Electrifying Terminal Trucks

To optimize freight yards

Metropolitan ENERGY CENTER

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Introduction

Acknowledgements

This project would not have been possible without the dedicated efforts and invaluable contributions of our partners and community members.

We're grateful for Orange EV, the Johnson County Wastewater Department, Hirschbach Motor Lines and Lazer Spot for their contributions and unwavering collaboration. Their combined efforts ensured the success of this project.

Thanks to the U.S. Department of Energy (DOE) for financial support and commitment to advancing sustainable transportation solutions, and to Pennsylvania State University (Penn State) for conducting research crucial to the project.

Lastly, we want to thank community members for their participation, feedback and support. The community's involvement was essential in shaping a project that truly meets the needs of its people. This collaborative effort has set a solid foundation for future advancements in sustainable transportation.

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Executive Summary

This project was an innovative initiative by Metropolitan Energy Center (MEC), in partnership with electric vehicle manufacturer Orange EV and researchers from Penn State University. The project seeks to demonstrate the feasibility of battery-powered terminal trucks and accelerate their deployment to improve public health and provide economic benefits by reducing transportation emissions.

MEC is a nonprofit organization dedicated to the mission of creating resource efficiency, environmental health, and economic vitality in the Kansas City region and beyond. Since 1983, MEC has provided resources, outreach, and training to make alternative fuels and energy efficiency commonplace. This demonstration project evaluates the overall operational and financial feasibility of electric terminal tractors based on field-tested uses, ranging from municipal to industrial to distribution yard and other real-world customer experiences. The project pursued a data-driven research model designed to examine utilization of truck charging infrastructure, technical feasibility, and cost.

This project was funded by the U.S. Department of Energy (DOE) and awarded to MEC through a competitive proposal process. The novelty and complexity of this project required an organization that could facilitate collaboration across levels of government, researchers and industry partners. For the past 25 years, through Kansas City Regional Clean Cities, MEC has worked with numerous public and private fleets on a variety of projects to improve the environmental performance and efficiency of the regional vehicle fleet. To advance affordable, efficient, and clean transportation efforts, DOE Clean Cities and Communities coalitions create local networks of public and private sector stakeholders and engage communities. Rooted within their local communities, the coalitions serve as experts and ambassadors, bringing to bear the collective knowledge, experience, and practical know-how of the entire network from within DOE, its national laboratories, and diverse stakeholders in the field.

MEC and its project partners made in-kind contributions to leverage federal dollars for the benefit of the state of technology for this transportation niche. Findings from this project will help determine the bredth of applications for electric terminal tractors to maximize funding impact and serve global needs.

Background

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 simultaneously fulfilled aspects of MEC's energy transformation strategy and met the objective to accelerate the deployment of commercially available alternative fuel and electric vehicles, as well as supporting infrastructure.

Objectives

The objectives of this project were to demonstrate the feasibility of electrification for freight yards' diesel terminal fleets through pilot projects with two or more fleets, and to generate outreach material that can be used regionally and nationally to promote electrification in other terminal fleets. We planned to leverage the data into a model program for adoption of zero emissions freight handling and make information about this project, its outcomes, and the business case for zero emission deployments available to the larger freight marketplace.

Project Partners

The project was executed by MEC with support from:

Orange EV

The technology put into service by the participating fleets is manufactured by Orange EV. Founded in 2012 in Riverside, MO, Orange EV was the nation's first manufacturer to offer 100% electric Class 8 vehicles. Through the project, Orange EV also acquired a demonstration unit for use in no-cost short-term rentals by interested fleets across the U.S. Demonstration fleets participated at no cost, except a shipping fee up to $500.

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

Johnson County Wastewater Department

Johnson County is one of 14 counties in the Kansas City metropolitan area. The Johnson County Wastewater Department deployed one truck to run trailers for solids at its new wastewater treatment facility located in Leawood, KS.

Hirschbach Motor Lines

Hirschbach is a private long-haul carrier with an emphasis on refrigerated and other specialized services. It deployed one truck at a client site in Wyandotte County, KS, located in the Kansas City metropolitan area. Hirschbach was acquired by Lazer Spot shortly after this project ended.

Lazer Spot

Lazer Spot, which specializes in yard logistics solutions to optimize throughput at transition points across the supply chain, deployed two trucks in the Chicago metropolitan area.

Pennsylvania State University

During Year 2 and 3 of the project, Xianbiao (XB) Hu, Assistant Professor at Penn State, was responsible for conducting supplementary research and analyzing the telematics, supported by interviews and operational evaluation, from the participating fleets. XB and his research team focuses on transportation engineering. They previously also partnered with MEC on its Electric Vehicle Streetlight Charging Research Project.

Approaches and Outcomes

Approach

Year 1 of the project focused on putting four Orange EV T-Series all-electric terminal trucks into permanent service by the three participating fleets as well as the demonstration truck.

Year 2 of the project focused on data collection and community outreach. In addition to quantitative data collection of the trucks deployed, MEC distributed questionnaires to the pilot fleets focused on the following topics: pre-deployment, charging infrastructure, telematics, and vehicle operation and maintenance. Roundtables were also held to allow the pilot fleets to share lessons learned and best practices in their unique deployment settings. Feedback collected in the questionnaires and roundtables helped inform key message refinement, identify project champions and provide content for community outreach activities. Near the end of Year 2, MEC, the participating fleets, Orange EV, and Penn State University hosted a community workshop sharing their real-world experiences and best practices with zero-emission freight handling. A successful workshop and follow-up would provide a basis of relationships to generate new strategic deployment opportunities.

In the final year of the project, Penn State University began its data analysis to inform the final project report. That same year, MEC and members of the project team presented a case study at the Green Transportation Summit and Expo, a national conference, providing a reliable and replicable basis (and resources) for more companies to choose electric terminal trucks in the future.

Project Highlights

In late 2019 through early 2020, the pilot fleets deployed two Orange EV T-Series trucks in the Kansas City metro and two in Chicago, including the deployment by Lazer Spot of Orange EV's all new T-Series Tandem terminal truck. The customer-driven tandem axel model was first deployed under this project and spreads weight over an additional axel, designed to legally transport loads up to 81,000 pounds on public roads. Despite national supply chain issues due to the COVID-19 pandemic, there were no delays deploying any of the five trucks.

The team generated an informational video, *DRIVING THE FUTURE with Electric Terminal Trucks*, under the production of local contractor Blue Symphony, which shot footage and conducted interviews at each deployment location. The video demonstrates real-world operations of electric terminal tractors in various work settings, while sharing the practical and human benefits of heavy-duty vehicle electrification. The video is available on MEC's YouTube channel and has 652 views as of December 2024.

As of August 2023, the Orange EV demonstration truck available through the project has been deployed 25 times. Twenty-six trucks were purchased or rented by a demonstrating fleet after its company tested the truck in its work setting.

From a research perspective, three types of data were collected to establish the foundational basis for analyzing the financial and technical feasibility of all-electric terminal trucks. This report uses data from three distinct sources to analyze the operations of five electric terminal trucks. The data sources include daily usage reports, operating status snapshots, and weather conditions at the operational sites.

The first dataset is the daily usage report, which is presented in a spreadsheet that summarizes the operational statistics of electric trucks each day. As depicted in Figure 1, each row corresponds to a single truck's operations for one day, including metrics such as distance driven, total driving time, total State of Charge (SOC) used, kWh consumed, efficiency measures and cost savings. This dataset spans from Dec. 1, 2020, to Dec. 31, 2022, and contains 761 records, provided by Orange EV.

					Efficiency Measures			Cost Savings									
Date	Distance Driven (Miles)	Total Key On Time (Hours)	Total SOC Utilized	kWh Utilized	kWh/Mile	kWh/Hour	SOC/Hour	Diesel Saved (Gal)	Diesel Cost ($)	Diesel Cost Save ($)	DEF Saved (Gal)	DEF Cost ($)	DEF Cost Save ($)	Maint Saved ($)	kWh Cost ($)	Charging Cost ($)	Overall Save ($)
Average	38.68	11.91	59%	95	2.46	7.99	5%	29.77	$ 3.60	$ 107.19	0.89	$ 2.70	$ 2.41	$ 59.55	$ 0.10	$ 10.35	$ 158.80
Average >	41.64	12.76	64%	102	2.45	8.01	5%	31.91	$ 3.60	$ 114.87	0.96	$ 2.70	$ 2.58	$ 63.82	$ 0.10	$ 11.11	$ 170.16
							Annualized	11,646		$41,927	349		$943	$23,293		$4,054	$62,109
2020-12-01	-	0.53	2%	3		5.86	4%	1.33	$ 3.60	$ 4.77	0.04	$ 2.70	$ 0.11	$ 2.65	$ 0.10	$ 0.34	$ 7.19
2020-12-02	3.01	0.90	5%	8	2.82	9.44	6%	2.25	$ 3.60	$ 8.10	0.07	$ 2.70	$ 0.18	$ 4.50	$ 0.10	$ 0.92	$ 11.86
2020-12-03	-	0.03	0%	-		-	0%	0.08	$ 3.60	$ 0.27	0.00	$ 2.70	$ 0.01	$ 0.15	$ 0.10	$ -	$ 0.43
2020-12-04	0.56	0.10	1%	1	2.34	13.12	8%	0.25	$ 3.60	$ 0.90	0.01	$ 2.70	$ 0.02	$ 0.50	$ 0.10	$ 0.14	$ 1.28
2020-12-05	-	-	0%	-				-	$ 3.60	$ -	-	$ 2.70	$ -	$ -	$ 0.10	$ -	$ -

Figure 1: Data sample of the daily report

The second dataset comprises operating status snapshots for the five trucks, presented in three spreadsheets. Each spreadsheet records 1) distance driven (miles), GPS-based; 2) run meter, key-on time; and 3) State of Charge (SOC). As illustrated in Figures 2 through 4, each row captures data at 15-minute intervals over the same date range as the first dataset. These snapshots were also provided by Orange EV.

ID	S/N	Machine Ty	Event Time (Local)	Value Name	Tag	Value	Delta Value	Raw Value
TF0083	121612		2020/12/01, 0:09am	Distance Driven, J1939 Based, Miles	DDRIVENCAN	784	0	784
TF0083	121612		2020/12/01, 0:24am	Distance Driven, J1939 Based, Miles	DDRIVENCAN	784	0	784
TF0083	121612		2020/12/01, 0:39am	Distance Driven, J1939 Based, Miles	DDRIVENCAN	786	0	786
TF0082	121359		2020/12/01, 0:47am	Distance Driven, J1939 Based, Miles	DDRIVENCAN	3727	0	3727

Figure 2: Data sample of operating status snapshot (distance driven)

ID	S/N	Machine Type	Event Time (Local)	Value Name	Tag	Value	Delta Value	Raw Value
TF0083	121612		2020/12/01, 0:09am	Run Meter, Key-On Time	KONENGH	279.65	0.23	16779
TF0083	121612		2020/12/01, 0:24am	Run Meter, Key-On Time	KONENGH	279.9	0.25	16794
TF0083	121612		2020/12/01, 0:39am	Run Meter, Key-On Time	KONENGH	280.15	0.25	16809
TF0083	121612		2020/12/01, 0:54am	Run Meter, Key-On Time	KONENGH	280.4	0.25	16824
TF0082	121359		2020/12/01, 1:02am	Run Meter, Key-On Time	KONENGH	1259.5	0.25	75570

Figure 3: Data sample of operating status snapshot (Key-On Time)

ID	S/N	Machine Ty	Event Time (Local)	Value Name	Tag	Value	Delta Value	Raw Value
TF0082	121359		2020/12/01, 0:01am	State of Charge (SOC)	SOC	52.63		5263
TF0082	121359		2020/12/01, 0:04am	State of Charge (SOC)	SOC	53.46		5346
TF0082	121359		2020/12/01, 0:19am	State of Charge (SOC)	SOC	56.64		5664

Figure 4: Data sample of operating status snapshot (State of Charge)

The third dataset focuses on the weather conditions at the operational sites. Of the five trucks, Lazer Spot 1 (LS1) and Lazer Spot 2 (LS2) operate in Chicago, IL; Hirschbach 1 (HIR1) and Johnson County 1 (JOC1) operate in Leawood, KS; and Orange EV 4 (OEV4), an Orange EV-owned demo truck, travels to multiple locations across the US for demonstration purposes. Excluding OEV4, the weather data for Chicago and Kansas City were collected for analysis. As shown in Figure 5, the weather data spreadsheet logs daily temperature, precipitation and wind speed, among other variables. This data is sourced from the National Centers for Environmental Information.

NAME	LATITUDE	LONGITUDE	DATE	AWND	PRCP	TAVG	TMAX	TMIN
KANSAS CITY	39.29747	-94.73087	2020-12-01	4.3	0	0.6	10.6	-7.1
KANSAS CITY	39.29747	-94.73087	2020-12-02	3	0	3.7	11.1	-2.1
KANSAS CITY	39.29747	-94.73087	2020-12-03	2.2	0	2.6	7.8	-2.7
KANSAS CITY	39.29747	-94.73087	2020-12-04	3.2	0	2.5	12.2	-3.8
KANSAS CITY	39.29747	-94.73087	2020-12-05	3.1	0	5	11.1	-0.5

Figure 5: Data sample of weather conditions

Stakeholder and Community Outreach

In October 2021, MEC hosted a virtual fleet 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 real-world experiences with zero-emission freight handling in a roundtable format. Fifty-five individuals joined, including Clean Cities coordinators, fleets, energy justice advocates, nonprofit organizations and more. Post-workshop, MEC connected attendees with additional resources and facilitated a meeting with the roundtable participants to document what went well and what they would change for future events. A recording of the live workshop is available on MEC's YouTube channel and has more than 100 views at time of publication.

In April 2022, MEC staff, Orange EV, Penn State, and Lazer Spot participated in a fleet electrification panel, *Zero-Emission Freight Handling: Making the Case with Electric Yard Trucks,* at Green Transportation Summit and Expo in Tacoma, WA. The moderator for the season was Karl Pepple, West Coast Collaborative Lead, EPA Region 10. After MEC staff gave an overview of the project to a full room, Pepple opened the floor for questions for MEC and the other panelists. 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.

MEC continues to collaborate with Orange EV and the project fleets to host local events and deploy additional trucks in the region.

Research Results

In this section, we conduct a comprehensive analysis of the overall truck operating statistics, encompassing three main areas: a survey-based description of the truck operating sites, an analysis of truck daily usage, and statistics on charging events. Each component plays a vital role in understanding the performance and operational efficiency of electric terminal trucks. The findings from these analyses are detailed below.

Survey-based Description of Truck Operating Site

Of the five electric trucks, four were deployed to three sites (i.e. one to Hirschbach Motor Line, one to Johnson County and two to Lazer Spot). There is also a demo truck (denoted as OEV4) owned by Orange EV that has been at multiple locations across the U.S. for demonstration purposes. At the time of this writing, the demo truck had operated at 8 different work sites across Kansas and Missouri.

Hirschbach Motor Line's electric truck (denoted as HIR1) is deployed at a flat client site in Wyandotte County, KS. It typically works as a storage trailer that hauls frozen beef, pork, etc. The truck works two 12-hour shifts a day. There is a level two charging station installed by a utility company to serve this truck. As surveyed, in the daily usage log, it takes 5 hours to charge from 25% to full. Opportunity charging is also important to get an additional 10% SOC increase for about 15 minutes every 1 hour, on average.

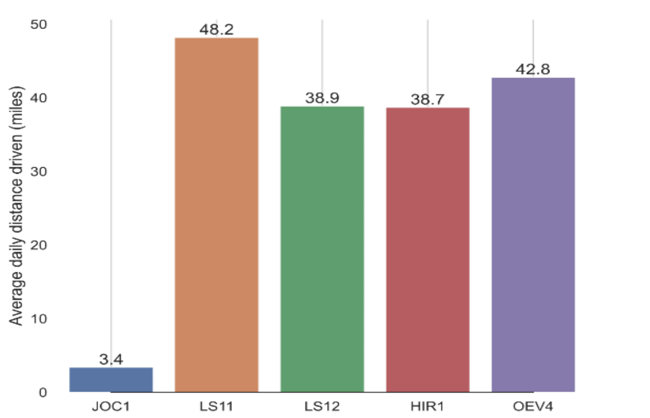
Hirschbach Motor Lines notified MEC that its truck previously located at a client site in Edwardsville, KS needed to move in early 2023 to a client site in Sikeston, MO. This move was requested due to the truck specs being more suited for the site as well as long-term food storage customers moving to the Sikeston site.

Johnson County uses an electric truck (denoted as JOC1) to haul solid waste in 4800 Nall Ave. in Mission, KS. It is a steep site with an over-15% grade. Thus, the electric truck may have restrained low speed and be less capable than a diesel truck. However, there is a charging station built for the truck, and the truck only needs to operate 1.5 hours a day. For the remaining time, the truck is under charging status, so the battery level is nearly full most of the time.

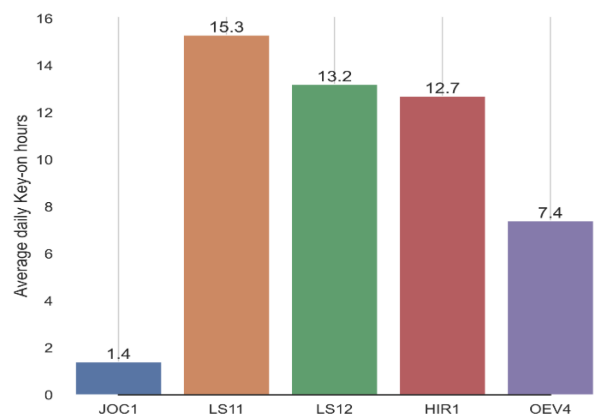
Lazer Spot deploys two electric trucks that are located at 716 E. 111th St. in Chicago. They are two mostly flat sites that are 0.5 miles apart. The two trucks (denoted as LS11 and LS12) typically haul raw materials, hard boxes, containers, liquids, washers, dryers, paper mill, etc. They work eight-hour shifts and spend an average of two hours charging per day. One Orange EV fast charger is installed that serves the two trucks. Cold weather may impact the driving range by 1-2KW per hour. In this case, the battery needs to be heated to support normal working conditions. It is also suggested the drivers be instructed to charge when the SOC level is under 20%.

Truck Daily Usage Analysis

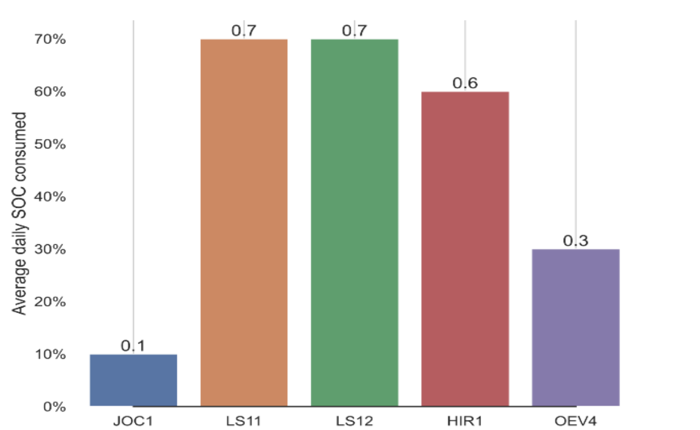
The daily usage statistics of the five electric terminal trucks are given in Figure 6. Therein, JOC1 was obviously the least used truck compared with the other four trucks in terms of average daily distance driven, key-on hours and SOC used. Among the other four electric trucks, LS11 was the most used of all three aspects. Furthermore, the average daily distance driven ranged from 38-48 miles. The average daily key-on hours ranged from 7-15 hours. The average daily SOC used ranged from 30- 70%. Each truck except JOC1 was heavily used daily.



(a) Average daily distance driven (miles)



(b) Average daily Key-on hours



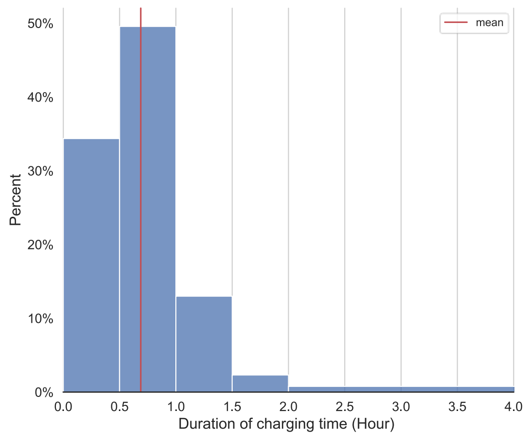
(c) Average daily SOC used

Figure 6: Daily usage statistics

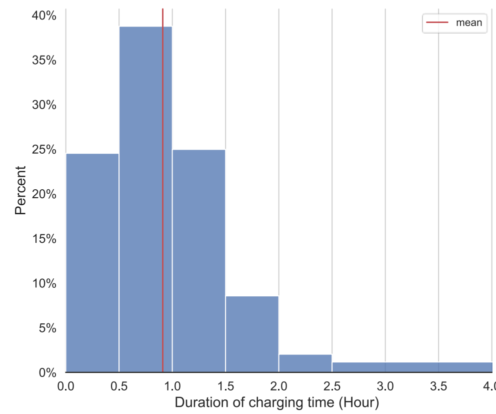
Charging Event Statistics

The overall truck operating statistics show that except for JOC1, the electric trucks were heavily used daily, and the charging behavior of electric trucks served by the fast charger is evidently different from that served by the non-fast charger. To specify, LS11 and LS12 have a shorter duration, more SOC improvement, more full charging events within a shorter time frame, faster charging speeds during each charge and longer milage after each charging event.

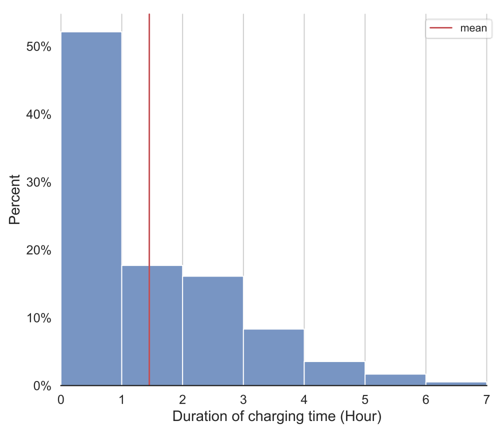
In Figure 7, the distribution of charging time duration for all five trucks is shown. The average duration of charging time ranged from 0.3-3 hours per charge. The charging duration of JOC1 was the shortest since it was rarely used. The duration per charge of LS11 and LS12 was 0.69 and 0.91 hours respectively, both less than one hour, which can be explained by the Orange EV fast charger installed at the site.



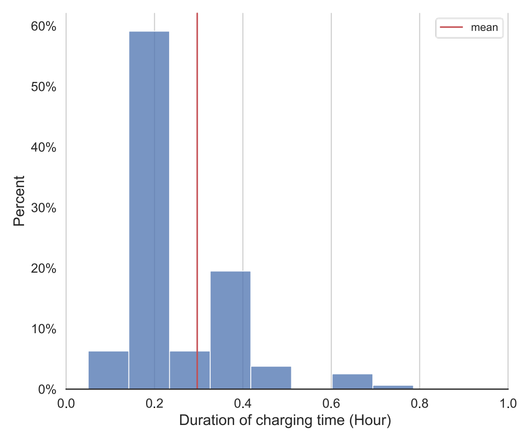
(a) LS11



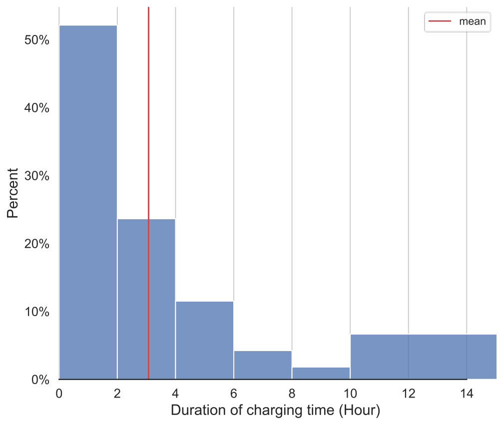
(b) LS12



(c) HIR1



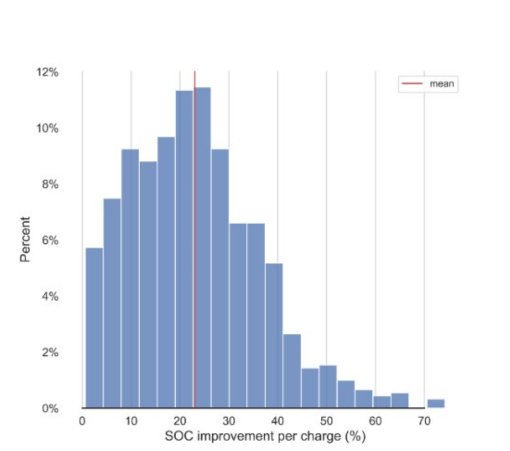
(d) JOC1



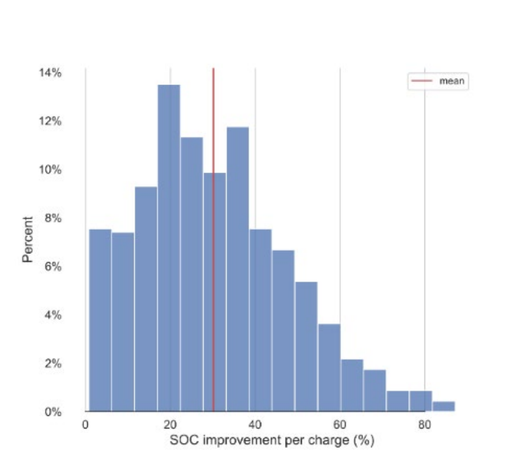
(e) OEV4

Figure 7: Distribution of charging time duration

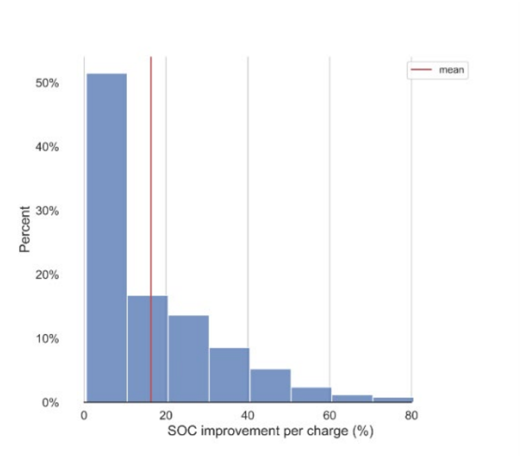
The distribution of SOC improvement per charge for all five trucks is given in Figure 8. The average value ranges from 3-30%, with JOC1 as the minimum and LS12 as the maximum. It can be observed that for HIR1, OEV4 and JOC1 that are served by non-fast charger, their SOC improvement per charge was mostly below 20%. While for LS11 and LS12 served by a faster charger, most of their SOC improvement per charge were between 20-40%. Combined with charging duration distribution, it can be concluded that electric trucks could get more electricity in a shorter duration with the fast charger.



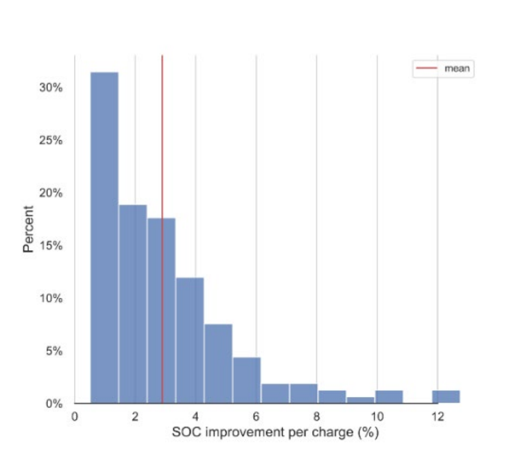
a. LS11



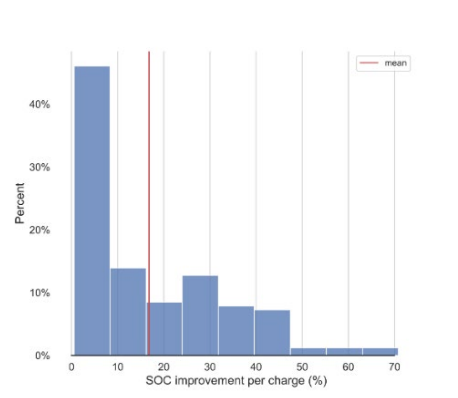
b. LS12



c. HIR1



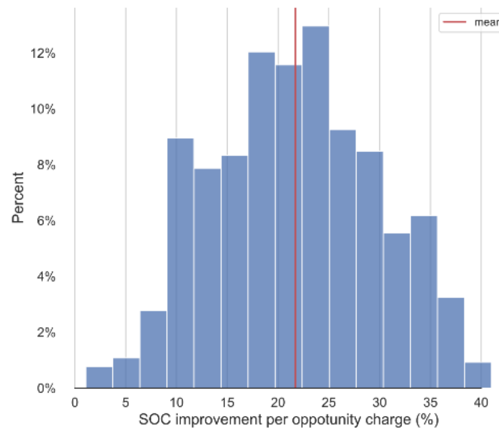
d. JOC1



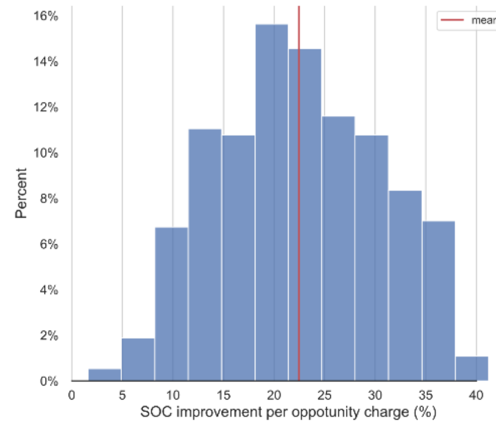
e. OEV4

Figure 8: Distribution of SOC improvement per charge

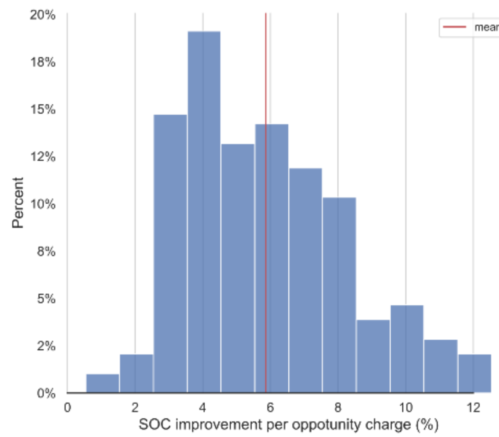
Further, we define "opportunity charge event" as charging events with durations ranging from 15 minutes to 1 hour for truck drivers to take a break. As Figure 9 shows, the average SOC improvement per opportunity charge was between 5-22%. Therein, the average values of HIR1, OEV4 and JOC1 served by a non-faster charger was around 5% while those of LS11 and LS12, served by a faster charger, was about 22%. This is consistent with the finding from SOC improvement per charge discussed above, i.e., a faster charger could provide more SOC improvement per opportunity charge.



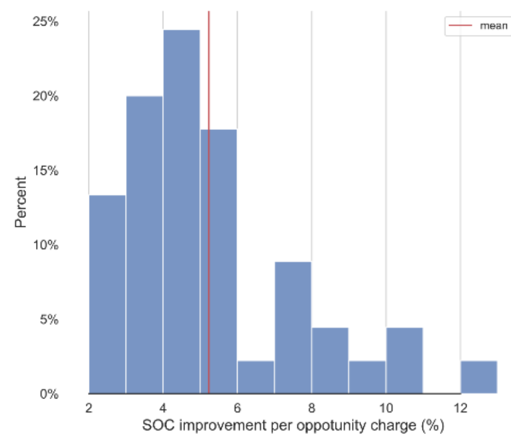
a. LS11



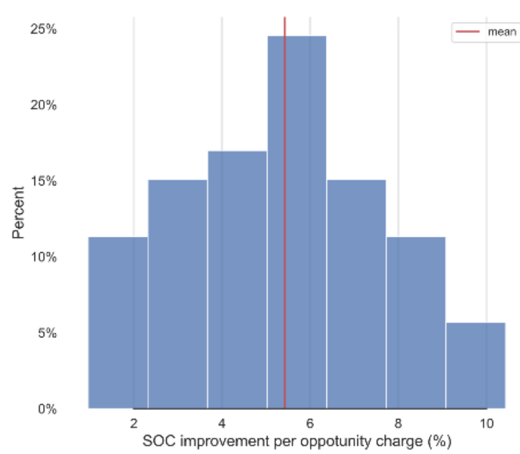
b. LS12



c. HIR1



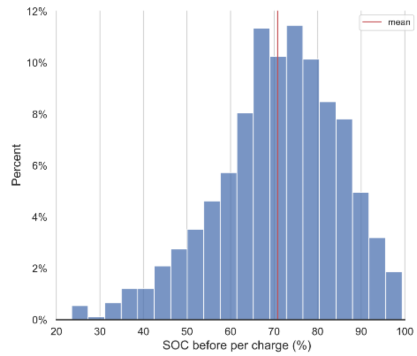
d. JOC1



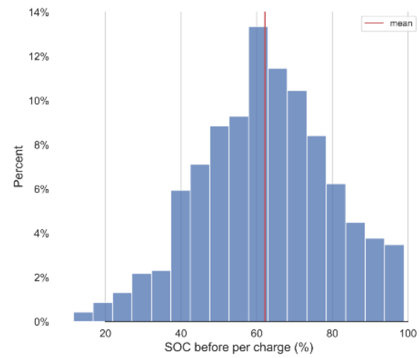
e. OEV4

Figure 9: Distribution of SOC improvement per opportunity charge

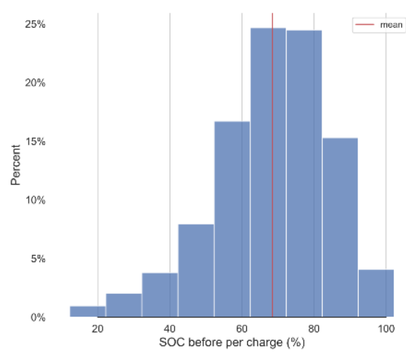
Figure 10 shows the distribution of SOC before per charge. The average value ranges from 62-97%, with JOC1 the highest, since it was least used and connected to chargers for the most time. It can also be observed from Figure 10 that for the other trucks, most of the charging events start with the initial SOC value, around 60%, which indicates truck drivers prefer to charge, even when the remaining SOC is relatively sufficient. That way, they can avoid high-range anxiety and ensure the truck could be ready to complete the upcoming work with enough milage.



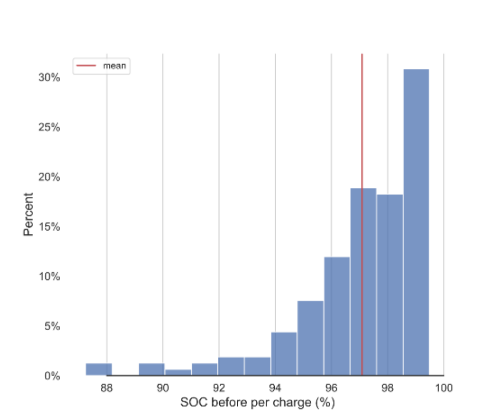
a. LS11



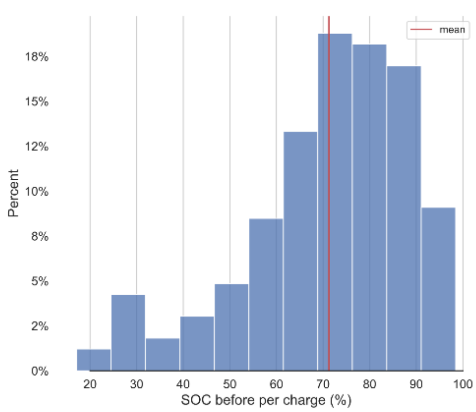
b. LS12



c. HIR1



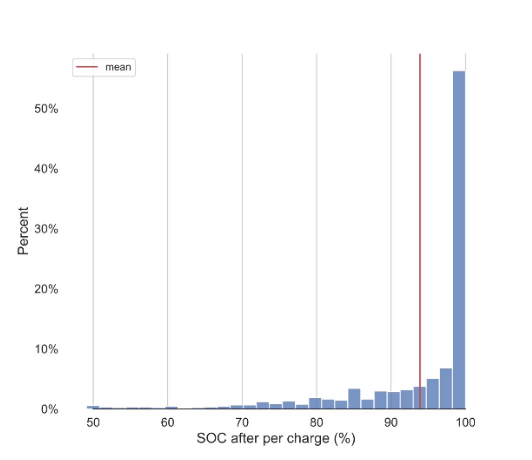
d. JOC1



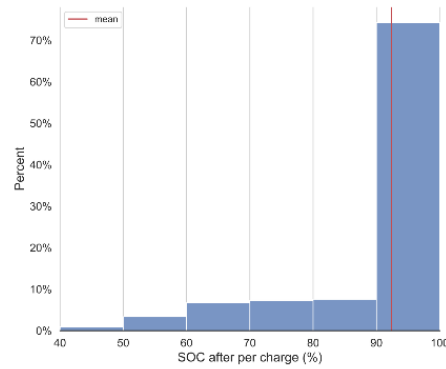
e. OEV4

Figure 10: Distribution of SOC before per charge

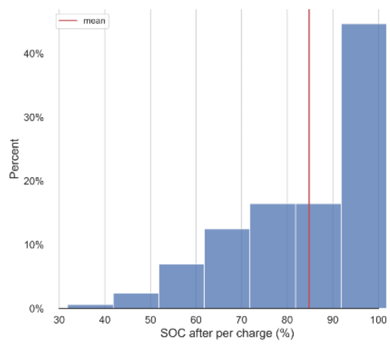
Figure 11 gives the distribution of SOC after per charge. The average value ranges between 84-100%. It can be observed that most of the charging events end with a full charge, especially for JOC1, LS11 and LS12, with the JOC1 seldom out of the charger, and LS11 and LS12 served by a faster charger. Thus, it can be concluded that charging with a faster charger can bring more full charging events.



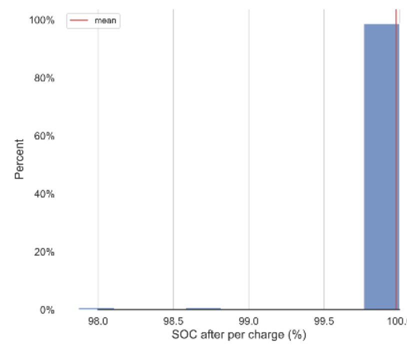
a. LS11



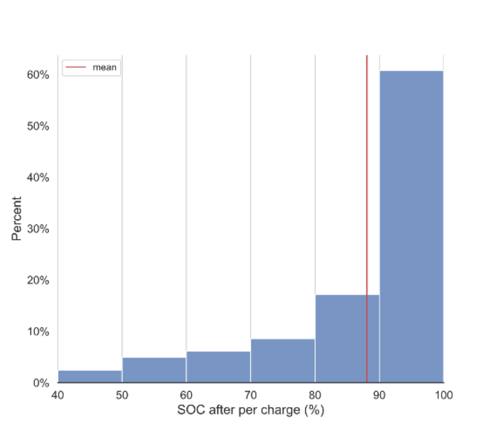
b. LS12



c. HIR1



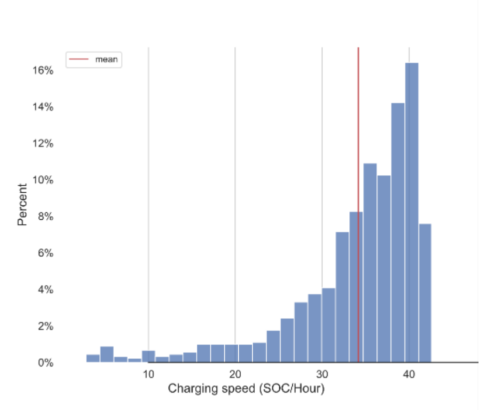
d. JOC1



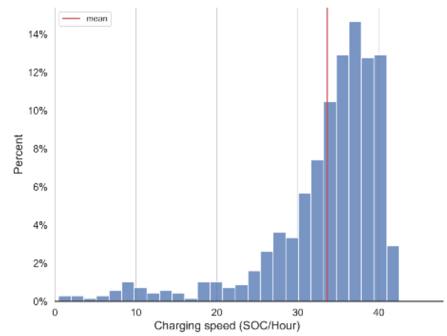
e. OEV4

Figure 11: Distribution of SOC after per charge

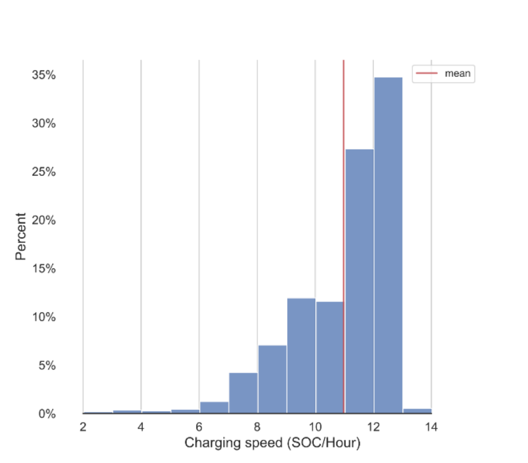
Figure 12 shows the distribution of charging speed measured by SOC/hour. It is evident the charging speed of the fast charger was significantly higher than the non-fast charger, given the average speed of LS11 and LS12 are around 34%/hour while that of JOC1, HIR1 and OEV4 were below 11%/hour.



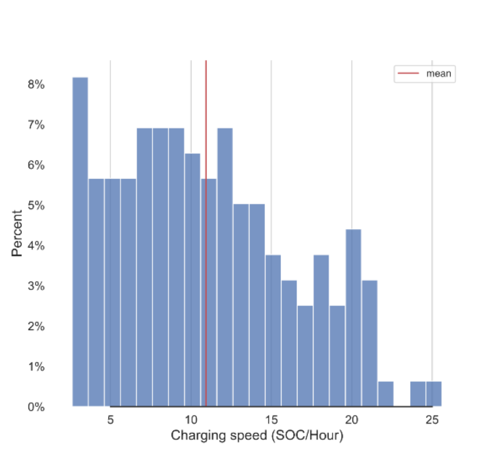
a. LS11



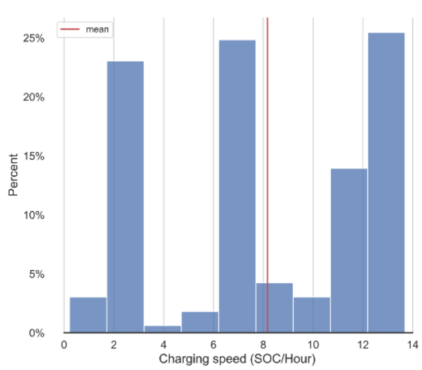
b. LS12



c. HIR1



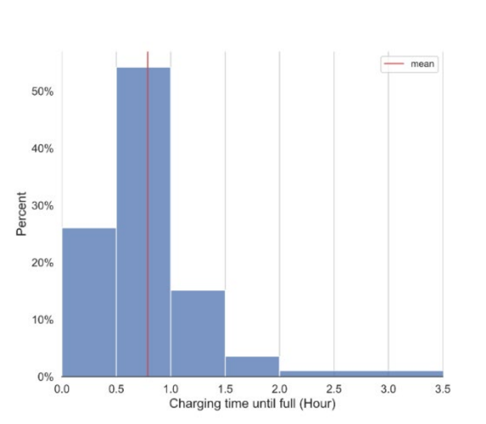
d. JOC1



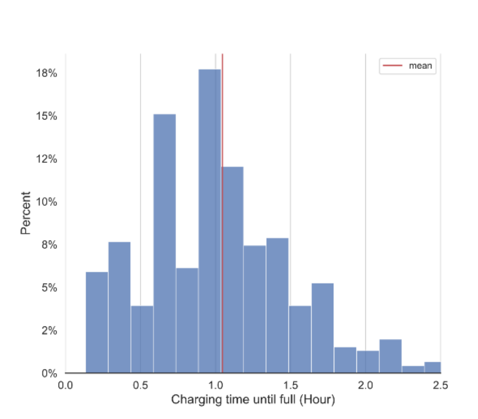
e. OEV4

Figure 12: Distribution of charging speed

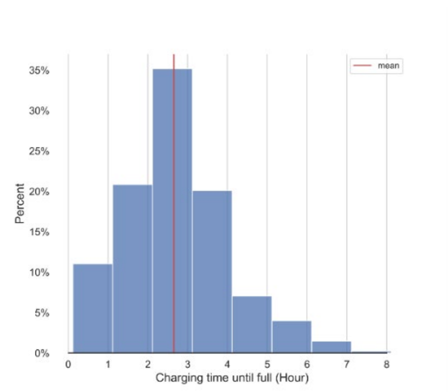
Further, we investigate the full charge event, defined as when charging ends with SOC level being 100%. Figure 13 shows the distribution of charging time for a full charge event. With the rarely used JOC1 excluded, it can be observed that the average full charging time for LS11 and LS12 was less than one hour while that of HIR1 and OEV4 was 2.65 hours and 3.93 hours, respectively. Hence, trucks served by the fast charger can be fully charged in a shorter time.



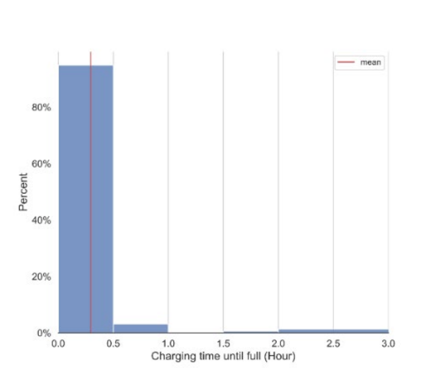
a. LS11



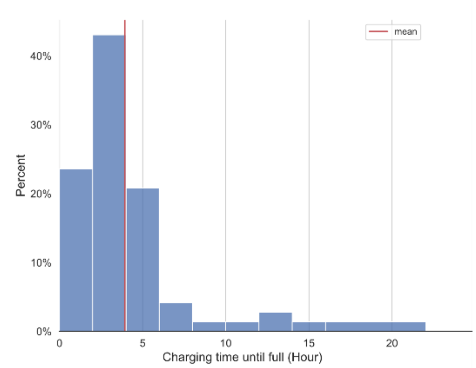
b. LS12



c. HIR1



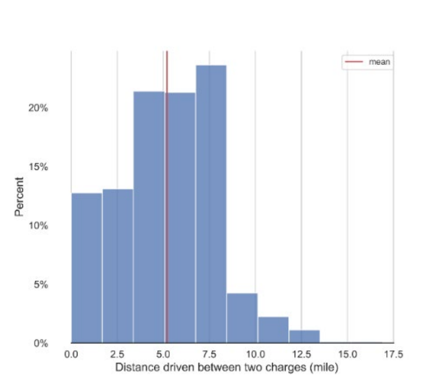
d. JOC1



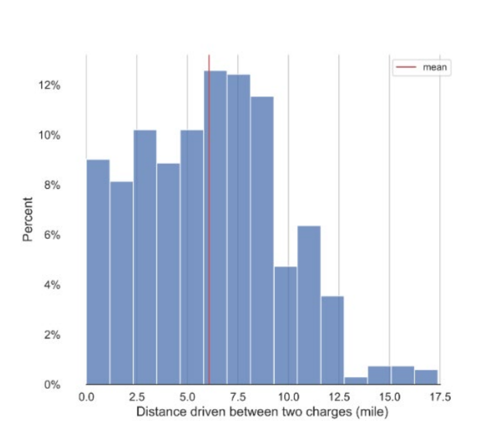
e. OEV4

Figure 13: Distribution of charging time for full charge event

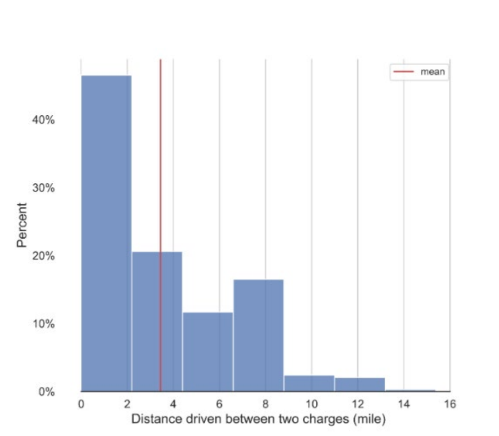
Figure 14 shows the distribution of the distance driven between two charge events. With JOC1 excluded, the average value ranges between 3.4 miles and 6.0 miles. Therein, the mean distance driven between two charge events of LS11 and LS12 is larger than that of HIR1 and OEV4. This can be explained by the faster recharge speed being able to support longer milage after each charging event.



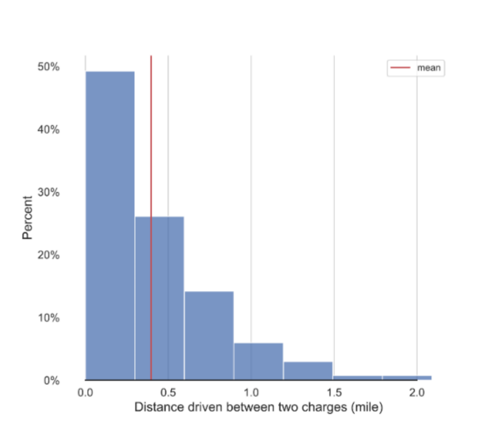
a. LS11



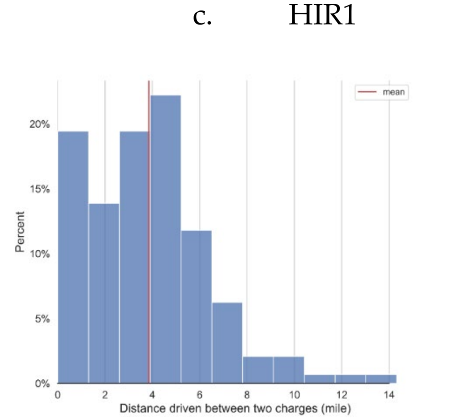
b. LS12



c. HIR1



d. JOC1



e. OEV4

Figure 14: Distribution of distance driven between two charges (mile)

Financial and Operational Insights

Monetary Cost Savings

In this section, we conduct a comprehensive analysis of the overall truck operating statistics, which encompasses three main areas: **a survey-based description of the truck operating sites, an analysis of truck daily usage, and statistics on charging events.** Each component plays a vital role in understanding the performance and operational efficiency of electric terminal trucks. The findings from these analyses are detailed below.

Based on the daily report of each electric truck, an analysis of monetary cost savings can be conducted. Monetary cost savings is the comparison of the expenses of electric terminal trucks compared to traditional diesel trucks. The expense of OEV is defined as the charging cost. The expenses of traditional diesel trucks include diesel cost, preventative maintenance cost and DEF cost. The monetary cost saving is the difference. The operational assumptions that are made are shown in Table 1.

TABLE 1 OPERATIONAL ASSUMPTIONS FOR MONETARY COST SAVINGS

Operational Assumptions	
Battery Size of HIR1, LS11 LS12 OEV4 (kWH)	160
Battery Size of JOC1 (kWH)	80
Diesel Consumption Rate (GPH)	1.50
Diesel Cost ($)	3.70
kWh Cost ($)	0.10
DEF Consumption Per Gal of Diesel (Gal)	0.03
Maintenance Reduction Per Hour	0.82
Annualized numbers based on 365 Days/Year	365
Charging Efficiency Rate	92%

Figure 15 shows the daily cost comparison of electric trucks and diesel trucks. It can be observed that the cost of an electric truck is much lower than a traditional diesel truck when completing equivalent tasks, especially for the intensely used LS11 and LS12. Hence, the economic feasibility of electric trucks can be demonstrated by the savings of electric trucks over diesel trucks.

In addition, total savings is significantly higher when adding savings related to: emissions control (100% savings); overall maintenance and repair (up to 75% savings); opportunity / downtime related costs; human health and employee morale including absenteeism and retention; work comp and liability related to health-impacting emissions and truck operation; and broad range of other savings due to improved safety, zero emissions/carbon reporting, process improvement, time savings, etc.

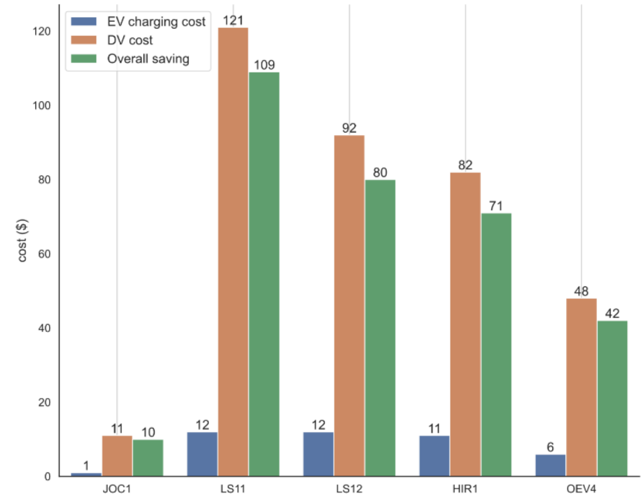


Figure 15: Daily cost comparison of electric truck and diesel truck

Health and Environmental Benefits Quantification

The analysis of environmental benefits quantification used Diesel Emissions Quantifier (DEQ) from EPA to produce the emission amount if the equivalent workload is conducted by diesel trucks, which is measured by NOx, PM2.5, HC, CO, and CO_2. It also used the Greenhouse Gas Equivalencies Calculator from (EPA) to obtain the emission amount, which is quantified by CO_2. The result of environmental benefits quantification is given in Table 2.

TABLE 2 RESULT OF ENVIRONMENTAL BENEFITS QUANTIFICATION

	Diesel Truck						Electric Truck	
Annual Results	**Fuel (gallons)**	**NOx (short tons)**	**PM2.5 (short tons)**	**HC (short tons)**	**CO (short tons)**	**CO_2 (short tons)**	**kWh used**	**CO_2(short tons)**
HIR1	11,646	1.39	0.14	0.105	0.698	131	35,687	16.97
JOC1	556	0.110	0.009	0.008	0.052	6.3	2,886	1.32
LS1	8,469	1.684	0.170	0.127	0.846	95.3	41,300	19.73
LS2	6,972	1.386	0.140	0.105	0.696	78.4	40,515	19.29
OEV4	4,562	0.847	0.085	0.064	0.425	51.3	19,638	9.37

The environmental benefits of OEV versus diesel trucks can be measured by the difference of CO2 emission and the NOx, PM2.5, HC, CO emission caused by diesel consumption. In Table 2, column two gives the annual diesel consumed by diesel trucks, and column eight gives the annual electricity by electric truck under the same workload. Columns three through six show the NOx, PM2.5, HC and CO emission amount, respectively. Columns seven and nine provide the CO2 emission by diesel truck and electric truck. It can be observed that diesel truck discharges NOx, PM2.5, HC and CO, while electric trucks don't. Meanwhile, diesel trucks produce much more CO2 emission than electric trucks, thus causing higher greenhouse impacts.

Since electric trucks can avoid the emission of PM2.5 caused by diesel consumption, its health benefits can be discussed as follows. Fine particles, also known as PM2.5, are extremely small particles or droplets in the air that measure 2.5 microns or less in width. To put this into perspective, a micron is a unit of measurement for distance, and there are approximately 25,000 microns in an inch. The larger particles in the PM2.5 size range are about thirty times smaller than the width of a human hair, while the smaller particles are so tiny that several thousand of them could fit on the period at the end of this sentence.

Fine particles in the PM2.5 size range can travel deeply into the respiratory tract, reaching the lungs and causing short-term health effects such as eye, nose, throat and lung irritation, coughing, sneezing, runny nose and shortness of breath. Exposure to PM2.5 can also worsen medical conditions like asthma and heart disease by affecting lung function. Research has linked increases in daily exposure to PM2.5 with higher rates of respiratory and cardiovascular hospital admissions, emergency department visits, and deaths. Long-term exposure to fine particulate matter has been associated with increased rates of chronic bronchitis, reduced lung function, and higher mortality from lung cancer and heart disease. People with respiratory and heart problems, the elderly, and children may be especially sensitive to PM2.5. The specific impacts of PM2.5 exposure have been evaluated using the distributed approach of simulating air quality by employing WRF-Chem modeling (Tuladhar et al. 2021). According to the US EPA (EPA 2010), health impact functions in studies assessing the effects of air quality changes most commonly use the log-linear relationship form. A typical health impact function utilizing this form specifies a logarithmic relationship between the risk and changes in air quality, as outlined by (1) (EPA 2010).

$$d = \left(\exp\left(\frac{logR}{10} * c\right) - 1\right) * \text{Total Population} * \text{Mortality Rate} \quad (1)$$

Where c is the average PM2.5 concentration, using a horizontal grid resolution of 3 × 3 km from WRF-Chem model; Total Population is the ward-wise population; Mortality Rate is the mortality rate for certain diseases per 100,000 people, takes 1.081 per 100,000 people for lung cancer; RR is the relative risk reported from various published epidemiological studies, takes 1.14 due to lung cancer mortality; dd is the estimated number of PM2.5-related total deaths one ward.

As Table 3 shows, the annual deaths as a result d by PM2.5 ranges from 0.02 to 0.29 per 100,000 people. It can be concluded that electric trucks can bring health benefits by avoiding the PM2.5 resulted death.

TABLE 3 PM2.5 RESULTED DEATH

Annual Results	PM2.5 Concentration (μg/m3$\boldsymbol{\mu g/m3}$)	PM2.5 resulted death
HIR1	0.38	0.24
JOC1	0.02	0.02
LS1	0.47	0.29
LS2	0.38	0.24
OEV4	0.23	0.14

Conclusion

Resources

- **Video:** Driving the Future with Electric Terminal Trucks
- **Webinar recording:** Electrifying Terminal Trucks: Best practices and lessons learned from deployments in the Kansas City region and beyond

Lessons Learned

- **Financially Beneficial:** Even in a low use-case scenario, terminal tractors will often see a financial benefit early in their deployment lifecycle.
- **Infrastructure Matters**: Access to fast-charging stations significantly enhanced operational efficiency and reduced downtime. Future projects must prioritize strategic placement of fast chargers to optimize deployment.
- **Tailored Deployment**: The variability in site conditions, such as steep grades or extreme weather, underscored the need for tailored solutions to maximize electric truck performance.
- **Stakeholder Engagement**: Close collaboration with fleets and drivers was instrumental in refining operations and addressing challenges, demonstrating the value of involving end-users early in the process.
- **Worker Health Benefits:** Due to the quiet and efficient motor, the wear on the truck operator's hearing and overall health is immediately noticeable. The reduction in air emissions is also a known health benefit for workers and the surrounding community.
- **Data-Driven Decisions**: Comprehensive data collection and analysis were crucial for validating the benefits and identifying areas for improvement, highlighting the importance of robust monitoring systems.
- **Public Awareness and Education**: Outreach efforts, including workshops and informational videos, proved essential in building support and encouraging adoption among other fleets.

Results

This project has successfully demonstrated the feasibility and benefits of deploying electric terminal trucks in freight yards. It contributed to new grants to Hirschbach, Lazer Spot and other fleets to deploy electric terminal tractors around the plains and Midwest states. By collaborating with industry leaders, research institutions and community stakeholders, the project highlighted significant economic, environmental and operational advantages, including reduced emissions, lower operational costs, and enhanced public health outcomes. The project also advanced understanding through data collection and analysis, yielding insights that can inform broader adoption of zero-emission freight solutions. As electric vehicle technology continues to evolve, initiatives like this pave the way for a cleaner and more sustainable transportation future.