginia University	WVU
University of Alabama	UA		

Approach

FY 2022 roughly aligned with the fourth and final year of the EcoCAR Mobility Challenge. This 4-year competition series launched in August of 2018 and ran through May of 2022. Over the four years of the EcoCAR competition, each team designed, built, and tested 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 (99% complete)

- Final ("production-ready") integration.
- Propulsion system is fully functional and can operate in all modes and reliably complete all mode transitions.
  - Vehicle propulsion controller contains fully functional advanced energy management strategies that were previously tested in the appropriate/available simulation environments (Model in the Loop [MIL] and/or Hardware in the Loop [HIL]).

  - Vehicle propulsion controller contains fully functional advanced fault detection and diagnostic strategies (e.g., limp modes, fault mitigation, etc.) that were previously tested in the appropriate/available simulation environments (MIL and/or HIL).

- Functionality on team vehicle at competition.

  - Propulsion system is reliable, breakdowns are infrequent.

  - Propulsion system supervisory controls are refined to optimize fuel economy and drive quality.

  - Vehicle ride quality and emissions are maintained at baseline vehicle level of quality.

  - Team vehicle completes all events with propulsion system is operating as intended.

CAV System Goals (90% complete)

- Simulate linear autonomy and energy consumption on Vehicle-to-Vehicle (V2V)-equipped highways and corridors with several Infrastructure-to-Vehicle (I2V) intersections.

- Achieve full speed range linear autonomy and refine for fuel efficiency and drive quality.

- Demonstrate successful vehicle control in response to Vehicle-to-Everything (V2X) inputs (vehicles, traffic signals, etc.).

- Functionality on team vehicle at competition:

  - Refined perception system with functional forward and capabilities.

  - Refined full speed range linear autonomy, including completion of both urban and highway drive cycles.

  - Adaptive Cruise Control (ACC) system is capable of re-engaging after the vehicle has come to a stop.

  - Perform partially automated eco-approach and departure at signalized intersections broadcasting I2V signals.

To assist teams in meeting these year-end goals, the competition held two in-person vehicle events prior to the year-end competition event. The first was a Workshop and Vehicle Evaluation (WAVE) in October 2021 at General Motors' Milford Proving Ground in Milford, Michigan. The Fall WAVE event accomplished two main objectives:

- Teams received training on their Cohda Wireless digital short-range communication (DSRC) radios. Teams used these for V2X applications, including the Connected Mobility Challenge during Year 4 competition.

- Each team vehicle received a thorough safety inspection by a group of competition inspectors. This was the first full vehicle inspection the team vehicles received during the Mobility Challenge due to COVID-19. (Vehicles are usually inspected multiple times per year starting in Year 2.) This inspection gave teams a clear list of safety issues to resolve prior to the year-end competition, which was a critical enabler to success during competition.

The second in-person event brought all teams and EcoCAR vehicles to the Transportation Research Center in East Liberty, Ohio in March 2022. Argonne personnel used this event to conduct a full-scale dry run of the Energy Consumption and Connected Mobility Challenge events that were scheduled to be run at the year-end competition. EcoCAR teams were able to test their vehicles using the actual test plan and test equipment that were to be used during the year-end competition. It also allowed the EcoCAR organizers to improve the test plan before the final competition event in May.

The final competition event for Year 4 of the Mobility Challenge was held in Yuma and Phoenix, Arizona. The event kicked off at General Motors' Desert Proving Grounds where team vehicles were challenged to complete a variety of dynamic vehicle testing events. Teams then drove their EcoCAR vehicles 175 miles from Yuma to the Phoenix International Raceway in a scored Over-the-Road event modeled after industry standard "Buyoff Rides". In Phoenix, team vehicles were evaluated for Consumer Appeal and teams delivered a variety of presentations to industry experts. Table II.2.2 summarizes the scored events that evaluated EcoCAR team performance during Year 4 Final Competition.

Table II.2.2. Vehicle Events and Presentations during Year 4 Final Competition

Vehicle Events		Judged Presentation Events
On-Road Safety Evaluation	CAV Perception System Evaluation	HMI/UX Presentation
CAV Safety Check	ACC System Evaluation	Propulsion Systems Integration Presentation
0-60 MPH Acceleration	ACC-Enabled Energy Consumption	Propulsion Controls & Modeling Presentation
Drive Quality Evaluation	Connected Mobility Challenge	CAV System Presentation
Over-the-Road Event	Consumer Appeal Event	Project Status Presentation
Human-Machine Interface & User Experience System Evaluation		Communications Presentation

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.2.3 summarizes total student participation during the 4-year EcoCAR Mobility Challenge series.

Table II.2.3. EcoCAR Mobility Challenge Student Participation by Major (to date)

	Total	% of Total	STEM?
Mechanical Engineering	1020	38.5%	Y
Electrical/Computer Engineering	604	22.8%	Y
Computer Science & Software Engineering	293	11.1%	Y
Mechatronics Engineering	153	5.8%	Y
Other STEM Majors	360	13.6%	Y
Non-STEM Majors	216	8.2%	N
Total	**2646**	**100%**	--

EcoCAR students secured internships, co-ops, and full-time jobs at a wide variety of companies; a total of 276 employers hired EcoCAR students during the EcoCAR Mobility Challenge. These employers are illustrated in the word cloud shown in Figure II.2-1. EcoCAR students found employment in a vast array of industries and geographic locations, but automotive industry companies are the number employer of EcoCAR students and hired students at a rate two times higher than any other industry sector. Additionally, EcoCAR students who accepted full-time jobs during this period commanded a salary premium compared to their non-EcoCAR peers, earning $5,500-$14,400 more in their first full-time professional job after graduating (depending on major).

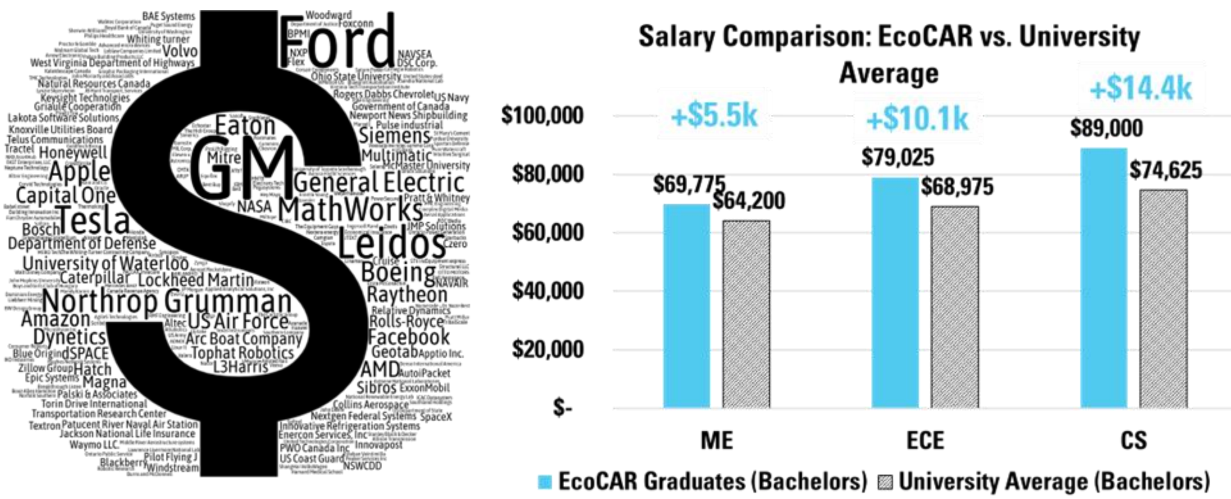

Figure II.2-1. EcoCAR student employers and salary outcomes

EcoCAR Team Local Outreach Activities

EcoCAR teams conducted a total of 22 youth outreach events, 11 campus events, and 10 community events to promote EcoCAR, clean energy, and STEM opportunities. These events reached a total of 4,576 students and 4,627 community members.

CAV Testing and Technology Demonstration

The competition organizers piloted a novel approach for energy consumption testing during Year 4 Final Competition. Argonne developed a system that enabled a Chevy Blazer to drive a full-feature drive cycle (such as the EPA Highway Fuel Economy Test [HwFET]) in a controlled and repeatable manner. This vehicle was used as the lead vehicle in an Energy Consumption test where EcoCAR team vehicles followed with their team-designed ACC systems engaged. The automated lead vehicle completed a pre-defined drive cycle and the energy consumption of the EcoCAR vehicle (following with ACC engaged) was measured after the test was complete (via gravimetric fuel measurement). This novel test procedure was successful in enabling teams to test the energy consumption impacts of their ACC system over standard EPA drive cycles without the need for an elaborate lab testing environment. It also allowed the EcoCAR organizers to repeat the test many times for numerous EcoCAR vehicles and use the results to compare EcoCAR teams for the purposes of scoring the EcoCAR competition. Argonne researchers have subsequently used data from this test beyond the EcoCAR program to further explore the impacts of ACC system design.

EcoCAR Competition Vehicle Testing and Overall Results

All EcoCAR teams were challenged to meet the following testing goals prior to Year 4 Final Competition:

- Accumulate at least 1200 total test miles with at least 300 test miles evaluating longitudinal control systems (e.g., ACC)

- Log a continuous drive of at least 200 miles with an average speed of at least 35 MPH. Spurred on by these goals, EcoCAR teams logged more than 20,000 combined test miles prior to the year-end competition.

Figure II.2-2. breaks down the test mileage accumulated by each EcoCAR team during Year 4.

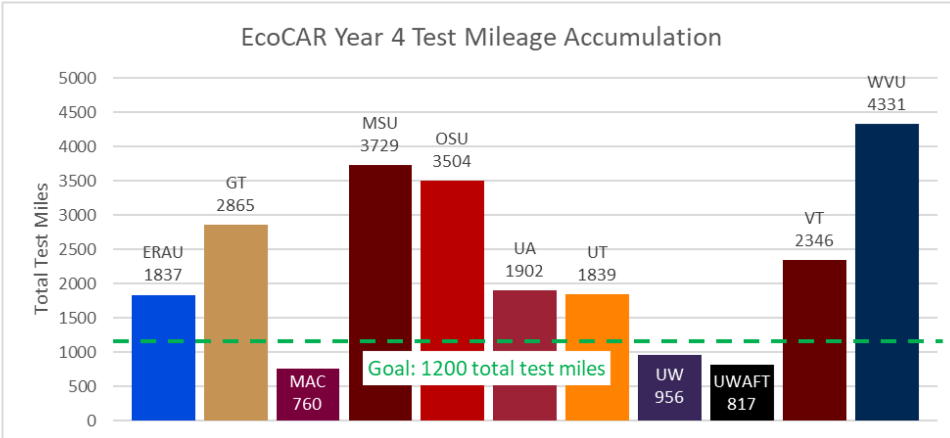

Figure II.2-2. EcoCAR Mobility Challenge team test mileage accumulation during 2021-2022 academic year

During Year 4 Final Competition, all teams produced a running vehicle and a majority of the teams achieved major functionality goals:

- Nine of 11 team vehicles qualified for and completed the 175-mile drive on public roads from Yuma to Phoenix in extreme temperatures (>105 deg F) without breaking down.
- Eight of 11 teams demonstrated a team-developed ACC system with full speed range.
- Seven of 11 teams demonstrated the ability to autonomously navigate a signalized intersection using vehicle-to-infrastructure technology.

Table II.2.46 summarizes the top three overall teams and the teams with the best Project Management and Communications programs.

Table II.2.4. Summary of Award Winners from Year 3 EcoCAR Mobility Challenge Final Competition

Award	Winner
1st Place Overall	GT
2nd Place Overall	OSU
3rd Place Overall	UA
1st Place Project Management Program	MSU
1st Place Communications Program	GT

Conclusions

The fourth and final year of the EcoCAR Mobility Challenge concluded during Fiscal Year 2022. Over the course of the program 2646 students participated and more than 276 employers hired an EcoCAR student. Despite numerous challenges posed by the COVID-19 pandemic over the course of the 4-year program (including during this fiscal year), EcoCAR teams were successful in achieving their technical goals and logged more than 20,000 test miles during this fiscal year alone. EcoCAR teams were also successful in demonstrating the functionality of student-built adaptive cruise control systems and vehicle-to-infrastructure systems designed to navigate a signalized intersection. Argonne also leveraged EcoCAR to pilot a novel approach to energy consumption testing for automated vehicles.

All of these successes were made possible via the public-private partnerships forged with more than 20 government and industry organizations in support of the EcoCAR program. Together, Argonne and all the EcoCAR sponsors will continue pursuing the mission of training the next generation of engineers.

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.2.57 summarizes the publications produced as a result of this funding during FY 2022.

Table II.2.5. Summary EcoCAR Team Publications (FY 2022)

Team	Publication/Presentation Title	Author Name	Conference / Journal
OSU	Fault Insertions into Hardware-in-the-Loop Simulation	Tyler Martin	The Ohio State University
OSU	Human-Machine Interface in Autonomous Rideshare Vehicles	Colin Knight	The Ohio State University
VT	Development of a Willans Line Rule-Based Hybrid Energy Management Strategy	Thomas D. Legg Douglas Nelson	WCX SAE World Congress Experience
VT	Evaluating Simulation Driver Model Performance using Dynamometer Test Criteria	Thomas D. Legg Douglas Nelson	WCX SAE World Congress Experience
VT	Willans Line Bidirectional Power Flow Model for Energy Consumption of Electric Vehicles	Daniel R. Harvey Douglas Nelson	WCX SAE World Congress Experience
WVU	A Full-Factorial Study of Sensor Fusion for Advanced Driver Assistance Systems	N. Janevski and B. Woerner	IEEE 94th Vehicular Technology Conference
WVU	Acquisition and Fusion Of V2X, Radar and Camera Data for Autonomous Vehicles	Clay Vincent	WVU Research Repository
WVU	Angular Gates: A Novel Approach to Validation Gating for Sensor Fusion	N. Janevski and B. Woerner	IEEE 95th Vehicular Technology Conference
WVU	Application of Project Management Strategies and Tools for an Efficient and Successful Competition-based Engineering Senior Capstone Design Project	Benton Duane Morris	WVU Research Repository

Team	Publication/Presentation Title	Author Name	Conference / Journal
WVU	Implementation of Fuzzy Logic Control into an Equivalent Minimization Strategy for Adaptive Energy Management of a Parallel Hybrid Electric Vehicle	Jared Alexander Diethorn	WVU Research Repository
WVU	Implementation of Radial Basis Function Artificial Neural Network into an Adaptive Equivalent Consumption Minimization Strategy for Optimized Control of a Hybrid Electric Vehicle	Thomas Harris Andrew Nix Mario Perhinschi Scott Wayne Jared Diethorn AaronMull	Journal of Transportation Technologies, Scientific Research Publishing Inc.
WVU	Mitigating Insider Threats in a Cooperative Adaptive Cruise Control System Using Local Intra-Vehicle Data	Alexander Francis Colon	WVU Research Repository
WVU	Performance of Sensor Fusion for Vehicular Application	Nikola Janevski	WVU Research Repository
WVU	Powertrain Fuel Consumption Modeling and Benchmark Analysis of a Parallel P4 Hybrid Electric Vehicle Using Dynamic Programming	Mull, A.R., Nix, A.C., Perhinschi, M.G., Wayne, W.S., Diethorn, J.A and Kellett, A.R.	Journal of Transportation Technologies, Scientific Research Publishing Inc.
WVU	Powertrain Fuel Consumption Modeling and Benchmark Analysis of a Parallel P4 Hybrid Electric Vehicle Using Dynamic Programming	Aaron Robert Mull	WVU Research Repository

II.3 Alternative Fuels Data Center (National Renewable Energy Laboratory)

Matt Rahill, Principal Investigator
National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
E-mail: matt.rahill@nrel.gov

Margo Melendez, Principal Investigator
National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
E-mail: margo.melendez@nrel.gov

Wendy Dafoe, Principal Investigator
National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
E-mail: wendy.dafoe@nrel.gov

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

Start Date: October 1, 2021 End Date: September 30, 2022
Project Funding (FY 2022): $1,428,000 DOE share: $1,428,000 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 31 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 or blogs. 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 offering 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 FY 2022, the AFDC boasted a 40% increase over FY 2021 in page views, with more than 9.2 million visitor sessions and 7.2 million unique visitors. Those visitors accessed pages on the AFDC website more than 24.3 million times. Visits to the site included an average of 13% returning visitors and 87% 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, 33% of all EERE website page views are from AFDC pages. Additionally, 11 of the top 30 most-viewed pages in the EERE portfolio are AFDC pages. Figure II.3-1. illustrates the AFDC's steady growth in FY 2022 compared to FY 2021. The traffic spike in March was the result of Tesla featuring a wall connector at shop.tesla.com that links to the AFDC laws and incentives search.

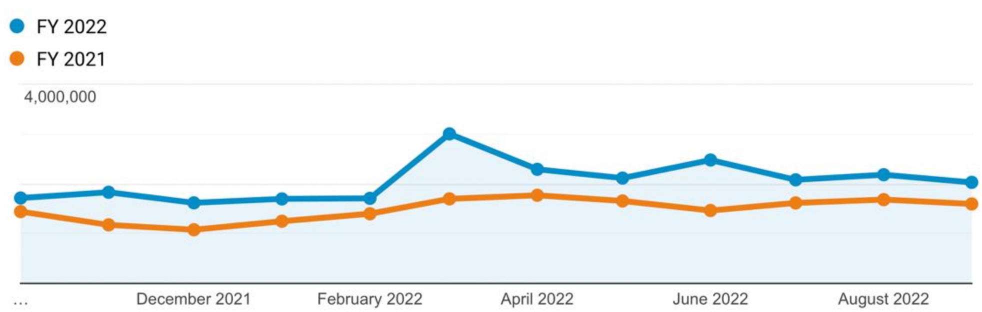

Figure II.3-1. Page views in FY 2022 compared to FY 2021

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 2022 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.3-2. shows a breakdown of sources of AFDC visits, based on the top 40 referrals.

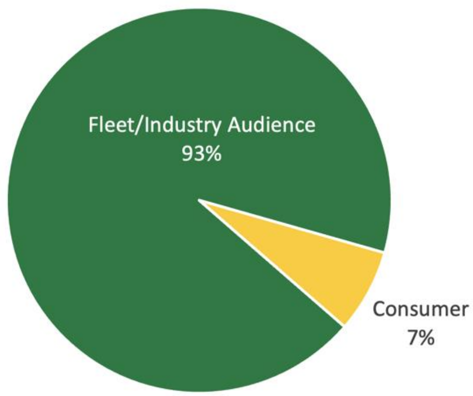

Figure II.3-2. Sources of AFDC visits based on the top 40 referrals

Some of the top referrers in FY 2022 included several vehicle Original Equipment Manufacturer (OEM) sites linking to the laws and incentives information, with Tesla leading the referral count. In FY 2022, the Federal and State Laws and Incentives pages were viewed 5.9 million times, particularly via referrals from numerous vehicle manufacturers. During FY 2022, there were more than 11,000 websites linking to the AFDC, resulting in 1.8 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.3.1. for the top 20 referrers in FY 2022.

Table II.3.1. Top 20 Referrers to the AFDC Website in FY 2022

Referrer	Sessions
shop.tesla.com	154,916
shop.ford.com	141,549
toyota.com	120,286
bmwusa.com	96,301
ford.com	92,315

Referrer	Sessions
fueleconomy.gov	85,777
irs.gov	82,263
tesla.com	40,505
gmc.com	34,399
kandiamerica.com	32,481
kia.com	30,379
subaru.com	28,917
vw.com	28,479
electrek.co	27,286
automobiles.honda.com	24,939
m.facebook.com	22,775
cars.com	22,800
theverge.com	18,691
miniusa.com	12,615
kbb.com	12,579

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 2022, interest in fuels and vehicles information accounted for 35% of the total page views on the AFDC, compared to 34% in FY 2021. Historical data shows that the most frequently accessed pages by fuel type vary from year to year. In FY 2022, electricity was the most popular topic in terms of page views for fuels and vehicles information with 41% of the total traffic, followed by ethanol with 25% of the total page views.

Figure II.3-3. depicts the breakdown of interest in content by fuel type in FY 2022.

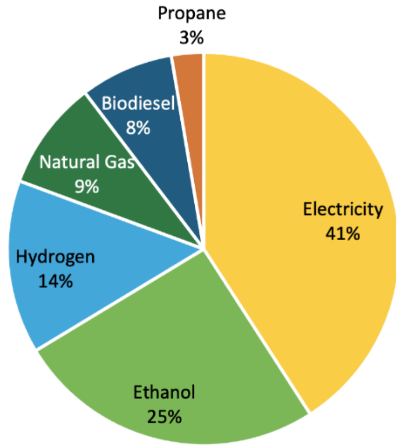

Figure II.3-3. Interest in fuels and vehicles information by subject based on page views in FY 2022

As shown in Figure II.3-4., 38% of the queries for fueling station locations involved electric charging. This is a slight decrease compared to electric charging's 41% share in FY 2021.

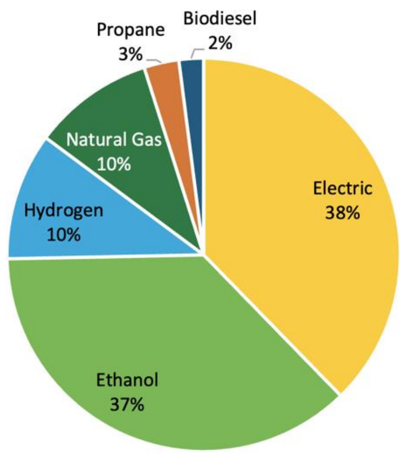

Figure II.3-4. Interest in stations information by subject based on page views in FY 2022

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 18,200 views in FY 2022; 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.3.22 shows primary tools on the AFDC website by popularity. Notably in FY 2022, the Vehicle Search tool saw a 137% increase in page views compared to FY 2021. The Laws and Incentives Search and the Alternative Fueling Station Locator also saw a significant increase in page views compared to FY 2021. Together, the tools accounted for 68% of the total page views on the AFDC in FY 2022.

Table II.3.2. Page Views for the Primary Tools on the AFDC Website

Tool	FY 2022 Page Views	FY 2021 Page Views	% Change
Alternative Fueling Station Locator	8,179,961	6,099,770	34%
Laws and Incentives Search	5,877,881	4,054,636	45%
Maps and Data Search	1,023,364	828,238	24%
Vehicle Cost Calculator	822,460	664,647	24%
Vehicle Search	642,319	270,794	137%
State Information Search	101,751	77,461	31%
Case Studies Search	53,387	46,209	16%
Publications Search	38,769	35,586	9%
EVI-Pro Lite	38,048	34,145	25%
Fuel Properties Comparison	33,097	30,407	-3%

Several of these tools are available as widgets that allow users to embed the tools on their own websites. In FY 2022, the Alternative Fueling Station Locator widget was the most popular widget, with nearly 1.1 million page views while embedded on other websites, accounting for 13% 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.3.33 summarizes the data activity in FY 2022 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.3.3. API Requests, Users, and Downloads in FY 2022

Data	API Requests	Unique API Users	Downloads
Alternative Fueling Stations	34,671,481	6,141	5,350
Laws and Incentives	114,458	58	4,849
Vehicles	76,915	50	2,143

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 34.6 million requests in FY 2022, which was up from about 29.2 million requests in FY 2021.

The laws and incentives API received more than 114,000 requests in FY 2022, which was up from about 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 2022 was the fuel properties comparison chart, with more than 27,000 downloads. The high-resolution images for vehicle illustrations had more than 486,000 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.4 EPAct Regulatory Programs (National Renewable Energy Laboratory)

Ted Sears, Principal Investigator
National Renewable Energy Laboratory
901 D St. SW, Suite 930
Washington, DC 20024
E-mail: ted.sears@nrel.gov

Mark Smith, DOE Program Manager
U.S. Department of Energy
E-mail: mark.smith@ee.doe.gov

Start Date: October 1, 2021 End Date: September 30, 2022
Project Funding (FY 2022): $806,335 DOE share: $806,335 Non-DOE share: $0

Project Introduction

The National Renewable Energy Laboratory's (NREL's) Transportation Technology Integration group, within the Center for Integrated Mobility Science, 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 2022, NREL's work focused on two areas: State and 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, 2021, covered MY 2021 vehicle acquisitions. In reports submitted at the end of 2021, 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. More than 310 fleets used Standard Compliance and exceeded their aggregate MY 2021 acquisition requirements by more than 37%. 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 seven covered fleets that used Alternative Compliance exceeded their aggregate MY 2021 petroleum use reduction requirements by more than 32%.

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 decreased from over 17 million gallons in MY 2020 to under 12 million gallons in MY 2021. Unsurprisingly, DOE also saw a drop in total biodiesel credits earned, with fleet earning a total of 1,426 credits in MY 2021 for using biodiesel, a decrease from 1,655 credits earned in MY 2020. The divergence in the reported amount of biodiesel used and the number of biodiesel 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 (7,905) in MY 2021, which includes light duty AFVs, non-AFV hybrid-electric vehicles (HEVs), and neighborhood electric vehicles (NEVs), when compared to MY 2020 (12,015). MY 2021 marked the ninth 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 681 credits for partial-credit vehicles and 344 credits for investments in alternative fuel infrastructure and non-road equipment in MY 2021 (a negligible decrease, for the three categories combined, over MY 2020 (1053.5)).

Conclusions

The data for MY 2021 demonstrated 100% compliance by all entities within the program, and the extent of over-compliance suggests an ongoing interest on the part of EPAct-covered state and alternative fuel provider fleets in supporting the AFV and advanced technology vehicle markets.

Key Publications

Booth, Sarah, Jesse Bennett, Matthew Helm, Devin Arnold, Bridget Baker, Remmy Clay, Mary Till, and Ted Sears. 2022. Impacts of Increasing Electrification on State Fleet Operations and Charging Demand. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-81595. www.nrel.gov/docs/fy22osti/81595.pdf.

Booth, Sarah, Jesse Bennett, Matthew Helm, Devin Arnold, Bridget Baker, Remmy Clay, Mary Till, and Ted Sears. 2022. Identifying Electric Vehicles to Best Serve University Fleet Needs and Support Sustainability Goals. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-81596. https://www.nrel.gov/docs/fy22osti/81596.pdf

II.5 Technical Assistance/Technical Response Service (National Renewable Energy Laboratory)

Margo Melendez, Principal Investigator
National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
E-mail: margo.melendez@nrel.gov

Wendy Dafoe, Principal Investigator
National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
E-mail: wendy.dafoe@nrel.gov

Michael Laughlin, Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

Start Date: October 1, 2021 End Date: September 30, 2022
Project Funding (FY 2021): $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 that 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 help 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, states, and cities 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 and vehicle operators into sustainability leaders. Yet as they evaluate their options to use alternative fuels and advanced vehicles, these users and managers 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 or emerging 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 or technical investigation, DOE provides technical assistance through Tiger Teams, a group of highly skilled experts from national laboratories and industry. NREL identifies industry experts and subcontracts with them through a competitive process. 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 neutral third-parties, Tiger Teams provide technical expertise, help address problems, resolve differences, and get stalled projects moving again.

Results

A sampling of FY 2022 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?

A state DOT representative asked about the development and deployment status of solid-state batteries and who the leaders are in manufacturing this technology. The TRS explained that solid-state battery manufacturing is in the nascent stages in the United States and that the market and deployment for solid-state batteries is several years away. TRS pointed to the VTO *Batteries 2020 Annual Progress Report*, which describes current solid-state battery Research and Development (R&D) projects and noted the Federal Consortium for Advanced Batteries supports R&D in solid-state batteries.

A VTO staff person asked for examples of state and local policies for battery recycling centers. The TRS responded with a summary of battery recycling policies and included specific examples, sourced from DOE's Battery Policies and Incentives Search database. Additionally, the TRS referred to a memorandum of understanding (MOU) Argonne National Laboratory (ANL) has signed with the National Electrical Manufacturers Association to cooperate on developing recycling standards for lithium-ion batteries. TRS also pointed to NREL's report *A Circular Economy for Lithium-Ion Batteries Used in Mobile and Stationary Energy Storage: Drivers, Barriers, Enablers, and U.S. Policy Considerations*.

A private electrical contractor inquired about the electric vehicle (EV) charger installation process for electrical contractors. The TRS recommend visiting the Alternative Fuels Data Center (AFDC) Charging Infrastructure Procurement and Installation page for information on EV charging station development and installation. TRS referred the contractor to the Electric Vehicle Infrastructure Training Program's Find a Contractor page and suggested contacting the local Clean Cities coalition for on-the-ground assistance.

A tribal representative asked what funding opportunities are available for EV charging stations for a tribal government in their state. The TRS explained how to search the AFDC Laws and Incentives database and pointed to relevant federal and state incentives and where to go to access more information. TRS recommended reviewing the Bipartisan Infrastructure Law (BIL) Guidebook for summaries of funding opportunities. Lastly, TRS suggested contacting the local Clean Cities coalition for on-the-ground support.

A representative from a town in Texas inquired about the infrastructure and space requirements for EV charging stations. The TRS replied and referred to the E*V and Infrastructure Codes and Standards Citations* document for EV charging infrastructure requirements, and noted the space required for stations may vary by site type or ownership model as well as the local jurisdiction's permitting laws. The TRS also referred to an EV charging equipment memo published by the Texas State Department of Licensing and Regulation, as well as various state and local government and industry association guidebooks on EV charging equipment installation.

An electric truck (Class 5-8) manufacturer asked how to identify state incentives and contacts for commercial fleet EVs and charging stations and asked specifically about Oklahoma. The TRS provided guidance on searching the AFDC Laws and Incentives database to identify relevant incentives in each state. For information on Oklahoma's activities related to electrification, TRS recommended reviewing state or local energy or transportation plans, such as *Oklahoma Energy and Environment Plan 2021*. Lastly, for assistance identifying any local transportation electrification efforts, the TRS recommended contacting Oklahoma Clean Cities coalitions.

A major tire corporation inquired about examples of large companies that have installed workplace charging, and the lessons from those projects. Additionally, they asked about federal or state incentives for companies offering workplace charging. For workplace charging case studies and guidance, the TRS referred them to resources from the AFDC and DOE Workplace Charging Challenge reports, provided guidance on searching the AFDC Laws and Incentives database, and listed potential incentives for which the company may qualify.

A K-12 school system representative from the Midwest inquired whether contracted buses are eligible for funding programs that assist in converting from diesel to compressed natural gas. The TRS provided information about the U.S. Environmental Protection Agency's (EPA) Diesel Emissions Reduction Act (DERA) Program and School Bus Rebate program, which confirmed that contracted bus companies are eligible applicants. TRS noted that similar eligibility requirements apply to the BIL Clean School Bus Program and their state DERA grant program.

An administrative services representative from a large city asked if the TRS could provide the hydrocarbon, carbon monoxide, particulate matter, and nitrogen oxide values for biodiesel tailpipe emission reductions from a figure on the AFDC (Average Emissions Impact of Biodiesel for Heavy-Duty Engines). The TRS referred the inquirer to EPA's draft technical report, *A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions,* and pointed to the specific emissions data and accompanying details in the report.

A utility representative asked for resources that evaluate the accuracy of the measurement functionality on EV chargers, such as kilowatt-hours consumed for charging, and whether there are standards for accuracy testing of EV charging equipment. The caller indicated that industry stakeholders have expressed concern regarding the lack of equipment to accurately test the output of EV charging equipment and the inconsistency in measuring how much electricity EV charging equipment dispenses. The TRS provided an example of accuracy testing equipment for EV chargers, sourced from an ANL presentation, as well as other commercially available testing equipment. Additionally, the TRS noted that while there are no federal standards for EV charger accuracy testing, several states have adopted accuracy requirements for commercial charging transactions through the National Institute of Standards and Technology (NIST) Handbook 44 Section 3.40. Most states have adopted NIST Handbook 44 Section 3.40, but only California has legally mandated its enforcement.

A Metropolitan Planning Organization representative asked for cost estimates for make-ready EV charging station installation and equipment to inform proposed EV make-ready language in a draft zoning code. While make-ready costs are highly variable from site to site the TRS referred to studies on make-ready costs, including the Energy Marketers of America's *Utility Investments and Consumer Costs of EV Charging Infrastructure* report and cost guides and resources from utilities. TRS also pointed to the NREL and Idaho National Laboratory *Levelized Cost of Charging EVs in the United States* for equipment costs and the Rocky Mountain Institute's *Reducing EV Charging Infrastructure Costs* for information on equipment, transformer, and conduit costs.

A Clean Cities director inquired about how long it would take to charge an electric school bus with a battery capacity of 110 kilowatt-hours (kWh) with a Level 2 EV charger rated at 19.2 kW, a DC fast charger rated at

60 kW, and a DC fast charger rated at 125 kW. The TRS provided estimates of the charging time for an electric school bus by dividing the battery capacity by the power output of the specified chargers and noted that maximum power acceptance and state-of-charge influence charging times. Finally, the TRS mentioned that most vehicle manufacturers recommend charging an EV battery only up to 80% of the state-of-charge to preserve battery life.

A Clean Cities director who was tasked with updating their state EV infrastructure plan asked for examples of federal and state EV infrastructure incentives and mandates, and examples of proposed state legislation, and for a current list of zero emission vehicle (ZEV) states and associated goals. The TRS referred the caller to the AFDC Laws and Incentives database and provided lists of states that offer various incentives for the purchase of EV charging equipment. Additionally, the TRS pointed to the expired federal Internal Revenue Service (IRS) Alternative Fuel Infrastructure Tax Credit and the U.S. Department of Transportation (DOT) Rural EV Toolkit for an overview of federal funding opportunities for EV charging equipment. Additional resources include the Atlas Public Policy EV Hub and industry associations' reports for examples of state EV charging policies. TRS also provided a list of states that have adopted California's ZEV sales requirements and low emission vehicle standards, sourced from the AFDC Laws and Incentives database.

A Clean Cities director inquired on behalf of a small private truck fleet whether there were biodiesel stations in some Midwest states that sell B100 and also accept the WEX fleet card. The TRS explained that B100 is not a commonly used transportation fuel, sourcing information from the AFDC Biodiesel Blends page. The caller was provided with guidance on how to use the Advanced Filters tab of the AFDC Station Locator to identify biodiesel fueling stations according to station details and payment type, and the TRS provided spreadsheets of biodiesel fueling stations that accept WEX cards in each requested state.

A Clean Cities director inquired about comparing the emissions and cost of hydrogen, CNG, renewable natural gas (RNG), and diesel in Class 8 freight trucks for a large fleet, using Argonne National Laboratory's (ANL) Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool. The TRS provided an emissions comparison of a fleet of 100 long-haul trucks fueled by hydrogen, CNG, RNG, and diesel using the AFLEET Payback - Onroad Calculator. TRS included the emissions and cost output and explained the results.

A Clean Cities director asked for examples of fuel efficient or idle reduction technologies (IRTs) for ambulances that other fleets have used with success. The TRS referred the director to case studies from ANL and publications from the AFDC, which provide an overview of IRTs for ambulances. Additionally, TRS referenced a 2018 presentation from Dallas-Fort Worth Clean Cities, which covers case studies of IRTs for ambulances, and referred to information from the Fire Department of New York on ambulances with IRTs.

Tiger Teams Technical Assistance Activities

A major Original Equipment Manufacturer (OEM) wheel supplier that operates in multiple states requested technical assistance to identify the root cause of a fuel system problem with propane forklifts. The supplier sent samples of the forklifts' fuel for analysis. The Technical Assistance team will explore options to address and resolve the issue and consider how to communicate the findings to other fleets. Depending on the root cause and potential solutions, new codes and standards may need to be developed to help mitigate the risk of similar occurrences in other propane-fueled vehicles and fleets.

Codes and standards work continues to be part of proactive technical assistance. Subcontracted experts are chairing a task force and working with the National Fire Protection Association (NFPA) to identify opportunities for consolidating and re-organizing NFPA 52 code language, which addresses vehicular natural gas fuel systems. The consolidated code will provide clearer, more concise guidance for code officials, make it easier to interpret the code, and lay the foundation for more consistency for future CNG station development, while ensuring state-of-the-art safety measures are implemented.

The Technical Assistance team coordinated with different experts to analyze an accident and fire involving a CNG vehicle. Thorough investigation is critical to determine if there are any codes and standards that might have helped prevent the fire. Results show that the CNG system appeared to perform as intended.

A school district requested technical assistance to troubleshoot an issue with new electric buses that were receiving an incomplete charge overnight. It was quickly determined that the school district was on an energy management program through the local electric utility that curtailed power every night for several hours. Further investigation determined that when power was restored, the charging event would not restart automatically. Depending on the bus manufacturer different steps are required to resume charging. As a result of the interaction OEMs are exploring solutions to this issue.

A state agency requested technical assistance for review of a Request for Proposals for electric school bus deployment and requested advice on how to refine the program to best help fleets leverage BIL funds. The state has requested that additional technical assistance be made available for rural districts that may need assistance beyond what OEMs can provide.

Understanding how to successfully utilize electric school buses (ESBs) continues to be a topic of significant interest. The need for real-world data on electric school bus vehicle performance is clear. Fleets that are considering ESBs do not have reliable real-world performance and efficiency data to evaluate how they would compare to their existing conventional vehicles. NREL defined an ESB data logging project and data collection began in FY 2022. NREL will publish a report in FY 2023 about ESB performance that will help school districts make informed decisions. Additionally, school districts have indicated they need “soup to nuts” information to use as they explore and consider ESB options. NREL developed the “Flipping the Switch on Electric School Buses” series to help school bus fleets explore their ESB options, understand challenges, and find the help they need to get started. Each part has a 5–10-minute video and printable resources discussed in the videos. The series can be found at https://afdc.energy.gov/vehicles/electric_school_buses.html.

Conclusions

The ready availability of industry experts, through the TRS and the Technical Assistance project, makes it possible for broad transportation audiences to understand, select and integrate new transportation technologies. These experts can offer transportation stakeholders valuable insights into the various technology options, along with advice on making informed decisions, and anticipating, mitigating, or altogether avoiding common problems, thus increasing the chances of project success. Additionally, the interactions with end-users of real-world technologies provide valuable feedback that can provide a foundation for future DOE research.

II.6 Technologist-in-Communities (National Renewable Energy Laboratory)

Stanley Young, Principal Investigator
National Renewable Energy Laboratory
15013 Denver West Parkway, MS 1625
Golden, CO 80401-3305
E-mail: stanley.young@nrel.gov

Andrew Duvall, Co-Principal Investigator
National Renewable Energy Laboratory
15013 Denver West Parkway, MS 1625
Golden, CO 80401-3305
E-mail: andrew.duvall@nrel.gov

Mark Smith, DOE Program Manager
U.S. Department of Energy
E-mail: mark.smith@ee.doe.gov

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Project Introduction

As cities around the country launch efforts to use data and mobility technology in more innovative and effective ways than ever before, Smart Cities are serving as living laboratories for increasing the energy efficiency and reducing the emissions of urban mobility systems, while increasing 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, continuing through FY 2022 in a reduced capacity as the Smart Columbus project transitions to a subsequent phase.

The Smart Columbus initiative was supported by two grants, totaling $50 million. A $40-million DOT grant supported multiple projects, including smart mobility hubs, automated electric shuttles, enhanced communications such as dedicated short-range communications, and truck platooning. Complementing the DOT grant was 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 has since grown beyond Columbus, to engagements in a range of settings, expanding 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; the 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 2022, 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. This culminated in a site visit to Columbus by DOE program and technology managers, who were able to experience first-hand the outcomes of the project. Such interaction works toward integrating 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, on-demand transit alternatives, 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, inform mobility equity strategies, 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 community and other emerging initiatives includes a variety of activities, methods, and approaches, as outlined below:

- Maintain a direct presence with partners/collaborators at adequate frequency to develop and sustain working relationships and serve liaison roles. Although the COVID-19 pandemic has limited physical presence since March 2020, collaboration continues through online interaction and 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, on-demand transit, 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 those using OpenPATH and 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.
- Serve as 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.
- Engage with NYSERDA in development of a Fellows program, comprised of early career sustainable transportation professionals enabled by mentorship and access to knowledge and other resources via the National Renewable Energy Laboratory (NREL) TIC team.
- Coordinate rural mobility research through support of DOE Funding Opportunity Announcement (FOA) projects and stakeholder engagement.

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. A strong emphasis on equity and environmental justice issues is integrated within 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. 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 development of 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 grand prize projects, announced in Fall 2022. 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:
    - <u>Emphasis on metrics and data support:</u> 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.
    - <u>Community resource collaboration:</u> 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
    - <u>Emphasis on case studies:</u> 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:** An NREL TIC team initiative supports cities with significant disadvantaged communities. The TIC team has held 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. A project that has emerged is a DOE Small Business Innovation Research (SBIR) grant in St. Louis with Labyrinth Technologies, a provider of on-demand electric shuttle services focused on low-income areas. In addition, the TIC team continues to collaborate with the humanitarian engineering program at the Colorado School of Mines. This effort includes facilitating 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 completed the next edition of this document, published in FY 2022. This second edition not only provides summaries of the new developments and lessons learned for 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. Continuing work is focused on automated mobility solutions for medical campuses and similar settings.
- **Case studies of on-demand transit (ODT) alternatives for small communities:** In less-dense exurban areas where traditional transit is not feasible, latent demand for mobility options exists, particularly among population subgroups who do not own or have access to a car. Such unmet needs for mobility options affect access to employment and education opportunities, healthcare, and other critical transportation needs. In exploration of potential solutions, the NREL TIC team observed a trend emerging for on-demand transit (ODT) alternatives. Key operational characteristics include right-sized vehicles, typically minivans or other light-duty vehicles, which may be requested via smartphone app, phone call, or hailed from the street, serving a defined area. Several ODT implementations were identified as subjects of case studies. Of these, an ODT service in Fort Erie, Ontario had sufficient data for further evaluation. The Fort Erie ODT service expanded access to a larger population and resulted in about double the number of passengers as compared to the previous fixed route transit service. Other benefits include lower wait times for passengers, reduced operational costs per ride, and reduced fuel and emissions. Figure II.6-1. shows the evolution of the service, from the initial fixed route service, the effects of the pandemic in reducing transit use, which aligns with transit overall, and the rebound following implementation of ODT service.

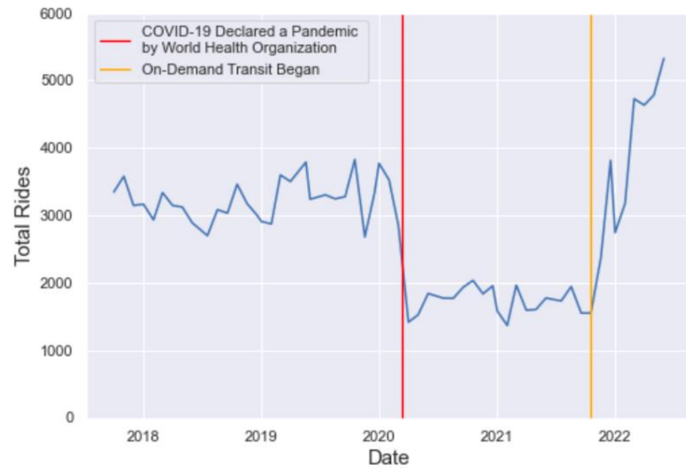

Figure II.6-1. Total monthly ridership before and after the Fort Erie on-demand transit system was instituted (October 4, 2017, to June 30, 2022)

- **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 FOA, through regular engagement and quarterly online forums. Most of these projects are nearing completion after initial delays related to the pandemic. NREL plays an active research support role in two of the five projects and has relationships with the other three awardees. An NREL news feature on the PBS television program MotorWeek [3] highlighted rural mobility support by the NREL TIC team. Rural mobility efforts continue to grow, and engagement is fostered through online webinars.
- **The future of ground access to airports:** The Dallas/Fort Worth International Airport (DFWIA) enlisted the NREL TIC team to explore emerging automated mobility technologies relevant to ground-side access to airports. This effort resulted in a technical report that identified opportunities to improve mobility options to benefit airport operations. These included focal points on mobility for travelers, employees, goods/cargo operations, and alignment with mobility electrification [4]. The initial engagement with DFWIA led to other connections with airports and related entities, resulting in a collaborative grant through the North Central Texas Council of Governments (NCTCOG) for a pilot project for low-speed automated parking and active curb management at DFWIA, to be conducted in 2023. Additional connections have emerged with the Port Authority of New York and New Jersey, Cincinnati International Airport, and the University of North Carolina Charlotte. The confluence of emerging mobility technology applications at airports has opened new doors for the NREL TIC team, which will be expanding in FY 2023.
- **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. The TIC team serves on the EmPOWERment Program's External Advisory Council. In 2022 NREL supported the program through a bootcamp for students, serving as invited speakers and informing applied student research projects.
- **COVID-19 data science:** The Centers for Disease Control and Prevention funded a second stage of pandemic research. The NREL TIC team is leading efforts to develop integration of long-distance travel modeling and epidemiologic modeling to improve the ability to respond to the next infectious

disease challenge. This work is in collaboration with Sandia and Los Alamos National Laboratories, as well as other entities.

Conclusions

During FY 2022, TIC continued to collaborate with several smart communities in their efforts, expanding beyond the initial focus on Columbus. Though Smart Columbus continues to be a valued partner and resource, the next phase of that program is evolving to meet the needs of the community. The NREL TIC team has been shaping lessons learned from the Columbus effort to apply to a spectrum of other communities and projects. Key among these emerging efforts is the collaboration with NYSERDA in supporting the Clean Transportation prizes through the Fellows program, the quickly growing implementation of ODT projects in multiple locations, and a focus on ground-side mobility at airports as places where new applications of automation and electrification are being tested and explored.

The NREL TIC program is refining some objectives to identify needs of community partners and to provide options for possible solution strategies. This is meant to leverage national laboratory research outcomes to inform design and implementation of community projects. Several community partners are leading the way among their peers and may generate methods for replication elsewhere. As advised by DOE TI leadership, NREL has identified themes and priorities for FY 2023, including:

- Continued engagement with smart communities, with emphasis on mobility improvements to enhance access to economic opportunities, mitigate equity concerns, and develop metrics for evaluation.
- A focus on cities with significant disadvantaged communities (e.g., Cleveland, St. Louis, Baltimore).
- Inclusion of issues related to rural mobility, workforce mobility, and access to jobs.
- Support for the NYSERDA Clean Transportation Fellows program.
- Investigation of opportunities for automated public mobility, and related demonstration and pilot-scale projects.
- 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.

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[1] The EEMS Program uses the term mobility energy productivity (MEP) to describe the value derived from the transportation system per unit of energy consumed. Increases in mobility energy productivity result from improvements in the quality or output of the transportation system, and/or reductions in the energy used for transportation.

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[3] https://www.motorweek.org/features/auto_world/electric-vehicles-in-rural-communities

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DOE: Mike Laughlin.

II.7 Fuel Economy Information Project (Oak Ridge National Laboratory)

Stacy Davis, Principal Investigator
Oak Ridge National Laboratory – National Transportation Research Center (NTRC)
2360 Cherahala Blvd.
Knoxville, TN 37932
E-mail: davissc@ornl.gov

Dr. Janet Hopson, Principal Investigator
University of Tennessee – Center for Transportation Research, NTRC
2360 Cherahala Blvd.
Knoxville, TN 37932
E-mail: hopsonjl@ornl.gov

Michael Laughlin, DOE Technology Development Manager
U.S. Department of Energy
E-mail: michael.laughlin@ee.doe.gov

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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 45,000 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 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 *2022 Fuel Economy Guide* currently contains information for 1,303 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. It also provides additional information, such as driving range and charge time, for plug-in electric vehicles (PEVs). 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 45,800 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 Motor Week 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 (MPT) 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 FY 2022, the FEI Program continued to help DOE meet its statutory requirement to produce an annual *Fuel Economy Guide* for light-duty vehicles. Model year 2022 was the fifth 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 2022 *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 2023 *Guide* available to the public on FuelEconomy.gov, as of the third quarter of FY 2022. This preliminary version contains data for model year 2023 vehicles already released by manufacturers. The 2023 *Guide* will be finalized and distributed in the first quarter of FY 2023.

Since its launch in 1999, FuelEconomy.gov has hosted more than 550 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.7-1.). In FY 2022, FuelEconomy.gov hosted more than 30 million user sessions, more than 410 million page views, and more than 83,000 daily visits on average.

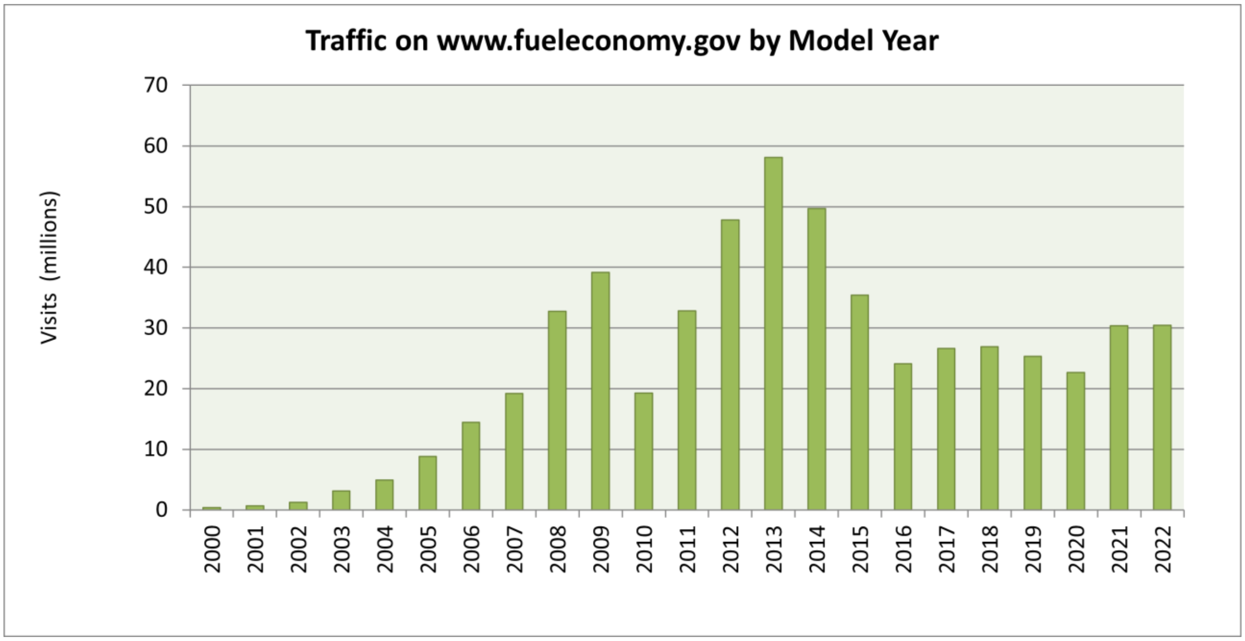

Figure II.7-1. Traffic on FuelEconomy.gov grew steadily after its initial launch in 1999, peaking in 2013 when fuel prices were high.

FuelEconomy.gov's My MPG tool continues to be popular with consumers. More than 35,500 drivers have shared fuel economy estimates for more than 51,000 vehicles. This fuel economy data has become a valuable resource for both the car-buying public and researchers looking to understand the relationship between on-road fuel economy and EPA estimates. In fact, My MPG data has been used to evaluate EPA test methods and identify potential problems with fuel economy estimates provided to EPA by manufacturers.

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.

MotorWeek segments completed in FY 2022 included five segments related to electric vehicles (Electric School Buses Clear the Air in the Mid-Atlantic, Electric Vehicles in Rural Communities, Electric Vehicles Take Charge in Chicago, Maryland State Fleet Commits to Zero-Emission Vehicles, and College Students Engineer Next-Generation Vehicles in EcoCAR Mobility Challenge), one on biodiesel (Students Whip up Biodiesel in South Carolina), and one on renewable natural gas (Wastewater Powers Renewable Natural Gas Trucks in Colorado). [2] Also, an entire show devoted to EVs that was filmed in FY 2021 aired in FY 2022.

ORNL completed work on two fuel economy research projects in FY 2022: a study of the impact of gasoline additives on fuel stability and a study of the impact of vehicle stop-start systems on fuel economy. ORNL presented results of the fuel stability study at the 2022 SAE World Congress and published the results in an SAE technical paper. A paper on the stop-start research has been accepted for the 2023 SAE World Congress. ORNL began new research in FY 2022 to evaluate the impacts of vehicle speed and replacement tires on electric vehicle energy use and range. The results of this work will be documented in journal articles 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 reduce their energy use. 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 2,032 times in the technical literature. Finally, the FEI Program responded to 640 email inquiries submitted by media and users through FuelEconomy.gov in FY 2022.

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 2022, 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. 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. 2021. Model Year 2022 Fuel Economy Guide. https://www.fueleconomy.gov/feg/pdfs/guides/FEG2022.pdf.

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