Net-Zero Farming and Freight Facility Demonstration Project:

San Joaquin Valley Electric Truck and Electric Transport Refrigeration Unit Development and Deployment

Final Report:

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PROJECT CLEAN AIR
HUMMINGBIRD ELECTRIC VEHICLES
TECHTRUTH CONSULTING
MOONLIGHT
ROSA BROTHERS MILK COMPANY
CALIFORNIA CLIMATE INVESTMENTS
CALIFORNIA AIR RESOURCES BOARD

San Joaquin Valley Electric Truck and Electric Transport Refrigeration Unit Development and Deployment

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Acknowledgements

Project Clean Air (PCA), along with the Project Team, expresses our appreciation to the California Air Resources Board (CARB) for the opportunity to apply to the Net-Zero Farming and Freight Facility Demonstration Project solicitation in 2018. PCA further acknowledges that this project would not have been possible without the hard work and dedication of the entire project team. Special thanks go to HummingbirdEV, the project technology partner, for designing, developing, and manufacturing five all-electric Class 8 trucks (eTrucks) equipped with all-electric transport refrigeration units (eTRU); TechTruth Consulting, for performing detailed data analysis to assess the eTruck/eTRUs overall performance, emissions and GHG reduction potential, lifecycle costs, and user satisfaction; and to the end-users Moonlight Companies, Rosa Brothers Milk Company and Joseph Gallo Farms for their patience and valuable insights throughout the project. This report was submitted in fulfillment of the Net-Zero Farming and Freight Facility Demonstration Project: *SJV Electric Truck and Electric TRU Development and Deployment*. PCA bears sole responsibility for the work presented here.

PHOTO: A Rosa Brothers Milk Company employee loading the HummingbirdEV eTruck/eTRUs for the day's deliveries.

Executive Summary

To meet California's health-based air quality standards and greenhouse gas emission reduction goals, trucks operating in the state, and the fuel they use, must be transformed away from petroleum. This commitment is highlighted by Executive Order N-79-20, signed by the Governor of California, that sets a goal of 100 percent of medium- and heavy-duty vehicle operation in the state to be zero-emissions by 2045. Another source of transportation-

related emissions targeted by the state comes from transport refrigeration units (TRU). TRUs control the environment of temperature-sensitive products that are transported in refrigerated trucks. CARB is currently developing requirements to transition diesel-powered TRUs to zero-emission technology.

These standards, targets and goals require rapid market penetration of zero emission trucks and TRUs into fleets operating medium- and heavy-duty trucks. To demonstrate the feasibility of these new technologies in real-world applications, CARB provided funding for the design, manufacture, and deployment of 5 all-electric trucks (eTruck) equipped with electric TRUs (eTRU). These 5 eTrucks with eTRUs, the first of their kind, address two prominent diesel emission sources being addressed by CARB. They were tested in challenging agricultural applications but the market potential for the technology crosses into many other industrial sectors. This demonstration project proved that electric trucks, equipped with electric TRUs, can perform as well as conventionally fueled vehicles, be cost competitive, and significantly reduce emissions and greenhouse gases.

The eTrucks/eTRUs were deployed in two different locations in the central San Joaquin Valley, a prime location for introducing emission-reduction technologies. Air quality across this agricultural region is among the worse in the nation. Of the 277 metropolitan areas in the country, the American Lung Association's State of the Air 2012 ranked the Fresno-Madera Area in the top five most polluted cities for all three indicators of high ozone days, 24-hour particulate pollution, and annual particulate pollution. Consequently, the surrounding communities benefit disproportionally from emission-reduction technologies. The eTrucks and eTRUs operated 100 percent of the time within a Disadvantaged Community (as per CalEnviroScreen 2.0), providing immediate health benefits where they are needed most.

HummingbirdEV, a California-based company, designed and built the five Class 8 all-electric trucks. These trucks were then equipped with third-party all-electric, battery powered TRUs. The first two units were built with an independent TRU, where the TRU had a separate battery pack. The following three units were built with a "non-independent" TRU, where the truck propulsion battery was used for eTRU operation.

Two of the eTrucks were used by Moonlight Companies to transport packaged fruit and produce from the packing plant to nearby cold storage facilities. (Third eTruck was delivered but was damaged by an electrical infrastructure incident upon two days of use after delivery.) This application addresses GHG reduction in the back and forth of "first 5-15" miles of agricultural freight movement. An eTRU-equipped eTruck was also used for agricultural purposes by Rosa Brothers Milk Company (Rosa Brothers) to deliver milk to local vendors. In addition, each truck was tested extensively by HummingbirdEV before being delivered to the end-user. This included loading the eTrucks up with an artificial payload and test driving them with full eTRU operation. While the last eTruck was scheduled to be used by Joseph

Gallo Farm, due to administrative delays was not used for the reminder of the project and the same vehicle is in-service currently. This eTruck that was test-driven over 4,000 miles as a mule vehicle in real-world conditions by HummingbirdEV in this manner.

Two unprecedented hardships: the China-United States Trade War beginning in 2018 and the global Coronavirus (COVID-19) Pandemic and subsequent economic shutdowns, raw material and chip shortages pushed this project back almost two years. The delayed project timeline led to staff turnover with the various partners and impacted deployment of the eTrucks. Collectively, the deployed eTrucks still accumulated 15,032 miles during the demonstration. Four trucks placed into service are still being operated by the end-users.

Despite the setbacks, HummingbirdEV (HBEV) did meet project goals and objectives during the development stage of the project. However, there was an additional challenge during the demonstration period. The first two trucks sent to Moonlight Companies could not be used for their intended application. The box was designed with a door height of 94", Moonlight application needed 96" for forklifts to drive in. Hummingbird suggestion of using pallet jacks to load was not taken into consideration and used minimally till HummingbirdEV found alternative users. This design was changed on the remaining eTrucks, which were subsequently put into service by Moonlight. In addition, the eTrucks were originally designed to be Class 7 but the weight of the vehicle resulted in a Class 8 classification. To drive a Class 8 truck, drivers must have a commercial driver's license (CDL). Only two drivers at Moonlight had these qualifications which limited eTruck usage.

During the course of the demonstration, a large amount of data was collected on the eTrucks and eTRUs. Three different datasets were used from three different data logging devices. This data was synthesized and analyzed by TechTruth Consulting. Evaluation of the eTrucks and eTRUs focused on four areas 1) Overall performance and durability of the technology, 2) Emission and GHG reduction potential, 3) Near-term cost-effectiveness of the technology, and 4) End-user experience and acceptance.

The eTrucks performed well and were well-suited for the assigned applications and tasks. Technical glitches did occur in the field, as expected. However, many of these incidents were minor (some caused by driver error) and most were immediately resolved. The original third-party eTRU manufacturer withdrew from the project. Their untimely withdrawal created additional problems and delays integrating the eTRU into the eTrucks. A recently established eTRU manufacturer from Canada was contracted and the technical issues were overcome, thus proving that the eTrucks can be used with a "standard" third party electric TRU.

A 40-kW charging station was installed for each vehicle in a convenient location. The full capacity of the chargers was not realized by Rosa Brothers because of site infrastructure limitations, therefore charging took a little longer (the two independent eTRUs charged at 4 kW). All eTrucks were fully charged during the allotted charging time (overnight during off-peak electricity hours) and peak demand charges were reportedly not significantly affected

by eTruck charging. HummingbirdEV incorporated measures in the battery management system (BMS) to maintain maximum battery conditioning. At the end of the demonstration period, the battery state of health (SOH) remains at 100% in all the trucks.

A key component of this analysis included a comparison of the eTruck greenhouse gases and foregone emissions to a baseline diesel truck. The eTrucks with eTRUs proved to be a cost-effective means for reducing greenhouse gases and criteria emissions. GHG and emission reductions are based on the emission rate of the baseline diesel truck. A single 2008 model year diesel truck at Moonlight replaced by an eTruck saved 27.76 metric tons (MT) of GHG each year at a cost of $353/MT over a 10-year period. Criteria pollutant emission were reduced by 0.0932 tons/year (weighted emission reductions of NOX, ROG and PM_{10}) at a cost of $105,204/ton over a 10-year period. These calculations are based the actual baseline truck operation during the demonstration. The observed annual mileage was only about 36% of the eTruck range capacity given a single charge per day (assuming a 100-mile range). Emissions and GHG reductions would be significantly greater if an eTruck replaces a conventional diesel truck with higher mileage.

At a cost of $400,000 to manufacture, the first five eTrucks with eTRUs cannot compete economically with conventional reefers. However, they present a tantalizing prospect in the near- to mid-term as manufacturing costs are expected to drop greatly with production of the next few units. Engineering estimates from the manufacturer suggest that the near-term cost of the eTruck could drop to approximately $280K, at relatively low production volumes. At this price and a resale value of $100K, the eTruck/eTRU combination could net a significant lifetime savings in the right application. For example, if an eTruck is used 100 miles/day for 345 days/year and efficiency increases 7%, an eTruck/eTRU unit could save approximately $148,357 over 15 years, compared to a $187.5K diesel unit with a resale value of $15K. Perhaps more importantly, the payback period (the time it takes for operating cost savings to offset the higher purchase cost) is only 6.65 years. This scenario is very plausible in the medium-term and is not too much of a stretch in the short-term. Under slightly more favorable conditions, the eTruck/eTRU unit savings could be doubled and have a payback period of 3 years or less.

Finally, the eTrucks and eTRUs were well received by the end-users. The drivers generally liked “the feel” of the truck, the regenerative braking, and the quietness. However, certain amenities, like a radio and USB port, were missed. Management also had high praise for the technology, although one end-user expressed the desire for more range. Another manager expressed concern about the price but said it would become a viable option at around $240K - $260K, slightly lower than the manufacturers short-term cost estimate. The end-users were ideal candidates for this demonstration. They understood that technical and logistical problems were likely and, when problems did occur, responded with understanding, tolerance, and patience.

PHOTO: The HummingbirdEV eTruck/eTRU (left) being loaded up for the day.

Introduction

In 2007, the California Alternative and Renewable Fuel, Vehicle Technology, Clean Air, and Carbon Reduction Act of 2007 (AB 118, Statutes of 2007, Chapter 750) was signed into law. AB 118 created the Air Quality Improvement Plan (AQIP), a voluntary incentive program administered by the California Air Resources Board (CARB), to fund clean vehicle and equipment projects, air quality research, and workforce training.

As required in Health and Safety Code (HSC) Section 44274(a), the Board adopted regulatory guidelines in 2009 for AQIP. The Guidelines for the AB 118 Air Quality Improvement Program (Guidelines) define the overall administrative requirements and policies and procedures for program implementation based on the framework established in statute. Central to the Guidelines is the requirement for a Board-approved annual funding plan developed with public input. The funding plan is each year's blueprint for expending AQIP funds appropriated to CARB in the annual State Budget. The funding plan focuses AQIP on supporting the development and deployment of the advanced technologies needed to meet California's longer-term, post-2020 air quality goals.

In 2012, the Legislature passed and Governor Brown signed into law three bills –AB 1532 (Pérez, Chapter 807), SB 535 (De León, Chapter 830), and SB 1018 (Budget and Fiscal Review Committee, Chapter 39) that established Green Gas Reduction Fund (GGRF) to receive Cap-and-Trade auction proceeds and to provide the framework for how the auction proceeds will be administered in furtherance of the purposes of AB 32, including supporting long-term, transformative efforts to improve public health and develop a clean energy economy. The suite of implementing legislation offers strong direction for investing a portion

of the auction proceeds to benefit disadvantaged communities, including specific allocation requirements in SB 535.

In 2014, the Legislature appropriated $200 million in GGRF monies to establish a Low Carbon Transportation GGRF program that CARB is implementing in coordination with the AQIP AB 118 programs. In May of 2016, Governor Brown's proposed budget included $500 million in GGRF monies toward the Low Carbon Transportation program. Projects funded by the Low Carbon Transportation GGRF program must reduce GHG emissions and further the purposes of AB 32, with a strong emphasis on benefiting disadvantaged communities.

California Climate Investments began in 2013 and received guidance specifically for disadvantaged communities from the Legislature through Senate Bill (SB) 535 (2012). It set minimum investments for projects that benefit disadvantaged and low-income communities and projects that are located within disadvantaged communities.

In 2016, AB 1550 (2016) amended the investment minimums for disadvantaged communities created by SB 535 to require that a minimum percentage of projects be located within and provide a benefit to disadvantaged communities. AB 1550 also established new investment minimums for low-income communities and low-income households. To date, California Climate Investments is meeting and exceeding these minimum levels while providing more than a half-million projects in communities statewide. CARB's April 2015 Sustainable Freight: Pathways to Zero and Near Zero Emissions discussion draft document details a long-term vision for transitioning the freight sector to near-zero and zero-emission and lists strategies for overcoming barriers to commercialization. The truck and bus commercial pilot projects funded under this Solicitation will support the Sustainable Freight document vision to overcome the technical and economic challenges with zero-emission technology advancement.

Net-Zero Farming and Freight Facility Demonstration Project solicitation was funded through the Low Carbon Transportation Investments and the Air Quality Improvement Program. This program provided mobile source incentives to reduce greenhouse gas, criteria pollutant, and toxic air contaminant emissions through the deployment of advanced technology and clean transportation in the light-duty and heavy-duty sectors. Low Carbon Transportation Investments were supported by Cap-and-Trade Auction proceeds. The Air Quality Improvement Program (AQIP) was established by the California Alternative and Renewable Fuel, Vehicle Technology, Clean Air, and Carbon Reduction Act of 2007 (AB 118, Statutes of 2007, Chapter 750). Each year, the legislature appropriates funding to CARB for these incentives to reduce emissions and support advanced technology demonstrations and deployments.

In December 2017, the Board approved the Fiscal Year 2017-18 Funding Plan, which identified projects that both provide immediate emission reductions from the vehicles and/or

equipment directly funded and, more importantly, set the stage for greater, indirect reductions in the future by accelerating large-scale market penetration and technology transfer to other sectors. The foundation for the Freight Facilities Project solicitation was established with this plan to support technology evolution through three phases of technology advancement: demonstration, commercialization, and transition to widespread deployment.

HummingbirdEV and Moonlight Companies asked Project Clean Air to apply for funding for an all-electric truck equipped with an all-electric TRU. Project Clean Air, based in Bakersfield, and Moonlight Companies, based in Reedley – both in the central San Joaquin Valley – understand the amount of pollution that comes from the transportation cycle of the region's largest economic driver: agriculture. All project partners were excited about designing and implementing an all-electric technology to help reduce emissions during the agricultural product movement.

Project Clean Air and CARB executed the original grant agreement on April 30, 2018. The agreement was subsequently amended on April 16, 2021, and again on January 23, 2023.

Hummingbird went well over projected budget as shown below in Table 1 as of to date. Final billing from HummingbirdEV to be submitted along with this report & hence numbers can further change.

Approved Budget			
Description	**ARB Funding**	**In-Kind**	**Total**
HummingbirdEV	$3,113,910.53	$1,256,320.52	$4,370,231.05
Users	$0.00	$2,000,000.00	$2,000,000.00
PCA	$74,370.00	$11,870.00	$86,240.00
TechTruth Consulting	$95,455.00	$9,545.00	$105,000.00
CTR	$0.00	$6,000.00	$6,000.00
	$3,283,735.53	$3,283,735.52	$6,567,471.05

HummingbirdEV End of Project Expense Summary			
Description	**ARB Funding**	**In-Kind**	**Total**
As of 2/13/23	$2,846,128.00	$2,523,906.33	$5,370,034.33
Yet to Bill	$263,237.00	$53,000.00	$316,237.00
	$3,109,365.00	$2,576,906.33	$5,686,271.33
		Overspent	**$1,320,585.81**

Table 1

Project Background

The focus of this project was to design, manufacture, and deploy five all-electric Class 7, eTrucks equipped with all-electric transport refrigeration units (eTRUs), then test the functionality and emission reduction potential of those units in real-world conditions. The electric technology would supplant diesel trucks with diesel TRUs operating in an agricultural environment in a Disadvantaged Community. The chosen project site was a produce growing operation in the San Juaquin Valley in central California. This site provides an ideal opportunity for the implementation of clean transport technology because the surrounding communities are exposed to extremely poor air quality. Of the 277 metropolitan areas in the country, the American Lung Association's State of the Air 2018 report ranked Fresno-Madera (the demonstration location) in the top five for most polluted cities for high ozone days, 24-hour particulate pollution, and annual particulate pollution. Farming transport activities are a significant source of this pollution, exacerbating the high soil-related NOx emissions associated with large agriculture areas. This area is also a Disadvantaged Community based on CalEnviroScreen 3.0.

The intended end-user for the new eTrucks/eTRUs was Moonlight Companies. Moonlight Companies, based in Reedley, is a major Stone Fruit Grower in the United States with nearly 5,000 acres producing Peaches, Plums, Nectarines, and Cherries. They also produce oranges and pomegranates, making this a 12-month operation. Moonlight Companies has thirty-five properties, spanning three Counties – Fresno, Tulare, and Kings. Their fleet includes eight, trucks ranging in size from Class 5 to Class 8, used for transporting product between their facilities. Diesel trucks are an integral part of Moonlight's operations. The trucks run, on average, six days per week up to eight hours per day (up to 16 hours/day, 7 days/week during peak season), operating mostly at relatively low speeds with many stop/starts and long idling periods. They operate along a fixed route, which is ideal for limited-range electric trucks, moving produce from the packing warehouse to the cold storage facility. Each truck combusts approximately 2,190 gallons of diesel per year.

HummingbirdEV, a California-based electric vehicle manufacturer, was tasked with developing, designing, and deploying all five eTrucks/eTRUs. TechTruth Consulting was tasked with providing third party data collection and analysis.

Another key component of this project was to create a market for all-electric heavy-duty eTrucks/eTRUs in the agriculture and freight industries by improving existing technology. This includes working with government agencies to develop standards for commercialization; developing strategies to reduce the cost of eTruck/eTRU production; and garnering interest among prospective buyers in the agriculture community and other commercial sectors. A campaign plan would focus on community and media relations, fleet outreach, and informational efforts that included exhibits and educational events.

Project Goals

Goals

All project goals in the original grant application, as stated below, were realized:

- Goal 1: Customize, manufacture, and deploy five all-electric class 7, single vehicle, eTrucks and all-electric transport refrigeration units (eTRUs)

- Goal 2: Demonstrate the functionality and GHG Emissions Reductions of the electric fleet (specifically in Disadvantaged Communities)

- Goal 3: Create a market for all-electric heavy-duty eTRUs in the agriculture and freight industries by improving existing technology.

Goal 1: Five eTrucks equipped with eTRUs – were successfully built, tested, and demonstrated. HummingbirdEV delivered the first eTruck to Moonlight Companies on November 11, 2021. The first two eTrucks, after being driven and tested by Moonlight for several weeks, were re-deployed because the door height was incompatible with Moonlight equipment. Two new end-users were brought into the project. The first, Rosa Brothers, used eTruck 1 for the delivery of dairy products to regional vendors. The second end-user was not able to deploy the truck because of administrative delays. Instead, that truck underwent additional testing and was driven - with a simulated payload and full eTRU operation - extensively by HummingbirdEV at their headquarters in CA. Three additional trucks were delivered to Moonlight several months later. Two were deployed transporting produce from the packaging warehouse to cold storage for the duration of the project. Soon after delivery, the Moonlight eTruck incurred electrical damage, believed to be caused by a surge in the electric grid. That eTruck was returned to HummingbirdEV where it was repaired and routinely driven and tested by employees for the duration of the project. In addition to testing, the trucks that were not used by third parties were driven by HummingbirdEV to exhibitions and events across California to showcase the technology.

The eTRU units were manufactured by a company in Canada that was contracted when the original partner, a major TRU manufacturer with facilities local to the demonstration site, backed out of the project. The eTRUs initially had several problems and many had to be sent back for repair on at least one occasion (which delayed eTruck deployment even more, by about 6 months). Although the eTruck performance assessment includes eTRU performance, it is important to point out that many of the technical malfunctions were eTRU-related. However, the eTRU is now functioning on every eTruck and has been tested well below the 68°F needed for the initial project application of transporting produce short distances at Moonlight. The Rosa Brothers unit maintained 37°F for milk delivery, even when ambient temperatures exceeded 100°F. In addition, they were tested for comparison.

In order to fully test the technology, HummingbirdEV opted to test and compare two fundamentally different eTRU architectures. The different approaches to integrating the eTRU – as an independent or non-independent unit - has implications for manufacturing, performance, and end-user satisfaction. Both types of units were field tested and compared, with those factors in mind.

eTruck design and manufacturing also exceeded grant application requirements. Hummingbird built Class 8 trucks instead of Class 7 trucks (to accommodate a larger battery pack). The structural integrity of the frame is significantly greater for the larger Class 8 truck. The battery pack and the driving range of the eTruck far exceeded what was needed in the Moonlight application (the original and only identified end-user on the project application). Reducing the range would engender significant manufacturing and operating cost savings. A smaller/lighter frame with a smaller/lighter battery pack (only a fraction of the battery energy was used on most days) would cost less to produce and be more efficient to operate.

Goal 2: Collectively, the 5 eTrucks have accumulated 15,032 miles to date while in service with the end-users. Several thousand additional miles were put on the trucks during pre-release testing. The three eTrucks placed into real world applications for a significant period, functioned well. In the Moonlight application the energy storage could have been downsized significantly and still met all the operating demands. In the Rosa Brothers Milk Company application, the end-user made changes to the routes to accommodate the eTruck range, however, these changes did not significantly impact their operations. Still, more range would have increased the eTrucks' functionality, in this application.

Truck emissions of NOx, ROG, and PM_{10} decreased 100% and GHG reductions were 81%, relative to the baseline diesel truck. This amounted to a weighted emission reduction of 0.0932 tons/year/truck over conventional diesel trucks and a reduction of 27.76 MT of CO2/year/truck. These reductions were realized in an application that demanded only a small fraction of the eTruck mileage capacity. Much greater emission and GHG reductions are possible if more diesel miles are displaced by eTrucks miles. In the ideal application, the eTrucks could realize approximately 64% more emissions and GHG reductions.

Goal 3: Although there are a few electric trucks in the freight industry, there is no known all-electric truck with and an all-electric battery TRU. Likewise, in the agricultural sector, there is no other known electric truck/electric TRU (eTruck/eTRU) combination. The project eTrucks received quite a bit of attention and publicity during the demonstration. They represent a new way of thinking for both public and private entities.

HummingbirdEV, was steadfast in establishing a reliable eTruck supply-chain amidst the U.S.-China trade issues, COVID pandemic shutdown, and the pandemic-caused product shortages throughout the U.S. The supply chain will increase efficiency and lower cost, helping create a market for eTrucks. HummingbirdEV has also refined the manufacturing

process in anticipation of increased production. These manufacturing changes will also expedite technology improvements through rapid process adaptation. The changes are also being implemented to facilitate market expansion by increasing efficiency and production levels, while simultaneously lowering costs.

A key component of market expansion is public engagement and education. To this end, HummingbirdEV participated in several public and private industry showcases. The eTruck was also made available for demonstrations at industry gatherings and conferences. The largest showcase was the World Ag Expo where an eTruck was on display in 2020, 2021 (virtually), and 2022. In 2022, HummingbirdEV's eTruck/eTRU was named a "Top-10 New Product Winner" at the World Ag Expo. This prestigious, high-profile award is widely recognized by farmers, ranchers and other industry professionals. HummingbirdEV will continue to promote the eTrucks. Already they have participated in tutorials and online educational events. The team's marketing and educational efforts extend to all forms of media from traditional print and television to social media, such as Facebook, Twitter, and Instagram.

The HummingbirdEV eTruck/eTRU – along with the Expo's "Top 10 New Product Winner" feather flag - on display at the 2022 World Ag Expo.

Project Implementation

Timeline

Throughout the life of this project, the Project Team faced two unprecedented hardships: the China-United States Trade War beginning in 2018, global pre and post Coronavirus (COVID-19) Pandemic and subsequent economic shutdown, which together, pushed this project back a full two years. As HummingbirdEV navigated through the supply-chain changes, the Coronavirus Pandemic hit and governments across the globe mandated lockdowns and quarantines, which impeded the movement of goods. This was followed by record-high unemployment due to exposure and illness from, COVID-19, which also further compounded the supply-chain issues for goods. Supply-chain disruption on manufactured goods started during the China-United States Trade War and became worse through the Pandemic. HummingbirdEV was unable to obtain the material needed to build the eTrucks.

Even the ability to test drive vehicles on local roads and acquiring vehicle registrations were affected, as many state offices were closed and California mandates kept employees at home. The delayed project timeline also led to staff and project partner turnover, most notably at PCA which resigned largely to an observational role. One critical partner, the eTRU manufacturer, dropped out of the project completely, further delaying the project while the search for a replacement took place. All of these unforeseen and unpreventable events caused a two-year delay in the project.

The project team stayed engaged and responded to challenges through monthly meetings with CARB, quarterly reports, progress reports, and two contract amendments that included time extensions. Despite the setbacks, the Project Team succeeded in building and demonstrating the eTruck/eTRU technology. However, end-user exposure had to be shortened, along with the data collection.

Additional End-Users

The intent of this project was for the eTrucks to deploy to multiple sites owned by Moonlight Companies in Fresno County. The eTrucks were not deployed to all the planned sites during the demonstration phase because of unpreventable project delays. Furthermore, the sole, pre-project identified end-user, Moonlight Companies, decided to use fewer trucks than planned. Two factors contributed to that decision 1) Truck box door incompatibility problem prevented two of the eTrucks from being used at their facilities and 2) They didn't have enough qualified drivers to operate all the Class 8 eTrucks (the original plan called for Class 7 trucks which does not require drivers to have a CDL).

In an effort to test the eTruck/eTRU units under real-world demands and challenges, HummingbirdEV found another end-user within the same region.

Rosa Brothers Milk Company (Rosa Brothers) is a third-generation family-owned dairy that produces and delivers wholesome, fresh milk and other dairy products. They use diesel

trucks to deliver milk and dairy products to regional markets. This application was even more demanding as the routes required longer travel between charges and the box temperature had to be kept much colder (the consequence of failing to maintain 37°F is damaged, unusable product).

Joseph Gallo Farms was founded in 1946 in the northern San Joaquin Valley. After working in the dairy business, the company built a cheese plant in 1982. One eTruck was intended to transport cheese to their customers. However, due to administrative delays, the eTruck was not used during the data collection time frame. This eTruck is in-service currently. The eTruck that remained largely in HummingbirdEVs possession were tested continuously and accumulated significant mileage, including trips to shows and exhibits. Testing included driving with a full payload, using brick weights to simulate product, and operating the eTRU at maximum capacity.

eTruck Manufacturing and Delivery

eTruck #1 (VIN# 1 H 9 8 B 1 E 0 3 L 1 7 0 7 0 0 1):

Once the design was finalized to specifications, HummingbirdEV went into the design phase primarily focused on working with a chassis OEM.

- From Q3-2019 to Q2-2020, HummingbirdEV narrowed down on Spartan for chassis, Volta Air for refrigeration units and Utilimaster. Issued POs for the same.
- Hummingbird received first 2 gliders in Q3-2020

Upon receiving first 2 gliders, HummingbirdEV worked on finalizing the design, manufactured, and shipped eTruck to Utilimaster & Volta Air in Q1-2021 and back to HummingbirdEV in Q4-2021 upon box and Electric refrigeration unit installation.

Unit was delivered to Moonlight Companies in Q4-2021 upon completion of certification and vehicle insurance (as vehicle cost was high, Moonlight declined to add to their policy, Hummingbird had to personally take up insurance) along with 2 charging stations and training completed with Moonlight team.

Moonlight however only used the truck minimally as the box was not tall enough to drive forklifts in and out.

HummingbirdEV quickly worked with Rosa Brothers Milk Company during Q2-2022 and communicated the same to Project Clean Air and partners. Project Clean Air worked on a sub-agreement with Rosa Brothers and the eTruck/eTRU vehicle has been in-service since Q2-2022.

eTruck #1 was driven 4532 miles in total at the time of this report.

User summary Truck#1

Location	Payload (Lbs)	Type of load	Avg run time (Hrs)	Hours of Operation	Avg travelled distance/day (Miles)	E-Tru used	E-Tru set temp ©	Type of Route
Tulare, CA	24,000	Dairy, Ice-cream	7	4am-11am	90	Yes	37	Urban, Freeway

Table 2

eTruck # 2 (VIN# 1 H 9 8 B 1 E 0 3 L 1 7 0 7 0 0 2):

As design and manufacturing of Trucks 1 & 2 happened at same time, there was no change between trucks.

HummingbirdEV worked on finalizing the design, manufactured, and shipped eTruck to Utilimaster & Volta Air in Q2-2021 and back to HummingbirdEV in Q4-2021 upon box and electric refrigeration unit installation.

While the truck was ready to be delivered to Moonlight Companies in Q4-2021 upon completion of certification and vehicle insurance, it stayed back at HummingbirdEV as a test vehicle and went through extensive on-road real time testing till HummingbirdEV found a potential new user.

During Q2-2022, HummingbirdEV had provided Joseph Gallo Farms as a potential demonstration site to Project Clean Air and partners. After several delays, Project Clean Air worked on a sub-agreement with Joseph Gallo Farms and the vehicle was delivered during Q4-2022 and training performed. However, vehicle was unused for the remainder of data collection activities.

eTruck #2 was driven 2373 miles in total at the time of this report.

User summary Truck#2

Location	Payload (Lbs)	Type of load	Avg run time (Hrs)	Hours of Operation	Avg travelled distance/day (Miles)	E-Tru used	E-Tru set temp ©	Type of Route
Livermore, CA	10,000	Bricks	Mixed	Mixed	110	Yes	34	Urban, Freeway

Location	Payload (Lbs)	Type of load	Avg run time (Hrs)	Hours of Operation	Avg travelled distance/day (Miles)	E-Tru used	E-Tru set temp ©	Type of Route
Atwater, CA	20,000	Cheese	7	7am-2pm	100	Yes	37	Urban, Freeway

Table 3

eTruck # 3 (VIN# 1 H 9 8 B 1 E 0 3 L 1 7 0 7 0 0 3):

Based on lessons learned from the first 2 trucks, HummingbirdEV had lot of design modifications not only to the hardware, but also to the software - some including:

- Increased the box height to accommodate more end users such as Moonlight Companies.
- Removed the auxiliary 24v battery pack from Volta Air (eTRU) by supplying power to refrigeration units from electric truck high voltage battery pack itself. Helped in reducing the overall weight of truck, improved system efficiency, less parts, less cost & smoother transition in running eTruck and eTRU either independently or together.
- Increased range abilities by introducing 'Eco' mode driving through the truck's UI/UX display.
- Worked with Geotab at the request of TechTruth Consulting for more seamless data collection.
- Integrated HVAC directly into the UI/UX display.
- Improvements made to the gearbox to prevent leaks.
- Better vehicle calibrations in place including Regen capabilities.
- Introduced single plug charging allowing users to charge using either one or two plugs.
- Production release documents streamlined including whole truck wiring harness to speed up production ready to handle volumes.

HummingbirdEV finished manufacturing and shipped eTruck to Utilimaster & Volta Air in Q4-2021 and directly shipped to Moonlight Companies in Q1-2022 upon box and Electric refrigeration unit installation. Truck has since been in-service at Moonlight Companies.

eTruck #3 was driven 3637 miles in total at the time of this report.

User summary Truck#3

Location	Payload (Lbs)	Type of load	Avg run time (Hrs)	Hours of Operation	Avg travelled distance/day (Miles)	E-Tru used	E-Tru set temp ©	Type of Route
Reedley, CA	20,000	Fruit	10 hrs	7am-11pm	60	Yes	34	Rural

Table 4

eTruck # 4 (VIN# 1 H 9 8 B 1 E 0 3 L 1 7 0 7 0 0 4):

Truck built identical to Truck#3 and production streamlined.

HummingbirdEV finished manufacturing and shipped eTruck to Utilimaster & Volta Air in Q1-2022 and directly shipped to Moonlight Companies in Q2-2022 upon box and Electric refrigeration unit installation. Truck has since been in-service at Moonlight Companies.

eTruck #4 was driven 4351 miles in total at the time of this report.

User summary Truck#4

Location	Payload (Lbs)	Type of load	Avg run time (Hrs)	Hours of Operation	Avg travelled distance/day (Miles)	E-Tru used	E-Tru set temp ©	Type of Route
Reedley, CA	20,000	Fruit	10 hrs	7am-11pm	60	Yes	34	Rural

Table 5

eTruck # 5 (VIN# 1 H 9 8 B 1 E 0 3 L 1 7 0 7 0 0 5):

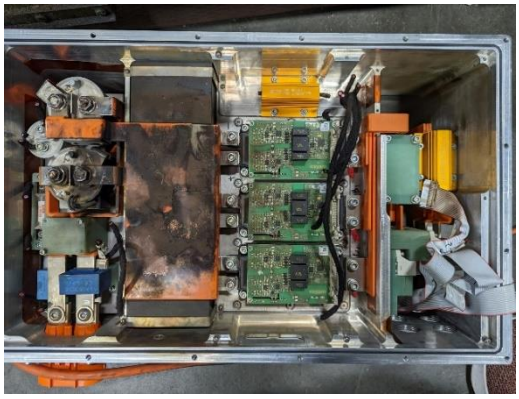
Truck built identical to Truck#3 and production streamlined.

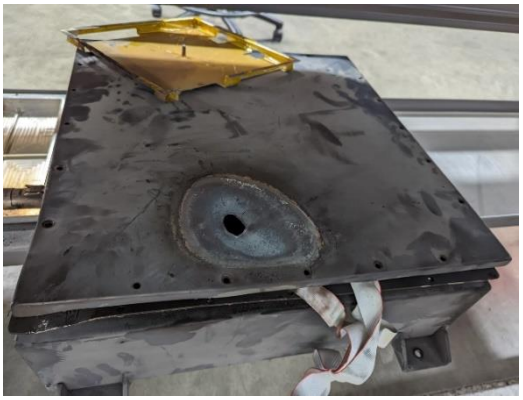
HummingbirdEV finished manufacturing and shipped eTruck to Utilimaster and Volta Air in Q2-2022. Unit shipped to Moonlight Companies in Q4-2022 upon box and Electric refrigeration unit installation.

Throughout the project, quality grid has been a major problem at Moonlight Companies causing several faults to trucks and in the case of this truck led to major system failures. HummingbirdEV has redundancy built into its systems both from hardware and software and was able to protect any major incidents. However, this incident caused a major service breakdown upon using the truck for only 2 days at Moonlight Companies.

Blown/burnt: Charger/Inverter, HV fuses to BMS, HV fuses to battery pack, major HV wiring from charge receptacle to HV PDU, HV PDU & several other electrical systems were compromised as shown in below pictures.

Hummingbird took the eTruck out of service and is in-process of servicing the unit by diagnosing the root cause and replacing the failed systems as mentioned above. Expected to ship truck back to Moonlight during Q1-2023.





eTruck #5 was driven 319 miles in total at the time of this report.

User summary Truck#5

Location	Payload (Lbs)	Type of load	Avg run time (Hrs)	Hours of Operation	Avg travelled distance/day (Miles)	E-Tru used	E-Tru set temp ©	Type of Route
Reedley, CA	20,000	Fruit	10 hrs	7am-11pm	60	Yes	34	Rural

Table 6

Once completed, the eTrucks were delivered to the end-users on the dates specified in Table 7. If the chargers were already installed, the eTrucks were placed into service immediately, otherwise they were deployed once installation was complete.

As can be seen in Table 7, eTrucks 1 and 2 were intended for Moonlight were re-assigned to accommodate Moonlight's need for a taller box door. eTruck 2 was delivered to Joseph Gallo Farms but was not successfully deployed (for administrative reasons, not technical issues) and was subsequently returned to HummingbirdEV. Likewise, eTruck 5 was delivered to Moonlight but was damaged due to - what was hypothesized to be – a problem with the electricity grid or infrastructure at the site (voltage spikes had previously damaged several components on other eTrucks). Both eTrucks 2 and 5 were retrieved and underwent continued testing at HummingbirdEV headquarters.

eTruck Delivery Dates

Unit #	Delivery to	Location	Delivery Date
eTruck #1	Moonlight - Returned due to box door height.	Reedley, CA	11/11/2021
eTruck #2	Joseph Gallo Farms	Atwater, CA	10/3/2022
eTruck #3	Moonlight	Reedley, CA	2/22/2022
eTruck #4	Moonlight	Reedley, CA	4/29/2022
eTruck #5	Moonlight	Reedley, CA	9/26/2022
eTruck #1	Rosa Brothers	Tulare, CA	5/13/2022

Table 7

Training

Workforce training was provided to Moonlight and Rosa Brothers Milk Company employees targeting drivers, managers, and mechanics. HummingbirdEV produced three supplementary training modules for on-site training: first responder training, driver training, and a technician

training module. These modules were specifically tailored to the needs of each audience. All training was meant to support the use of the eTrucks in their agriculture vocation, to keep the equipment operational, to train individuals in the new technologies of electric vehicles and equipment, to reduce accident risks for operators, and to ensure proper operation of the equipment on location.

Project Clean Air contracted with AVI On-Demand to offer an online training webinar during the COVID-19 Pandemic. The first responder training addressed light-duty, medium-duty, and heavy-duty vehicles as well as charging infrastructure scenarios. It included protocols for safely turning off the power and cutting into an electric truck in the case of an accident. Driver training included a system-level overview that included specifics such as how regenerative braking options affect starting/stopping, operator experience, emergency shut-off of batteries, and effective range. Two First Responder Training sessions were offered on January 20, 2021 (virtual) and November 2, 2021. Approximately 75 participants from 19 different agencies participated. The PowerPoint presentation can be found in Appendix E.

A second related-training session was held in person at Moonlight Farms in Reedley, California. PCA contracted with AFVEducate, to conduct training and develop a curriculum focusing on alternative fuel vehicle education for firefighters, law enforcement, EMS, tow operators, automotive salvage companies, automotive technicians, and collision repair specialists. Suggestions and ideas were brought back to HummingbirdEV to include in an updated manual.

The technician training allowed the technicians to learn about the basic operations, maintenance needs, how to troubleshoot the electric system, high voltage dangers, and precautionary safety-related issues pertaining to component maintenance.

Driver training and technician training were conducted upon delivery of the trucks. PCA collaborated with HummingbirdEV to provide direct, hands-on guided instruction for operator proficiency, preventative maintenance, repair, charging, and data collection. This training included electric truck familiarization and operation, understanding dashboard gauges and controls, recharging procedures, and best driving practices.

Training and educational materials were provided to Rosa Brothers and Moonlight Companies. Guided instruction was provided by the design engineers to familiarize all operators and maintenance personnel with best management practices, proper protocols, and safety requirements. The technician training included an overview of maintenance protocols and troubleshooting techniques. In addition, preventative maintenance training that includes routine inspections of the eTrucks was explained. eTruck instruction manuals, printed in English and Spanish, were provided to all end-users.

Despite these training and educational efforts, feedback from the drivers suggested that key individuals were missed in the process. Drivers confessed to being confused about simple operational procedures and eTruck responses to common practices they were accustomed to while operating diesel trucks. Instead of experiencing the training first-hand, drivers explained that they learned how to operate the eTruck from the mechanic, other drivers, or through trial and error. The fact that some drivers spoke very little English, compounded the problem. It appears that several people were trained at the demonstration sites but not always the key individuals. This may have been a result of uncertainty regarding which drivers would be operating the trucks. Regardless, the lack of direct hands-on trying was problematic throughout the project and emphasizes the need to identify key players before eTruck implementation, so they can be properly trained.

Performance Assessment

Diesel Baseline Truck

The Moonlight baseline truck was a 2008 Freightliner M2, 106 series, Class 6, single-unit straight truck fitted with a fully integrated refrigeration unit (Figure 1). It was equipped with a 26-foot box and powered by a 6.7-liter, 6 cylinder, 240 HP Cummings ISB diesel engine. The "non-independent" refrigeration unit was powered by the truck engine and does not have a separate fuel tank. A refrigerated truck - one equipped with a transport refrigeration unit (TRU) - is often referred to as a "reefer" truck.

The baseline truck was equipped with a Geotab data logger on July 20, 2020. The Geotab data logger can collect information on several hundred parameters at less than one second intervals. Approximately 50 parameters were used for this project. Operational vehicle data includes parameters described in Appendix F of the ZANZEFF solicitation, as well as several other key variables critical in assessing the eTruck technology. Significant data synthesis was required from the raw data to meet project needs.

Figure 1: Baseline truck: 2008 Freightliner M2 reefer

Fueling and mileage logs (Appendix A), driver records, and other operating information was collected to supplement data collected directly from the baseline truck. In-field observations and interviews were also used to supplement truck data, affording additional insight and

clarity. TechTruth Consulting participated in “ride-alongs” to better understand operational procedures and truck usage.

GPS mapping and real time monitoring of the baseline truck was important in helping identify “normal” usage and patterns critical to the eTruck performance analysis. TechTruth has been collecting and storing data from the baseline truck continuously since the data-logging equipment installation.

Operations and Usage

The baseline diesel truck was in full service at Moonlight Companies and operated most days during the demonstration period. It is used on the same routes and for the same purpose as the deployed demonstration eTrucks. Operational demands and duty cycles of the diesel baseline TRU-equipped truck were well-suited and representative of the demonstration eTruck assignments. However, the eTrucks were not used to the same extent as the baseline truck.

Figure 2: Route from packing plant to cold storage unit 1

Moonlight Companies, based in Reedley, California is a major stone fruit and citrus grower with nearly 5,000 acres producing peaches, plums, nectarines, cherries, oranges, and pomegranates. The primary function of Moonlight’s on-road truck fleet is to transport packaged produce from the packing plant to one of two cold storage facilities. It is a 12-month operation. The distance from the packing plant to cold storage unit 1 is 0.37 miles and the trip takes approximately 3 minutes (Figure 2). This facility is along the route to cold storage unit 2, resulting in trip-chaining during parts of the year. Cold storage unit 1 is used primarily in the late fall to early spring for citrus produce.

Cold storage unit 2 was reached by one of two primary routes. One route was 4.9 miles from the packing plant and the other was 3.7 miles. Both routes took approximately 12-15 minutes. Cold storage unit 2 was the primary storage used for stone fruits during the peak harvesting season. Drivers had discretion when choosing the route to and from storage unit 2 and, at times, small route variations were made. Traffic controls (e.g., stoplights and stop signs), traffic congestion levels, and school-related traffic along the route are a few of the reasons for variations.

However, the routes did not deviate significantly in time or distance from the two dominant routes shown in Figures 3 and 4. Routes to and from each storage unit were consistent over the course of the project. After arriving at the storage plant, the drivers either backed the truck immediately up to the dock or, if the dock was occupied, entered the truck queue and waited their turn to unload. As the queue moved, the trucks would back up incrementally until they reached the loading dock. It is left to driver discretion whether to turn off the truck between movements toward the dock. One driver was observed turning off the baseline diesel truck between movements in the loading dock queue to avoid unpleasant diesel fumes. Others explained their preference to idle the truck to maintain box temperature or cab comfort (e.g., listening to the radio, climate control, or charging a cell phone).

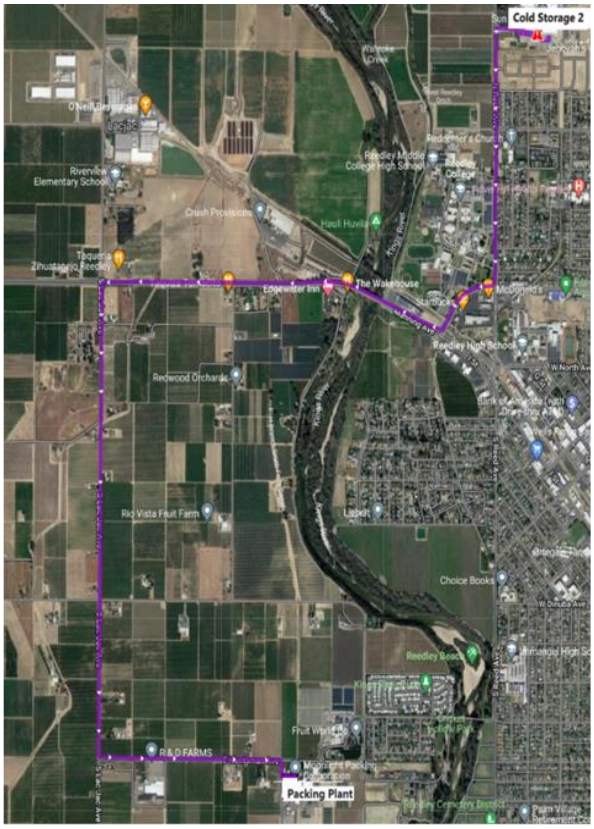


Figure 3: Route 1 from packing plant to cold storage unit 2

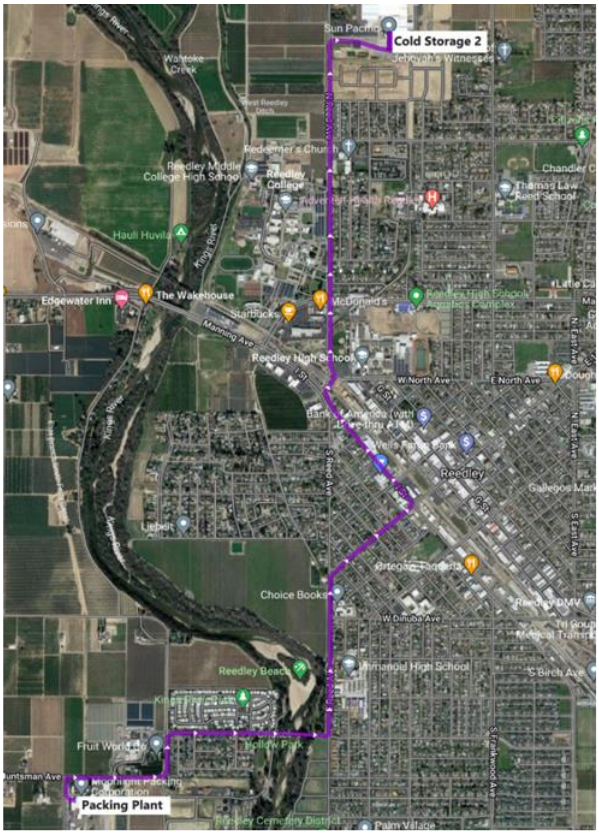


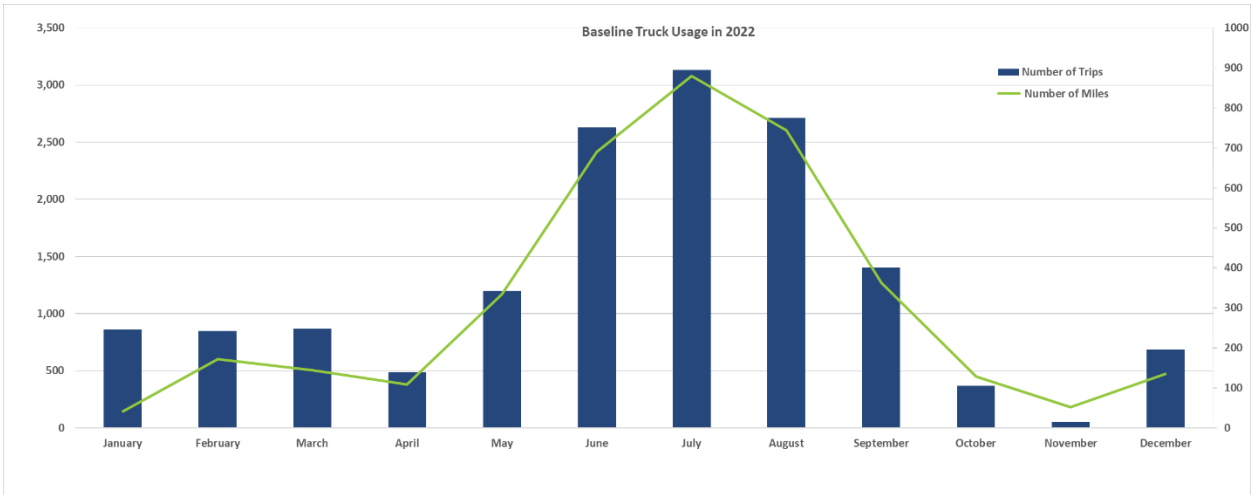
Figure 4: Route 2 from packing plant to cold storage unit 2

On rare occasions, trips were made to destinations other than a cold storage unit. A "trip" is defined as any travel greater than 0.3 miles that resulted in a key-off event at the destination. Defining a trip as > 0.3 miles captures all travel between the packing plant and cold storage units. Trips less than 0.3 miles were generally very small movements within the facility area to position the truck for loading/unloading, to move out of the way of other trucks, or to park the truck during breaks or at the end of the day. Although, these short movements did not constitute a trip, their cumulative mileage was significant and was included in mileage totals.

Five different drivers drove the baseline truck during the demonstration period but no discernible differences were found in the data among the drivers with regard to trip times, travel speeds, or fuel consumption.

Season Variability

Moonlight truck operations have significant seasonal variations, operating 12-14 hours/day, 7 days/week in the summer peak-season to sitting idle for several days at a time during the winter off-season. Peak season for harvesting and produce transport is during the summer months (June-August). During this time, the baseline truck averaged 26 trips/day with daily travel averaging 88 miles. (This period of high mobility overlaps with peak ozone events in the region and exacerbates high soil NOx emissions from agriculture activity.) Graph 1 shows the monthly trip and mileage distribution for the baseline truck.



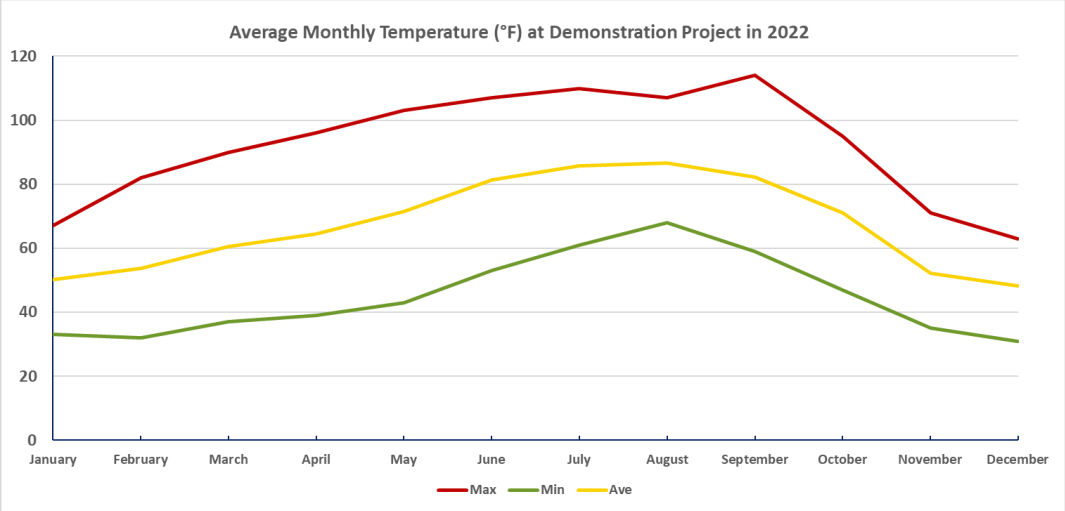
Graph 1: Monthly trip and mileage distribution for baseline

Baseline Transport Refrigeration Unit

TRU utilization largely tracked the baseline truck mileage with large seasonal fluctuates. Ambient temperatures in the region fluctuated from a high of 114° F to a low of 31° F, with the highest temperatures corresponding to the periods of highest truck usage (Graph 2). Inside the packing facility the temperature was kept at 68° F, while the temperature inside the cold storage facility was kept at 36°F.

Demands on the TRU at Moonlight were relatively minor but critical at times. The longest route time from packing warehouse to storage facility was approximately 15 minutes; the unloading time 20-30 minutes; and during peak periods, a queue time of approximately 15 minutes. Therefore, the produce being transported had to be kept at about 68° F in the truck for up to 60 minutes. This 60-minute window was a crucial period when temperatures soared to 90°F or higher (sometimes much higher). Rosa Brothers had a more critical reliance on the

eTRU. They had to keep the box temperature at 37° F for several hours each day in order to deliver dairy products).



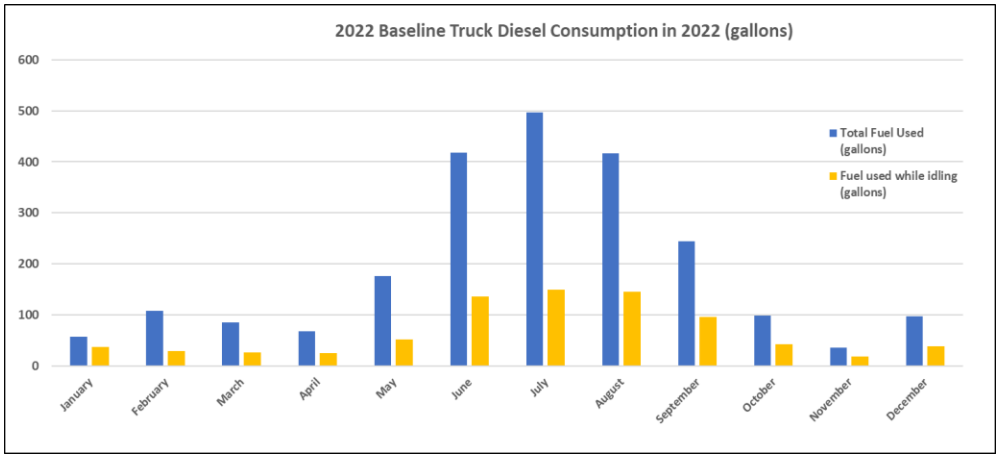
Graph 2: Ambient temperatures at demonstration site

Unlike Rosa Brothers, there was little or no consequences if the Moonlight box temperature exceeded the 68° F, sometimes by several degrees for short periods. The produce could withstand, without damage, relatively short periods of warmer temperatures. The baseline box temperature was never precisely known. Box temperature control on the baseline truck was a simple adjustment knob with no meaningful demarcations. The drivers crudely adjusted the temperature dial knob in effort to account for diurnal changes in ambient temperature. This heuristic practice contrasts with the demonstration eTRU that allows drivers to lock in a precise setting which is regulated via thermostatic control. During unloading while the truck doors are open, the truck abuts the cold storage unit access doors. This results in a slight temperature dip at each unloading. The box interior is slightly cooled as some of the warmer (68° F) air inside the box was displaced by the 36°F air from the cold storage unit.

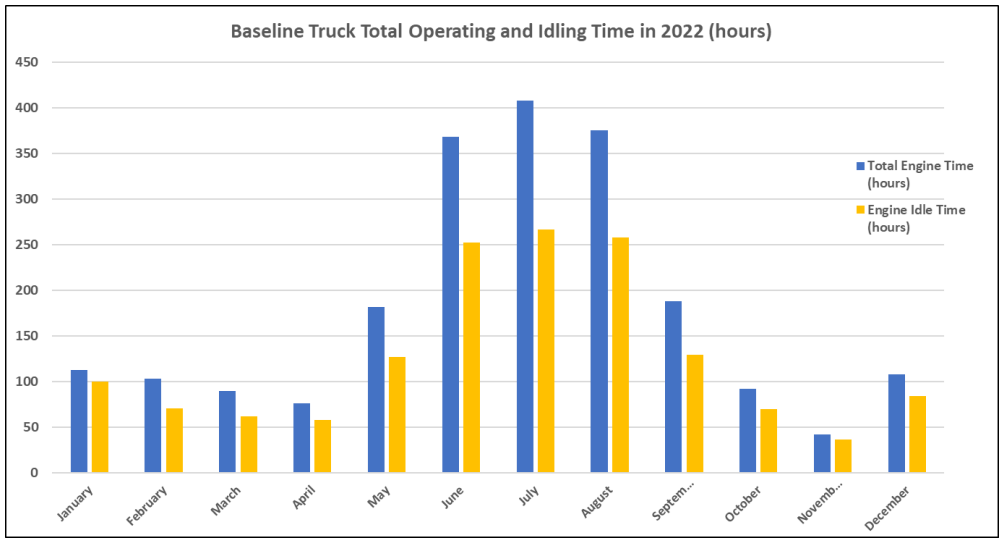
Idling

Frequent and long idling periods were common during the baseline truck operation. Extended idling periods were associated with truck movement during loading/unloading, truck positioning at various facilities (sometimes to park the reefer in shade to keep the box cool), beginning of the day warm up, and other activities. Because the baseline truck is a non-independent reefer (truck operation is required to run the TRU), the truck must be in near-continuous operation during warm days, which results in long idling periods.

Idling time accounted for more than 30% of the total diesel fuel consumed by the baseline truck (Graph 3) and constituted well over 50% of the baseline truck operating time (Graph 4).



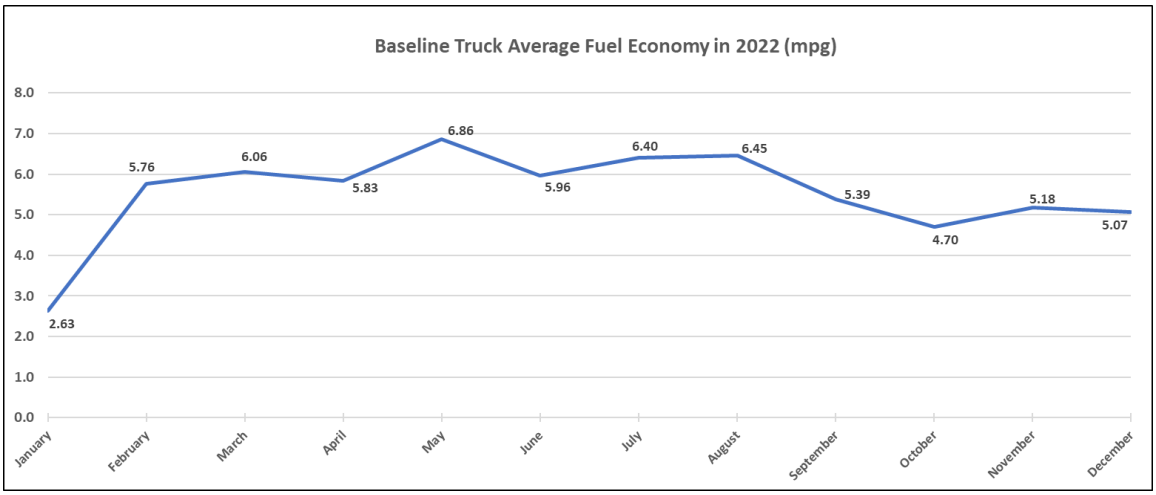
Graph 3: Baseline truck diesel consumption



Graph 4: Baseline truck operating and idling time

Energy Use

The baseline truck average fuel economy, which includes diesel for TRU operation, is shown in Graph 5. Months with lower fuel economy generally correspond with off-peak cold months. During these months, the baseline truck was used primarily between the packing plant and cold storage unit 1, a short 0.37-mile trip. These trips involved more braking/acceleration per mile and more re-positioning in the loading zone (more braking activity will benefit electric trucks that have regenerative braking). Although the TRU load was not as great during these cold
months, the truck idled longer during the warm-up period and was turned off less frequently because of cab heat needs and concerns associated with restarting the diesel engine in cold weather. In January 2022, 247 total trips were made - all were to cold storage unit 1. These short trips exacerbate fuel consumption, evident by the extremely low average fuel economy (2.63 mpg). Contrast that to March of the same year with 248 trips and a 6.06 mph average fuel economy. The vast majority of trips in March were longer distance trips to cold storage unit 2. The mileage-weighted average fuel economy for 2022 was 5.5 mpg. During that period, 13,696 miles were driven, and 2490 gallons of diesel were consumed by the baseline truck.



Graph 5: Monthly fuel economy

Data

Data Collection and Analysis Plan

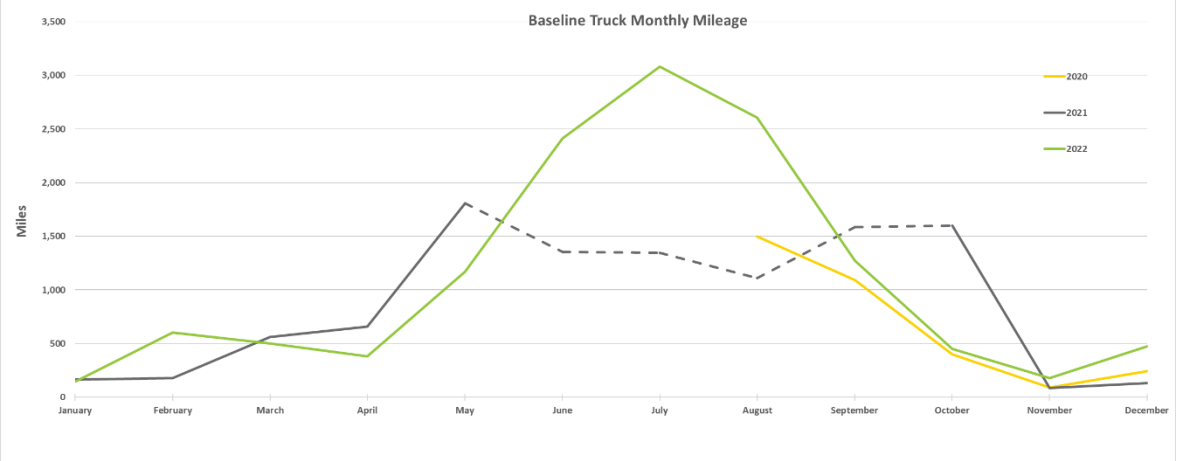
TechTruth Consulting submitted a data plan (Appendix B) describing the type and amount of data to be collected and the procedure for analyzing that data. The data manual was based on the initial proposal and demands of PCA. As the project progressed and varied from the original proposal because of delays and other unforeseen factors, the data manual became

outdated. TechTruth submitted two amendments during the project in an effort to reconcile data collection with real-world deployments and actual timelines.

Data Collection Period

Although the baseline truck was equipped with a data logger in July 2020, the 2022 calendar year is the baseline period used for this project. A few anomalies interrupted baseline truck usage during the first year of the project. Extended repair times caused by supply chain issues and a driver shortage during the same period where two significant issues impacting operations. The impact of the driver shortage can be clearly seen in Graph 6. During the summer of 2021, because there were more trucks than drivers, the baseline truck drivers often switched to driving other available trucks that were newer, had more amenities, and were more comfortable. Consequently, the baseline truck usage was drastically curtailed. This can be seen by the recorded mileage represented by a dashed line in Graph 6.

The 12 months of 2022 appear to be more reflective of normal operations with a prominent mileage increase during the busy harvest season. Also, during this period, the latest version of eTrucks (with integrated eTRUs) were fully deployed, charging stations were fully functional, and most of the initial operating logistics and technology issues were resolved.



Graph 6: Monthly baseline truck mileage over demonstration period

Data Sources

Data for this analysis was drawn from five different data sources: 1) a Geotab datalogger on the trucks, 2) data collected from the eTrucks by the manufacturer, 3) data collected from the eTRU systems by the eTRU manufacturer, 4) driver-kept fuel logs, and 5) first-hand observations from ride-alongs, driver feedback, and discussions with the management team. These data sources focused on different parameters and were implemented by different

sources for different reasons. Collectively, with synthesis and concatenation, they provided a robust dataset for analysis. However, individual databases had significant geographic constraints, parameter restrictions and nuances, instances of data corruption, download limitations and other qualifications that prevented analysis over long periods of time. Therefore, dozens of shorter periods were analyzed. These periods ranged from one battery depletion event to a full day of operation. Data were collected and analyzed across all trucks during different seasons, at various ambient temperatures, and during all levels of truck operation.

This analysis focuses on eTruck 1 (operated at Rosa Brothers for milk delivery) and eTrucks 3 and 4 (operated at Moonlight for produce transport). In addition to these three eTrucks, two other HummingbirdEV eTrucks have been used and extensively tested by the manufacturer, for the duration of the project. Although eTrucks 2 and 5 were not placed in third party applications for significant lengths of time, comparable mileage was put on these trucks and corresponding data was collected and analyzed. The data and operating performance of these two eTrucks is consistent with the other fully-deployed eTrucks.

eTruck Performance Results

Five all-electric trucks equipped with all-electric eTRUs were built and deployed in real-world applications during the demonstration. Onboard battery-stored electricity provided 100% of truck propulsion, as well as 100% of eTRU operation. The first two trucks built (eTruck 1 and eTruck 2) have independent eTRUs, where a separate battery pack provides electricity for eTRU operation (the battery is the same LiFePO4 technology as the truck battery pack). The eTRU battery must be charged separate from the main truck battery (although they are usually charged simultaneously). The remaining three trucks (eTrucks 3-5) incorporate a “non-independent” eTRU. This architecture allows the eTRU to share the same battery pack used for propulsion of the electric truck. A single battery pack is charged and used for both propulsion and refrigeration. The eTrucks are charged with a 240V, 40 kW charger. eTruck batteries can be safely and sustainably charged at a rate of 1C and can be charged from 20% SOC to 80% SOC in 4 hours. The independent eTRUs are charged with a 120V, 4 kW charger and can be fully charged in under 3 hours. eTruck, eTRU and charger specifications are given in Tables 8 & 9.

All five trucks were designed to be deployed by a single end-user, Moonlight Companies. The five trucks were intended to be used on the same routes and for the same purpose as the baseline truck, to transport fruit and produce from a packing warehouse to nearby storage facilities. However, Moonlight was only able to implement two of the electric trucks. The eTrucks had to be registered as Class 8 vehicles (because of weight) and only two Moonlight employees held the required commercial driver license (CDL) required to drive Class 8 trucks. Also, the dimensions of the box door on the first two eTrucks were slightly too small, prohibiting the use of Moonlight's standard loading equipment. The two eTrucks that were implemented into the fleet were driven and used in the same application and in the same manner as the baseline truck. However, the eTrucks were not used to the same extent as the baseline diesel truck.

eTruck/eTRU Specifications	
Key Specifications	
Type	Battery Electric
GVW (lbs)	60,000
Payload (lbs)	24,000
Chassis	Spartan
Axle	3
Wheelbase	252"
Box	Utilimaster
Box size (Trucks 1&2)	
Max Vehicle Speed (mph)	55
Peak Mechanical Torque (Nm)	3600
Range (Mi)	120-140
Rated Mechanical Torque (Nm)	1200
Low Voltage Battery (v)	12
Powertrain Cooling	Liquid & Refrigerant
Box Dimensions	
Height	58" is high point to the steering (4.8 ft)
Width	62" tire to tire (5.16 ft)
Length	132" (11 ft)
Battery Specifications	
Type	Lithium-Ion Ferrous Phosphate
Battery Capacity/Usable (KWh)	288KWh/259KWh
Nominal Voltage	610V
Max Voltage	630V
Motor Specifications	
Motor Type	AC Permanent Magnet Motors
Continuous Rated Power (Kw)	240
Peak Power (Kw)	400
Max Torque (Nm)	1200
Transmission Specifications	
Type	Single speed
Actuators (Engage/Disengage)	Air

Number of Gears	N/A
Charger Specifications	
Type	40 KW Onboard Fast AC Charger
Configuration	480Vac, 3-phase US only
Charging Time (20-90% SOC)	4.5 Hours on AC

Table 8

eTRU Specifications	eTrucks 1 and 3	eTrucks 3, 4 and 5
Supplier	Volta Air	Volta Air
Battery Voltage (v)	24	24
Battery Capacity/Usable (KWh)	22KWh/14KWh	N/A. Part of eTruck battery (converted from 610vdc to 24vdc)
Run Time (Hrs)	4-8 (depending on ambient and set temp)	N/A. Part of eTruck
Min set Temp ©	32	N/A. Part of eTruck
Charging Time (Hrs)	8	N/A. Part of eTruck

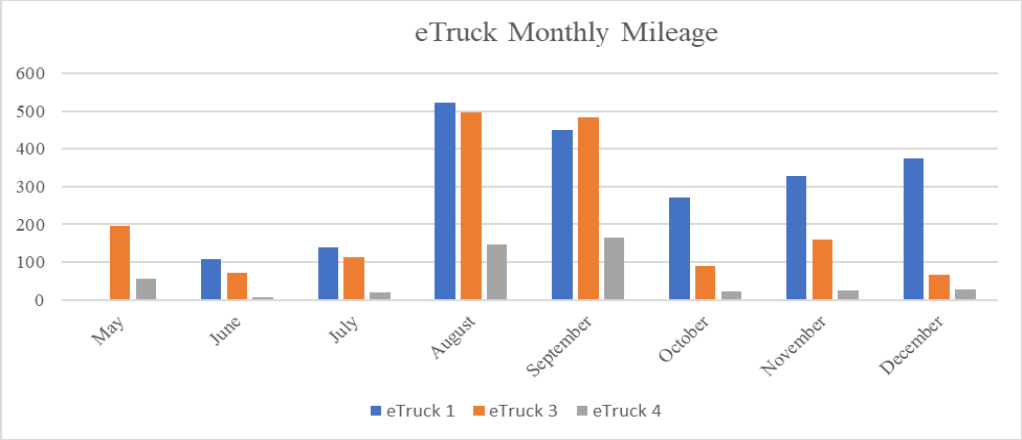
Table 9

One of the two CDL-drivers certified to drive the eTruck, was required to use a diesel truck at least once a week for long-route deliveries (> 200 miles). Further complicating the situation was the fact that the drivers had discretion as to when and how often they drove the eTrucks. Consequently, the trucks were not driven every day, or even full days, during the demonstration. At times, usage was sporadic. Repairs and upgrades took the trucks offline for periods of time, further limiting usage. However, both eTrucks 3 and 4 were used enough to fairly assess overall performance.

A third eTruck was put into service by a different end-user under different circumstances. It was used regularly three days a week by Rosa Brothers for dairy product deliveries, primarily milk. The roundtrip delivery route varied from approximately 55-80 miles per day and involved about 6 stops per day. The driver had to maintain a box temperature of 37° F, significantly lower than Moonlight's targeted 68°F.

eTrucks 3 and 4 were put into service at Moonlight in March and April of 2022, respectively and data were analyzed from that time through December 31, 2022.

Truck1 was delivered to Rosa Brothers in May of 2022 and data analyzed through December 31, 2022. Graph 7 shows the extent that each vehicle was driven by the end-user during the demonstration.



Graph 7: Monthly eTruck mileage over demonstration period

Energy consumption varied considerably during the demonstration period for trucks 3 and 4 operating at Moonlight. The observed energy economy ranged from 1.8 kWh/mile to 3.2 kWh/mile with an average of approximately 2.7 kWh/mile. The primary factor for this variance was the eTRU energy load. During the hottest and longest days of the demonstration, the peak harvesting season, the eTRU was operating several hours/day to maintain a targeted box temperature of approximately 68°F. Long idle periods, partly due to trucks waiting in the unloading queue, also increased energy use during hot summer days (energy consumption did benefit from the truck box doors interfacing with the open cold storage doors during unloading). Recorded box temperatures varied considerably daily and hourly. Temperatures often and significantly exceeded 68° (however, box temperatures much lower than 68°F were also realized even on the hottest days, suggesting that frequent thermostat adjustments were cause for much of the variation).

Because the eTRU on eTruck1 had a designated battery and operated independently of the propulsion energy, eTruck 1 energy economy was more consistent. Truck 1 energy economy average was consistently around 2.4 kWh/mile. A comparison of the eTRU energy loads between eTrucks 3 and 4 versus eTruck 1, including periods when the eTRU was not needed, shows that the difference in energy economy is explained almost entirely by eTRU usage. The propulsion-only energy economy was essentially the same for all three eTrucks. Overall, the eTrucks operating eTRUs got approximately 12.5 miles/diesel-equivalent gallon, compared to 5.75 miles/diesel gallon for the baseline diesel truck under the same conditions and usage. This represents a 217% improvement in energy-equivalent fuel economy.

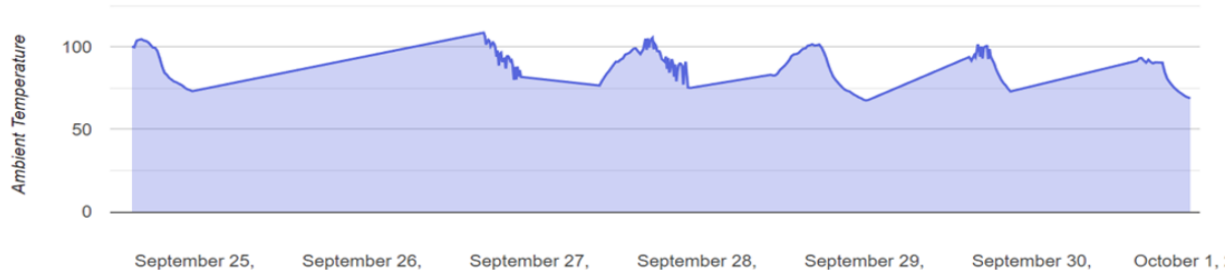
Another factor that significantly and directly affected energy usage was regenerative braking. Although there was no discernable difference in regenerative braking between drivers at Moonlight, trips made closer to the cold storage unit (only 0.3 miles away) did have a higher rate of regenerative braking. Overall, regenerative braking reduced energy consumption by approximately 12% to 17%. That is, 12-17% of total energy use came from regenerative braking, depending on the trip distance and the number of stops en route.

eTRU Performance Results

All project eTRUs proved capable of maintaining box temperature at or below the target or set temperature for the duration of daily travel. However, the eTRU duty-cycles at the two demonstration locations differed significantly. eTRU use by Moonlight was less predictable and less uniform. The box temperature was more likely to change slowly in response to changes in ambient temperature. The box temperature rose well above the 68° F target temperature before cooling began and then dropped well below 68° F. This cycle repeated several times during hot days. It is possible that the drivers were adjusting the temperature setting throughout the day. Usage of the two Moonlight eTrucks was also highly variable on any given day, thus the starting box temperature varied depending on when the truck was used.

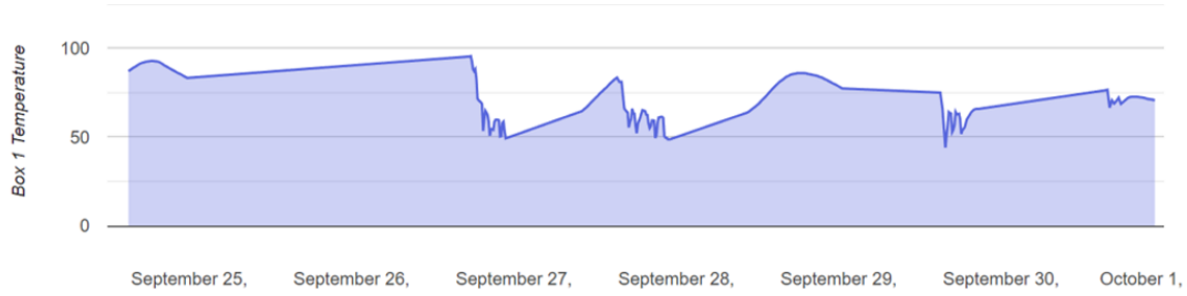
At Rosa Brothers the box was cooled to 37° F before the beginning of every workday. This occurred very early in the morning to accommodate early delivery departures (approximately 4 a.m.). After the last delivery, cooling ceased until the next day of usage. More rigorous control of the temperature was necessary because relatively small increases above 37° F could spoil the milk being transported. Pre-cooling was possible because of a regular operating schedule and because night shift personnel were available to plug in the eTRU during the night. Rosa Brothers used eTruck 1 for deliveries on Mondays (70 miles), Tuesdays (80 miles) and Thursdays (55 miles).

The difference in eTRU usage and effectiveness can be seen in Graphs 8-12. A relatively hot 8-day period in September 2022 illustrates the difference in eTRU usage between the two different end-users. The ambient temperatures in the demonstration area during the week (September 25 to October 1) exceeded 100° F nearly every day (see Graph 8).

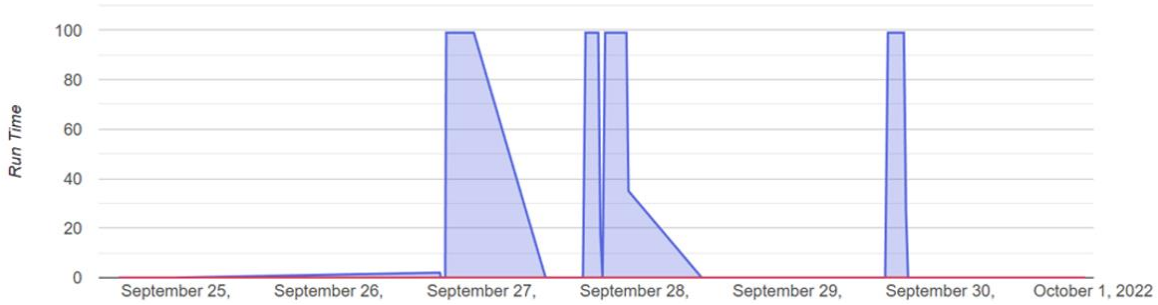


Graph 8: Ambient Temperature at Demonstration Site, September 25 – October 1

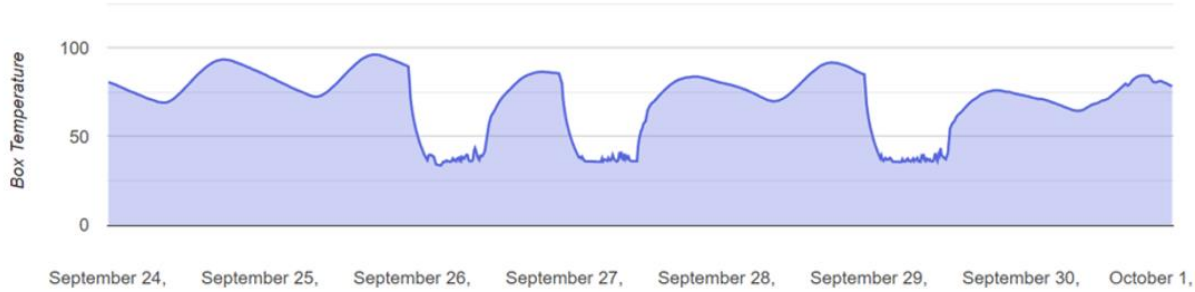
During this week, the Moonlight eTruck 4 was used for four days usually starting around 2:30 pm and continuing well into the evening. As can be seen in Graphs 9 and 10, the eTRU was intermittently operated to decrease the box temperature as needed rather to maintain 68° F (eTruck 4 was not used September 25th). During the same week, the Rosa Brothers eTruck 1 was used for three days from approximately 4:00 a.m. to 11:00 a.m. (September 26, 27, and 29). As can be seen in Graphs 11 and 12, the eTRU was used steadily to maintain a box temperature of 37° F.



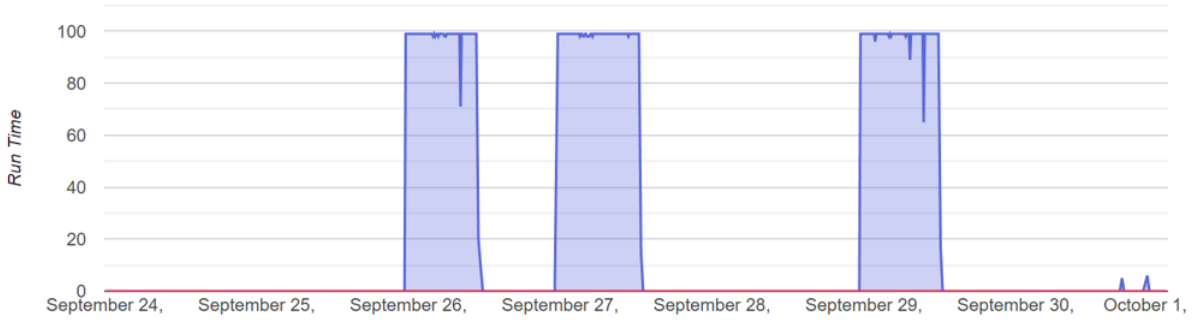
Graph 9: eTruck 4 Box Temperature, September 25 – October 1



Graph 10: eTruck 4 eTRU use, September 25 – October 1



Graph 11: eTruck 1 Box Temperature, September 25 – October 1



Graph 12: eTruck 1 eTRU use, September 25 – October 1

Other Performance Parameters

All the eTrucks in this demonstration, performed well and were placed in applications that were well-suited for the technology. The charging rate for eTrucks 3, 4, and 5 was 40 kW, enabling a full charge in approximately 7 hours. Trucks 1 and 2 were capable of 40 kW but infrastructure constraints limited eTruck 1 to 25 kW in the field and 4 kWh for its eTRU. There were ample charging opportunities during off-peak electricity hours for both end-users. The physical act and logistics of charging did not present a problem. HummingbirdEV worked with the end-users to install chargers at convenient locations. Because Rosa Brothers had an additional eTRU battery to charge (independent of the propulsion battery), they had an additional charger installed at the loading dock.

The range limit did not seem to be a factor for Moonlight which typically recharged before the SOC dropped below 40%. In addition to lower usage demand, they had other trucks nearby that were readily available, including the second eTruck. eTrucks 3 and 4 were seldom used simultaneously and were often used for only part of the day.

Rosa Brothers made delivery route and schedule changes to accommodate the eTruck range and regularly drove the truck to 20% SOC or less. Based on battery capacity and energy consumption, the effective range was approximately 100 miles/charge (the eTRU was "independent" and thus did not rob energy from the propulsion energy storage). The SOC dropped at a rate of about 1% SOC per mile driven (this rate was also observed in the field by the driver and used to help gauge the remaining range). Approximately 10% of the 288-kWh battery was not used. End-users were instructed to remain above 10% SOC for reasons related to maintaining battery health. At the top end, the battery management system stopped charging at SOC of 98%, to protect the battery from damage. Once the battery SOC reached this level, battery energy (up to 4% of the total capacity) was used to level the battery cells, again for the purpose of maintaining battery health. This confused the drivers because the battery SOC would start dropping after it reached 98%. However, these battery preservation measures were successful and the battery state of health (SOH) stayed at or near 100% for the duration of the project.

GHG and Emission Analysis

The following emission and GHG parameters were derived from operating data:

- GHG annual emission reductions from each proposed demonstration vehicle and for project.
- Criteria pollutant and toxic air contaminant annual pollutant emissions reductions for each proposed vehicle and for project.
- GHG reduction cost-effectiveness for a two-year life during the time of the proposed project field demonstration.
- GHG reduction cost-effectiveness for a 10-year life, two years after the end of the proposed demonstration project, assuming technology commercialization.
- Criteria pollutant and toxic air contaminant cost-effectiveness for a two-year life during the time of the proposed project field demonstration.
- Criteria pollutant and toxic air contaminant cost-effectiveness for a 10-year life, two years after the end of the proposed demonstration project, assuming technology commercialization.

Appendix C shows all assumptions and supporting calculations for the emission results.

Currently, the Moonlight Packing Corporation operates several "reefer" trucks in the San Joaquin Valley. They are class 6 straight trucks with Transport Refrigeration Units (TRUs) powered by the vehicle's diesel internal combustion engine. The main function of the trucks is to transport produce from the packaging facility to the cold storage warehouse. They make several roundtrips daily over a fixed route: averaging approximately 13,696 miles/year and 5.5 miles/gallon. Because the growing season overlaps with seasonal ozone peaks, these trucks are operated most heavily during the time of year that experiences the worst pollution and ozone episodes.

In addition to the emissions resulting from vehicle movement, the TRUs must be in near-continuous operation for the duration of the workday. Because the TRU operates off the primary vehicle engine, there are significant idling emissions associated with these operations. During the busiest times, it is not unusual for these trucks to be deployed 15 hours/day and idle for half that time. Because the trucks must be in close proximity to the enclosed loading/unloading sites, workers have extremely high, prolonged exposure to idling-generated emissions.

In addition to long idling periods, other "real-world" factors make farm operations a disproportionate contributor to air pollution. Trucks used in the farming industry, much like drayage trucks at ports a few years back, are some of the oldest and dirtiest trucks in

operation. Farming operations are usually the 2nd or 3rd owner of these trucks, which are utilized as long as possible before scrappaging. Thousands of reefer trucks are used in farm applications, the vast majority of which lend themselves to electrification.

Moonlight initially planned to place 5 all-electric reefer trucks into regular duty for the duration of the demonstration. Two electric trucks were deployed. The two trucks were assumed to have the same duty cycles, mileage, and operating time as the baseline diesel truck. Because the Moonlight baseline truck had a "non-independent" TRU (i.e., the TRU operated using the truck's propulsion engine), a significant amount of truck idling was required to keep the box at the right temperature. ARB-provided fuel conversion factors were used in the calculations to express emissions rates in terms of fuel consumption. This allows for idling related GHGs and criteria pollutants to be fully captured in the baseline calculations.

Table 10 shows the results of the emissions and GHG analyses. The calculations adhere strictly to ARB's prescribed methodology in Appendix D of the Grant Solicitation. Operational and cost values used in the calculations were derived using data from the manufacturer, the end-user, ARB sources, and engineering judgement.

Project eTRU/ eTruck	GHG Emission Reductions (MT/yr)	Weighted Criteria Pollutant Emission Reductions (tons/year)	GHG Cost-Effectiveness for 2 yr. life ($/MT)	GHG Cost-Effectiveness for 10 yr. life ($/MT)	Criteria Pollutant Cost-Effectiveness for 2 yr. life ($/ton)	Criteria Pollutant Cost-Effectiveness for 10 yr. life ($/ton)
1	27.76	0.0932	3889	353	1,158,262	105,204
2	27.76	0.0932	3889	353	1,158,262	105,204
3	27.76	0.0932	3889	353	1,158,262	105,204
4	27.76	0.0932	3889	353	1,158,262	105,204
5	27.76	0.0932	3889	353	1,158,262	105,204
Total	**138.8**	**0.466**	**3889**	**353**	**1,158,262**	**105,204**

*Assumes 5 diesel trucks replaced by 5 eTrucks

Table 10: eTruck with eTRU GHG and Emission Results*

The GHG and emission calculations were based on Moonlight's operations. Baseline truck operation during the demonstration was approximately 55% of what the end-user foretold and only about 36% of the eTruck range capacity given a single charge per day. A much higher mileage diesel truck with greater idling demands could have been displaced by an eTruck, yielding significantly greater environmental benefits. Furthermore, emission reduction estimates were originally based on a 2006 model year truck which was no longer in the fleet when the demonstration commenced. Instead, a 2008 model year truck was used. The emission standards for a 2008 truck are much lower than the 2006 model (new standards

were implemented in 2007). These factors render vis-à-vis comparisons between projected and actual emission reductions misleading. Nonetheless, GHG and emission reductions were significant as can be seen in Table 5, along with the cost-effectiveness of those reductions.

Lifecycle Cost Analysis

Using TechTruth Consulting's proprietary Fleet Asset Cost Model (FACM), three cost scenarios were modeled to show the effect of cost parameter impacts (see appendix D for a description of the cost model). Scenario 1 is the closest representation of the demonstration project. However, instead of comparing a used diesel truck, both trucks are purchased new. The diesel truck acquisition price, provided by Moonlight, is their cost for a delivered Class 6 truck with a TRU. The eTruck current and projected price is based on the manufacturing cost of the first 5 eTrucks with eTRUs used in this demonstration project.

A 15-year service-life timeframe was chosen for comparison; that is the age at which Moonlight retires trucks from their fleet. Because there are fewer moving parts; a stronger frame structure; less vibration; easy-to-replace, inexpensive electronic components; and no engine combustion, the eTruck is expected to last much longer than 15 years. If depleted to the same DOD and charged at the same rate as the demonstration project, the battery pack should also last well beyond 15 years. HummingbirdEV estimates the eTruck to be worth $100,000 (nominal dollars) after 15 years, while the comparative diesel truck is worth $15,000 (the average resale price for Moonlight's trucks).

A diesel price of $5.30/gallon and an electricity price of $0.266/kWh reflect averages paid in 2022 by Moonlight. Escalation rates for fuel and energy prices are not estimated, however, the current inflation rate of 6.5% is used for the analysis period. Based on California operation, there is no (de)-escalation rate assumed for the vehicle license fee (VLF) component of registration (the component of the registration based on vehicle value). Registration, license, and permit fees are assumed to average $1000/year for both vehicles.

The average lifetime maintenance cost based on data from Moonlight is estimated at 38¢/mile. Because there is no maintenance data available on the nascent eTruck/eTRU technology, we estimate a value of 20¢/mile, approximately half of the diesel maintenance cost, based on data from light-duty electric vehicles.

Insurance cost for the diesel truck is based on Moonlight's historical data. Insurance for the eTruck is proportional to the diesel truck, based on purchase price (the comprehensive and collision component of the insurance premium increases with truck value).

The diesel truck fuel economy input, 5.5 miles/gallon, was calculated from the baseline vehicle over the course of the demonstration period. The eTruck electricity consumption rate was calculated from eTrucks 3 and 4 with eTRU operation during the demonstration period.

Likewise, the range, days of operation, and annual mileage are based on baseline diesel truck operation during 2022.

Scenario 1 is the demonstration scenario; high eTruck/eTRU costs with low usage. Results of Scenario 1 show that the eTruck, at initial manufacturing costs, cannot compete with a conventional diesel reefer truck on a life-cycle cost basis. It cost over $100K more to own and operate than a comparable diesel truck. The operating cost savings do not offset the higher purchase cost of the eTruck within the 15-year lifetime. This result is expected given the high manufacturing cost of the very first units and the low usage of the eTrucks. One of the most significant cost savings of the eTruck results from the reduced fuel cost. In scenario 1, only about 1/3 of the available electric miles (assuming 1 charge per day) was realized. If an eTruck were to be put into this application a much smaller battery pack could be used, thus significantly reducing the purchase price and lowering the total life-cycle cost.

In Scenario 2 market potential projections and engineering estimates provided by HummingbirdEV, lower the acquisition cost of the eTruck/eTRU to $280K. It reflects the near-term cost of a Class 8 eTruck with an integrated eTRU. In this scenario, it is assumed that the electric mileage capacity is fully realized (100 mile per day for 345 days). It is also assumed that successive eTruck models are 7% more efficient. Results of Scenario 2 show a lifetime savings of $148,357. The payback period in this scenario is 6.65 years.

Scenario 3 is more favorable for eTruck/eTRU implementation but still within the realm of short-term possibilities. This scenario promotes the use of clean technologies. It keeps the changes in Scenario 2 but increases the average diesel price to $5.85/gallon, reduces the purchase price with a $20,000 incentive, lowers the electricity price to 20.0¢/kWh (electricity prices in the demonstration region are approximately 50% higher than the national average), and includes a $1,500 annual carbon credit. In this scenario, the total lifetime savings from the eTruck is $284,543. The payback period is 3.0 years.

Table 11 shows the inputs and assumptions for each scenario.

	Scenario 1		Scenario 2		Scenario 3	
	HummingbirdEV eTruck / eTRU	Freighliner M2 Diesel Truck/Diesel TRU	HummingbirdEV eTruck / eTRU	Freighliner M2 Diesel Truck/Diesel TRU	HummingbirdEV eTruck / eTRU	Freighliner M2 Diesel Truck/Diesel TRU
Inputs						
Truck purchase price incl. taxes, credits & charges	$400,000	$187,500	$280,000	$187,500	$280,000	$187,500
Purchase incentives	$0	$0	$0	$0	$20,000	$0
Useful life of truck(s) or depreciation period	15 years		15 years		15 years	
Cost of diesel		$5.30/gal		$5.30/gal		$5.85/gal
Ave. cost change		0%/yr		0%/yr		0%/yr
Cost of electricity	$0.266/kWh		$0.266/kWh		$0.20/kWh	
Ave. electricity cost change	0%/yr		0%/yr		0%/yr	
Average Lifetime Maintenance cost	$0.20/mile	$0.38/mile	$0.20/mile	$0.38/mile	$0.20/mile	$0.38/mile
Average Annual insurance cost	$2,000	$1,500	$2,000	$1,500	$2,000	$1,500
Average annual license, registration & permits	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
License and registration adjustment rate	0%/yr	0%/yr	0%/yr	0%/yr	0%/yr	0%/yr
All-electric range (miles)	100		100		100	
Number of full charges per driving day	1		1		1	
Annual vehicle mileage	13,696 miles/yr		34,500 miles/yr		34,500 miles/yr	
Ave. annual days operated	345 days/year		345 days/year		345 days/year	
Fuel economy	5.5 miles/gal		5.5 miles/gal		5.5 miles/gal	
Truck electricity consumption rate (kWhr/mile)	2.70 kWh/mile		2.5 kWh/mile		2.50 kWh/mile	
Charging efficiency losses	3.0%		3.0%		3.0%	
Annual inflation rate	6.5%		6.5%		6.5%	
Annual discount rate	4.5%		4.5%		4.5%	
Ave. Annual Carbon Credits	$0.00		$0.00		$1,500.00	

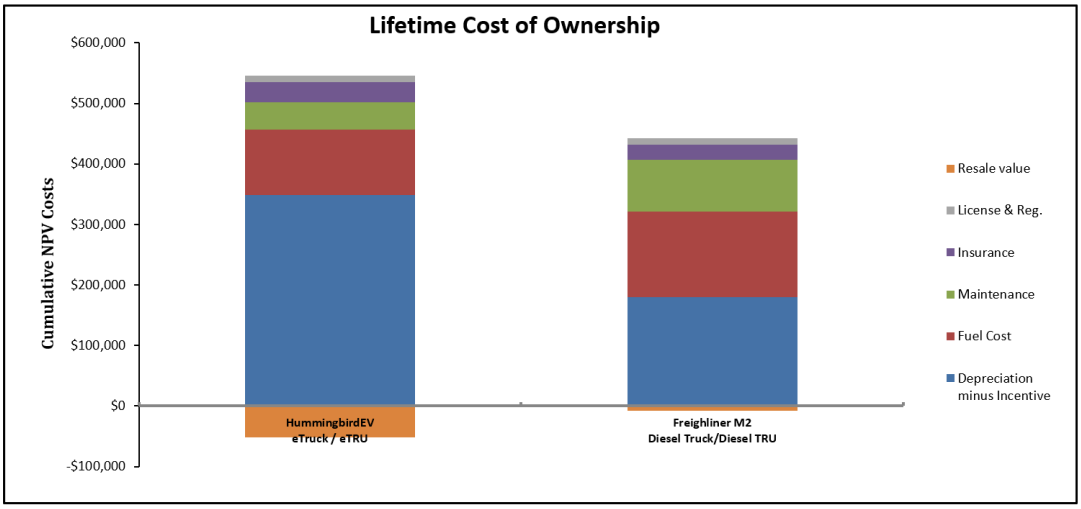
Table 11: Model Inputs

Lifecycle Cost Results

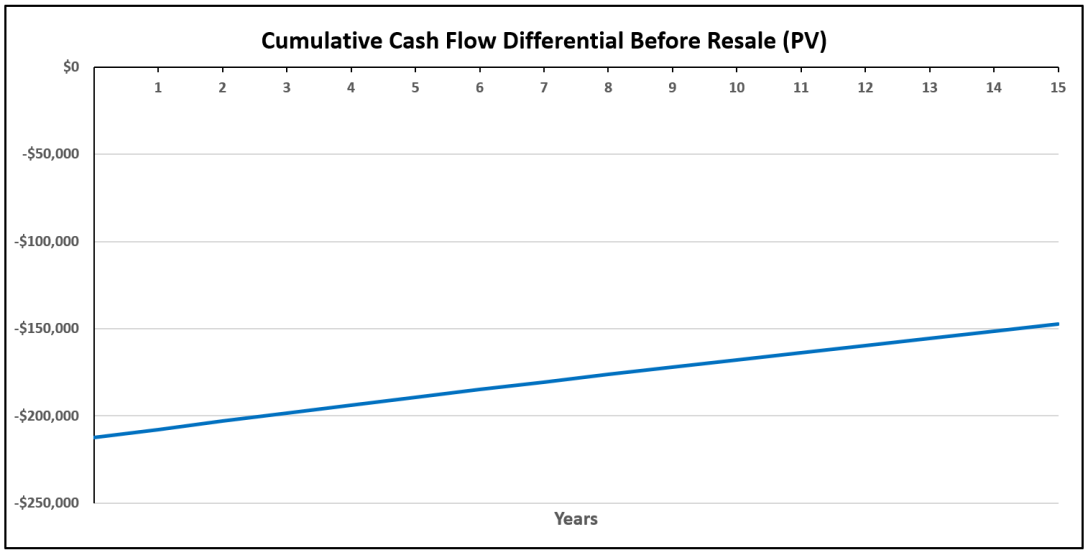
Lifecycle costs results for each scenario are shown Table 12 and Graphs 13-15.

Scenario	eTruck/eTRU Cost Savings	Payback Period
1	- $103,423	>15 years
2	$148,357	6.65 years
3	$284,543	2.99 years

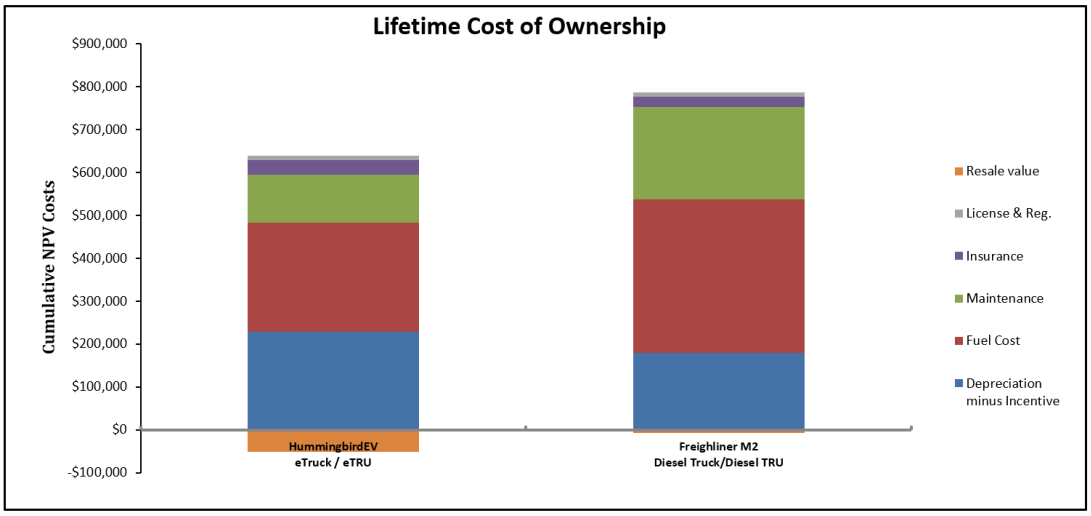
Table 12: Life-cycle cost analysis results



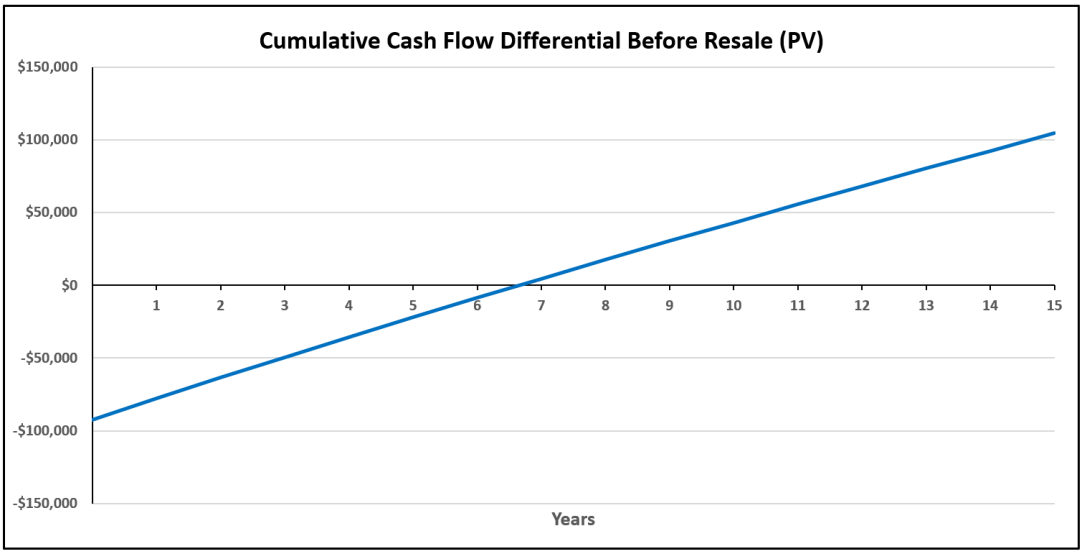
Graph 13.1: Scenario 1 Results



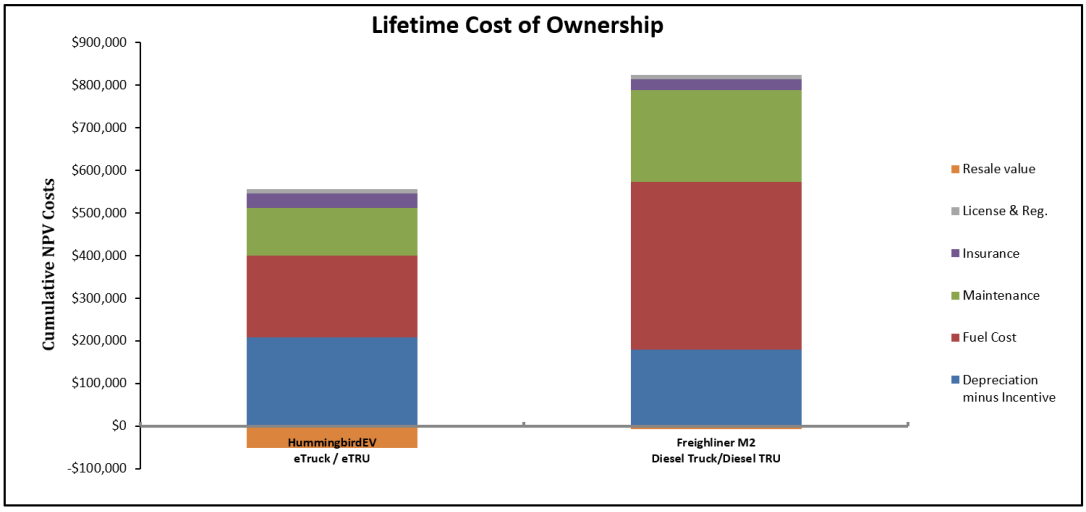
Graph 13.2



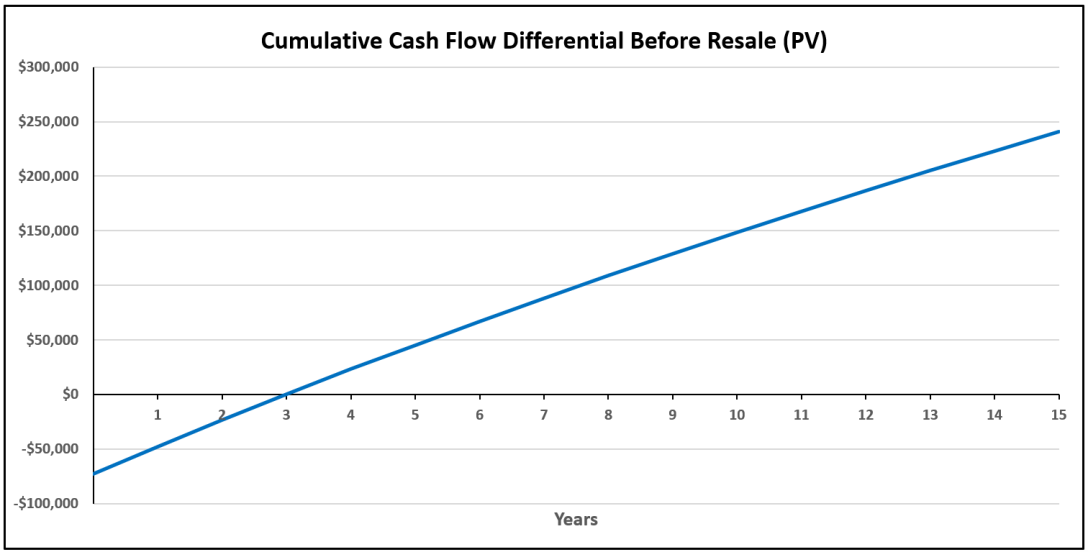
Graph 14.1: Scenario 2 Results



Graph 14.2



Graph 15.1: Scenario 3 Results



Graph 15.2

Supply Chain and Manufacturing

An established reliable supply chain is imperative to scaling up production of the eTruck, and one of two key strategies for lowering the cost of the eTruck/eTRU units (the other being modularity). As a result of foreign trade complications and COVID pandemic-related supply shortages, HummingbirdEV experienced extremely challenging supply issues for the duration of the demonstration; yet despite these challenges and after pursuing several dead-ends, HummingbirdEV prevailed in establishing a strong supply chain. The supply chain was developed and modified as the project progressed, until strong pathways were developed.

Going forward, this supply chain will prove critical to lowering the cost of manufacturing the next batch of eTrucks.

Along with establishing a supply chain, HummingbirdEV developed a manufacturing process through first-hand experience, engineering innovation, and some improvisation. It was an iterative process that led to enormous increases in manufacturing efficiency. Coupled with the established supply chain, the newly developed manufacturing practices will lead to an improved product, decreased manufacturing times, and lower costs.

One strategy for scaling up and reducing costs is to incorporate modularity into the eTruck design. HummingbirdEV is already working on the next generation of modular eTrucks that will be more customized while maintaining commonality of chassis and powertrain platforms. Software development is also underway to increase versatility, making one solution fit a wider spectrum of range and power demands.

Commercialization is achieved in three phases working towards short-, mid-, and long-term goals. The following manufacturing phases provide some insight into the key factors of production:

Phase 1: Engineering Validation Testing (EVT)

Number of eTrucks: 5

Through this project, HummingbirdEV was able to successfully complete the EVT phase by designing, developing, building, and demonstrating five engineering validation units which are still with multiple users – post grant period – collecting data for future eTruck generations.

Implemented as below:

- ***Re-power Chassis:*** During this phase, HummingbirdEV worked with an OEM towards a re-power platform by selecting a conventional chassis and modifying the same to accommodate refrigeration and freight handling needs.

- ***Modular Energy Storage Systems (ESS):*** HummingbirdEV worked with a battery pack supplier based on energy capacity needs with a modular approach which allows future scale-up or scale-down on the battery capacity based on HP, duty cycle, and energy demands. Battery packaging is handled with safety in mind and placed in-between frame rails for maximum crash protection.

- ***Software Driven Powertrain (SDP):*** HummingbirdEV has built powertrain systems towards future proofing and using the same system to work between a range of vehicle requirements (class 5-8). Software driven systems will enable HummingbirdEV to tune the vehicles on the production line based on user requirements while minimizing the need for an increase in production and vehicle costs with improved commonality between product lines.

- ***Electric Refrigeration (eTRU):*** Upon extensive research, HummingbirdEV not only understood different duty cycle requirements but also worked with suppliers to integrate two different types of eTRUs to work in congestion with eTrucks for this demonstration project with the intent to capture and learn from both systems.

  While the first eTRU system is isolated from the eTruck batteries, the second eTRU system gets power from the eTruck batteries directly. Using eTruck batteries directly to power up eTRU is one among the first in the industry and helped Hummingbird to reduce the cost of each system by $20,000, reduced unladen weight of each truck by 475lbs, reduced moving parts, no need for 2 chargers, better user experience through software, less dependency on suppliers, fast charging and most importantly run time of eTRU while idling increased from 6 hours to 65 hours.

- ***Charging:*** Our unique software driven powertrain enabled for fast onboard Level 2 AC charging of up to 40kw using dual plugs and 20kw using single plugs. Charging power was determined and software tuned by Hummingbird for each user location depending on power availability at each site.

- ***UI/UX/Telematics:*** HummingbirdEV has built its own UI/UX/Telematics unit which not only gives real time truck information to drivers but also fleet operators and HummingbirdEV engineering team via cloud. Features include real time GPS location, user level system information, engineering level system information, vehicle logs at every 5 second intervals, vehicle diagnostics predicting failures and potential down the road warnings, service reminders & complete visual interface of truck display to drivers.

  For the data logging needs HummingbirdEV also had a separate controller and display unit for eTRU unit as well. Features include GPS location, trip information, number of door openings, real time temperature monitoring and current demand.

Phase 2: Design Validation Testing (DVT)

Number of eTrucks: 125

Over the next 18-24 months HummingbirdEV will work towards low volume production while implementing lessons learned from the EVT phase with a mix of re-power and ground up Hummingbird IP light-weight composite skateboard architecture.

Some improvements from EVT include:

- Interchangeable and scalable battery packs with improved thermal systems to enable better performance while charging including HummingbirdEV's own pack design.

- Efficient eTRU seamlessly integrated to eTruck's battery pack and converting the 24v eTRU architecture into a nominal 610Vdc architecture reducing cost and weight.

- Improved vehicle controls, integrated vehicle telematics and implemented diagnostics.

- eTruck eTRU integrated into a single UI/UX/Telematics unit which gives user controls all in one place.

- Implement 80Kw onboard AC charging as standard across all platforms and implementing DC fast charging to handle up to 200kw for the same.

- Reduce and streamline wiring, components/systems, suppliers, manufacturing, and assembly processes to get costs more on par with diesel truck variants (Localized manufacturing).

During the DVT phase HummingbirdEV will also work on designing and building a skateboard allowing batteries to be packaged in between frame rails, uni-structure, lightweight and adjustable chassis platform. HummingbirdEV is also looking for partnerships to enable our long-term goals of building a modular frame that has low step height that can be scalable to accommodate different variants of battery sizes.

Phase 3: Production Validation Testing (PVT)

HummingbirdEV is working towards mid volume production while implementing lessons learnt from DVT phase over the next 36-48 months with a ground up HummingbirdEV vehicle platform.

Alongside DVT, HummingbirdEV is working on a skateboard chassis platform to further minimize the mechanical systems such:

- Reduce unladen bare chassis and cab weight by up to 30% compared to traditional trucks with HummingbirdEV skateboard platform.

- Modular and structural battery packaged in between the frame rails to provide improved safety, weight distribution and reduced costs as well as capabilities to increase (or decrease) the energy capacity based on applications.
- Smart and independent axles with built-in powertrains, steering, suspension, and braking systems.
- Efficient and improved charging speeds both for onboard AC and DC charging.
- Working with industry partners to support infrastructure growth and standards.
- Plug and play assembly lines.
- Reducing costs.

HummingbirdEV is working toward the design with a combination of both in-house engineering and partnership models.

Manufacturing: Asset minimalist approach towards manufacturing using micro-factories (final assembly lines) and contract manufacturing primarily focused on localizing all supply chain related activities – including batteries manufactured in the U.S. (See Figure 5). The need for this is to decrease the time to market/product and reduce overhead costs to enable cheaper/modular/scalable product lines on the production line.

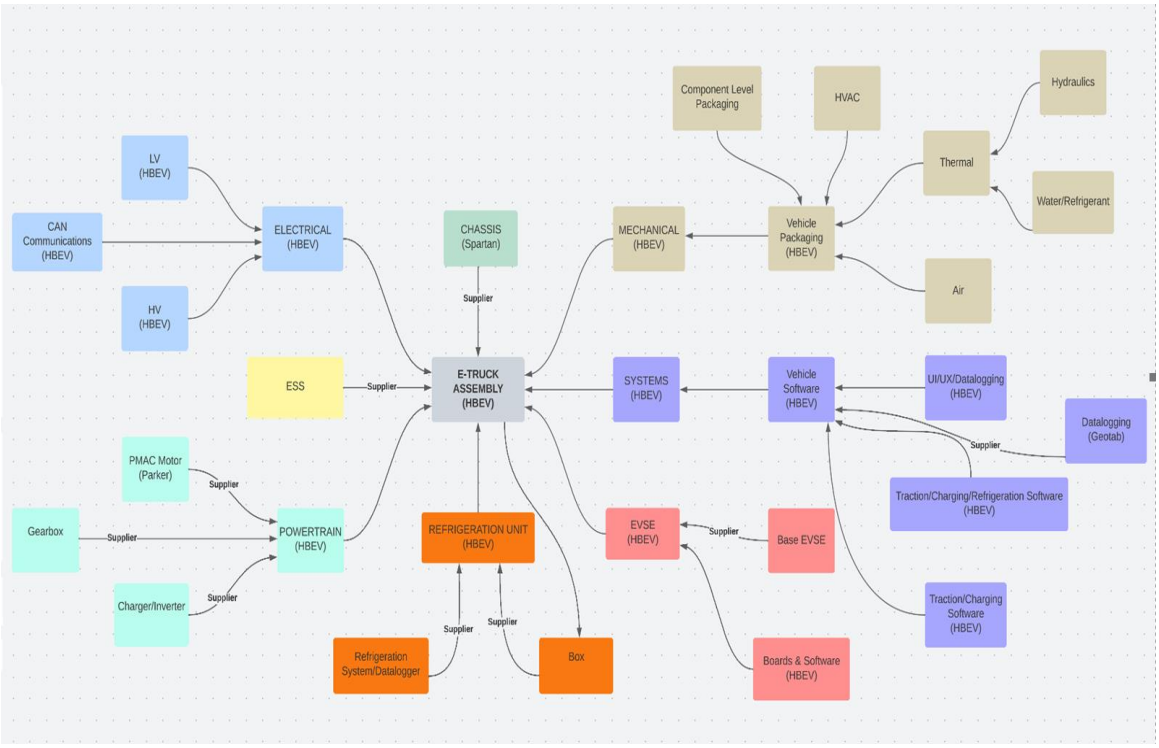


Figure 5: Schematic of the final supply chain and manufacturing process

Public Engagement and Marketing

While electric vehicles are not new, they do represent a new way of thinking for both public and private entities. This project provided an opportunity to explore a new tantalizing market for all-electric trucks with electric TRUs. Although tested in the agricultural community, the market potential of this technology reaches far beyond agriculture into the industrial and commercial sectors.

Participation in public and private industry showcases was a great way to promote eTrucks/eTRUs. The eTruck will continue to be made available for demonstrations during industry gatherings, and HummingbirdEV will continue to take these trucks out for public exhibits, as well as engage prospective buyers.

HummingbirdEV has participated in tutorials and online educational events. The team's marketing and educational efforts extend to all forms of media from traditional print and television to social media, such as Facebook, Twitter, and Instagram. They have also been recognized in trade publications, major newspapers, and on TV news shows. They have generated brochures, informational spec sheets, press releases, and professionally produced videos that reside on several internet platforms (Appendix E).

HummingbirdEV purchased booth space at the World Ag Expo (WGE) to display the eTruck in 2020, 2021 (virtually), and 2022. The World Ag Expo is a week-long, annual event held in Tulare, California. It is the largest annual outdoor agricultural exposition in the U.S. with over 1,450 exhibitors and an attendance of more than 100,000 each year. In the three years of participation, HummingbirdEV successfully shared information with hundreds of potential buyers and generated a great deal of interest in the technology. Some of participants of the WAE were interested in receiving more information and others were interested in becoming a demonstration site. PG&E and San Joaquin Valley Air Pollution Control District discussed potential funding and infrastructure opportunities.

In 2022 the HummingbirdEV eTruck/eTRU was named a "Top-10 New Product Winner" at the World Ag Expo, the largest agricultural exposition in the U.S. (see Figure 6). Winners were selected by farmers, ranchers, and other industry professionals. This is a very prestigious award in the agriculture community, and it garnered a lot of publicity for HummingbirdEV and the electric truck technology.

Figure 6: Photo of the "Top-10 New Product Winner" Award from the World Ag Expo 2022

The Hummingbird eTruck/eTRU series was also on public display as posters and brochures in both the HummingbirdEV booth at the CARB open house in Riverside, CA (May 20, 2022) and at the Electric Truck Symposium

(Medium/Heavy Duty) in Fresno, CA (August 30, 2022). Numerous articles are also on the internet regarding the introduction of the HummingbirdEV eTruck/eTru as well as its Top 10 award from World Ag Expo.

End-User Experience, Satisfaction and Acceptance

The first interviews were conducted in July of 2020, before the primary end-user, Moonlight, had any exposure to the eTrucks. These in-person entry interviews were conversational and focused on understanding expectations and pre-demonstration knowledge of the technology. They provided insight into how management was preparing for deployment in terms of charger installation and operational changes necessary to accommodate the different attributes of an eTruck, as well as other preparatory changes being considered. The same interview approach was taken at the second demonstration site, Rosa Brothers, before the eTruck was implemented.

Moonlight had some experience with electric vehicle technology resulting from a CARB-funded project to replace four diesel tractors with electric tractors, intended to be fueled in the fields by a Class 6 all-electric truck. This project was underway at the time and difficulties associated with the electric tractor design being mismatched with the intended application were just emerging. These problems were complicated by several issues, including supply chain problems, the COVID pandemic, and other on the ground issues. Moonlight management was disappointed by the delays and developing problems but remained extremely optimistic about the eTruck/eTRU technology. Management had “high hopes” for the eTrucks/eTRUs and had more “need for them.” They had a good understanding of infrastructure requirements and what to expect in terms of performance. Despite some disappointments with the electric tractors, this optimism was expressed for the duration of the project. Moonlight viewed the eTruck/eTRU as something they would incorporate into their fleet immediately if the technology worked and the cost was within budget. Rosa Brothers did not have the same exposure to electric technologies but was very receptive to using and understanding the technology.

During the project, opinions, and knowledge of the eTruck/eTRU were monitored through conversations and monthly project meetings. Both end-users were clearly aware that this was a demonstration and things were likely to go wrong. When things did go wrong, they reverted to a backup plan to keep their operations running. It was critical that both end-users had back up vehicles that were used when the eTrucks - or more often - the eTRUs had problems, needed maintenance, or underwent upgrades. Another factor that really buoyed the attitude of the end-users was the prompt response of the manufacturer, HummingbirdEV, when things did go wrong. Small items could sometimes be resolved with a phone call, but more significant issues were dealt with, hands-on, by HBEV employs who always availed themselves for unscheduled site visits.

A second set of phone interviews were conducted at the end of the project in early January 2022. These interviews were conducted in a semi-structured manner. An interview protocol was developed consisting of several questions and an outline of topics and for the interviewer to cover, but respondents were encouraged to speak at length in their own manner. The questions were not read in succession like a list, and several were skipped completely. Instead, these topics and questions were used to guide the interview. Many times, new topics were introduced by the interviewee or interviewer. As new topics evolved, the interviewer managed the interview to garner additional insights. See Appendix F for interview questions.

The final set of interviewees comprised seven individuals, including all the drivers of the eTrucks along with managers who oversaw the transportation operations. These two groups offer different perspectives on the challenges and acceptance of the eTrucks/eTRUs. The driver insights were more directly related to the truck features and performance, whereas managers had a much broader focus. Two of the drivers spoke very little English, therefore a translator was used for those interviews.

End-User Feedback

Much of the drivers' assessment of the vehicles focused on comfort, although reliability and safety were also important to them. Drivers were also eager to share any event that disrupted normal daily routines. Drivers commented on the lack of certain amenities and features. Top among these was the absence of a radio in the cab and no USB port for charging phones. The drivers unanimously liked the cab and instrument panel layout. Visibility (window placement and size) was also very good. The instrument panel itself was intuitive and easy to use. The eTRU temperature setting was also simple to use and the eTruck SOC was always easily viewable. Both the air conditioning and heating in the cab was adequate. However, there was one incident when the A.C. stopped working. After the repair, it was reportedly not as effective at cooling the cab.

Another benefit of the eTruck was charging rather than refueling with diesel. Diesel refueling takes longer and sometimes involves an out-of-the-way trip. The drivers much preferred

simply plugging in when done for the day. The chargers were located in convenient locations and were simple to use. Only once was a gate locked blocking access to the chargers, which was a problem easily resolved. To facilitate the uptake and use of electric vehicles, charger location must be carefully planned.

All the drivers appreciated the regenerative braking "feel" although they were not clear what was happening. They liked the fact that the truck slowed down without much braking effort and an emergency hand brake did not have to be engaged when stopped. They also liked the fact that the eTruck did not vibrate much and was quiet. The quietness was less stressful and allowed drivers to focus more on driving and their surroundings. However, one driver stated that he was concerned about "getting sleep" without the noise and wondered if others (drivers and pedestrians) could hear the truck. He thought noise might help him be seen and, therefore, be safer. One driver described the truck as having a rough ride. He felt that there was too much suspension for his light loads (the eTrucks were intended for heavier loads).

Headlights were good, but in one truck the driver thought they needed adjustment because oncoming drivers were flashing their headlights at him. He was also concerned that there were no fog lights. During part of the year, the San Joaquin Valley often experiences a heavy layer of tule fog when conditions are just right. Although, there were no issues with this during the demonstration, one driver pointed out that it would be difficult to see with just the regular headlights because they would likely exacerbate poor visibility. He also pointed out that the emergency lights do not come on if the truck loses power. This happened once and the driver was concerned about the safety of other drivers who may not be able to see his truck on the side of the road. HummingbirdEV has reportedly fixed this problem, so that the emergency flashing red lights are always operable even when the truck loses all other power.

Most of the problems stated above can be resolved with relatively simple design or engineering changes. In fact, one driver came up with his own creative solutions. He explained how he purchased a flashlight from Amazon with an emergency flash mode. He explained how it could be used for emergencies and had a USB charging outlet for his phone. The same driver bought a "seat donut" to increase ride comfort. Because the eTruck had no radio, his son bought him a Bluetooth speaker that he paired to his phone to listen to music. Many of the driver-perceived eTruck "problems" were simple inconveniences, that can be easily remedied on the very next eTruck manufactured (and in most cases the existing eTrucks can be retrofitted or modified).

It was also noticed that the truck did not have the same acceleration as the diesel truck they normally drove, and the top-speed was slightly less. This was especially noticeable with a full load. However, for the speed limits and routes driven during the demonstration, it did not appear to be a significant problem. The drivers were not too bothered by it, although one noted that impatient drivers would occasionally "flip him off" or honk at him because of the

slow acceleration. However, for applications requiring more highway travel (particularly, non-agricultural applications), it could be problematic. The trade-off between speed and acceleration versus range, will have to be assessed for different applications.

A more substantial concern of one driver was the truck shutting off unexpectedly. Although this only happened once while in motion, it was disconcerting. When the truck lost power, the power- steering became disabled making it difficult to pull onto the shoulder. Also, there is no sign forewarning the driver that the truck may disengage or suddenly stop. Other times the truck seemed to shut off after being stopped for a short period (that may be a design feature) but the driver simply rebooted the truck by going through the power startup sequence.

The eTRU was effective at cooling the box but had several initial technical problems. Once these were remedied and reliability increased, the unit (independent configuration) could fully recharge in about 3 hours and cooled the box faster than the diesel unit. The box also stayed colder longer. There were a few times when it failed to keep the box at 37°F towards the end of the route on the hottest days (>110°F), however, it was still cold enough to prevent product damage. All the units were sent back to the manufacturer at one point for repairs. The repairs took over three months in some cases (this occurred when the eTrucks were still being tested), causing project delays. Another concern was the eTruck or eTRU not being adequately charged when needed. This happened on a couple of occasions. It was speculated that the electricity went out very briefly at night causing charging to cease. Neither the eTruck nor the eTRU resumed charging when the electricity was restored. An important design change would ensure charging resumes after electricity outages.

Despite HummingbirdEV's extensive onsite training and supplemental operating manual (Appendix G), none of the drivers were directly trained or given firsthand information. All information and training were passed down to the drivers from someone else in the organization (e.g., the mechanic). In one case, the driver did not receive any training or the operating manual. He learned by trial and error. In another situation, one driver taught another. In every situation, critical people did not receive the training directly. This created significant problems. For example, there is a starting sequence to follow in order to initiate operation of the vehicle. When this sequence is not followed correctly, the truck defaults. This was the cause of several service calls. Another frequent problem was related to the end-user letting the battery drop below the minimum SOC threshold (this could happen if the eTruck/eTRU was not properly turned off). In one case the driver drove the battery below

10% SOC. This put the truck into “limp home” mode which significantly limits acceleration and top speed (to about 35 mph). This unusual performance confused the driver who was not aware of the consequences of going below 10% SOC. HummingbirdEV is making updates allowing full performance of the truck below 10% SOC.

From the end-user perspective, there is little to no distinction between types of service calls. They did not distinguish between service visits for the purpose of improving eTruck performance (e.g., software updates) from service calls necessary to make repairs. Moreover, the end-users were not usually aware of the cause of the problems (a situation exacerbated by the language barrier). Repairs were often required because of avoidable mistakes such as over-discharge of the battery or improper start up practices (HummingbirdEV is already working on making future models more foolproof). Others repair visits were necessary because of voltage spikes in an unreliable grid system with insufficient infrastructure voltage protection. The eTRU also required many hours of service and some units had to be sent back to the manufacturer for repair. However, whether the reason for downtime was user-induced, utility caused, or eTRU related, the end-users only saw a non-working eTruck. User errors or troubles with one component can forge opinions regarding this new electric technology.

During the project, HummingbirdEV made 22 service site visits. However, half those visits were responding to issues caused by “user error” or damage resulting from “grid failure.” Of the 11 remaining visits, 5 were for brief software updates, and 3 were to repair eTRUs. Only 3 visits were for the purpose of repairing or adjusting something on an eTruck (non-eTRU related). However, in addition to the Hummingbird service visits, there were 7 significant repairs or replacements needed on the eTRUs which were performed by the eTRU manufacturer. These eTRU malfunctions took a total of 364 days for diagnostics, repairs, and replacements. eTRU issues were all resolved but the delays and unreliability were not conducive to forming favorable opinions of the eTruck technology.

The eTRUs had to be turned on and adjusted with a phone app rather than using dashboard instrumentation. Reliance on an app for eTRU functionality could be problematic. In one case, the driver was not aware of the need for an app, and it took a co-worker several days of trial and error to figure out how it worked. Also, none of the drivers responsible for charging understood the BMS system that limits the SOC to 98%. They did not understand why charging stopped at 98% and then the SOC started decreasing (the SOC can drop about 4% for cell balancing to maintain battery state of health (SOC). At Rosa Brothers, a nightshift worker unplugged the truck as soon as it reached 98% because he did not know how much the battery would discharge and was afraid it would be too depleted for the next day.

Despite technical glitches and user errors, the drivers and managers noticed that things improved and there were fewer problems as the time progressed. Also, they all supported the

larger goal of eliminating emissions and reducing GHGs (more often expressed as reducing climate change). Drivers noticed the absence of diesel fumes. One driver had allergies exacerbated by diesel fumes and noted that he felt great while driving the eTruck. He even noted that he did not have to carry tissues when driving the eTruck. Drivers and managers were also cognizant that the eTrucks were helping reduce climate change. In fact, one driver explained that his son was very interested in environmental issues and asked every day if he drove the electric truck. The driver felt proud to be making a positive impact on the environment and sharing the experience with his son. Similarly, another driver has a niece who owns and enjoys driving a Tesla. He enjoyed that fact that got to share his "electric vehicle" experience with her after hearing her endorse the technology for many years. Beyond close relatives, there were not too many educational opportunities. The eTruck drivers did discuss the eTruck much with fellow drivers.

Manager opinions varied. At one site the manager was very optimistic and said there was a place in his fleet for eTRU equipped electric trucks, if the price was in the $240K- 260K range. The other manager felt that the current range limit was too restrictive but a longer-range eTruck might work. He also felt their electricity bill increased significantly but was not sure how much it increased. However, both managers were somewhat laissez faire with regard to transportation operations, so most of what they knew about the performance was reported to them. Furthermore, neither manager was aware of the potential lifecycle cost benefits of using the technology nor the potential operating cost reductions. However, both were curious to learn more about eTruck economics.

Discussion and Recommendations

This project successfully demonstrated the first ever all-electric TRU installed on an all-electric agricultural work truck. Five eTRU-equipped eTrucks - two different configurations - were designed, manufactured, and deployed in a functioning fleet, performing the same duties as the diesel trucks they displaced.

This project demonstrated the GHG and emission reduction potential of this technology. These emission benefits accrued where they were needed most, in disadvantaged communities. Truck drivers and those working around the loading docks also realized direct health benefits from the zero-emission trucks.

Electric trucks with electric TRUs hold promising potential to lower truck costs. Cost estimates show that this technology can be competitive in the near-term with diesel trucks and, at relatively low production volumes, could potentially save almost $200K over a 15-year service life. Programs, policies, regulations and incentives aimed at facilitating the market growth of eTrucks could bring the lifecycle cost down even lower and realize a payback period less than 3 year.

During the course of this project - despite trade wars, major international supply shortages, and a world-wide pandemic - the manufacturer managed to establish a secure supply-chain for continued production of the eTruck/eTRU. Though establishing this supply-chain under difficult conditions was challenging, it ensures the continued production of eTrucks at decreasing cost. Between the first and last eTrucks produced for this demonstration, the manufacturer significantly improved and refined the manufacturing process. These improvements increasing efficiency and allow faster integration of new technologies, as they become available.

This project also included an aggressive education and marketing campaign that introduced the new technology to thousands of prospective buyers in the agricultural community. Marketing efforts culminated with a prestigious award honoring the HummingbirdEV eTruck/eTRU as a “Top-10 New Product Winner” at the World Ag Expo. The initial focus on farming applications has generated a lot of positive feedback. However, the eTruck/eTRU is also well-suited for commercial and industrial sectors, suggesting it could have an outsize role in the transition to truck electrification.

Recommendations

Recommendations focus only on observations and feedback from the demonstration project.

One end-user significantly under-utilized the eTruck/eTRUs, not only with regard to their projected usage, but also based on the range capability of the eTrucks (assuming one charge per day). Battery size customization or a range of battery size offerings, could increase market potential while lowering cost and reducing weight. The eTruck reclassification from a Class 7 truck to a Class 8, due primarily to battery weight, had a big unforeseen consequence. This change narrowed the field of perspective drivers significantly, because only drivers with commercial driver licenses could drive the demonstration truck. Smaller lighter battery packs could make the eTruck more versatile and useable in different markets. The manufacturer is already taking measures to reduce truck weight which includes, but is not limited to, lighter battery packs and battery technologies with higher energy density.

Several technical service calls resulted from end-user error. Although extensive training was conducted at both end-user sites, it appears some drivers did not directly participate. Instead, they learned about the eTruck/eTRU second-hand from other drivers, the mechanic, or other

employees within the company. Complicating the issue was the fact that some of the drivers understood only a minimal amount of English. Even though the operating manuals were published in both languages and a translator was available during training, the drivers did not have all the information needed to properly operate the eTruck. It is important that training targets everybody involved with the truck and is ongoing and available for new drivers.

The drivers were satisfied with eTruck performance in general and appreciated the zero-pollutant aspect from both a personal health perspective and environmental aspect. They also liked the quietness and regenerative braking. However, they commented on the feel of braking without knowledge that the battery was being regenerated. Education and knowledge about new electric trucks could instill pride and improve operation. The slower acceleration and lower top-speed of the eTruck, compared to their usual diesel truck, was noticed by the drivers but not considered too bothersome. The acceleration and maximum speed were sufficient for the demonstration applications. However, this could limit usage to certain applications in the early years of market development.

The absence of certain amenities and cab features, like USB ports and a radio, were mentioned by all the drivers. These items should be included in all models to ensure driver satisfaction. Cab climate conditioning was satisfactory during the demonstration, but AC performance may be challenged in similar weather conditions. Although temperatures over 100° F were common , the drivers were constantly moving in and out of freezers all day which took some of the burden off the cab air conditioning. Once the eTRU issues were resolved, it seemed to work satisfactorily. However, the extreme high to low swings of the box temperature suggests that the drivers were reacting to the to the temperature with constant manual adjustments. Again, this might be resolved with more training and education.

Safety features were very important to the drivers. In one incident the eTruck lost power while in motion. The eTruck stopped abruptly and lost power steering making it difficult to pull onto the shoulder. Adding to the safety concern, the emergency lights did not work under this no-power condition. These safety issues are of paramount importance and solutions should be - and in some cases already have been -- identified and implemented by the manufacturer.

Management was curious but receptive to the prospect of an eTruck in their fleet. They understood the purpose of the demonstration and were patient when things didn’t work exactly right (as is often the case during demonstrations). However, they wanted to know more about the eTruck and technology in general. How much electricity does it use? How will it impact our electric bill? Will future models have a longer range? What will be the purchase price when they are available? Although these questions were premature given the fact that this was a demonstration, it will be important to be able to address these questions

when the product nears commercialization. It is also imperative that decision-makers have a thorough understanding of lifecycle cost. eTrucks will be cost-competitive on a lifecycle cost basis long before their purchase price will beat that of their diesel counterpart.

Management was also concerned about reliability in the long run. Downtime was avoided during the demonstration period because end-users had back-up trucks. Some type of back up assurance may be necessary in the early market. Reliability is especially important with agricultural usage because a disproportionate amount of revenue is generated in relatively short seasonal timeframes. Downtime is always expensive but could be even more detrimental on a farm operation. Reliability includes grid reliability. One eTruck was severely damaged because of a spike in the electric grid. Electric infrastructure should be inspected to protect against these types of spikes, before an electric vehicle is placed at the site.

Finally, implementation of electric trucks must flow from the top down. Management should convey the importance of implementing the technology and share their commitment with those charged with maintaining and driving the electric trucks. During the demonstration, some of the eTrucks were not driven regularly. The drivers had discretion when deciding whether to drive the electric trucks. It is not exactly clear why they often elected not to drive the eTrucks, perhaps the lack of a radio or the heavy responsibility of driving a new, expensive, unfamiliar piece of equipment. Regardless, it seemed like the commitment to using and testing the eTrucks was inconsistent from top to bottom of the organization.

Conclusion

The San Joaquin Valley demonstration project successfully developed, deployed, and demonstrated five electric trucks equipped with electric TRUs. This zero-emission technology has the potential to capture significant market share across several TRU transport operations throughout California. Even at low production levels, it provides a cost-effective strategy for reducing pollution and greenhouse gas emissions. The demonstration trucks performed well, even under the most challenging conditions involving extreme temperatures and less-than-ideal operating environments. Areas of improvement in the manufacturing process (complicated by COVID and unprecedented supply chain issues), as well as truck performance, have been identified and are being pursued. There was a tremendous amount of data collected, and knowledge gained from this demonstration project. Lessons learned will contribute significantly to all-electric refrigerated transport, bringing the technology one step closer to commercialization.

HummingbirdEV is committed to keeping all five of the demonstration trucks in service and will continue to collect in-field operating data. This data, along with user feedback, will be used to identify ways to enhance performance, improve reliability, and provide even better

driver satisfaction. The demonstration eTtrucks will continue to be used by the project partners – Moonlight Companies, Rosa Brothers Milk Company, and Joseph Gallo Farms – for the foreseeable future. HummingbirdEV and Moonlight Companies are currently discussing leasing options for eTrucks. In addition, HummingbirdEV is actively searching for other prospective users to provide more opportunities to demonstrate the technology under real-world conditions. Two large, high-profile companies have already expressed interest in using several Hummingbird eTrucks in their fleets. The goal at this stage of production is to give the HummingbirdEV eTruck/eTRU technology exposure, while continuing to move towards commercialization.

As production of the eTruck/eTRU progresses, cost reductions and performance improvements are already being realized from incorporating 1) Unique composite chassis platform that increases payload capacity while reducing unladen truck weight, 2) Modular system that increase eTRU versatility and compatibility allowing a “skateboard platform” strategy and, 3) 610Vdc refrigeration system that provides significant advantages over the existing 24-volt architecture.

HummingbirdEV is on track to meet its goal of becoming a fully operating, all-electric TRU/truck OEM by the end of 2023. With ongoing production ramp-ups and the benefits of key industry partnerships, HummingbirdEV plans to produce and sell 50 eTruck/eTRUs units in 2024, 300 units in 2025, and at least 1000 units every year thereafter.

Glossary of Terms, Abbreviations, and Symbols

AQIP	Air Quality Improvement Program
AC	Alternate Current
BMS	Battery Management System
Cal/EPA	California Environmental Protection Agency
CARB	California Resources Air Board
CDL	Commercial Driver License
DAC	Disadvantaged Community
DC	Direct Current
eTruck	Electric Truck
eTRU	Electric Transport Refrigeration Unit
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment (Chargers)
GGRF	Greenhouse Gas Reduction Fund
GHG	Greenhouse Gas
GVWR	Gross Vehicle Weight Rating
HBEV	Hummingbird EV
HP	Horsepower
kW	Kilowatt
kWh	Kilowatt Hour
lbs.	Pounds
LCC	Lifecycle Costs
MPH	Miles Per Hours
MT	Metric Ton
NOx	Nitric Oxide
OEM	Original Equipment Manufacturer
PCA	Project Clean Air
PM10	Particulate Matter (≥10 microns)
ROG	Reactive Organic Gases
SOC	State of Charge
SOH	State of Health
SJV	San Joaquin Valley
TRU	Transport Refrigeration Unit
TTC	TechTruth Consulting
V	Voltage

SECTION

APPENDIX A

Moonlight Cold Storage

Fuel Log

Date	Truck	Mileage	Fuel	Gallones	Truck driver
Todays date	Number	Current Miles	Type	Amount pumped	Name
1/4/21	416	256535	Diesel	10	David C
1/5/21	416	256539	Diesel		David C
1/6/21	416	256545	Diesel		David C
1/7/21	416	256549	Diesel		David C
1/8/21	416	256575	Diesel		David C
1/23/21	416	256614	Diesel		David C
1/25/21	416	256674	Diesel		David C.
2/2/21	416	256771	Diesel		David C.
2/12/21	416	256805	Diesel		David C

Moonlight Cold Storage

Fuel Log

Date	Truck	Mileage	Fuel	Gallones	Truck driver
Todays date	Number	Current Miles	Type	Amount pumped	Name
2-22-21	416	256857.8	Diesel	36	Emilio
3-5-21	416	256921.0	Diesel	31.6	Emilio
3-19-21	416	257064.7	Diesel	37.0	Emilio
3-28-21	416	257439.8	Diesel	58.13	Emilio
4-19-21	416	257718.8	Diesel	69.87	Emilio
4-26-21	416	258081.8	Diesel	68.67	Emilio
5-3-21	416	258395.4	Diesel	56.32	David
5-10-21	416	258749.4	Diesel	60.06	David
5-17-21	416	259108.4	Diesel	52.37	David
5-24-21	416	259488.2	Diesel	57.01	David
5-31-21	416	259805.2	Diesel	66.42	David
6-7-21	416	260181.1	Diesel	58.27	David
6-14-21	416	260,509.1	Diesel	56.33	Antonio
6-21-21	416	260,831.9	Diesel	69.01	Antonio
6-28-21	416	261,161.7	Diesel	54.67	Antonio
7-5-21	416	261,531.8	Diesel	57.81	Antonio
7-12-21	416	261,886	Diesel	68.03	Antonio
7-19-21	416	262,205.5	Diesel	67.21	Antonio
7-26-21	416	262,551.3	Diesel	62.97	Antonio

Moonlight Cold Storage

Fuel Log

Date Todays date	Truck Number	Mileage Current Miles	Fuel Type	Gallones Amount pumped	Truck driver Name
12-14-21	416	267,645.9	Diesel	48.2	Alfredo
12/27/21	416	267,692.9	Diesel	42.5	Alfredo
1/10/22	416	267,771.2	Diesel	28.3	Alfredo
1/17/22	416	267,987.7	Diesel	51.6	Antonio
1/26/22	416	268,107.2	Diesel	37.2	Antonio
2/4/22	416	268,213	Diesel	44.8	Antonio
2/10/22	416	268,295.3	Diesel	36.4	Alfredo
2/15/22	416	268,335.8	Diesel	39.7	Sebastian
3-3 22	416	268,526.7	Diesel	74	ANTONIO
3-24-22	416	268,925.1	Diesel	69	ANTONIO
4-13-22	416	269,230.4	Diesel	62	ANTONIO
5-07-22	416	269.517.1	Diesel	66	ANTONIO
5-19-22	416	269,922.0	Diesel	71	ANTONIO
5-26-22	416	270,329.8	Diesel	70	ANTONIO

Moonlight Cold Storage Fuel Log

Date	Truck#	Mileage	Fuel	Gallons	Truck Driver
		Current Miles	Type	Amount	Name
6-21-22	416	272,233.9	Diesel	69gl	Antonio
6-24-22	416	272,556	Diesel	34gl	Emilio
6-25-22	416	272 676	Diesel	29	Emilio
6-28-22	416	272881	Diesel	71	Antonio
7-2-22	416	273219	Diesel	36	Emilio
7-5-22	416	273415	Diesel	74	Emilio
7-8-22	416	273822.3	Diesel	66	Antonio
7-11-22	416	274188	Diesel	67	Emelio
7-14-22	416	274587	Diesel	68	Antonio
7-18-22	416	274966.9	Diesel	69	Antonio
7-21-22	416	275296	Diesel	64	Emilio
7-25-22	416	275617	Diesel	24	Emilio
7-26-22	416	275709.8	Diesel	56	Antonio
7-28-22	416	276086	Diesel	60	Antonio
8-1-22	416	276317	Diesel	30	Emelio
8-3-22	416	276595	Diesel	62	Antonio
8-6-22	416	276892	Diesel	66	Emelio
8-10-22	416	277324	Diesel	73	Antonio
8-13-22	416	277685	Diesel	55	Emelio
8-17-22	416	278016	Diesel	75	Emelio
8-22-22	416	278348	Diesel	54	Emelio
8-29-22	416	278666.1	Diesel	72	Antonio
9-1-22	416	279006	Diesel	64	Emelio
9-12-22	416	279326	Diesel	61	Sebastian
9-15-22	416	279.625	Diesel	64	Emilio
9-22-22	416	279.888	Diesel	63	Emilio
9-30	416	280.219	Diesel	48	Emilio
10-20-22	416	280 446	Diesel	74Ga	ANTONIO

Moonlight Cold Storage Fuel Log

Date	Truck#	Mileage	Fuel	Gallons	Truck Driver
		Current Miles	Type	Amount	Name
6-21-22	416	272,233.9	Diesel	69gl	Antonio
6-29-22	416	272,556	Diesel	34gl	Emilio
6-25-22	416	272 676	Diesel	29	Emilio
6-28-22	416	272881	Diesel	71	Antonio
7-2-22	416	273219	Diesel	36	Emilio
7-5-22	416	273 415	Diesel	74	Emilio
7-8-22	416	273823	Diesel	66	Antonio
7-11-22	416	274 188	Diesel	67	Emelio
7-14-22	416	274587	Diesel	68	Antonio
7-18-22	416	274966.9	Diesel	69	Antonio
7-21-22	416	275296	Diesel	64	Emilio
7-25-22	416	275617	Diesel	24	Emilio
7-26-22	416	275709.8	Diesel	56	Antonio
7-28-22	416	276086	Diesel	60	Antonio
8-1-22	416	276 317	Diesel	30	Emelio
8-3-22	416	276595	Diesel	62	Antonio
8-6-22	416	276892	Diesel	66	Emelio
8-10-22	416	277314	Diesel	73	Antonio
8-13-22	416	277685	Diesel	55	Emelio
8-17-22	416	278016	Diesel	75	Emelio
8-22-22	416	278548	Diesel	54	Emelio
8-29-22	416	279066	Diesel	72	Antonio
9-1-22	416	279006	Diesel	64	Emelio
9-15-22	416	279326	Diesel	61	Sebastian
9-19-22	416	279.625	Diesel	64	Emilio
9-22-22	416	979.888	Diesel	63	Emilio
9-30	416	280,219	Diesel	48	Emilio
10-20-22	416	280 446	Diesel	74Gl	ANTONIO
12-10-22	416	281 091	Diesel	55Gl	ANTONIO
12-26-22	416	281353	Diesel	69Gl	ANTONIO

SECTION

APPENDIX B

Zero- and Near Zero-Emission Freight Facilities Project

All-Electric Truck with Electric TRU Demonstration

Data Collection and Analysis Plan

TechTruth Consulting

February 2021

Table of Contents

Background and Objective

This manual describes the strategy for data collection, reporting, and analysis to be conducted for the All-Electric Truck with Electric Transport Refrigeration Unit (TRU) Demonstration Project (the Demonstration Project). The Project is funded through the Zero- and Near Zero-Emission Freight Facilities program as part of the Clean Transportation Incentives plan administered by the California Air Resources Board (ARB). The Demonstration Project is a collaboration involving Project Clean Air, HummingbirdEV, Moonlight Companies, and TruthTech Consulting. These companies have partnered to develop and test, in real-world applications, five battery all-electric class 8 trucks (eTrucks), each equipped with an all-electric transport refrigeration unit (eTRU). These trucks will be built, from the ground up, by HummingbirdEV and then deployed by Moonlight Companies in central California. During the demonstration the trucks will be used for moving harvested produce between cold storage, packaging, and warehouse facilities located near Reedley, California.

TechTruth Consulting will provide data collection, reporting, and analysis for the project. This manual is intended to be comprehensive and meet all the ARB requirements for data collection and reporting, as specified in the original project solicitation and accompanying Appendix F. The data collection and analysis described in this manual is contingent on the manufacturer and end-user sharing information and providing the means and opportunity to collect the data.

TechTruth will work with project participants in effort to:

- Equip all demonstration vehicles, including one baseline vehicle, with data logging equipment or data collection software.
- Supplement onboard data collection with in-field observation and data collected from both the end-user and manufacturer. Develop and implement data collection tools and methodologies including in-person interviews, in- field observations, and information reporting forms.
- Establish a baseline for current TRU truck operations, duty cycles, and energy use.

- Collect data on new technology vehicles that are deployed in representative applications, with similar duty cycles, and operating demands.
- Collect data and assess eTRU performance.
- Conduct analytical assessment of new technology, vis-à-vis conventional baseline technology, with regard to performance, life-cycle cost, environmental impact, and user satisfaction.
- Provide data for quarterly reports and write summary of findings for final report.

Baseline Conditions

Data will be collected over twelve consecutive months for one baseline truck in daily operation and for the first two demonstration e-trucks. Data will be collected over six months for the remaining three demonstration e-trucks, commencing at the time of deployment. Each demonstration e-truck will be put into regular service in applications similar to the baseline vehicle. Truck utilization and fleet composition at Moonlight is relatively homogeneous, therefore the baseline vehicle provides a good representation of every vehicle in the fleet. The baseline vehicle is a model year 2008 Freightliner M2 Bobtail class 7 refrigeration truck. The eTruck will be a class 8 vehicle (rather than class 7) because of design constraints, however the classification bump has no significant impact on this demonstration.

Figure 1: Baseline truck: 2008 Freightliner M2

Truck operating demands at Moonlight have significant seasonal variations, operating 15 hours/day, 7 days/week in the summer peak-season to sitting idle for several days during the winter off-season.

Peak season for harvesting and produce transport is during the summer months (June-August). During this time the trucks average approximately 60 miles per day

and as much as 85 miles in a single day. Each trip is made with a maximum load and the trucks are often driven up to 15 hours/day. Throughout the day, the TRU-equipped trucks make dozens of stops to load/unload and there is significant idling associated with each trip.

Moonlight trucks are operated in extreme temperatures during much of the year. During the summer, temperatures often exceed 100° F. The high temperatures and frequent door openings put significant demands on the TRU.

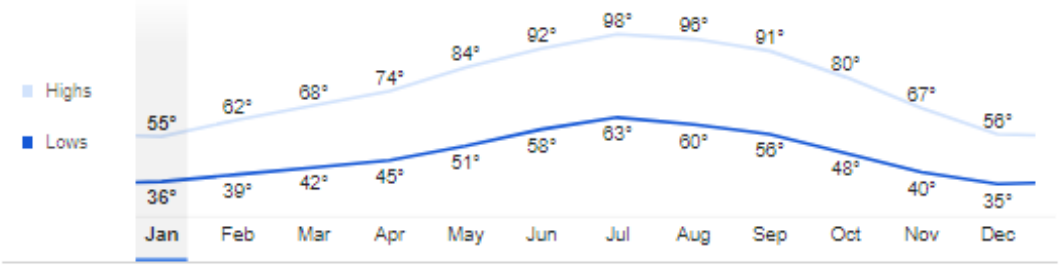


Figure 2: Average monthly temperatures for Reedley, CA. Source: NOAA

Telematic data will be collected from the vehicles. The manufacturer will supply all hardware, software and subscription services needed for data collection and storage. TechTruth, in conjunction with the project partners, installed a Geotab data-logger on the baseline vehicle in July 2020. Working with Sawatch Labs, a web-based analytics management company, TechTruth has been collecting and storing data from the baseline truck continuously since the equipment was installed. Operational vehicle data being collected (and to be collected on the eTrucks) includes the parameters described in Appendix F of the ZANZEFF solicitation, as well as several other key variables. Onboard vehicle data will be collected for the duration of the project.

Data Collection Tools and Methods

The granularity, diversity of amount of data collected directly from the vehicles will be key to assessing the eTruck and eTRU technologies. However, other types of data are necessary for a comprehensive analysis. Therefore, TechTruth will supplement vehicle-generated data with interviews, in-field observations and

information reporting forms. Interviews will be used in two ways. First, they will provide a follow up for clarification and additional information from the manufacturer or various end-user participants. Second, they will be a primary means of collecting data to evaluate the “user/fleet experience”, in accordance with Appendix F. The interviews in this latter function will have a free flow format but predetermined topics will be addressed. Two interviews will be conducted for each driver of the new technology – the first when the new technology is introduced into the fleet and again at the end of the demonstration period.

In-field observations will be important for obtaining information and data that is not available via other means. For instance, observations will enable accurate infrastructure descriptions, a better understanding of charging logistics, insights into the synergies and issues arising from several electric vehicles operating in one fleet, and identification of daily routine variables that could affect vehicle performance. TechTruth personnel will visit the demonstration site as needed but no less than four times over the course of the project. Notes from field visits will be taken and incorporated into quarterly reports and the final document.

The final collection tool is the information reporting forms. These forms will be used to collect specific and detailed Information. For instance, the end-user will be asked to provide specific historical cost data for vehicle maintenance and repair. Forms will also be used to collect data, such as baseline vehicle fueling frequency and the amount of diesel taken onboard during each refueling event (not available through the onboard data logger). The forms will be submitted to the manufacturer and end-user to fill out and return. This will allow them sufficient time to collect the data requested. Reporting forms will be administered digitally to expedite responses, especially in cases where more than one respondent must provide information.

The amount and detail of data collected from the information reporting forms is dependent on the availability of the data and the willingness of the manufacturer and end-user to share that information. Likewise, in-field observations and interviews

depend on access to facilities and interviewees. Both the manufacturer and end-user have agreed and demonstrated a willingness to cooperate to the fullest extent possible on these matters. The manufacturer may integrate software into the eTrucks to provide real time data collection, instead of installing third party equipment. The manufacturer has agreed to work with TechTruth to ensure data is collected for all the required parameters.

Table 1 illustrates how these various tools and methods will be used, individually and collectively, to ensure that all the required data listed in Appendix F is collected for the baseline and advanced electric trucks.

Table 1: Summary of data to be collected			
Data Category	**Data**	**Method of Collection**	**Comment**
Vehicle Specification	Vehicle specification Full propulsion system specification	IRF	IRF to manufactuer
Vehicle Operation	Description of daily use	IO, OVD, I	Ride-alongs, driver interviews, data frm vehicle
	GPS data: O-D, ave speed, # stops, trip duration, Idle/queue time	OVD	Processed at trip level
	Weight of Loads	IRF	IRF to end-user. Ave for each season
	Battery degradation	IRF, OVD	IRF to manufact. and SOC data from veh
Vehicle / Equipment Performance	Miles btwn roadcalls; Number of roadcalls	IRF	IRF to end-user, per occurance.
	Battery degradation, ZEV range	IRF, OVD	IRF to manufact. and SOC data from veh
	Vehicle availability	OVD, I	OVD to determine non-charging idle, I w/ end-user to confirm veh is functional.
Fuel / Energy Consumption	Amount of electricity, odometer, date, price State of Charge Recharging time Distance to refueling Charging source Load shifting potential Refueling/charge frequency Energy consumption rate	IRF, OVD, I	IRF for baseline refueling details (freq & amt). OVD for both baseline and new tech. Interview with end-user for add'l info re: load shift potential.
Maintenance	Type of maintenance Repairs: date, problem, repair, cost Time-out-of-service details	OVD, IRF	IRF to both manuf. & end-user, per occurance. OVD for time out of service.
Service Calls	Service details Time Out of Service Service Response Time	OVD, IRF	IRF to manufacturer. OVD for time out of service.
Safety	Accidents or Incidents	I, IRF	I and IRF to end-user, per occurance.
Emissions Testing	Not applicable	N/A	
Charging/ Maint. Infrastructure	Infrastructure Facility Description	IO, I	Site-visits, Interview end-user
	Infrastructure Reliability	OVD, I, IRF	I and IRF from end-user. OVD to alert.
Capital Costs	Vehicle Capital Costs (baseline +demo veh)	IRF, I	IRF to manufact with follow-up interview.
	Infrastructure Capital Costs	IRF, I	IRF to end-user with follow-up interview.
Operating and Maintenance Costs	Operating Costs (baseline + demo veh) Maintenance Costs (baseline + demo veh) Charging and maint. infrastructure costs		IRF to end-user for op cost, maint cost and infra cost. IRF to manuf for maint. costs. OVD for op costs. Interviews for clarification and details.
C-ITS	Not applicable	N/A	
User / Fleet Experience Survey	End-user experience/ application suitability	I, OVD	Interview drivers, mechanics, managers, and execs at beginning and end of demo. OVD to confirm suitability.
	Workforce Training Programs Warranty Claims and Insurance Policies Manufacturer Response/Service	IO, IRF, I	I and IRF from end-user

OVD = Onboard vehicle data-logger
IRF = Information reporting forms
IO = In-field observation
I = Interviews

Data Analysis

Data collected throughout this project will be used to analyze and assess the eTruck and eTRU. This objective will be met through four distinct tasks. These tasks are:

1. Assess technology operation and performance
2. Conduct comprehensive life-cycle cost analysis
3. Calculate changes in greenhouse gas (GHG) and criteria pollutant emissions
4. Evaluate and document end-user experience

Each task, explained in detail below, will be treated and expensed separately. Each will be conducted over the course of the project as data is generated and becomes available. Task activities will be concurrent and may be ongoing for the duration of the project. Quarterly progress reports will be submitted providing the status of each task.

Assess eTruck operation and performance

Using data collected from onboard data loggers, in-field observations and information provided by the project partners, TechTruth will assess eTruck operation and performance.

Operational data directly available or derived from the data logger outputs include:

Vehicle Operation

- Duty cycle, description of vehicle use
- Vehicle usage: hours of operation/day, days/year, odometer
- GPS data, moving and not moving
- Trip Origin-Destination
- Miles per trip
- Average trip speed
- In-trip and daily idle time
- Vehicle availability
- Charging opportunities

Vehicle/Equipment Performance

- Number and type of repair events
- Cumulative downtime
- Battery degradation over data collection period

Fuel/Energy Consumption

- Fuel/electricity consumption and vehicle fuel economy
- Fueling/charging location, time, frequency and duration (driver logs will supplement telematics for baseline vehicle)

- Battery state of charge at time of charging events
- Off-peak and/or renewable energy load shifting potential

The type and quantity of data to be collected from the baseline vehicle, although it exceeds project requirements, is necessary for a comprehensive assessment of the new technology. One year of baseline vehicle operating data will be collected for vis-à-vis comparisons across several performance parameters.

In addition to data collected onboard the vehicles using data-loggers, additional information and cost data will be collected from the end-user Moonlight (including drivers, in-house mechanics, fleet managers, and other decision-makers) and HummingbirdEV.

This type of data will include:

- Maintenance and repair needs
- Vehicle reliability
- Vehicle specifications
- Load and range limits
- Ton-miles realized
- eTRU operation and performance

Maintenance and repair data will include items such as the type of maintenance required (scheduled vs. unscheduled, technology troubleshooting, etc.); description of problem; odometer reading and date; description of repairs; parts replaced or adjustments made; estimated cost of repair (if applicable); and repair related downtime. Vehicle reliability will be largely derived based on downtime and unscheduled repairs. Charger reliability will also be taken into account for the assessment.

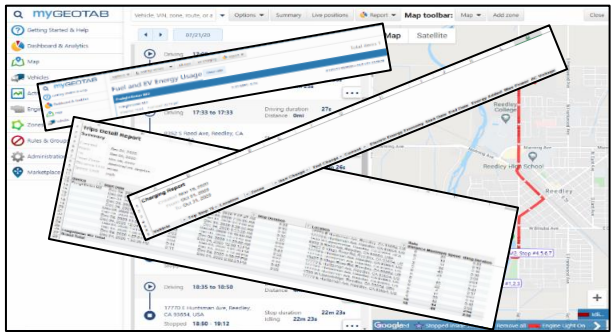


Figure 3: Data loggers provide a rich dataset.

Vehicle specifications, including range limitations under various operating loads, will be evaluated based on data provided by the manufacturer and from data collected in the field. If load weights are available or can be readily derived, ton-miles - a better indicator of eTruck performance than total mileage - will also be included in the analysis.

Finally, although not specifically stated, the eTruck will be assessed on overall application suitability. Was the eTruck on par or better than the diesel baseline truck? Did it satisfactorily complete typical in-use operations reliably? This assessment will be specifically focused on the demonstration application. It will not speculate on performance measurements in different applications. TechTruth will also use recorded data to assess the challenges associated with a single fleet implementing several eTrucks at one time. This includes items like availability of vehicle parts, driver training, truck assignments, and charging strategies and space requirements.

Assess eTRU operation and performance

A full assessment of the technology demonstrated in this project comprises two components – the eTruck and the eTRU. The performance of the eTRU will be evaluated based on its reliability and capacity to maintain a set temperature. A simple measure of performance is to place a digital temperature gauge, with the ability to record and store temperatures over time, inside one or more of the eTruck cargo boxes. Alternatively, the manufacturer has proposed the possibility of an integrated temperature gauge (in either case, data collection will rely on manufacturer-supplied equipment). The truck drivers may also be asked to monitor the temperature, in a fundamental way that does not interfere with their day-to-day operations.

If the necessary equipment is available, eTRU operating data will be collected and analyzed to determine energy consumption, separate from eTruck propulsion energy needs. Given the vast ambient temperature variations and extreme heat, frequent door opening for loading/unloading, short trips, frequent cargo exchanges, and relatively narrow range of acceptable temperatures, the eTRU will operate under very demanding conditions. TechTruth will take these extreme operating conditions into account when assessing the technology that is proposed for applications with varied operating conditions and duty cycles.

The baseline vehicle TRU runs off of the truck engine and does not have a separate fuel tank. Therefore, the baseline truck and TRU will be treated as one unit for purposes of energy consumption and performance. If operating specifications are available for the baseline TRU, an effort will be made to calculate the fuel consumption attributed to each energy component of the diesel truck – vehicle propulsion and refrigeration.

All operating data will be presented in a format or report that allows easy and immediate interpretation.

Comprehensive life-cycle cost analysis

TechTruth will collect data and conduct a detailed life-cycle cost (LCC) analysis for both the eTruck and baseline vehicle, including sensitivity modeling to determine the effects of cost uncertainties. TechTruth will perform the LCC using its proprietary cost model. The model comprises several modules with a capacity to input over 200 separate cost variables. Cost analysis results will depend heavily on information and data provided by the manufacturer and end-user.

Vehicle-related costs are categorized into capital and operating costs. Capital outlay estimates will be derived from manufacturer data and engineering estimates for various levels of production. The lifecycle cost analysis will be conducted representing near, mid and long-term production scenarios. In addition, variances in residual/resale value, depreciation rates, and useful life will be accounted for under changing circumstances.

In addition to upfront vehicle-related costs, detailed operating costs can be incorporated into the LCC analysis such as fuel, tires, fluids, brakes, emission control device maintenance, taxes, credits and incentives, engine overhauls and repowers, general maintenance and repairs, battery replacement, registration, licenses, permits, and insurance. If applicable, other factors that may also be included such as carbon credits and changes in labor costs (resulting from onsite charging, HOV lane use time-savings, etc.). Inflation, discount rates and long-term fuel price elasticities (electricity and petroleum) will be based on reasonable projections and publicly available forecasts.

All costs are treated as base year values equivalent to present-day dollar amounts. The LCC analysis calculates all dollar values to future year occurrence equivalents and then discounts all those values to base year present values.

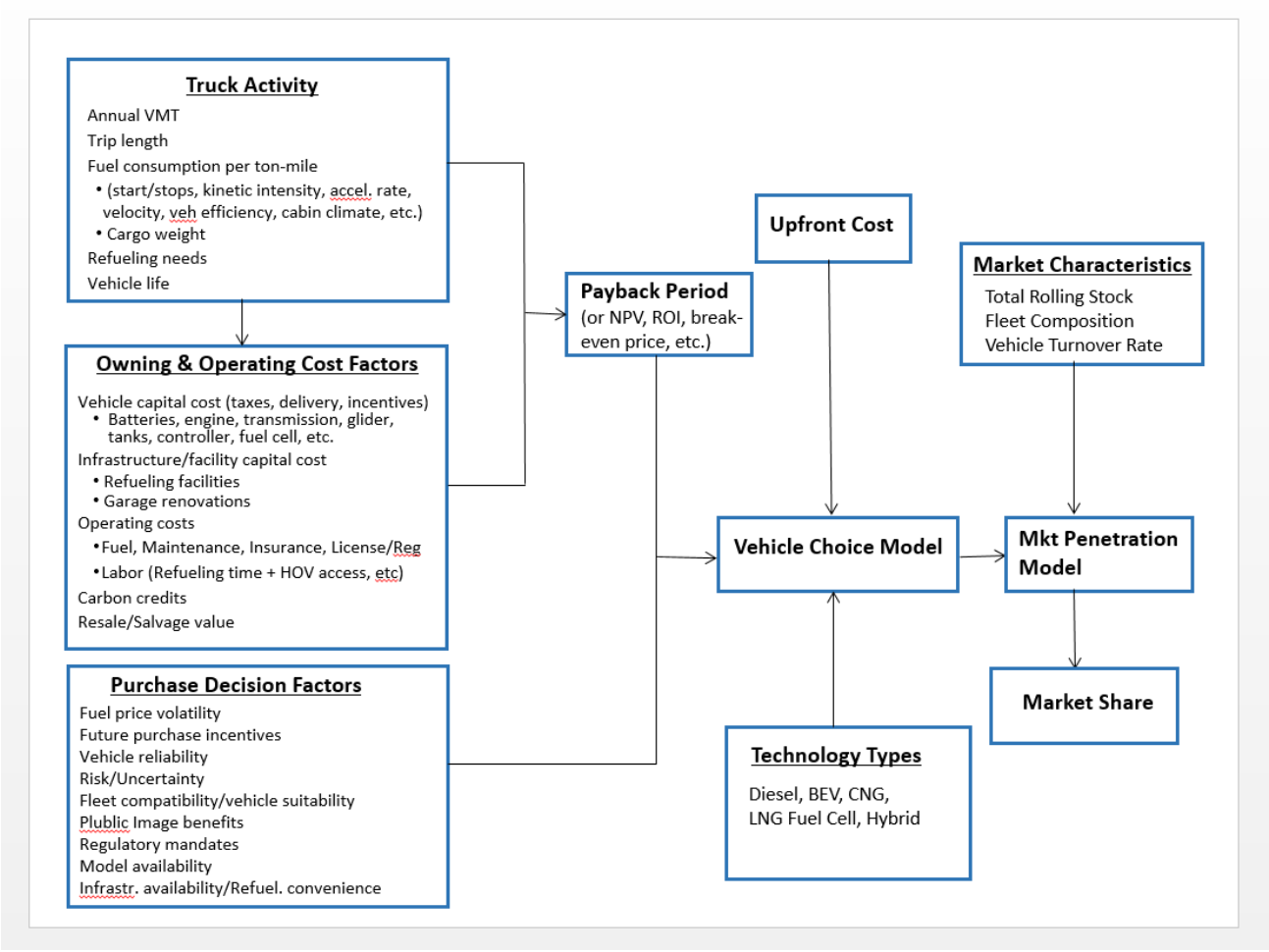
The combined cost of the eTruck system (truck and eTRU) will be directly compared to the baseline vehicle system. The primary parameter for comparison is the payback period - i.e., the number years needed for the eTruck operating cost savings to offset its higher upfront capital costs (using an equivalent present value cost factor). Other model outputs, such as return on investment (ROI), or breakeven petroleum prices can also be used for comparative purposes.

Infrastructure related-costs will be reported in the final report but will not be included in the lifecycle cost analysis. Uncertainty regarding infrastructure expected lifespan, the number of vehicles using the equipment over its life, and the lifetime electricity throughput makes it difficult to amortize and attribute costs accurately to electric vehicles.

A limited number of model runs will be conducted for the purpose of sensitivity or “what if” analyses. This is performed by changing one model input variable at a time to see how that particular variable affects the lifecycle cost results. TechTruth will work with ARB to determine the variables to change for a limited number of “what if” scenarios.

The general input/output format of the TechTruth lifecycle cost model (including the predictive market penetration modules not used for this project), is shown in Figure 4.

Figure 4: TechTruth Lifecycle Cost Model



Calculate changes in GHG and criteria pollutant emissions

Because both, the eTruck and eTRU of the replacement demonstration vehicle are both zero emissions, the full emission reduction resulting from the implementation of the demonstration vehicle is the emissions produced by the baseline vehicle during the normal course of operation. The total greenhouse gas emission reductions can be expressed as the difference between the GHG emission factor associated with the baseline vehicle and the GHG emission factor associated with the electric vehicle. This in turn is a function of the respective fuel energy densities and the energy economy ratio.

The method for calculating both the greenhouse gas and criteria pollutant emission reductions that result from supplanting petroleum trucks with electric trucks is described in Appendix D of the solicitation for the Zero- and Near Zero-Emission Freight Facilities Project titled *Methodology for Determining Emission Reductions and Cost Effectiveness* (March 21, 2018). Calculations for

greenhouse gas and criteria pollutant emission reductions will be in accordance with the methods and formulae presented in Appendix D. The 2017 Carl Moyer Guidelines will be used if additional analysis or emission factors are needed.

The baseline vehicle TRU runs off of the truck engine and does not have a separate fuel tank. Therefore, the baseline truck and TRU will be treated as one unit for purposes of the emission analysis. Fuel consumed when the baseline truck is stopped but idling for the purpose of running the TRU, will be accounted for in the GHG and emission analysis. TRU criteria pollutant emissions during truck idle will be calculated as truck emissions.

Electricity consumption, and consequently GHGs (or CO_2 equivalence) from the eTRU will be calculated separate from the eTruck, if energy specifications are available or if metered charging is separate from the truck. This will allow for independent evaluations of the eTRU and eTruck and provide information on the contribution of each component to total energy consumption and emissions.

The eTRU results will be combined with the eTruck to get total pollutant and GHG reductions. The project pollutant and GHG reductions will be the cumulative reduction from each of the eTrucks with eTRUs. Data will be collected on a single baseline diesel truck. However, the usage and duty cycle of all five demonstration eTrucks is expected to be very close to the baseline vehicle because they will function in the same general application. The baseline truck and TRU will serve as the baseline for all eTruck assemblages, with regard to annual fuel consumption and operating demands. The eTrucks will be displacing and equal number of diesel trucks within the Moonlight fleet during the demonstration.
Because the advanced technology vehicle is a zero-emission technology, the ARB has agreed that PEMS testing is not needed. Therefore, no PEMS testing will be performed for this project.

Evaluate and document end-user experience
User acceptance of the eTruck/eTRU - imperative to its success - is inextricably tied to performance and appropriate vehicle-application matching. Based on the number of short-haul TRU trucks operating in California, the market potential for this technology is promising. However, prospective buyers need to be confident that the vehicle will fit seamlessly into their operations and that includes

acceptance throughout the organization. This task will focus on soliciting feedback from the end-user, Moonlight Companies. We will conduct one-on-one interviews with several individuals within the organization who had firsthand experience with the demonstration vehicles. Individuals to be interviewed include drivers, mechanics, fleet managers and vehicle purchase decision-makers.

Drivers will provide feedback on vehicle performance from their perspective. TechTruth will speak to each driver immediately after eTruck implementation and again at the end of the demonstration. The second interview will commence after drivers have had 6 months to one year of first-hand eTruck driving experience. Interviewers will seek feedback regarding positive and negative driving experiences, the utility of specific features (e.g., regenerative braking), how long it took to get used to the new technology, charging practices and logistics, and training recommendations.

Most repairs and maintenance for the demonstration vehicles will be performed by the manufacturer, however initial evaluations will be sought from onsite mechanics. The value or concerns of eTrucks will be solicited after an explanation of the maintenance specifics, compared to conventional trucks. Decision-makers and fleet managers will provide insight on key design issues, viable cost structures (e.g., importance of TCO tools), application suitability, practical daily issues, the necessary adjustments to cost evaluations (resulting from longer life, higher upfront cost, etc.), and the likelihood of purchase at different price points. TechTruth will also seek feedback on issues pertaining to the challenges and solutions associated with introducing several advanced technologies into a fleet in a relatively short time period.

The interviews will follow a free-flow format where pre-specified topics will be covered but individuals will also be given ample opportunity to discuss issues they feel are important. TechTruth will collaborate with the ARB to determine the primary interview topics. In some cases, the interviews will require a translator, to be provided by Moonlight. COVID restrictions may also limit person-to-person interactions, in which case online or phone interviews will be conducted.

This data collection and analysis procedural manual is complete and supersedes any and all other prior and contemporaneous agreements and understandings, both written and oral.

SECTION

APPENDIX C

San Joaquin Valley Net-Zero Farming and Freight Facility Demonstration Project:

Emission Reductions and Cost-Effectiveness Calculations

The following calculations were performed in support of the five refrigeration trucks submitted for funding consideration under this grant solicitation. Results are provided below for the following:

- GHG annual emission reductions from each proposed demonstration vehicle and for project.
- Criteria pollutant and toxic air contaminant annual pollutant emissions reductions for each proposed vehicle and for project.
- GHG reduction cost-effectiveness for a two-year life during the time of the proposed project field demonstration.
- GHG reduction cost-effectiveness for a 10-year life, two years after the end of the proposed demonstration project, assuming technology commercialization.
- Criteria pollutant and toxic air contaminant cost-effectiveness for a two-year life during the time of the proposed project field demonstration.
- Criteria pollutant and toxic air contaminant cost-effectiveness for a 10 year life, two years after the end of the proposed demonstration project, assuming technology commercialization.

The following calculations adhere strictly to the methodology presented in Appendix D of the grant solicitation.

TRU Truck Description

Currently, the Moonlight Packing Corporation operates several “reefer” trucks in the San Joaquin Valley. They are class 6 straight trucks with Transport Refrigeration Units (TRUs) powered by the vehicle’s diesel internal combustion engine. The main function of the trucks is to transport produce from the packaging facility to the cold storage warehouse. They make several roundtrips daily over a fixed route: averaging approximately 13,696 miles/year and 5.5 miles/gallon. Because the growing season overlaps with seasonal ozone peaks, these trucks are operated most heavily during the time of year that experiences the worst pollution and ozone episodes.

In addition to the emissions resulting from vehicle movement, the TRUs must be in near-continuous operation for the duration of the workday. Because the TRU operates off the primary vehicle engine, there are significant idling emissions associated with these operations. During the busiest times, it is not unusual for these trucks to be deployed 15 hours/day and idle for half that time. Because the trucks must be in close proximity to the enclosed loading/unloading sites, workers have extremely high, prolonged exposure to idling emissions.

In addition to long idling periods, other "real-world" factors make farm operations a disproportionate contributor to air pollution. Trucks used in the farming industry, much like drayage trucks at ports a few years back, are some of the oldest and dirtiest trucks in operation. Farming operations are usually the 2nd or 3rd owner of these trucks, which are utilized as long as possible before scrappage. Thousands of reefer trucks are used in farm applications, the vast majority of which lend themselves to electrification.

Moonlight initially planned to place 5 all-electric reefer trucks into regular duty for the duration of the demonstration. Two electric trucks were deployed. The two trucks were assumed to have the same duty cycles, mileage, and operating time as the baseline diesel truck. Because the Moonlight baseline truck had an "non-independent" TRU (i.e., the TRU operated using the truck's propulsion engine), a significant amount of truck idling was required to keep the box at the right temperature. ARB-provided fuel conversion factors were used in the calculations to express emissions rates in terms of fuel consumption. This allows for idling-related GHGs and criteria pollutants to be fully captured in the baseline calculations.

Table 1 shows the results of all required components of the emissions and economic analyses. The calculations adhere strictly to ARB's prescribed methodology in Appendix D of the Grant Solicitation. Operational and cost values used in the calculations were derived using data from the manufacturer, the end-user, ARB sources, and engineering judgement.

The GHG and emission calculations were based on Moonlight operations. Baseline truck operation during the demonstration was approximately 55% of what the end-user foretold and only about 36% of the eTruck range capacity given a single charge per day. Furthermore, emission reduction estimates were originally based on a 2006 model year truck which was no longer in the fleet when the demonstration commenced. Instead, a 2008 model year truck was used. The emission standards for a 2008 truck are much lower than the 2006 model (new standards were implemented in 2007). These factors render vis-à-vis comparisons between projected and actual emission reductions misleading. Nonetheless, GHG and emission reductions were significant as can be seen in Table 1, along with the cost-effectiveness of those reductions.

Table 1: eTruck with eTRU Results*

Project eTRU/ eTruck	GHG Emission Reductions (MT/yr)	Weighted Criteria Pollutant Emission Reductions (tons/year)	GHG Cost-Effectiveness for 2 yr. life ($/MT)	GHG Cost-Effectiveness for 10 yr. life ($/MT)	Criteria Pollutant Cost-Effectiveness for 2 yr. life ($/ton)	Criteria Pollutant Cost-Effectiveness for 10 yr. life ($/ton)
1	27.76	0.0932	3889	353	1,158,262	105,204

2	27.76	0.0932	3889	353	1,158,262	105,204
3	27.76	0.0932	3889	353	1,158,262	105,204
4	27.76	0.0932	3889	353	1,158,262	105,204
5	27.76	0.0932	3889	353	1,158,262	105,204
Total	**138.8**	**0.466**	**3889**	**353**	**1,158,262**	**105,204**

*Assumes 5 diesel trucks replaced by 5 eTrucks

Baseline Class 6 TRU Diesel Truck

MY 2008 M2 Freightliner w/ integrated TRU operated using vehicle engine

GVWR = 19.5-26k lb

Annual mileage = 13,696/yr (source: data logger and fuel logs): 100% use in CA

Fuel economy = 5.5 miles/gallon (source: data logger and fuel logs)

Demonstration Vehicle = battery, all-electric Class 8 straight truck with non-independent, battery all-electric TRU

Greenhouse Gas Reductions

$$Fuel\ Usage\left(\frac{gal}{yr}\right) = \left(\frac{miles}{yr}\right) x \left(\frac{miles}{gal}\right)$$

$$= \left(\frac{13696\ miles}{year}\right) / \left(\frac{5.5\ miles}{gal}\right)$$

$$Baseline\ fuel\ usage = \frac{2{,}490\ gal_{dsl}}{yr}$$

ED_{Dsl} = 134.47 MJ/gal
ED_{Elec} = 3.60 MJ/kWh
EER_{elec} = 5.5

Energy Density Values from Table II-1 App D
EER value from table II-3 App D

Equivalent electricity consumption (Formula 3)

$$\left(\frac{kWh}{yr}\right) = \frac{gal_{Dsl}}{yr} \times ED_{Dsl} \times \frac{1}{ED_{Elec}} \times \frac{1}{EER_{Elec}}$$

$$= \frac{2490\ gal_{Dsl}}{yr} \times \frac{134.47\ MJ}{gal_{Dsl}} \times \frac{1}{\frac{3.60\ MJ}{kWh}} \times \frac{1}{5.5}$$

$$= 16{,}911\ \text{kWh/yr}$$

Annual GHG Emissions (Formula 1)

$CO2_{Dsl}$ = 102.01 g CO_2e/MJ
$CO2_{Elec}$ = 105.16 g CO_2e/MJ

Fuel Carbon Intensity Values from Table II-2, App D

$$GHG\ EF_{Base\ Dsl} = \frac{102.01\ gmCO2_{DSL}}{MJ} \times \frac{134.47\ MJ}{gal\ Dsl} \times \frac{2{,}490\ gal\ Dsl}{year} \times \frac{1\ metric\ ton\ CO2e}{1x10^6\ grams}$$

$$= 34.16\ \frac{metric\ tons\ CO2e}{year}$$

$$GHG\ EF_{Elect} = \frac{105.16\ gmCO2_{DSL}}{MJ} \times \frac{3.60\ MJ}{gal\ Dsl} \times \frac{16{,}911\ kWH}{year} \times \frac{1\ metric\ ton\ CO2e}{1x10^6\ grams}$$

$$= 6.40\ \frac{metric\ tons\ CO2e}{year}$$

$$Vehicle\ GHG\ ER_{annual} = GHG\ EF_{baseline} - GHG\ EF_{elect}$$

$$= 34.16\ \frac{metric\ ton\ CO2e}{year} - 6.40\ \frac{metric\ tons\ CO2e}{year}$$

$$Vehicle\ GHG\ ER_{ann} = \mathbf{27.76}\ \frac{metric\ ton\ CO2e}{year}$$

Criteria Pollutant Emission Reductions

EO Cert. Std. Conv. (g/lgal)	NOx	ROG	PM10
	29.42	1.52	0.148

EO Cert. Stds. from Table IV-1, App D
EO # Series A-021-0463, Cummings MHDD, Engine Fam 7CEXH0408BAC

$$Ann.\,Emission\ Reduction = \left[\frac{EF\ \left(\frac{g}{gal}\right) \times Activity\left(\frac{gal}{yr}\right) \times \%\ Operation\ in\ CA}{\frac{907{,}200\ gm}{ton}}\right]$$

$$Ann.\ ER_{NOX} = \left[\frac{29.42\ \frac{g}{gal} \times 2{,}490\left(\frac{gal}{yr}\right) \times 100\%}{\frac{907{,}200\ g}{ton}}\right]$$

$$\boldsymbol{Ann.\ ER_{NOX} = 0.081\ \frac{tons}{yr}}$$

$$Ann.\ ER_{ROG} = \left[\frac{1.52\ \frac{g}{gal} \times 2{,}490\left(\frac{gal}{yr}\right) \times 100\%}{\frac{907{,}200\ g}{ton}}\right]$$

$$\boldsymbol{Ann.\ ER_{ROG} = 0.0042\,\frac{tons}{yr}}$$

$$Ann.\ ER_{PM10} = \left[\frac{0.148\ \frac{g}{gal} \times 2{,}490\left(\frac{gal}{yr}\right) \times 100\%}{\frac{907{,}200\ g}{ton}}\right]$$

$$\boldsymbol{Ann.\ ER_{PM10} = 0.0004\,\frac{tons}{yr}}$$

Weighted criteria pollutant emission reductions (WER).

$$WER = NOx\ reducts\ \left(\frac{tons}{yr}\right) + ROG\ reducts\ \left(\frac{tons}{yr}\right) + \left[20 \times PM10\ reducts\ \left(\frac{tons}{yr}\right)\right]$$

$$WER = \mathbf{0.081}\ \left(\frac{tons}{yr}\right) + \mathbf{0.0042}\left(\frac{tons}{yr}\right) + \left[20 \times \mathbf{0.0004}\ \left(\frac{tons}{yr}\right)\right]$$

$$\boldsymbol{WER = 0.0932\ \frac{tons}{yr}}$$

Greenhouse Gas Cost-Effectiveness (Formula 5)

$$TRU\ Truck\ CE\ \left(\frac{\$}{MT}\right) = \left[\frac{CRF * incremental\ cost}{GHG\ ER_{annual}}\right]$$

Where CRF = capital recovery factor

CRF_{2yr} = 0.508

CRF_{10yr} = 0.106

From Table IV-24, App. D

Baseline Diesel TRU Truck Cost (source: Moonlight Companies)

At time of demonstration	$187,500
Two years after demonstration	$187,500

Electric TRU Truck Cost (source: HummningbirdEV)

At time of demonstration	$400,000
Two years after demonstration	$280,000

The GHG and the criteria pollutant cost-effectiveness are both calculated for 2 years at the time of the project and for a period of 10 years, starting 2 years after the project.

GHG cost-effectiveness for two years at time of project

$$CE_{2yr} = \left[\frac{.508 \times (\$400{,}000 - \$187{,}500)}{27.76\ \frac{metric\ tons\ CO2e}{year}}\right]$$

$$\boldsymbol{CE_{2yr} = \frac{\$3,889}{MT}}$$

GHG cost-effectiveness for ten years, two years after project

$$CE_{10yr} = \left[\frac{.106 \times (\$280{,}000 - \$187{,}500)}{27.76\ \frac{metric\ tons\ CO2e}{year}}\right]$$

$$\boldsymbol{CE_{10yr} = \frac{\$353}{MT}}$$

WER Cost-Effectiveness

$$CE\left(\frac{\$}{ton}\right) = \left[\frac{CRF \times Annualized\ Cost\ \left(\frac{\$}{yr}\right)}{WER\ \left(\frac{tons}{yr}\right)}\right]$$

Where Annualized Cost = CRF x technology incremental capital cost difference

Cost-effectiveness for two years at time of project

$$CE_{2yr} = \left[\frac{.508 \times (\$400{,}000 - \$187{,}500)}{0.0932\ \left(\frac{tons}{yr}\right)}\right]$$

$$\boldsymbol{CE_{2yr} = \frac{\$1,158,262}{ton}}$$

Criteria pollutant cost-effectiveness for ten years, two years after project

$$CE_{10yr} = \left[\frac{.106 \times (\$280{,}000 - \$187{,}500)}{0.0932 \left(\frac{tons}{yr}\right)}\right]$$

$$\boldsymbol{CE_{10yr} = \frac{\$105,204}{ton}}$$

Projected Total Reductions

Project GHG Reduction and Project GHG Cost-Effectiveness

$$Project\ GHG\ ER\ (MT) = \sum_{i=1}^{5} Truck\ TRU\ GHG\ ER_i$$

The 5 baseline trucks involved in the demonstration are considered identical in size, age, and operating demand. Therefore, the total project GHG emission reductions can be calculated by multiplying the above results by 5.

$$= 5\ x\ 27.76\ \frac{metric\ ton\ CO2e}{year}$$

Total project GHG ER **= 138.8** $\boldsymbol{\frac{metric\ ton\ CO2e}{year}}$

Project cost-effectiveness for GHG emissions:

$$Project\ GHG\ CE\ \left(\frac{\$}{MT}\right) = \left[\frac{CRF \times \sum_{i=1}^{5} TRU\ Truck\ annualized\ cost\ \left(\frac{\$}{yr}\right)_i}{\sum_{i=1}^{5}\ TRU\ Truck\ GHG\ Reductions\ \left(\frac{MT}{yr}\right)_i}\right]$$

Because the baseline vehicles are the same, the numerator (differential cost) and denominator (GHG reductions) are both multiplied by 5. Therefore, the total project C-E is the same as any single vehicle.

$$\boldsymbol{Proj\ GHG\ CE_{2yr} = \frac{\$3,889}{MT}} \qquad \boldsymbol{Proj\ GHG\ CE_{10yr} = \frac{\$353}{MT}}$$

Projected WER and Project WER Cost-Effectiveness

$$Project\ WER\ (tons) = \sum_{i=1}^{5} Truck\ TRU\ WER_i$$

$$= 5\ x\ 0.932\ \frac{tons}{year}$$

Project WER $\boldsymbol{= 0.466\ \frac{tons}{year}}$

Project cost-effectiveness for criteria pollutants:

$$Project\ Crit.Pollutants\ CE\ \left(\frac{\$}{ton}\right) = \left[\frac{CRF \times \sum_{i=1}^{5} Tractor\ annualized\ cost\ \left(\frac{\$}{yr}\right)_i}{\sum_{i=1}^{5}\ Tractor\ WER\ \left(\frac{ton}{yr}\right)_i}\right]$$

$$\boldsymbol{Project\ WER\ CE_{2yr} = \frac{\$1,158,262}{ton}} \qquad \boldsymbol{Project\ WER\ \ CE_{10yr} = \frac{\$105,204}{ton}}$$

SECTION

APPENDIX D

Fleet Asset Cost Model Description

Fleet Asset Cost Model

TechTruth Consulting's Fleet Asset Cost (FAC) model is intended to help fleet decision-makers and truck buyers make informed purchase decisions. It provides a straightforward economic assessment of investment options based on total cost of ownership (TCO) and can be used to compare the economic viability of multiple purchase options. The FAC model comprises several modules that can be used across various truck types, technologies, and size classifications. The following describes the medium and heavy-duty truck module for plug-in electric trucks, hybrid trucks, and petroleum trucks (diesel and gasoline). Because we are comparing trucks with non-independent TRUs, the TRU module for electric power take-off technologies is not required. Results provide a complete breakdown of ownership cost components and payback period for the compared trucks and technologies. The payback period is the time it takes for the lower operating cost of an asset to completely offset its higher incremental purchase cost, relative to a specified baseline asset. Results can also be expressed as breakeven petroleum price, minimum resale value, or several other parameters.

The FAC model analyzes, in detail, annual cost and savings for each year over the useful life of the asset. This year-to-year representation of present value cumulative costs and savings is the most accurate way to determine payback periods. It also allows users to determine the optimal time to resell/retire assets, the minimal acceptable resale price needed for financial viability, and the maximum purchase price that will result in an overall lifetime cost savings, vis-à-vis other purchase options. The model is a tool for conducting sensitivity analyses to account for uncertainties and for determining the effect of any given variable on the total lifetime cost. In addition to showing the complete cost component breakdown, results are also presented in a graphical format for quick, easy interpretation.

Some of the key parameters, inputs, and results are describe below.

Total Cost of Ownership and Payback Period

Total cost of ownership (TCO) compares the key cost elements of owning and operating a fleet asset from the time of purchase or lease until ownership is relinquished. It is the most thorough and robust approach for financial comparisons among purchase choices. The fundamental components for calculating the TCO is:

TCO = Depreciation (Original MSRP- Incentives-Resale Value) + Fuel + Maintenance + Insurance + License and Registration

The net present value method of TCO determination is used in order to account for inflation, the cost of capital, and non-uniform cash flows over the life of the asset. The net present value (NPV) for all cash flows are calculated for each cost component for each year of the specified useful life.

Resale value is one of the largest cost uncertainties associated with new truck technologies. The model allows users to manually enter a projected or actual resale value. The depreciation cost is then re-calculated based on the entered value.

The payback period is the time it takes for operating cost savings to offset the incremental purchase cost difference between compared trucks (in the case where operating savings are realized). It is the time at which the cumulative present value cash flow differential negates the incremental acquisition cost difference for the compared trucks. All model input parameters are changeable and direct cost comparisons can be made within or across technology groups. Results are expressed in constant dollars in the year which the purchase is made.

The two basic components of TCO analyses are acquisition and operating costs. The user begins by entering a baseline truck purchase price and the comparison truck purchase price. They then select the type of truck from a drop-down menu. The FAC model can compare many truck type combinations including plug-in hybrids, diesel, gasoline and conventional hybrids.

Acquisition Costs

Non-recurring acquisition costs include purchase cost and associated sales taxes, credits, delivery charges, etc. Many advance technology trucks also qualify for state and federal incentives that can be given as a discount at the time of purchase, as a refund after the purchase, or as a tax credit. Incentives are an independent input in order to accommodate changing incentive programs and eligibility requirements. The useful life of the truck is the number of years of operability, ownership, or the analysis period.

Operating Costs

Fuel costs are entered directly. Total diesel fuel cost is compared to total electricity cost (in the case of an electric truck). The model provides an option for users to input cost escalation rates for petroleum and electricity. These escalation factors can be used to better estimate fluctuating fuel prices. Because of the volatility of energy prices, reporting of inflation rates (core inflation rate) does not always include energy.

Maintenance cost input format is cost/mile. Resolution of the maintenance cost is not limited by the model. If available, every maintenance cost component for every year can be entered individually into the detailed spreadsheet linked to the maintenance input. However, maintenance costs are often aggregated and provided by the user as a lump sum. Detailed maintenance costs for new technologies such as BEV HD trucks is based primarily on engineering estimates at this point.

Annual insurance costs can vary by provider, truck type, usage, accident history, technology, and age of truck. License and registration vary significantly from state to state and, in some locations, can change significantly over the life of the truck. Therefore, a license and registration escalation rate can be entered to account for cost variance over time.

Plug-in electric trucks generally have an all-electric range which, along with the number of full or partial charges each day, determine how much petroleum and electricity is used, as well as the total fuel cost. Annual mileage is necessary to calculate fuel and maintenance costs while number of days driven each year is needed for determining the number of electric miles traveled. The user also has the option of inputting charging efficiency or charging associated energy losses. The model prevents overestimation of electric miles for BEVs, using range and charging events.

Expenses are assumed to increase or decrease each year in harmony with the inputted inflation rate, with the exception of petroleum, electricity and registration. Separate escalation rates are provided for those three cost elements.

The declining balance depreciation method is used to determine the net present value of deprecation. Users can vary the depreciation rate over the life of the truck for non-linear depreciation, using a linked spreadsheet. The depreciation rate can also be overridden by entering a resale/salvage value under *optional resale value*. If this input box is left blank, the declining balance depreciation rate or customized variable depreciation is used.

The payback period is the amount of time needed to recoup the higher incremental cost of a particular purchase when compared to a baseline asset. Payback periods are calculated using annual present value cash flow streams generated by the model. It is possible for a higher priced truck to have a favorable TCO compared to the baseline truck but not realize full payback until the truck is sold. The model is capable of incorporating the resale value into the TCO calculation. TCO comparisions are based on net present value. NPV is a standard measure in life-cycle cost analyses to determine and compare the cost effectiveness of new technology proposals. All costs are expressed in net present value for a simple, straightforward comparison of different technologies.

The mathematical expression of the total costs for each cost factor is:

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_o$$

Where:

- Ct = net cash inflow during the period ‘t’
- Co = total initial investment costs
- r = discount rate
- t = number of time periods

The total cost is the summation of the NPV of each component cost.

TRU Associated Costs

The lifecycle cost analysis includes a non-independent diesel TRU for the baseline truck and a non-independent eTRU for the comparison all-electric truck. The capital cost of the TRUs are included in the truck purchase and all operating costs are subsumed in the truck calculations and included in the respective cost categories. Resale or salvage values also include the TRUs. If the TRUs were "independent" (used an energy source different than the propulsion energy), the cost impacts could be computed in a separate fully-integrated TRU module.

SECTION

APPENDIX E

Reduce costs on fuel and maintenance with 100% all-electric refrigerated trucks

Transport your cold products with the all-new Hummingbird® 100% zero-emission Class 8 eTRU (Electric Transport Refrigeration Unit) vehicles.

You and your staff will appreciate having quiet, clean, and efficient 100% electric Hummingbird® trucks in your fleet. That means no fumes, no roaring engine, and no particulate matter being added to your product. ***Call us today to learn more!***

Specs | Zero-Emission Class 8 eTRU	
Maximum Load	Up to 24,000 lbs.
Length of Refrigerated Box	22 ft.
Battery Pack	288kwh Thermally-Managed
Charging Time (20% to 80%)	4 Hours
Miles per Full Charge	140 Miles
Batteries	LiFePO4
Designed and Assembled	USA
Emissions	Zero
HVIP Discount	Coming Soon
Price & Availability	Coming Soon

Proud Partners on Our Valley's Clean Air Projects

HummingbirdEV is a developer and manufacturer of 100% all-electric powertrains, vehicles, and charging stations based in Livermore, CA.

Project Clean Air, Inc. is a 501(c)(3) non-profit organization which strives to enhance the community by improving air quality through education and collective action throughout the San Joaquin Valley and Eastern Kern County.

The Net-Zero Farming and Freight Facility Demonstration Project is part of California Climate Investments, a statewide initiative that puts billions of cap-and-trade dollars to work reducing greenhouse gas emissions, strengthening the economy and improving public health and the environment — particularly in disadvantaged communities. California Climate Investments also creates a financial incentive for industries to invest in clean technologies and develop innovative ways to reduce pollution.

Moonlight Companies is testing the initial five electric refrigerated trucks in its fleet.

TechTruth Consulting is responsible for data-logging and analysis efforts.

MOONLIGHT

CALIFORNIA CLIMATE INVESTMENTS
Cap and Trade Dollars at Work

PROJECT CLEAN AIR

TECHTRUTH CONSULTING

HUMMINGBIRD®
ELECTRIC VEHICLES

Rakesh Koneru, COO
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11/2021

www.HummingEV.com

PRESS RELEASE

Contact: Diane Tjerrild, Cell: (559) 696-6553 | Livermore, CA
For Immediate Release: Nov. 1, 2021 | Marketing@HummingbirdevUSA.com

World Ag Expo Top-10 New Product Winner 2022!

The First Zero-Emission Class 8 Truck - Coupled with a Zero-Emission Transportation Refrigeration Unit (eTRU) Arrives in the San Joaquin Valley

Hummingbird® - the leader in 100% electric commercial vehicles, powertrains, equipment, and technologies - is delivering a new first-of-its-kind, all-electric Class 8 truck equipped with an all-electric Transport Refrigeration Unit (eTRU) to Moonlight Companies in Reedley, California this week. It is the first of five units Hummingbird is building and testing in real-world agriculture applications.

Each zero-emission refrigerated truck will be used to transport up to 24,000 lbs. of fruit or other Ag/Dairy/Refrigerated products and drive up to 140 miles per charge. The Hummingbird® eTRU truck has been designed to meet demanding agricultural needs, handling all sectors of the refrigerated journey of products from FARM to TABLE – from the field, orchards, groves and vineyards; to the warehouse; to packing houses; to cold storage; to retail warehouses; to the stores that sell them to the consumers.

Benefits of this quiet, clean, and efficient 100% electric refrigerated truck will be appreciated by the drivers and staff working around the vehicle – no fumes and significantly reduced noise levels.

The Chief Operating Officer for HummingbirdEV, Rakesh Koneru, said, “These trucks are simple to use, making them an easy transition for Ag Companies and Growers who want to add zero-emission trucks to their fleet with a minimal learning curve for those new to electric vehicles. Maintenance is also significantly less on electric trucks due to the motor – which has no moving parts, the opposite of a traditional fossil-fuel powered

engine - and our proprietary Hummingbird® all-electric powertrain keeps everything running smoothly, just as in our other Hummingbird® all-electric tractors and vehicle-to-vehicle charging tender trucks already working in applications throughout Central California and the San Joaquin Valley. We are proud to bring this technology to the refrigerated truck needs of the Ag industry."

The new 54,000lbs rated vehicle comes with a 288Kwh thermally-managed battery pack with a rated nominal voltage of 610Vdc, two traction motors coupled to a single speed gearbox that produces up to 3600Nm of torque to the wheels, a refrigeration system with a 22' insulated battery-powered box and a standard on-board fast charger rated to 80kw of charging power.

HummingbirdEV's electric refrigerated truck units (eTRUs) being delivered this week are partially funded through a California Air Resources Board grant awarded to and administered by the 501(c)(3) non-profit Project Clean Air, Inc. (Bakersfield, CA) with funding coming from California Climate Investments for the "Net-Zero Farming and Freight Facility Demonstration Project" from its 2017-2018 Clean Transportation Incentives Zero- and Near-Zero Emission Freight Facilities Project. The project includes Moonlight Companies, responsible for operating the eTRUs and TechTruth Consulting, responsible for data-logging and analysis.

Manufacturers of vehicles and equipment interested in these types of all-electric technologies or HummingbirdEV's technologies - such as Vehicle-to-Vehicle charging tenders – are welcome to contact HummingbirdEV directly for further details or visit its YouTube Channel.

# # #

HummingbirdEV *is a developer and manufacturer of 100% all-electric powertrains, vehicles, and charging stations based in Livermore, CA.*

HUMMINGBIRD®
ELECTRIC VEHICLE

Project Clean Air, Inc. *is a 501(c)(3) non-profit organization which strives to enhance the community by improving air quality through education and collective action throughout the San Joaquin Valley and Eastern Kern County.*

PROJECT CLEAN AIR

The Net-Zero Farming and Freight Facility Demonstration Project *is part of* ***California Climate Investments****, a statewide initiative that puts billions of cap-and-trade dollars to work reducing greenhouse gas emissions, strengthening the economy and improving public health and the environment — particularly in disadvantaged communities. California Climate Investments also creates a financial incentive for industries to invest in clean technologies and develop innovative ways to reduce pollution.*

Photos of the Hummingbird® all electric Class 8 refrigerated truck at Moonlight Companies in Reedley, CA start on the next page:


HUMMINGBIRD


MOONLIGHT
Yale


VOLTAIR
HUMMINGBIRD

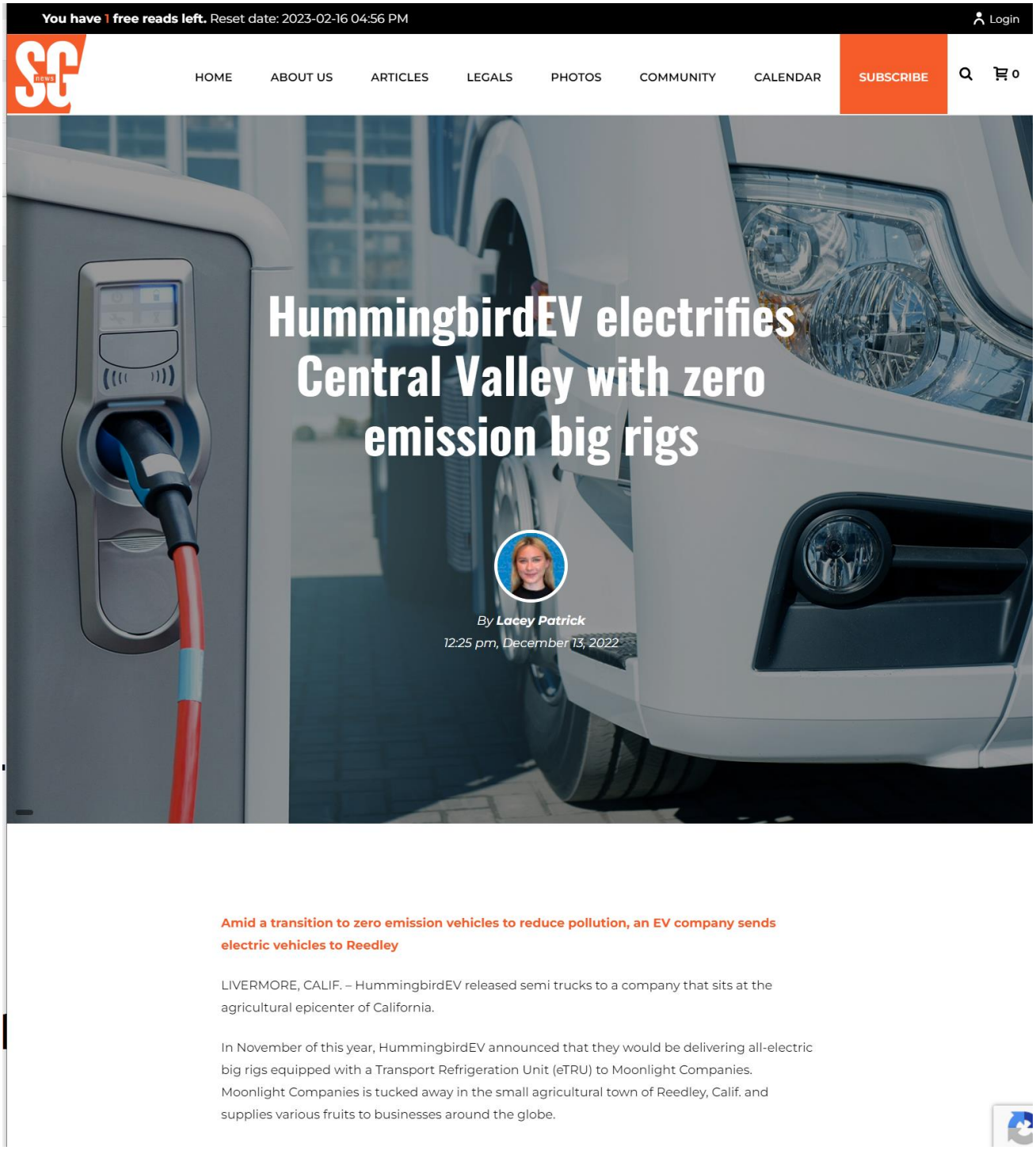

5
4
3
2
VOLTAIR
2


VOLTAIR

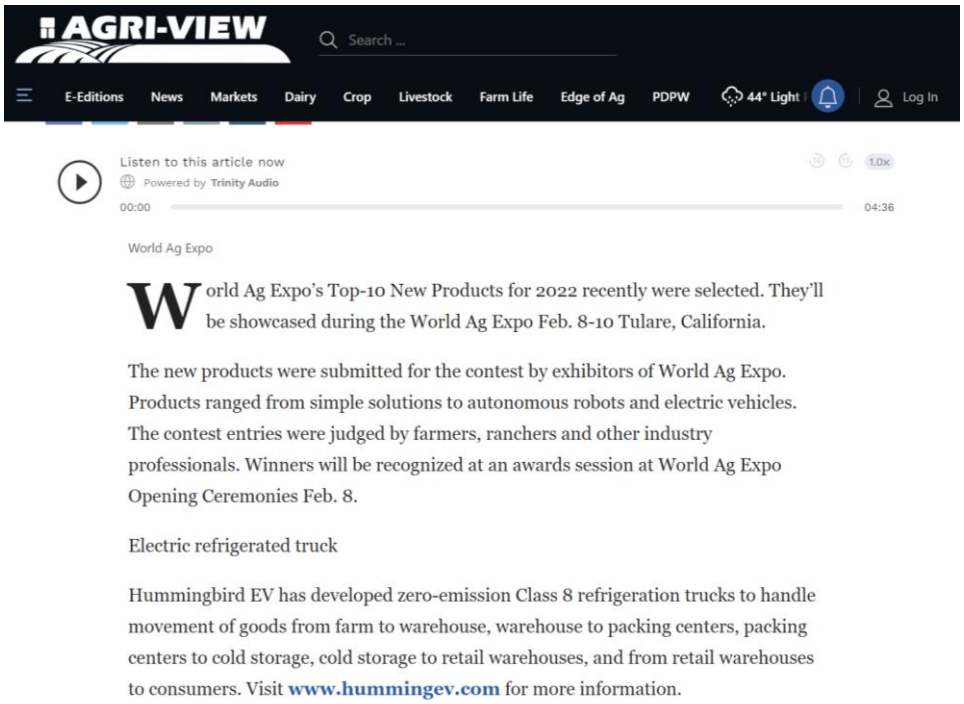
HummingbirdEV eTruck/eTru - On **YouTube:**

Watch it here (1:54 minutes):
https://www.youtube.com/watch?v=_rePVVk_1VA

HummingbirdEV eTruck/eTru - **In the News:**



To read more of the article, go to: https://thesungazette.com/article/business/2022/12/13/hummingbirdev-electrifies-central-valley-with-zero-emission-big-rigs/



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World Ag Expo

World Ag Expo's Top-10 New Products for 2022 recently were selected. They'll be showcased during the World Ag Expo Feb. 8-10 Tulare, California.

The new products were submitted for the contest by exhibitors of World Ag Expo. Products ranged from simple solutions to autonomous robots and electric vehicles. The contest entries were judged by farmers, ranchers and other industry professionals. Winners will be recognized at an awards session at World Ag Expo Opening Ceremonies Feb. 8.

Electric refrigerated truck

Hummingbird EV has developed zero-emission Class 8 refrigeration trucks to handle movement of goods from farm to warehouse, warehouse to packing centers, packing centers to cold storage, cold storage to retail warehouses, and from retail warehouses to consumers. Visit www.hummingev.com for more information.

https://www.agupdate.com/agriview/news/business/world-ag-expos-top-10-selected/article_1c4b5377-b3e5-5bdd-b94f-a2cc7a5c2442.html

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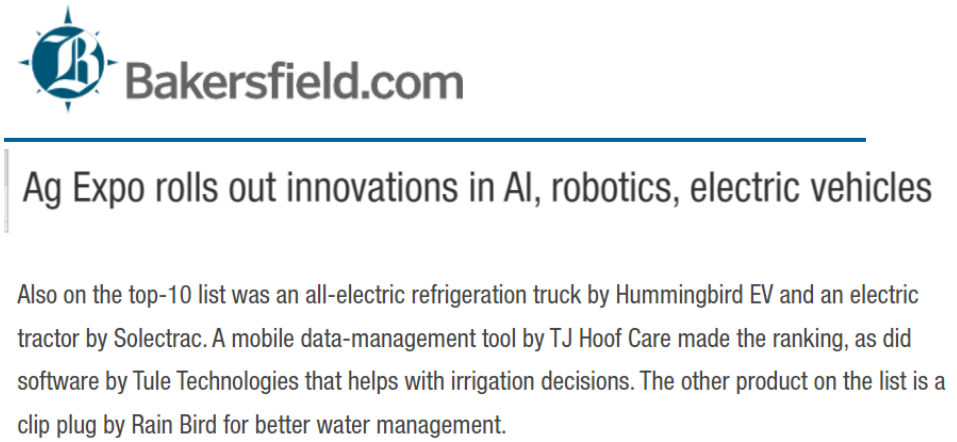
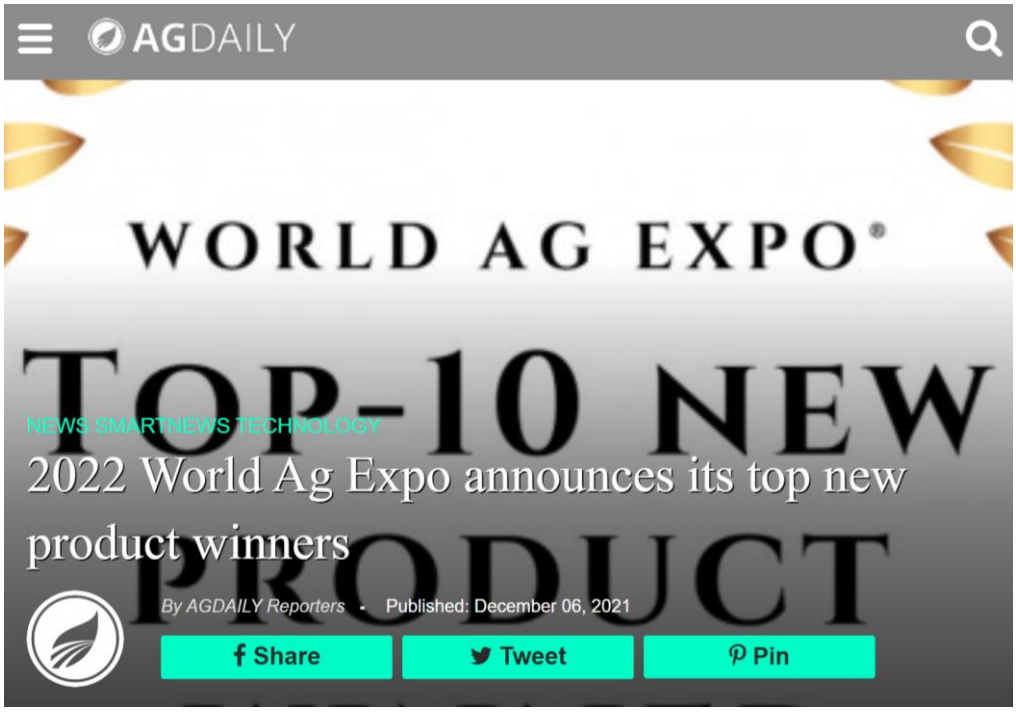


Bakersfield.com

Ag Expo rolls out innovations in AI, robotics, electric vehicles

Also on the top-10 list was an all-electric refrigeration truck by Hummingbird EV and an electric tractor by Solectrac. A mobile data-management tool by TJ Hoof Care made the ranking, as did software by Tule Technologies that helps with irrigation decisions. The other product on the list is a clip plug by Rain Bird for better water management.

https://www.bakersfield.com/news/ag-expo-rolls-out-innovations-in-ai-robotics-electric-vehicles/article_38b241a4-85f7-11ec-8e7c-e75b11b41564.html (mentioned)



The Top 10 new products were:

1. All-Electric Class 8 Refrigerated Truck by Hummingbird EV

These zero-emission Class 8 refrigeration trucks handle the movement of Ag goods from farm to warehouse, warehouse to packing centers, packing centers to cold storage, cold storage to retail warehouses, and from retail warehouses to consumers.

Hummingbird EV's website

https://www.agdaily.com/news/2022-world-ag-expo-announces-top-new-product-winners/

RE: HummingbirdEV's Zero-Emission Class 8 Refrigerated Trucks (Transport Refrigeration Unit, or TRU)

Audience

Anyone moving perishable foods to the next location in the "farm to table" process

- Growers/Farmers (Orchards, Groves, Vineyards, etc.)
- Fruit Packing Houses
- Dairy Processors

Market Context & Problem

The San Joaquin Valley in Central California is the top ag production region of the United States. *Ag report statement of crop values?*

Current Regulation The California Air Resources Board (CARB) enacted a Truck and Bus Regulation requiring that by January 1, 2023 all vehicles must upgrade to 2010 or new model year engines. As of January 1, 2020, the DMV cannot register any vehicle that does not meet the requirements of the Truck and Bus Regulation. The regulations specific to TRUs can be found here: https://ww2.arb.ca.gov/our-work/programs/transport-refrigeration-unit.

In 2022, the TRU regulation was amended. https://ww2.arb.ca.gov/resources/fact-sheets/2022-amendments-tru-atcm

Future Regulation In August 2021, CARB initiated the Advanced Clean Truck Regulation, considering it a "holistic approach to accelerate a large-scale transition of zero-emission medium-and heavy-duty vehicles from Class 2b to Class 8. The regulation has two components including a manufacturer sales requirement, and a reporting requirement" on companies and fleets. Under this regulation, the transition to zero emission vehicles ramps up between 2024 and 2035. By 2035, 75% of class 4-8 straight truck and 40% of truck tractor sales must be zero emission vehicles.

HummingbirdEV Leadership In 2018, CARB awarded a grant to HummingbirdEV to lead the truck manufacturing industry by providing a new zero-emission solution for eTRUs (electric Transportation Refrigeration Units) to move perishable items in all steps from farm to table.

Effect

Without clean, refrigerated transportation available in 2024, growers/farmers, food, and beverage processors in the San Joaquin Valley would not be able to provide food to the country.

Need

Food demand across the USA would outweigh the dwindling supply chain if the San Joaquin Valley could not move its perishable products through all of the stops from the farm to the table. Fruit is freight!

Our Solution

The First Zero-Emission Class 8 Truck - Coupled with a Zero-Emission Transportation Refrigeration Unit (eTRU) designed by HummingbirdEV and partially funded by the Net-Zero Farming and Freight Facility Demonstration Project, a part of California Climate Investments.*

HummingbirdEV® - the leader in 100% electric commercial vehicles for the Ag industry, including powertrains, equipment, and technologies – designed, built, and is testing five (5) all-electric Class 8 trucks equipped with all-electric Transport Refrigeration Units (eTRU) in real-world agriculture applications, including grower and fruit packer Moonlight Companies in Reedley, CA.

Benefits

The drivers and staff working around the vehicle will appreciate the benefits of this quiet, clean, and efficient 100% electric refrigerated truck and 100% electric refrigerated unit – no fumes and significantly reduced noise levels. Plus, there is no air pollution and will be a good replacement vehicle for the current diesel, refrigerated trucks on the road today that will need to go out of service by 2030.

Use Cases

Each Hummingbird® zero-emission refrigerated truck is (or will be) used to transport up to 24,000 lbs. of fruit or other Ag/Dairy/Refrigerated products and drive up to 140 miles per charge. The Hummingbird® eTRU trucks have been designed to meet demanding agricultural needs, handling all sectors of the refrigerated journey of products from FARM to TABLE – from the field, orchards, groves, and vineyards; to the warehouse; to packing houses; to cold storage; to retail warehouses; to the stores that sell them to the consumers.

Differentiation

FIRST!

When this idea and grant first started, Hummingbird, in conjunction with the California Climate Investments, became the first to envision and begin to build zero-emission electric trucks with electric transport refrigerated units.

(In mid-2022, as the grant is finishing up, other companies are now attempting to do similar projects.)

Validation

The Hummingbird® all-electric refrigerated trucks are currently being validated via third-party data collection by Tech-Truth Consulting.

**** The Net-Zero Farming and Freight Facility Demonstration Project** is part of **California Climate Investments**, a statewide initiative that puts billions of cap-and-trade dollars to work reducing greenhouse gas emissions, strengthening the economy, and improving public health and the environment — particularly in disadvantaged communities. California Climate Investments also creates a financial incentive for industries to invest in clean technologies and develop innovative ways to*

reduce pollution.

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HummingbirdEV Marketing Plan

Zero- and Near Zero-Emission Freight Facilities (ZANZEFF) Truck Project

Executive Summary

Electric *transportation* is the future - and California is leading the way to make it happen! Zero-emission *TRUCKS* are an integral part of that transformation and - thanks to partial funding by the California Climate Investments – new eTruck technology is being developed by the experienced team at HummingbirdEV.

HummingbirdEV and its project partners, Project Clean Air and Moonlight Packing, are working together to help improve technology, test the electric trucks in real-life applications, and spread the word about zero-emission trucking capabilities. During this development process, HummingbirdEV will also work towards HVIP certification through the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Program which incentivizes end users to adopt new zero-emission technology into their fleet operations.

OUR TWO MAIN MARKETING GOALS

1. **<u>Create Visibility</u> for Zero Emission Trucking for Freight Facilities - in California and other Climate-Conscious Markets – notably regarding the HummingbirdEV Electric Class 7 / Class 8 Trucks & Supporting Technology**
    a. **<u>Draw attention</u>** to the HummingbirdEV zero-emission electric power train system, Vehicle-to-Vehicle (V2V) charging, less maintenance, PTO capabilities, and more
    b. **<u>Educate audiences</u>** about the varied uses for this new zero-emission truck technology, including applications for freight facilities, fire departments (water trucks), refrigerated trucks, airport jet refueling, military applications, delivery trucks, utility fleets, refuse trucks, hay haulers, local dairy/meat/produce deliveries, dry box haulers, wine deliveries, etc.

2. **<u>Become Certified by CARB & HVIP</u>**

a. Apply for and receive certification/approvals from:
    i. Executive Order from California Air Resources Board (CARB)
    ii. HVIP Certification (Note: New HVIP voucher requests will not be accepted until at least November 2020, but we will work to establish a dealer relationship and get the HummingbirdEV ZANZEFF Trucks HVIP Certified as soon as possible.)

Marketing Calendar & Budget

Immediately after the first truck(s) are completed at HummingbirdEV, the Marketing Calendar will go into effect. With COVID-19 slowing down many parts of this project - including delivery of glider kits and not being able to have the doors open at HummingbirdEV - the dates of this marketing calendar may change. The calendar covers the timelines and budgets for each step of meeting the two goals (Electric Truck Visibility/Education & CARB/HVIP Certification).

The calendar includes steps and budget for:

- Product Documentation
- HVIP Certification
- Press Releases
- Brochure
- Print Ads
- User Manual & Video
- Tradeshows
- Social Media
- Posters

At the end of the Marketing Calendar are additional marketing considerations if time and budget allow:

- Media Blitz
- Website Updates
- Feature Stories/Articles
- Roadshow
- Event Sponsorships
- Newspaper Invitations
- Newsletter & Opt-In

Industry Snapshot

Additional attachments include industry snapshots (from May, 2020) including:

- California HVIP – Certified Vehicles & Eligible Technologies
- California HVIP – Approved Vendors/Dealers/Distributors
- Magazines that have run a story about electric trucks for potential press release submissions (in addition to local media outlets throughout Central California)
- Top 83 Electric Vehicle Blogs & Websites (for additional potential press release submissions)

Measurements of Success

Implementing the attached Marketing Calendar, plus obtaining the HVIP Certification, will help pave the way for HummingbirdEV's zero-emission trucks to advance their way to becoming mainstream, by being added to fleets, replacing existing technology, lowering trucking emissions in CA, and attracting the Electrify America audience to upgrade infrastructure to include zero-emission trucks.

Advanced Clean Trucks

Accelerating Zero-Emission Truck Markets

Last Updated: August 20, 2021

CALIFORNIA AIR RESOURCES BOARD

This factsheet describes the Advanced Clean Trucks (ACT) Regulation and how the California Air Resources Board plans to accelerate the first wave of zero-emission trucks.

What are California's air quality and climate targets?

California faces very challenging mandates to reduce air pollutants to protect public health and to meet state climate change targets including:

- Federal health-based ambient air quality standards (key dates in 2023 and 2031)
- 40% reduction in greenhouse gases (GHG) by 2030;
- 80% reduction in GHGs by 2050; and
- 50% reduction in petroleum use by 2030

Meeting all of these goals requires a bold transformation in all sectors including stationary, industrial, residential, and transportation with significant contributions from public agencies, private businesses and individuals.

Why do we need zero-emission technology in the transportation sector?

Mobile sources and the fossil fuels that power them are the largest contributors to the formation of ozone, greenhouse gas emissions, fine particulate matter (PM2.5), and toxic diesel particulate matter. In California, they are responsible for approximately 80% of smog-forming nitrogen oxide (NOx) emissions. They also represent about 50% of greenhouse gas emissions when including emissions from fuel production, and more than 95% of toxic diesel particulate matter emissions. Zero-emission vehicles have no tailpipe emissions. When compared to diesel vehicles, they are two to five times more energy efficient, reduce dependence on petroleum, and reduce GHG emissions substantially.

What is the Advanced Clean Truck Regulation?

The Advanced Clean Truck Regulation is part of a holistic approach to accelerate a large-scale transition of zero-emission medium-and heavy-duty vehicles from Class 2b to Class 8. The regulation has two components including a manufacturer sales requirement, and a reporting requirement:

- **Zero-emission truck sales:** Manufacturers who certify Class 2b-8 chassis or complete vehicles with combustion engines would be required to sell zero-emission trucks as an increasing percentage of their annual California sales from 2024 to 2035. By 2035, zero-emission truck/chassis sales would

need to be 55% of Class 2b – 3 truck sales, 75% of class 4 – 8 straight truck sales, and 40% of truck tractor sales.

- **Company and fleet reporting:** Large employers including retailers, manufacturers, brokers and others are required to report information about shipments and shuttle services. Fleet owners, with 50 or more trucks, are required to report about their existing fleet operations. This information will help identify future strategies to ensure that fleets purchase available zero-emission trucks and place them in service where suitable to meet their needs.

What types of trucks are currently suitable for electrification?
Today, electric drivetrains are well suited to operating in congested urban areas for stop-and-go driving where conventional engines are least efficient. Battery-electric and fuel-cell electric trucks, buses, and vans already are being used by fleets that operate locally and have predictable daily use where the trucks return to base to be charged or fueled.

Are any zero-emission trucks commercially available?
There are more than 70 different models of zero-emission vans, trucks and buses that already are commercially available from several manufacturers. Most trucks and vans operate less than 100 miles per day and several zero-emission configurations are available to serve that need. As technology advances, zero-emission trucks will become suitable for more applications. Most major truck manufacturers have announced plans to introduce market ready zero-emission trucks in the near future.

What does it cost to charge a battery electric truck?
The electricity cost to charge battery electric trucks varies based on how fast you charge, the utility rate, and the time of day. A calculator for estimating electricity cost is at ACT Charging Calculator. In many cases, a fleet owner who also owns charging stations and charges trucks overnight can have little to no net electricity costs after the low carbon fuel standard credits in California are included (CARB LCFS Program).

How can fleet owners afford to operate zero-emission trucks?
Zero-emission trucks have higher upfront costs but have lower operating costs than conventional trucks. Today, the total cost of ownership in California can be comparable to conventional trucks for certain duty cycles without grants or rebates. As battery prices fall and technology continues to improve, the total cost of ownership is expected to become more favorable. Incentives are currently available to offset some or all of the higher vehicle capital costs and some of the early infrastructure costs to help fleets begin transitioning to zero-emission vehicles now.

What incentives are available for purchasing zero-emission trucks?
Several funding programs are available to support the use of advanced technologies administered by state agencies, federal agencies, and local air districts. For example, the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project provides point–of-sale rebates to offset the upfront cost of advanced technologies. A list of all zero-emission vehicles that are currently eligible for funding is available at California HVIP. For more information about funding opportunities visit CARB Incentive Programs.

Where can I get more information?
Information about the Advanced Clean Trucks Regulation and upcoming meetings and events is available at ACT Website. If you have questions or wish to obtain this document in an alternative

format or language, call (916) 323-2927. For TTY/TDD/Speech-to-Speech users, dial 711 for the California Relay Service.

RE: HummingbirdEV's Zero-Emission Class 8 Refrigerated Trucks (Transport Refrigeration Unit, or TRU)

Audience

Anyone moving perishable foods to the next location in the "farm to table" process

- Growers/Farmers (Orchards, Groves, Vineyards, etc.)
- Fruit Packing Houses
- Dairy Processors

Market Context & Problem

The San Joaquin Valley in Central California is the top ag production region of the United States. *Ag report statement of crop values?*

Current Regulation The California Air Resources Board (CARB) enacted a Truck and Bus Regulation requiring that by January 1, 2023 all vehicles must upgrade to 2010 or new model year engines. As of January 1, 2020, the DMV cannot register any vehicle that does not meet the requirements of the Truck and Bus Regulation. The regulations specific to TRUs can be found here: https://ww2.arb.ca.gov/our-work/programs/transport-refrigeration-unit.

In 2022, the TRU regulation was amended. https://ww2.arb.ca.gov/resources/fact-sheets/2022-amendments-tru-atcm

Future Regulation In August 2021, CARB initiated the Advanced Clean Truck Regulation, considering it a "holistic approach to accelerate a large-scale transition of zero-emission medium-and heavy-duty vehicles from Class 2b to Class 8. The regulation has two components including a manufacturer sales requirement, and a reporting requirement" on companies and fleets. Under this regulation, the transition to zero emission vehicles ramps up between 2024 and 2035. By 2035, 75% of class 4-8 straight truck and 40% of truck tractor sales must be zero emission vehicles.

HummingbirdEV Leadership In 2018, CARB awarded a grant to HummingbirdEV to lead the truck manufacturing industry by providing a new zero-emission solution for eTRUs (electric Transportation Refrigeration Units) to move perishable items in all steps from farm to table.

Effect

Without clean, refrigerated transportation available in 2024, growers/farmers, food, and beverage processors in the San Joaquin Valley would not be able to provide food to the country.

Need

Food demand across the USA would outweigh the dwindling supply chain if the San Joaquin Valley could not move its perishable products through all of the stops from the farm to the table. Fruit is freight!

Our Solution

The First Zero-Emission Class 8 Truck - Coupled with a Zero-Emission Transportation Refrigeration Unit (eTRU) designed by HummingbirdEV and partially funded by the Net-Zero Farming and Freight Facility Demonstration Project, a part of California Climate Investments.*

HummingbirdEV® - the leader in 100% electric commercial vehicles for the Ag industry, including powertrains, equipment, and technologies – designed, built, and is testing five (5) all-electric Class 8 trucks equipped with all-electric Transport Refrigeration Units (eTRU) in real-world agriculture applications, including grower and fruit packer Moonlight Companies in Reedley, CA.

Benefits

The drivers and staff working around the vehicle will appreciate the benefits of this quiet, clean, and efficient 100% electric refrigerated truck and 100% electric refrigerated unit – no fumes and significantly reduced noise levels. Plus, there is no air pollution and will be a good replacement vehicle for the current diesel, refrigerated trucks on the road today that will need to go out of service by 2030.

Use Cases

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CALIFORNIA AIR RESOURCES BOARD

March 17, 2022

2022 Amendments to the Airborne Toxic Control Measure for In-Use Diesel-Fueled Transport Refrigeration Units (TRU) and TRU Generator Sets, and Facilities Where TRUs Operate

Transport refrigeration units (TRU) emit multiple air pollutants, including diesel particulate matter (diesel PM), fine particulate matter (PM2.5), oxides of nitrogen (NOx), and greenhouse gases (GHG). TRUs typically operate at refrigerated warehouses or distribution centers (WHDC), grocery stores, seaport facilities, intermodal railyards, and other locations that are often near sensitive receptors. Toxic and harmful TRU emissions impact surrounding communities, many of which are environmental justice and Assembly Bill 617 communities. These communities bear a disproportionate health burden due to their close proximity to emissions generated from TRU activity.

The California Air Resources Board (CARB) adopted the Airborne Toxic Control Measure for In-Use Diesel-Fueled Transport Refrigeration Units (TRU) and TRU Generator Sets, and Facilities Where TRUs Operate (TRU ATCM) in 2004 (and amended it in 2010 and 2011) to reduce diesel PM emissions and resulting health risk from diesel-powered TRUs. Despite the progress made, additional TRU emission reductions are needed to further protect communities from near-source pollution impacts, help meet the current health-based ambient air quality standards across California, and support the State's climate goals. On February 24, 2022, CARB adopted amendments to the TRU ATCM (2022 Amendments) to achieve additional emission and health risk reductions from diesel-powered TRUs and increase the use of zero-emission (ZE) technology in the off-road sector. The 2022 Amendments will help meet the State's multiple risk reduction, air quality, and climate goals, as well as the directive of Executive Order (EO) N-79-20, which set a goal for 100 percent ZE off-road vehicles and equipment in the State by 2035.

Purpose of the 2022 Amendments

- Expand public health and environmental benefits by increasing the use of ZE technology.
- Provide PM2.5 and NOx emission reductions to help attain regional and federal air quality standards.
- Provide GHG emission reductions to help meet the State's GHG targets and climate goals.
- Address growth in emissions from trailer TRUs, domestic shipping container (DSC) TRUs, railcar TRUs, and TRU generator sets with less than 25 horsepower engines.

Key Elements of the 2022 Amendments

- **Lower global warming potential refrigerant -** Beginning December 31, 2022, newly-manufactured truck

TRUs, trailer TRUs, and DSC TRUs shall use refrigerant with a global warming potential (GWP) less than or equal to 2,200, or no refrigerant at all.

- **More stringent PM emission standard -** Beginning December 31, 2022, model year (MY) 2023 and newer trailer TRU, DSC TRU, railcar TRU, and TRU generator set engines shall meet a PM emission standard of 0.02 grams per brake horsepower-hour or lower (aligns with the United States Environmental Protection Agency Tier 4 final off-road PM emission standard for 25-50 horsepower engines).

- **Applicable facility requirements -** Beginning December 31, 2023, owners of refrigerated WHDCs with a building size of 20,000 square feet or greater, grocery stores with a building size of 15,000 square feet or greater, seaport facilities, and intermodal railyards (applicable facilities) shall register the facility with CARB, pay fees every three years, and report all TRUs that operate at their facility to CARB quarterly, or alternatively attest that only compliant TRUs operate at their facility.
- **Expanded TRU reporting -** Beginning December 31, 2023, TRU owners shall report all TRUs (including out-of-state based) that operate in California to CARB.
- **TRU operating fees and compliance labels -** Beginning December 31, 2023, TRU owners shall pay TRU operating fees and affix CARB compliance labels to their TRU every three years, for each TRU operated in California. Collected fees will be used to cover CARB's reasonable costs associated with the certification, audit, and compliance of TRUs.
- **Zero-emission truck TRU requirement -** Beginning December 31, 2023, TRU owners shall turnover at least 15 percent of their truck TRU fleet (defined as truck TRUs operating in California) to ZE technology each year (for seven years). All truck TRUs operating in California shall be ZE by December 31, 2029.
- **Zero-emission truck TRU assurances -** Manufacturers of zero-emission truck TRUs shall be required to provide a comprehensive warranty for zero-emission truck TRUs and have an authorized service-and-repair facility located in California to perform warranty repairs.
- **Compliance extensions due to private financing, equipment manufacture delays, or installer delays** – Compliance extensions due to private financing, equipment manufacture delays, or installer delays may be granted for a maximum of six months (previously four months).
- **Requirements for lessors and lessees -** TRU owners (lessors) may delegate compliance responsibility to the TRU operator (lessee) if the rental or lease agreement is for a period of one year or longer.

Cost Impacts of the 2022 Amendments

- Fewer statewide adverse health outcomes from 2022 to 2034 are valued at an estimated $1.75 billion.
- Total net cost of the 2022 Amendments from 2022 to 2034 is estimated to be $850.2 million.
- If the total net cost of the 2022 Amendments is fully passed through to consumers, the total cost per California household from 2022 to 2034 is estimated to be $64.06 with a yearly average of $4.93.

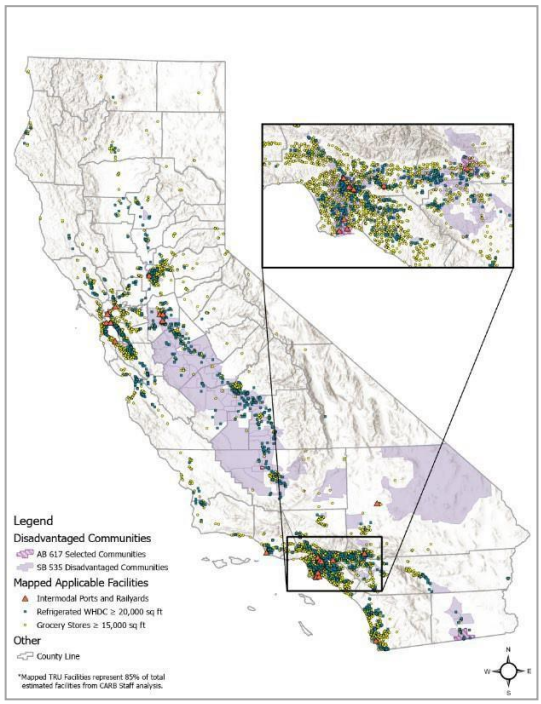
CALIFORNIA AIR RESOURCES BOARD

March 17, 2022

TRU ACTIVITIES IMPACT DISADVANTAGED COMMUNITIES

Many of the communities near facilities where TRUs operate bear a disproportionate health burden due to their close proximity to emissions from the diesel engines that power TRUs. There are several occurrences across the State where communities contain “groups” or “clusters” of facilities where TRUs operate. In many cases, these facilities are located in or near communities that are classified as disadvantaged by the California Environmental Protection Agency (CalEPA). CalEPA uses CalEnviroScreen to score California communities based on environmental pollution burden and socio-economic indicators. Based on staff’s analysis, approximately 40 percent of the applicable facilities identified are located in disadvantaged communities as designated by CalEnviroScreen 3.0.

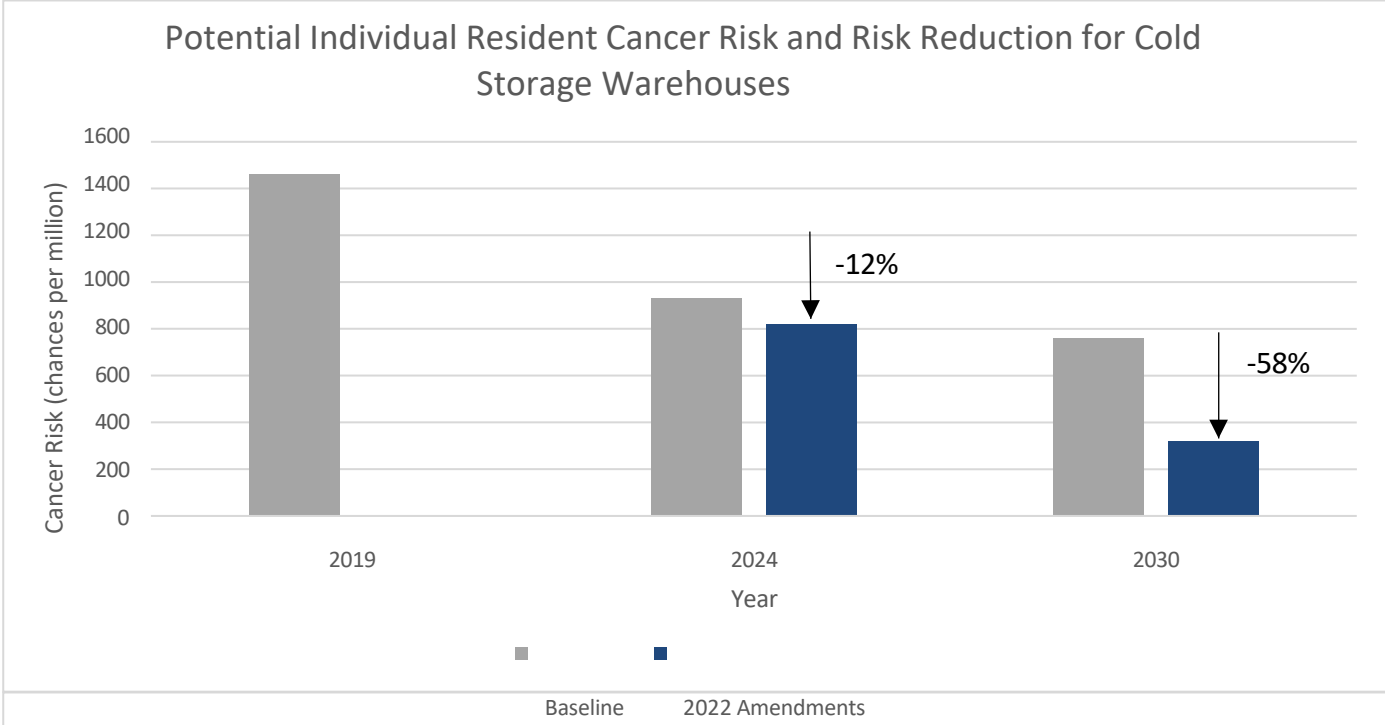
Statewide Distribution of Applicable Facilities, Including Those in Disadvantaged Communities (as of January 2021)

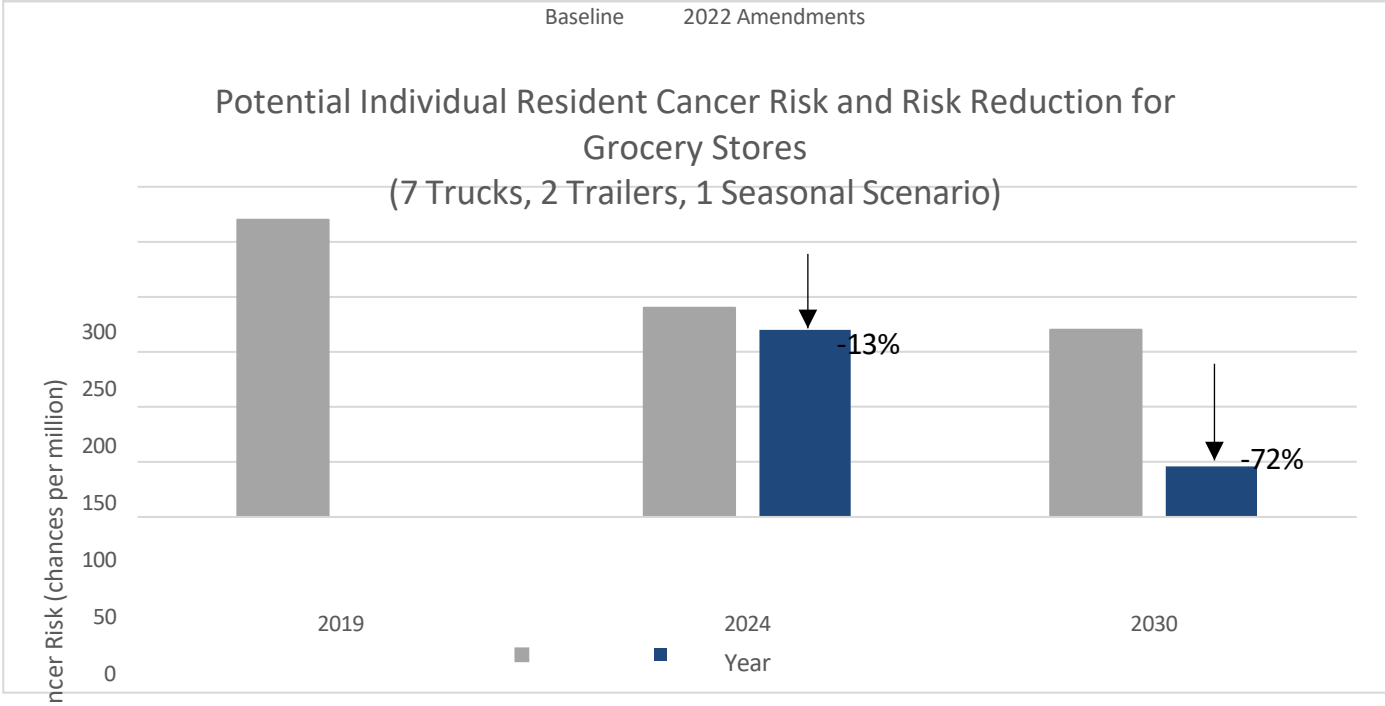


CALIFORNIA AIR RESOURCES BOARD

March 17, 2022

HEALTH ANALYSIS SHOWS REDUCTION IN POTENTIAL CANCER RISK





Note: Individual resident cancer risk estimates are based on a 30-year exposure duration using the Risk Management Policy method (95th percentile/80th percentile daily breathing rates. Fraction of time at home equals 1 for age bins <16 years and 0.73 for age bin 16-70 years.

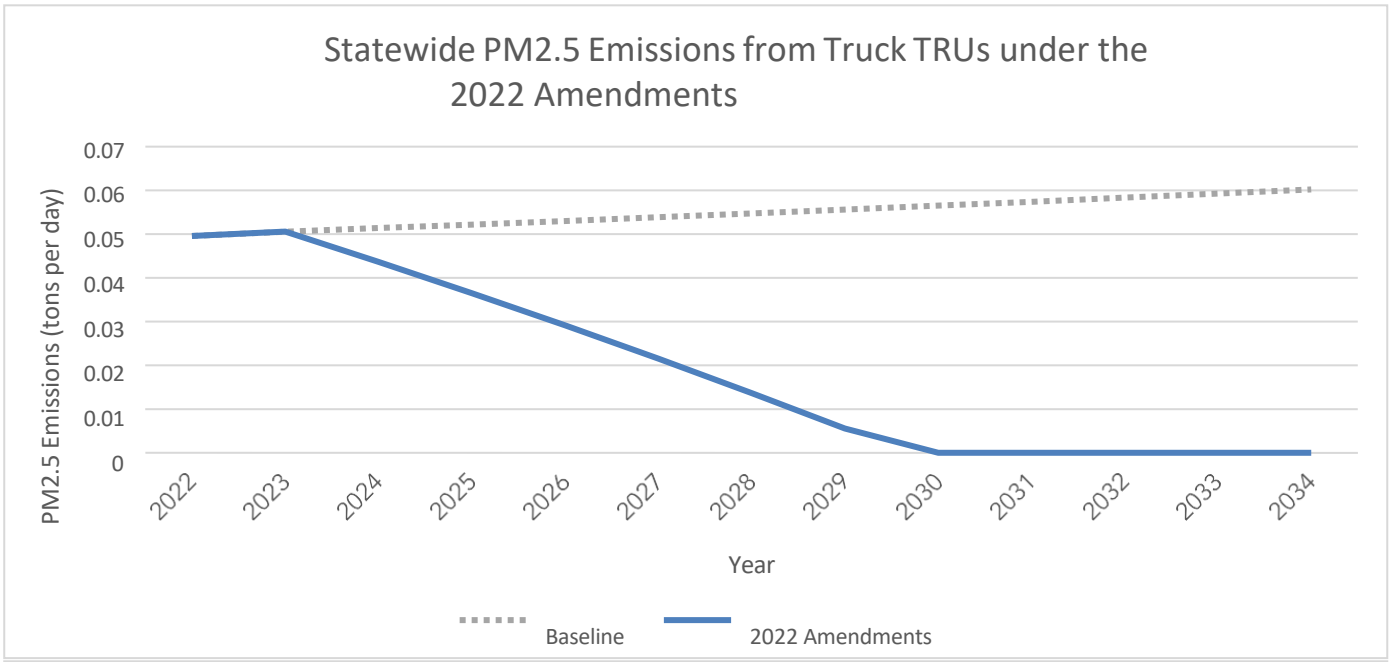
CALIFORNIA AIR RESOURCES BOARD

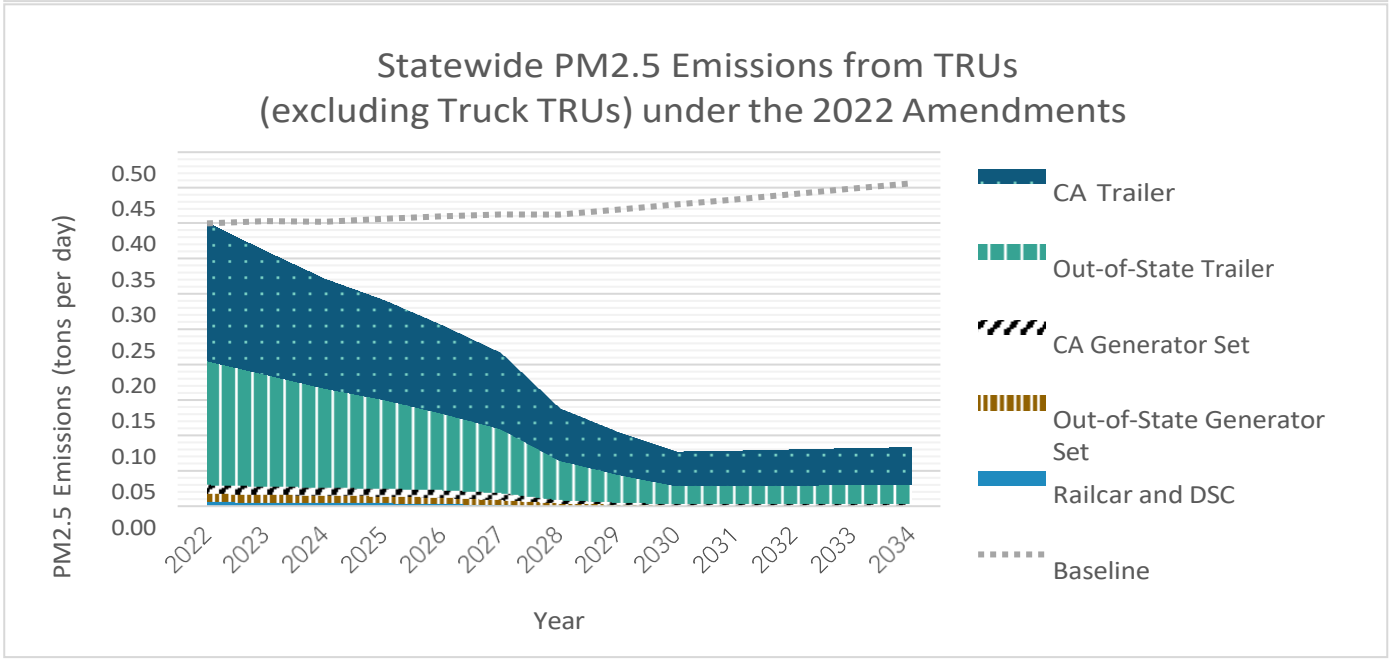
March 17, 2022

REDUCING EMISSIONS FROM TRUS

The 2022 Amendments will further reduce statewide TRU emissions from 2022 to 2034 by approximately:

- 1,258 tons of PM2.5
- 3,515 tons of NOx
- 1.42 million metric tons of carbon dioxide equivalents (MMTCO2e)



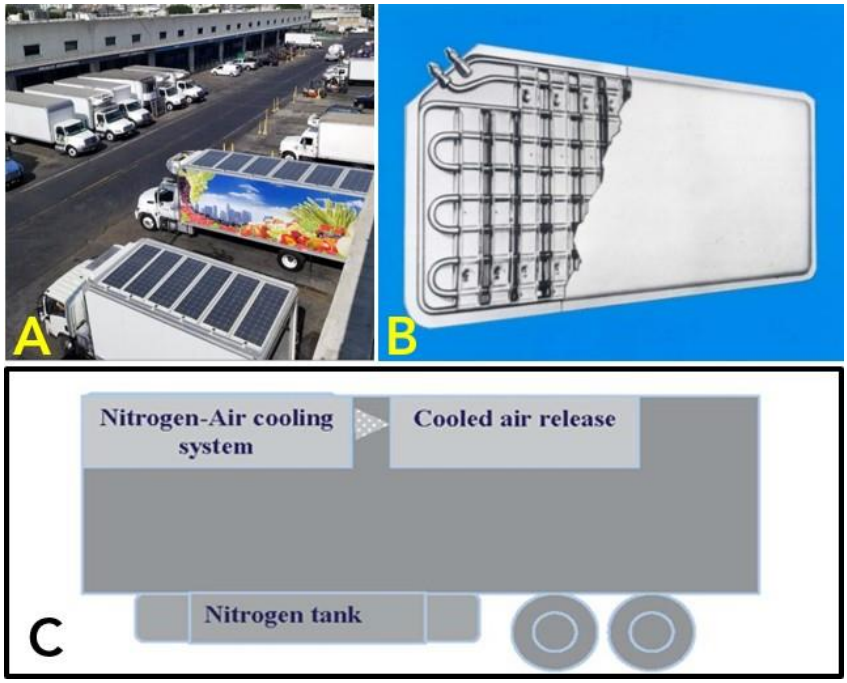


CALIFORNIA AIR RESOURCES BOARD

March 17, 2022

CURRENTLY AVAILABLE ZE TRUCK TRU TECHNOLOGY

- **(A) Battery-electric truck TRU.** The diesel engine powering the compressor and fans is removed and replaced with electric motors powered by a battery pack. To recharge the battery pack after daily operations, truck TRU owners may rely on publicly accessible chargers or choose to install chargers at their home base facility.
- **(B) Cold plate truck TRU.** These systems consist of a sheet metal shell, with cooling coils built inside to hold the eutectic fluid. They are similar to the gel packs used in lunch boxes and ice chests, but larger. These units would require access to electrical plugs to refreeze cold plates after daily operations.
- **(C) Indirect cryogenic truck TRU.** A cryogenic fluid (liquid CO2 or liquid nitrogen) is the cooling agent, replacing the diesel engine-driven refrigeration system utilized in a conventional TRU. These units would require access to a liquid CO2 or liquid nitrogen fueling station.



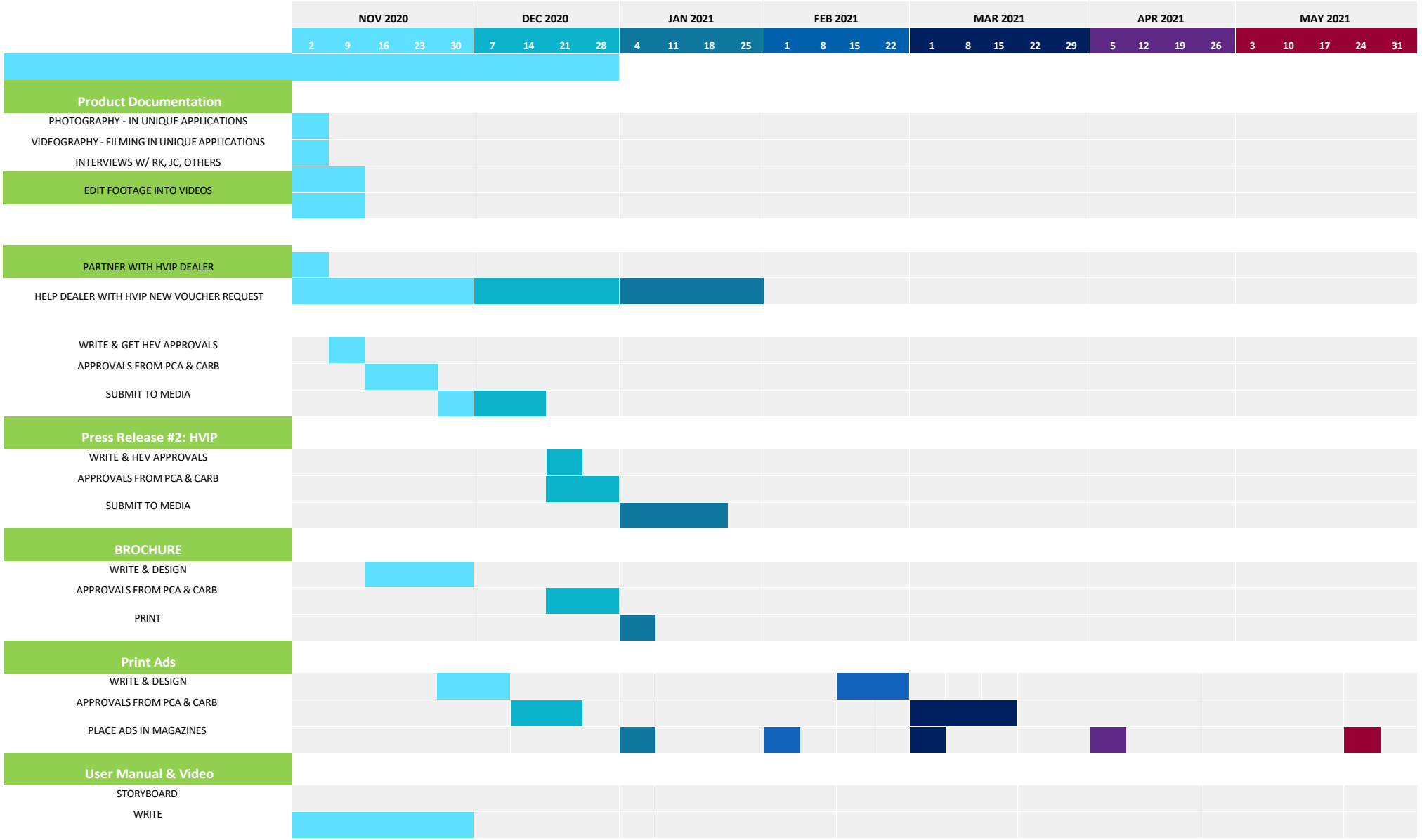
NEXT STEPS

- Staff will submit the final rulemaking package for the 2022 Amendments to the Office of Administrative Law.
- In response to EO N-79-20, staff are conducting a technology assessment to evaluate current and projected development of zero-emission technologies for non-truck TRUs (trailer TRUs, DSC TRUs, railcar TRUs, and TRU generator sets).
- Staff plan to start the development of a second rulemaking to transition non-truck TRUs to ZE technology in 2022. This second rulemaking is anticipated for Board consideration in 2025.

More Information: https://ww2.arb.ca.gov/new-transport-refrigeration-unit-regulation-development

HummingbirdEV Truck/ZANZEFF Marketing Calendar 2020-2021

Proposed Start Date: Nov. 2, 2020 (Will actually be the day Unit 1 is completed)



** Due to the Covid-19 pandemic all in-person events were cancelled. HummingbirdEV will still continue with the promotion of this technology as a part of the comercialization plan of the company.

Top 83 Electric Vehicle Blogs & Websites May 2020

1. Charged EVs | Electric Vehicles Magazine

Florida, United States**About Blog** Electric vehicle enthusiasts and industry ss the daily stream of newsworthy EV-related stories from around the globe. Covering the rapidly growing world of electric cars, trucks, trikes, and bikes. **Frequency** 4 posts / day **Since** Sep 2011 **Blog** chargedevs.com

Facebook fans 12.1K · Twitter followers 14.1K · Social Engagement 31ⓘ · Domain Authority 55ⓘ · Alexa Rank 412.8KⓘView Latest Posts·Get Email Contact

2. Electrek | Charge Forward

Fremont, California, United States**About Blog** Following the electric stry and green ecosystem, Tesla, SolarCity and more. Electrek is a news site tracking the transition from fossil fuel transportation to electric and the surrounding clean ecosystems. **Frequency** 14 posts / day **Since** Jul 2012 **Blog** electrek.co

Facebook fans 67.8K · Twitter followers 66K · Instagram Followers 10.8K · Social Engagement 683ⓘ · Domain Authority 81ⓘ · Alexa Rank 8.8KⓘView Latest Posts·Get Email Contact

3. Inside EVs | Electric Vehicle News, Reviews, and Reports

Miami, Florida, United States**About Blog** InsideEVs is the world's largest Internet site dedicated solely to plug-in electric vehicles. **Frequency** 21 posts / day **Since** Apr 2012 **Blog** insideevs.com

Facebook fans 81.6K · Twitter followers 33.8K · Domain Authority 72ⓘ · Alexa Rank 2.5Kⓘ View Latest Posts·Get Email Contact

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4. Green Car Reports - Hybrid and Electric Car News and Reviews

El Segundo, California, United States**About Blog** Green Car Reports is the urn to for help deciphering the world of 'green' cars, reporting on which ones nd which don't do as well. Get Reviews, Ratings, Photos & Specs of fuel efficient & high MPG vehicles. Read news and updates on the latest hybrids, electric cars and clean energy transportation. **Frequency** 4 posts / day **Since** Nov 2008 **Blog** greencarreports.com

Facebook fans 344.6K · Twitter followers 24.4K · Instagram Followers 8.1K · Social Engagement 104ⓘ · Domain Authority 75ⓘ · Alexa Rank 91Kⓘ View Latest Posts·Get Email Contact

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5. Clean Fleet Report - Electric, Hybrid, Clean Diesel & High- MPG Vehicles

California, United States**About Blog** Clean Fleet Report chronicles our world of choice in cars and trucks. Reports detail new cars including hybrids, d electric vehicles. Also covered is news of the auto industry and relevant events. **Frequency** 1 post / day **Since** Jun 2006 **Blog** cleanfleetreport.com
Facebook fans 485 · Twitter followers 3.3K · Social Engagement 8ⓘ· Domain Authority 43ⓘ· Alexa Rank 1.8MⓘView Latest Posts·Get Email Contact

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6. EV Obsession

About Blog Electric Vehicle site for the EV obsessed. Pure EVs, Plug-in Hybrids, & even some Hybrids. EV Charging Stations, Apps, Market Research, Policy, Etc. **Frequency** 1 post / week **Since** May 2008 **Blog** evobsession.com
Facebook fans 3.7K · Twitter followers 2.2K · Social Engagement 144ⓘ· Domain Authority 58 ⓘ· Alexa Rank 2.2MⓘView Latest Posts·Get Email Contact

Subscribe newsletter Continue

7. CleanTechnica Car Reviews

About Blog CleanTechnica is the #1 site in the US for cleantech news & commentary. Here we focus on electric cars, and other clean technologies. **Frequency** 1 post / day **Since** Nov 2011 **Blog** cleantechnica.com/category/c..

Facebook fans 43.3K · Twitter followers 111.8K · Social Engagement 581 · Domain Authority 80 · Alexa Rank 19.3KView Latest Posts·Get Email Contact

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8. Teslarati.com

California, United States**About Blog** Teslarati is your #1 source of news for covering Tesla news, rumors and reviews, the latest developments in the world of SpaceX, Elon Musk and the premium EV market. **Frequency** 8 posts / day **Since** Mar 2013 **Blog** teslarati.com

Facebook fans 20.4K · Twitter followers 156.2K · Instagram Followers 45.7K · Social Engagement 594 · Domain Authority 82 · Alexa Rank 14.8KView Latest Posts·Get Email Contact

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9. Electric Vehicle News

Sydney, New South Wales, Australia**About**

Blog ElectricCarCommunity.com is on online Q&A service for Electric Car Drivers. **Frequency** 1 post / month **Since** Mar 2016 **Blog** electric-vehiclenews.com

Facebook fans 28.6K · Twitter followers 11.9K · Social Engagement 4 · Domain Authority 52 · Alexa Rank 1.7MView Latest Posts·Get Email Contact

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10. Electric Vehicles The Truth About Cars

About Blog The Truth About Cars is dedicated to providing candid, unbiased and the latest in auto industry news. A battery of sometimes shocking but current news about EVs past, present, and future. **Frequency** 1 post / quarter **Since** Aug 2007 **Blog** thetruthaboutcars.com/catego..

Facebook fans 51.7K · Twitter followers 32.3K · Social Engagement 22 · Domain Authority 73 · Alexa Rank 116.5KView Latest Posts·Get Email Contact

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11. Reddit - EV news and products

San Francisco, California, United States**About Blog** Discuss everything to do ybrid cars and electric vehicles the Reddit community for EV

enthusiasts! **Frequency** 11 posts / day **Blog** reddit.com/r/electricvehicles
Facebook fans 1.4M · Twitter followers 674K · Social Engagement 273 · Domain Authority 91 · Alexa Rank 19View Latest Posts·Get Email Contact

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12. Schneider Electric Blog

Beijing, China**About Blog** Schneider Electric invents technologies that s where we live, work and play, empowering people to do more with less.The goal of this blog is to bring together a fun and engaging community of people who, like Schneider Electric, have made efficiency a priority in the way they work and live. **Frequency** 2 posts / quarter **Since** May 2012 **Blog** blog.schneider-electric.com/..
Facebook fans 1.7M · Twitter followers 51.7K · Domain Authority 81 · Alexa Rank 12.3KView Latest Posts·Get Email Contact

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13. Green Car Congress

About Blog Green Car Congress mission is to provide timely, high-quality ull spectrum of energy options, technologies, products, issues and policies related to sustainable mobility. Our audience comprises members of every segment of the energy and transportation markets: industry, government, academia and the public. **Frequency** 6 posts / day **Since** Apr 2004 **Blog** greencarcongress.com
Twitter followers 6.9K · Social Engagement 5 · Domain Authority 69 · Alexa Rank 135.6KView Latest Posts·Get Email Contact

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14. Blink Charging | Electric Vehicle Charging

Florida, United States**About Blog** Blink Charging Co. (OTC: CCGID) ('Blink Charging') is one of the leaders in nationwide public electric vehicle (EV) charging equipment and services, enabling EV drivers to easily charge at locations throughout the United States. We own, operate, and provide electric vehicle charging stations. We recently change the company name to BlinkCharging to integrate CarCharging and Blink Network. **Frequency** 1 post / day **Since** Feb 2017 **Blog** blinkcharging.com/companynews
Twitter followers 11 · Instagram Followers 1.5K · Social Engagement 7 · Domain Authority 44 · Alexa Rank 237.6KView Latest Posts·Get Email Contact

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15. PlugInIndia - Electric Vehicle India Blogs

Pune, Maharashtra, India**About Blog** We @PluginIndia promote Electric energy in India. We work with the EV industry and local businesses to bring about change! Our aim is to accelerate the shift to plug-in vehicles powered by clean, affordable, domestic electricity to reduce our country's dependence on imported oil and thus improve the global environment. **Frequency** 2 posts / week **Since** Aug 2013 **Blog** pluginindia.com/blogs
Facebook fans 2.5K · Twitter followers 1.9K · Instagram Followers 698 · Social Engagement 1 · Domain Authority 32 · Alexa Rank 336.9KView Latest Posts·Get Email Contact

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16. EV Connect

Los Angeles, California, United States**About Blog** EV Connect developed lustry's most robust and flexible cloud-based platform for the management of the Electric Vehicle (EV) ecosystem. We believe in the future, all parking spaces will offer EV charging - and EV Connect's network management software and management services will make it simple and cost-effective for all charge station owners. **Frequency** 1 post / week **Since** Aug 2010 **Blog** evconnect.com/blog

Facebook fans 537 · Twitter followers 10.3K · Instagram Followers 313 · Social Engagement 1 · Domain Authority 36 · Alexa Rank 362.9KView Latest Posts·Get Email Contact

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17. Zap-Map » Charging points and electric vehicles

Bristol, England, United Kingdom**About Blog** Zap-Map enables UK drivers e EV charging points in UK and Ireland. Provides advice, help and tools for current and potential electric car drivers. Our mission is to provide smart tools for EV drivers to enable mass e-mobility. **Frequency** 1 post / week **Since** Apr 2014 **Blog** zap-map.com/category/latest-..

Facebook fans 1.3K · Twitter followers 10.4K · Social Engagement 11 · Domain Authority 56 · Alexa Rank 418.8KView Latest Posts·Get Email Contact

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18. GM-VOLT : Chevy Volt Electric Car Site

 **About Blog** The definitive grassroots source of real-time news, information, and discussion about the Chevy Volt electric car and related topics. Our mission is to spread the word about the Chevy Volt electric car and help get this country and the world off of oil. **Frequency** 5 posts / month **Since** Jan 2007 **Blog** gm-volt.com
Facebook fans 3.4K · Twitter followers 14.5K · Domain Authority 61 · Alexa Rank 452.5KView Latest Posts·Get Email Contact

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19. Electra Meccanica - The SOLO - Three wheel Electric Car

 Vancouver, British Columbia, Canada**About Blog** Introducing the SOLO: an enger electric vehicle with spirited performance! The SOLO is the ideal commuter car that fits perfectly into your busy lifestyle being both good for you and the planet. Designed by a world-class development team, its good looks are matched by spirited performance and ultimate practicality. **Frequency** 1 post / month **Since** Mar 2015 **Blog** electrameccanica.com
Facebook fans 8.8K · Twitter followers 1.8K · Social Engagement 8 · Domain Authority 53 · Alexa Rank 456.5KView Latest Posts·Get Email Contact

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20. How-To Electric

About Blog How-To Electric is a blog dedicated to Electric Vehicles. Here we share news, reviews, and guides of the electric cars, bikes, scooters, bicycles and electronics gadgets in the market. **Frequency** 6 posts / quarter **Blog** howtoelectric.com
Domain Authority 6 · Alexa Rank 486.5KView Latest Posts·Get Email Contact

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21. Go Ultra Low | Electric Cars and Vans

London, England, United Kingdom**About Blog** Go Ultra Low is a ground-rnment and industry campaign which aims to increase purchase consideration of electric vehicles by helping motorists and fleets understand the benefits, cost savings and capabilities of the wide range of electric vehicles on the market. **Frequency** 1 post / quarter **Since** Dec 2014 **Blog** goultralow.com
Facebook fans 18.2K · Twitter followers 9.6K · Social Engagement 1 · Domain Authority 52 · Alexa Rank 492.2KView Latest Posts·Get Email Contact

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22. FleetCarma

Waterloo, Ontario, Canada**About Blog** Electric Vehicle News for EV Owners, Electric Utilities, Vehicle Researchers, the Auto Industry and Sustainability Experts.

The best telematics solutions for commercial and municipal fleet management, vehicle sustainability, load management utilities and automotive researcher. Our mission is to help accelerate the adoption of EVs, and strive to make the ownership experience better. **Frequency** 2 posts / quarter **Since** Nov 2010 **Blog** fleetcarma.com/blog
Facebook fans 362 · Twitter followers 1.5K · Social Engagement 5 · Domain Authority 52 · Alexa Rank 583.1KView Latest Posts·Get Email Contact

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23. Arcimoto | The Everyday Electric

Eugene, Oregon, United States**About Blog** Arcimoto is a technology
g ultra-efficient electric vehicles & vehicle platforms for the mass market. Our mission is sustainable transportation: we believe we shouldn't have to sacrifice the livability of our planet just for the convenience of getting from A to B. We're developing the SRK, a vehicle based on unique new electric vehicle platform & designed for the needs of drivers. **Frequency** 1 post / week **Blog** arcimoto.com
Facebook fans 16.9K · Twitter followers 4.8K · Instagram Followers 4.5K · Social Engagement 81 · Domain Authority 54 · Alexa Rank 682.6KView Latest Posts·Get Email Contact

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24. Plug'n Drive Electric Cars

Toronto, Ontario, Canada**About Blog** Plug'n Drive is a non-profit
omotes electric vehicles for their environmental and economic benefits. Our mission is to accelerate the electric vehicle industry in Canada. **Frequency** 1 post /

quarter **Since** Apr 2016 **Blog** plugndrive.ca

Facebook fans 1.3K · Twitter followers 6K · Instagram Followers 643 · Social Engagement 2 · Domain Authority 42 · Alexa Rank 898.6KView Latest Posts·Get Email Contact

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25. Meet Plugless | The Wireless EV Charging Station

Richmond, Virginia, United States**About Blog** Get the latest from Plugless ınity. Plugless by Evatran is the wireless L2 charging system for electric vehicles. Charge without plugging in. Used daily across the USA and Canada. **Since** Aug 2010 **Blog** pluglesspower.com/learn

Twitter followers 2.9K · Domain Authority 57 · Alexa Rank 969.2KView Latest Posts·Get Email Contact

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26. SemaConnect - Electric Vehicle (EV) Charging Stations

Bowie, Maryland, United States**About Blog** SemaConnect is an international leader in commercial electric vehicle (EV) charging stations and management software for commercial real estate, hotels, hospitals, universities, and more. Blog features news, thoughts & rants about Electric Vehicle Charging Stations. We provide best EV Charging stations for universities, healthcare. **Frequency** 1 post / week **Since** Dec 2010 **Blog** semaconnect.com/blog

Facebook fans 590 · Twitter followers 24 · Instagram Followers 247 · Domain Authority 42 · Alexa Rank 986.3KView Latest Posts·Get Email Contact

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27. EV Adoption

Danville, California, United States**About Blog** EV evangelist, contributor to alyzing & writing about the key variables that will drive mass adoption of electric vehicles. Analyzing key factors that will drive mass adoption of electric vehicles. **Frequency** 3 posts / quarter **Since** Aug 2016 **Blog** evadoption.com
Twitter followers 1.1K · Social Engagement 7 · Domain Authority 47 · Alexa Rank 1.1MView Latest Posts·Get Email Contact

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28. Electric Forum - Electric Car Blog

About Blog Electric Forum is an online community of like minded a conversation about electric vehicles, electric bikes, battery technology, and electric power. Our aim is to create a positive community to promote the vast benefits that Electric Vehicles offer. **Since** Dec 2008 **Blog** electricforum.com/blog
Facebook fans 948 · Twitter followers 2.3K · Domain Authority 28 · Alexa Rank 1.1MView Latest Posts·Get Email Contact

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29. EV Sales

About Blog Tracking down plug-in car sales all over the world. **Frequency** 1 post / day **Since** Dec 2012 **Blog** ev-sales.blogspot.com

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30. Plug In America

United States**About Blog** Plug In America is the leading US association promoting awareness of electric vehicles and programs such as National Drive Electric Week. As an association site, Plug-In America excels in providing a lot of tools and resources for consumers to determine if an EV is right for them, find the the right model, learn about national and state incentives and more. **Frequency** 4 posts / month **Since** Oct 2009 **Blog** pluginamerica.org

Facebook fans 11.2K · Twitter followers 14.9K · Instagram Followers 1.1K · Social Engagement 28 · Domain Authority 60 · Alexa Rank 1.5MView Latest Posts·Get Email Contact

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31. EVTV Motor Verks | Custom Electric Car Conversion Instructional Videos


Cape Girardeau, Missouri, United States**About Blog** Electric Vehicle Television - EVtv - a weekly video for custom electric car builders and conversions. Each week we review components and techniques you can use to convert any car to clean, quiet, powerful electric drive. EVtv brings you news, developments, the latest components, and techniques for building the future of electric vehicle transportation - in high definition video. **Frequency** 4 posts / year **Since** May 2009 **Blog** evtv.me
Facebook fans 802 · Twitter followers 1.2K · Social Engagement 1 · Domain Authority 41 · Alexa Rank 1.4MView Latest Posts·Get Email Contact

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32. Big Cat Electric Bikes

Patchogue, New York, United States**About Blog** Welcome to Big Cat Electric Bikes, your #1 source for electric bicycles and accessories. Premium quality e-bikes at an affordable price. **Frequency** 8 posts / year **Blog** bigcatbikes.com
Twitter followers 438 · Instagram Followers 2.5K · Social Engagement 4 · Domain Authority 19 · Alexa Rank 1.6MView Latest Posts·Get Email Contact

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33. EVmatch

Santa Barbara, California, United States**About Blog** We're on a mission to accelerate EV adoption by making charging easy, reliable, and accessible to all. **Frequency** 1 post / week **Blog** blog.evmatch.com
Facebook fans 713 · Twitter followers 634 · Domain Authority 36 · Alexa Rank 1.6MView Latest Posts·Get Email Contact

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34. Ev-Vin | Charge!!!

About Blog Senseless rants and the occasional lesson learned from an early 2013 **Blog** ev-vin.blogspot.com
Domain Authority 25 · Alexa Rank 1.6MView Latest Posts·Get Email Contact

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35. DriveElectric

Marlow, England, United Kingdom**About Blog** DriveElectric are the UK's leased Electric Vehicles and offer finance options for all makes and model, from all manufacturers, including the BMW i3, Renault Zoe, Mitsubishi Outlander PHEV and Nissan Leaf. Follow this blog to find more information on EV news and stories. **Frequency** 6 posts / month **Since** Oct 2011 **Blog** drive-electric.co.uk/blog

Facebook fans 542 · Twitter followers 6.2K · Social Engagement 3 · Domain Authority 32 · Alexa Rank 2.1MView Latest Posts·Get Email Contact

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36. ChargeYourCar

United Kingdom**About Blog** Charge Your Car is a network of EV charge UK. This includes Energise, GMEV, Source West and ChargePlace Scotland. CYC operates by providing a single national charge point management system to which charge point owners can connect charge points, making the posts visible to all EV drivers via the CYC live status map. **Frequency** 1 post / month **Since** Jun 2012 **Blog** chargeyourcar.org.uk
Facebook fans 792 · Twitter followers 9K · Domain Authority 37 · Alexa Rank 2.5MView Latest Posts·Get Email Contact

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37. Green Car Guide | Electric Cars & Hybrids

United Kingdom**About Blog** GreenCarGuide.co.uk is the UK's original green vides information to consumers about the latest green cars in a quality, informed and engaging way, to help them save money on rising fuel prices and CO2 taxation. The site focuses on cars that are best-in-class in terms of emissions, fuel economy and efficiency, but that are also great to drive. **Frequency** 10 posts / quarter **Since** Jan 2008 **Blog** greencarguide.co.uk
Facebook fans 592 · Twitter followers 3K · Domain Authority 43 · Alexa Rank 2.9MView Latest Posts·Get Email Contact

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38. EV Lens

About Blog EV Lens is a dedicated platform for all the information regarding the electric vehicles present across the world. Electric Vehicles have set up a new phase of disruption in the global automobile industry. EV Lens brings you all the latest news updates about all brands and segments of the electric vehicles out there in any part of the world. Let it be imported and luxury sedan or a cool hatchback commuter, if it's electric, EV Lens has all the information about it. **Frequency** 21 posts / quarter **Blog** evlens.com
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39. E Indian electrical

India**About Blog** Keep up with Electric Vehicles for future from E Indian ele**ency** 11 posts / year **Since** Nov 2019 **Blog** eindianelectrical.co.in/blog
Domain Authority 4 · Alexa Rank 4MView Latest Posts·Get Email Contact

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40. Drive Electric | smarter, cheaper, cleaner

 Auckland, New Zealand**About Blog** Drive Electric is a not-for-profit with one goal making electric vehicle ownership in New Zealand mainstream. Drive Electric's mission is to create financial, environmental, health and energy security benefits for all New Zealanders through facilitating innovation, education, demonstration and collaboration in the electric vehicle sector **Frequency** 2 posts / quarter **Since** Jan 2015 **Blog** driveelectric.org.nz

Facebook fans 1.1K · Domain Authority 29 · Alexa Rank 4.5MView Latest Posts·Get Email Contact

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41. Electric Vehicles_(India)

New Delhi, Delhi, India**About Blog** Get all news and technology updates related to the Electric Vehicles at a single place. Authentic, Relevant and In-depth information about the electric vehicle techno-commercial market and ongoing updates. **Frequency** 1 post / month **Blog** bijliwaligaadi.com

Facebook fans 126 · Twitter followers 48 · Domain Authority 3 · Alexa Rank 4MView Latest Posts·Get Email Contact

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42. Drive Electric Northern Colorado

Fort Collins, Colorado, United States**About Blog** Drive Electric Northern Colorado is a first-in-the-nation initiative to establish a comprehensive electric vehicle deployment community. **Frequency** 1 post / quarter **Since** Mar 2015 **Blog** driveelectricnoco.org
Facebook fans 581 · Twitter followers 1.1K · Social Engagement 2 · Domain Authority 29 · Alexa Rank 5.2MView Latest Posts·Get Email Contact

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43. EV Life

About Blog We're on a mission to reverse the climate crisis by making it easier for people to shift to sustainable, zero-emissions energy. **Blog** evlife.co/blog/m
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44. Eco Cars Blog

Orkney, Scotland, United Kingdom**About Blog** Specialists in Electric Vehicles **Frequency** 2 posts / year **Since** Oct 2014 **Blog** eco-cars.net/blog

Facebook fans 1.5K · Twitter followers 6.9K · Domain Authority 25 ·View Latest Posts·Get Email Contact

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45. EVIPOWER

Vancouver, British Columbia, Canada**About Blog** Keep up with information cle Types for EV enthusiasts! **Frequency** 1 post / quarter **Blog** evipower.com

Domain Authority 23 · Alexa Rank 10.8MView Latest Posts·Get Email Contact

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46. Electric Car Blogging

About Blog Information on Electric Car News, Hybrids, Alternative Fuel and een. **Frequency** 16 posts / week **Since** Jul 2008 **Blog** electriccarblogging.com

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47. DriveEV - Electric car news, reviews and advice

United Kingdom**About Blog** The UK's only online magazine dedicated to electric cars. Delivering EV news, reviews, tips and advice. **Frequency** 1 post / month **Since** Sep 2015 **Blog** driveev.net

Twitter followers 6.8K · Social Engagement 1 · Domain Authority 26 ·View Latest Posts·Get Email Contact

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48. Autovolt Magazine | The Electric and Hybrid Vehicle Magazine

United Kingdom**About Blog** Autovolt magazine is the UK's premier electric publication. We believe the world of vehicles is changing. Transport is no stion of petrol or diesel. Every major vehicle manufacturer is looking to electrified vehicles and have either already introduced electric cars and hybrids, or are developing them with release imminent. **Frequency** 2 posts / week **Since** Jul 2016 **Blog** autovolt-magazine.com

Twitter followers 3.3K · Social Engagement 1 · Domain Authority 31 ·View Latest Posts·Get Email Contact

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49. EV REPORT

 **About Blog** An EV Blog for Electric Cars **Frequency** 10 posts / week **Blog** evreport.com

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50. Yourevguide

 **About Blog** The guide to electric cars, vans, e-bikes and more. Your EV ick resource to the latest available model information so you can source the right EV (electric vehicle) for your needs wherever you are in the UK. **Since** Dec 2017 **Blog** yourevguide.com/blog

Twitter followers 198 · Instagram Followers 299 · Domain Authority 2 ·View Latest Posts·Get Email Contact

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51. EV Driver | EV Blog

Rendlesham, England, United Kingdom**About Blog** EVDriver specialise in port and management of revenue generating Electric Vehicle Charge

Points. **Frequency** 1 post / quarter **Since** Sep 2016 **Blog** evdriver.co.uk/ev-blog
Twitter followers 1.1K · Domain Authority 17 ·View Latest Posts·Get Email Contact

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52. Midwest EVOLVE

United States**About Blog** The Midwest (EVOLVE) Electric Vehicle Opportunities: Learning, eVents, Experience project is a partnership between the American Lung Association of the Upper Midwest (ALAUM) and eight Midwestern Clean Cities coalitions in seven states. **Frequency** 17 posts / year **Since** Feb 2017 **Blog** midwestevolve.org/news-blog/..

Facebook fans 1.4K · Twitter followers 1.3K · Social Engagement 19 · Domain Authority 26 ·View Latest Posts·Get Email Contact

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53. The Road Electric

Oregon, United States**About Blog** The age of the electric vehicle has arrived. offers unique news and a fresh perspective on electric cars & how they're changing our world. **Frequency** 4 posts / year **Blog** theroadelectric.com
Facebook fans 70 · Twitter followers 4.1K · Social Engagement 6 · Domain Authority 14 ·View Latest Posts·Get Email Contact

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54. My Electric Vehicle Journey

Dallas, Texas, United States**About Blog** America leads today in two guably started here: electric vehicles and the internet. Get latest updates on electric vehicles journey by Buzz Smith. **Frequency** 14 posts / quarter **Since** Mar 2011 **Blog** buzzsmith.us

Twitter followers 146 · Social Engagement 3 · Domain Authority 21 ·View Latest Posts·Get Email Contact

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55. rEVolution by EVBox

Amsterdam, Noord-Holland, Netherlands**About Blog** EVBox is the leading r of electric vehicle charging stations and charging management software. With an installed base of over 50,000 charging points across more than 980 cities worldwide, EVBox drives sustainable mobility, by bringing leading electric vehicle charging solutions to the world. **Since** Feb 2017 **Blog** blog.ev-box.com

Facebook fans 12.1K · Twitter followers 4.4K · Domain Authority 38 ·View Latest Posts·Get Email Contact

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56. TEQ Charging

Atlanta, Georgia, United States**About Blog** Every day thousands of EV drivers struggle to find access to charging outside of their homes. Furthermore, EV charging equipment is expensive to install and support. TEQ is here to change that. Through cloud-based algorithms and a smart add-on device, our technology provides greater accessibility to charging for drivers, without an increase in power infrastructure to the building. **Since** Nov 2016 **Blog** teqcharging.com/blog

Facebook fans 511 · Twitter followers 125 · Domain Authority 19 ·View Latest Posts·Get Email Contact

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57. E-zoomed | Electric Living Blog

London, England, United Kingdom**About Blog** E-zoomed, the first comprehensive platform of its type, makes your journey to electric car ownership easier by providing quotes and comparison. **Frequency** 10 posts / month **Blog** ezoomed.com/blog

Facebook fans 149 · Twitter followers 181 · Domain Authority 16 ·View Latest Posts·Get Email Contact

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58. Solisco

 Telford, England, United Kingdom**About Blog** Solisco was founded with a mission to inspire and support the emerging electric vehicle market with innovative solutions that harness the power of the sun. Having a wealth of experience in running electric vehicles, the team at Solisco were passionate about making a difference so that everyone can enjoy the true freedom of driving an EV without any compromises. **Frequency** 1 post / month **Since** Jun 2017 **Blog** solisco.co.uk/blog

Facebook fans 56 · Social Engagement 3 · Domain Authority 9 ·View Latest Posts·Get Email Contact

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59. Alysha Webb's ChinaEV Blog

 London, England, United Kingdom**About Blog** China-EV offers insightful pects of China's electric vehicle industry. Alysha Webb spent 14 years in China, 7 of them covering the auto industry. She has her own unique take on events there, and a loyal following. **Frequency** 5 posts / year **Since** Jun 2010 **Blog** china-ev.org

Facebook fans 95 · Social Engagement 6 · Domain Authority 23 ·View Latest Posts·Get Email Contact

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60. EV Club of CT

Westport, Connecticut, United States**About Blog** We are electric vehicle enthusiasts evangelizing the rapid adoption of EVs. Our mission is to be evangelists for EV adoption and to help the state meet the goals set forth in the Multi-state ZEV Action Plan. We do this by interacting with people in EV showcases and ride and drive events. We advocate for and help draft EV-friendly legislation. **Frequency** 3 posts / month **Since** Mar 2014 **Blog** evclubct.com

Facebook fans 1.1K · Social Engagement 8 · Domain Authority 18 ·View Latest Posts·Get Email Contact

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61. EV Info | Electric Car News and Reviews


About Blog EV news on the Electric Car industry plus reviews of best selling on Charging technology. **Frequency** 3 posts / month **Since** Dec 2012 **Blog** evinfo.info

Facebook fans 38 · Twitter followers 193 · Social Engagement 1 · Domain Authority 19 ·View Latest Posts·Get Email Contact

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62. Spark Powered

About Blog Electric all the things! **Frequency** 10 posts / quarter **Blog** sparkpowered.com

Domain Authority 2 ·View Latest Posts·Get Email Contact

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63. Electricvehicless

About Blog It is all about electric vehicles. This is a platform for updating ırmation, knowledge, new technology. **Frequency** 13 posts / year **Blog** electricvehicless.com

Twitter followers 269 · Domain Authority 4 ·View Latest Posts·Get Email Contact

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64. Atlanta Electric Vehicle Development Coalition

Atlanta, Georgia, United States**About Blog** The purpose of the AEVDC is to ic vehicle ownership and EV charging infrastructure and EV ownership in the 11 county metro Atlanta area. This blog will provide you with relevant Atlanta, U.S. and international news and information to help you learn about this exciting new (well not so new since the first electric car was introduced 100 years ago) way to drive. **Frequency** 4 posts /

year **Since** Jun 2014 **Blog** atlantaevdc.com
Twitter followers 792 · Domain Authority 18 ·View Latest Posts·Get Email Contact

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65. EVIOM Electric Vehicles Isle of Man

About Blog A blog site dedicated to Electric Vehicles, charging lean energy on the Isle of Man. EVIOM believes that Electric Vehicles are ideal for the Isle of Man. Vehicles on the market today have a range that easily covers all island journeys and together with the public charge points in Douglas, Ramsey, Peel , Castletown etc. **Frequency** 3 posts / year **Since** Apr 2015 **Blog** eviom.im
Facebook fans 475 · Twitter followers 319 · Social Engagement 7 · Domain Authority 2 ·View Latest Posts·Get Email Contact

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66. EV-Resource

Richmond, Virginia, United States**About Blog** The information you need to c Vehicles. **Frequency** 4 posts / quarter **Blog** ev-resource.com/blog
Twitter followers 111 · Social Engagement 5 · Domain Authority 8 ·View Latest Posts·Get Email Contact

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67. Sevadis

 England, United Kingdom**About Blog** A UK company that develop, install and supply electric car chargers to building projects, residential developments, businesses, and individual customers. Follow to get updates. **Frequency** 4 posts / quarter **Blog** sevadis.com

Facebook fans 9 · Twitter followers 203 · Domain Authority 18 ·View Latest Posts·Get Email Contact

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68. Supercharged EV

 **About Blog** My goal is to gather information about electric vehicles, clean ny favorite blog links. **Frequency** 5 posts / quarter **Blog** teslaorder.blogspot.com

Domain Authority 2 ·View Latest Posts·Get Email Contact

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69. XGEV Xtreme Green Electric Vehicle

 Las Vegas, Nevada, United States**About Blog** Xtreme Green Electric ; the new, environmentally green standard for police, security, maintenance, landscaping and off-road commercial users. The vehicles are designed with the latest technology

and the most advanced energy management and electric propulsion systems. **Since** Apr 2016 **Blog** xgev.com/blog

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70. evchels | Just a girl who plays with cars…

Los Angeles, California, United States**About Blog** Chelsea Sexton started 7 to put herself through college, but soon found her passion for electric vehicles (and her lead foot) as part of the General Motors EV1 program. In the two decades since, she has amassed unparalleled expertise in the electric transportation ecosystem, including market strategy, stakeholder engagement, retail processes, public policy, infrastructure. **Since** May 2009 **Blog** evchels.wordpress.com

Twitter followers 13.6K · Domain Authority 34 ·View Latest Posts·Get Email Contact

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71. Greenways Insurance | Electric Car Insurance

Shropham, England, United Kingdom**About Blog** At Greenways, we ing electric vehicle insurance and electric car insurance for pure electric, hybrid and plug-in hybrid cars. Get all the latest news new from Greenways, the electrical motor vehicle insurance and electric car insurance specialists, on our blog. **Frequency** 1 post / week **Since** Dec 2016 **Blog** greenwaysinsurance.co.uk/blog

Facebook fans 59 · Twitter followers 147 · Domain Authority 11 ·View Latest Posts·Get Email Contact

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72. Plug'n Drive's Blog

Toronto, Ontario, Canada**About Blog** Plug'n Drive is a non-profit itted to accelerating the adoption of electric vehicles (EV) to maximize their environmental and economic benefits. Over the past three years, Plug'n Drive established itself as a leader in the (EV) space; a trusted source of unbiased information on electric cars, charging stations and the electricity sector. **Since** Oct 2014 **Blog** plugndrive.wordpress.com Twitter followers 6K · Domain Authority 11 ·View Latest Posts·Get Email Contact

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73. EVGuernsey

Guernsey**About Blog** EV Guernsey exists, primarily to inform people in the 1 about electric vehicles including cars, bikes, e-bicycles and other electric powered powered transport innovations. It serves to provide a greater understanding about vehicle electrification. **Frequency** 2 posts / year **Since** Apr 2016 **Blog** evguernsey.org/blog

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74. Maryland EV

Maryland, United States**About Blog** Maryland EV is an electric vehicle education and outreach resource serving Maryland and the Mid-Atlantic. Organized by BEVI, the Baltimore-Washington Electric Vehicle Initiative, we enjoy key support from a broad coalition of clean cities supporters, including State agencies, local and county governments, universities, students and EV enthusiasts. **Frequency** 2 posts / year **Since** Oct 2017 **Blog** marylandev.org

Facebook fans 809 · Twitter followers 94 · Domain Authority 29 ·View Latest Posts·Get Email Contact

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75. FuelIncluded Blog

Northampton, England, United Kingdom**About Blog** A one-stop shop for nd plug-in hybrids. Get news and personal experiences with batteries, solar and electric cars. **Since** Sep 2014 **Blog** info.fuelincluded.com/blog

Facebook fans 216 · Twitter followers 155 · Domain Authority 23 ·View Latest Posts·Get Email Contact

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76. DiscoverEV

 United Kingdom**About Blog** Electric Vehicle and Hybrid Car reviews, features, news and more. Discover EV aims to unlock consumer confidence in electric, hybrid and plug-in hybrid models by providing independent and authoritative information all in one place. **Frequency** 1 post / day **Blog** https://www.discoverev.co.uk/**+ Follow** Facebook fans 487 · Twitter followers 241 · Social Engagement 27 · Domain Authority 9
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77. EV Innovate

About Blog EV Innovate is here to provide information on buying an electric car, converting your own electric car, creating your own green energy, and electric vehicle innovations. The goal is to provide the best information to help convert vehicles to electric power from gasoline or diesel. In order to provide the best information possible. **Since** Jul 2016**Blog** https://evinnovate.com/blog/**+ Follow**
Facebook fans 62 · Twitter followers 50 · Instagram Followers 49 · Domain Authority 16
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78. PluginCars

 United States**About Blog** The web's premier site for reviews, user forums, urchasing and owning a plug-in hybrid or electric vehicle. Stay current with e latest news on plug-in electric vehicle technology and tips for getting the most out of your electric car from those who own and drive the cars themselves. **Frequency** 9 posts / year **Since** Apr

2006**Blog** http://www.plugincars.com/**+ Follow**
Facebook fans 41.7K · Twitter followers 6.3K · Social Engagement 2 · Domain Authority 63 · Alexa Rank 613.1KView Latest Posts·Get Email Contact

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79. GreenMotor | green car and electric car blog

London, England, United Kingdom**About Blog** GreenMotor is a website hybrids and low-carbon motoring. Get Reviews, news and opinion about tric cars and hybrids in the UK. **Since** Jul 2005**Blog** http://www.greenmotor.co.uk/**+ Follow**
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80. My Electric Car

Western Australia, Australia**About Blog** My Electric Car is a community e on Electric Vehicles - new models, battery technology, health aspects, EV blog, forum and newsfeeds from around the world. Our mission is to bring the Australian public and others up to speed with the rapid evolution of electric car technology and explain the benefits of making the switch . **Frequency** 6 posts / year **Since** Aug 2012**Blog** https://myelectriccar.com.au/**+ Follow**
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81. Plug Me In Project | Netherlands to Australia by electric car


IndonesiaAbout Blog An electric road trip from the Netherlands to Australia. Without any money but by asking you to Plug Me In. Promoting electric vehicles and sustainability. **Frequency** 2 posts / year **Since** Jun 2015**Blog** http://plugmeinproject.com/blog/**+ Follow**
Facebook fans 36.8K · Twitter followers 3.9K · Instagram Followers 5.6K · Social Engagement 32 · Domain Authority 46 · Alexa Rank 6.1MView Latest Posts·Get Email Contact

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82. ChargeNet NZ Electric Vehicle Charging Network


Auckland, New ZealandAbout Blog Charge.net.nz is rolling out a robust ure of DC (rapid) and AC (standard) charging stations to encourage the ehicle technology in New Zealand. **Frequency** 1 post / year **Since** Jan 2016**Blog** https://charge.net.nz/**+ Follow**
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83. Workhorse | Electric Trucks, Delivery Drones, Telematics

Cincinnati, Ohio, United StatesAbout Blog The Workhorse Group designs and ectric power trains for its new Workhorse truck chassis. Stay up to date with all ss releases, and videos. **Frequency** 8 posts / year **Since** Apr 2015**Blog** https://workhorse.com/**+ Follow**

Facebook fans 3.5K · Twitter followers 2.7K · Domain Authority 55 · Alexa Rank 1.1MView Latest Posts·Get Email Contact

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Magazines that have run a story about electric trucks and that would be good to send press releases to (in no particular order):

www.wired.com

www.AutomobileMag.com

www.TruckTrend.com (Work Truck Magazine) www.OverdriveOnline.com (Overdrive Magazine)

www.ChargedEVs.com (Electric Vehicles Magazine)

www.GreenFleetMagazine.com

www.WorkTruckOnline.com

www.FleetEquipmentMag.com

www.TAAS.news (UK Magazine “Transportation As A Service”, TaaS Magazine) www.DieselTechMag.com

www.IowaMotorTruck.com (LifeLiner Magazine)

www.TruckingInfo.com (Heavy Duty Trucking Magazine)

www.InsideEVs.com

www.MetroFamilyMagazine.com

www.OutsideOnline.com

www.AustinMonthly.com

www.TruckingInfo.com

www.SAE.org

www.Trucker.com

www.FleetOwner.com

www.MotorTrend.com

www.AutoNews.com

www.Electrek.co

www.ConcreteConstruct

ion.net

www.Forbes.com

www.TruckNews.com

www.BigTruckMagazine.

com

www.DieselProgress.com (KHL) (was at booth at World Ag Expo: Chad Elmore,

chad.elmore@KHL.com) www.NewPowerProgress.com (also KHL, see above)

www.inc.com

www.ServiceTruckMagazine.com

www.CleanFleet Report.com

www.ElectricHybridVehicleTechnolo

gy.com www.EnergyDigital.com

www.GreenCarReports.com

Bloomberg Media (in booth at World Ag Expo:

- Dana Hull (Tesla stories) dhull12@bloomberg.net
- Ed Ludlow (EV News)

ELudlow2@bloomberg.net www.CALSTART.org

SECTION

APPENDIX F

Interview Intro

How long have you worked for Moonlight?

What Make, Model, Vintage truck do you usually drive? What is your usual usage, route, daily mileage, etc.?

How did it happen that you were the one to drive the demonstration truck? Were you chosen? Did you volunteer (if so, why)? Were you assigned to the truck?

Which truck number did you drive (or did you switch off)? How much did you know about the truck prior to driving it?

Were you encouraged or discouraged to drive the truck? What were you instructed to do?

When did you start driving the demo truck? How often did you drive it? What determined whether or not you drove it on any particular day?

How often did you drive the truck? Why didn't you drive it more?

What other vehicle(s) did you drive during the same period?

==========

Who trained you and how were you trained?

Do you think the training was adequate or would you suggest more time or information be provided?

==========

What did you like best about the truck (what attributes)?

What did you like least about the truck?

==========

Were you comfortable driving the truck?

How concerned were you to drive an expensive demonstration vehicle? Were you nervous?

How did it compare to your typical/other truck(s)?

Was the instrument panel understandable? Was it clear when the batteries were being charged? Did you have to pay attention to how low the battery charge was?

Was the reefer cold enough? Controls easy to operate and understand?

Were you concerned about the range limitations or the battery becoming depleted?

How did you know how much range was available and how cold the box was?

What is the ideal box temperature?

==========

Describe your charging routine. Was it adequately convenient? Did you always plug in both TRU and truck at same time? Did you ever forget to charge or experience a power outage?

Was the location of the charging station convenient?
How did the first version of the electric truck compare to the second version with integrated TRU? Did you notice a difference? What were those differences?
Were all your concerns about driving it addressed?
==========
Did you discuss the truck with others? Colleagues? Other drivers?
Do you think electric truck technology is a good idea?
==========
How long did it take to get used to driving the truck? What was the biggest difference between that truck and the one you usually drive?
Did your impressions/opinions change over the course of the project?
Any other feedback or suggestions you would like to offer?
Interview Outro

SECTION

APPENDIX G

Class 8 Trucks 1 & 2 - Operator's Quick Guide:

DRIVE:

ON:

1. Turn the **Master switch** '**ON**' as shown in the **pic1**.
2. Then turn the **Ignition switch** '**ON**' as shown in the **pic1**.
3. Press the **Brake pedal**.
4. Wait(30sec) Until the High Voltage system wakes up.
5. Display shows
6. Push the **Parking Brake** (see **Pic 2**) to release.
7. Turn on the inter-axle if necessary (this will enable 8-wheel drive), by pressing the inter-axle switch. (See **Pic 3**)
8. Press and hold the brake pedal then select/press Drive '**D**' button on the Gear Shift panel to move the vehicle. (See **Pic 4**)
9. Then the display shows '**Propulsion Enabled, Ready to drive'**.

Pic 1

Pic 2

Pic 3

REVERSE:

1. Push the **Parking Brake** (See **Pic 2**) to release.
2. Press and hold the brake and select/press Reverse 'R' button to move the vehicle. (See **pic 4**)

OFF:

1. Come to stop then press and hold the brake and select/press the Neutral 'N' button. (See **Pic 4**)
2. Pull the **Parking Brake** (See **Pic 2**) upwards.
3. Turn the Ignition switch '**OFF**'. (**Pic 1**)
4. Turn the Master switch '**OFF**'. (**Pic 1**)

Pic 4

CHARGE:

1. Make sure the Ignition switch and Master switch are '**OFF**' (**Pic 1**)
2. Make sure the Vehicle is completely turned '**OFF**' by looking at the light on Gear Shift panel. (**Pic 4**)
3. Insert the charger plug into the truck receptacle.

REMOVING CHARGE:

1. While in charge mode, go to truck cabin and press the thunder symbol on the gear panel for 3 seconds. (**Pic 4**)
2. Then wait for 1 minute until the vehicle completely shuts down.
3. Remove the charge plug from truck and return it to the station.

Class 8 Trucks – User/Training Manual Quick Guide:

DRIVE:

TURN ON SEQUENCE:

1. Turn Master and Ignition switch to the on position. (See pic 1)
2. Press brake pedal to initiate drive sequence.
3. Display will show ready to drive after 30 sec.
4. To start driving press and hold brake, release parking brake and select Drive or reverse on gear shift panel. (See pic 2)

Pic 1

TURN OFF SEQUENCE:

1. Come to a complete stop while holding brake press the Neutral 'N' button gear shift panel (See Pic 2)
2. Apply parking brake (See Pic 3)
3. If the reefer was turned on during drive, turn the Reefer off by pressing the OFF button on the Volta display. (See Pic 4)
4. Turn the Master and Ignition switch to the off position (See pic 5)

Pic 2

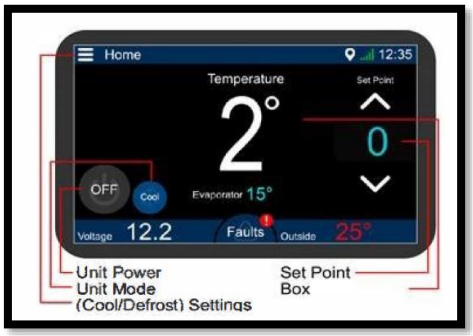
Pic 3

CHARGE:

START CHARGING:

1. Master and Ignition switch should be in the off position (See pic 5) *Note: (If vehicle has just been driven, please allow 1 minute after turning off sequence before starting charge sequence)*
2. Insert the Charge plug into receptacle.
3. State of charge should be displayed on main screen.

Pic 4



STOP CHARGING:

1. To stop charging press and hold the thunder bolt symbol on the gear shift panel for 5 seconds. (See pic 2)
2. Allow 1-2min for truck to completely shut down.
3. Remove the charge plug from truck and return it to the charging station.

Pic 5

Manual del Operador Para Camiones Clase 8

MANEJAR:

SECUENCIA DE ENCENDIDO:

1. Coloque los interruptores **'Master'** e **'Ignition'** en la posición de encendido 'ON' (Ver pic 1)
2. Presione el pedal de freno para iniciar la secuencia de manejo.
3. El tablero mostrara en la pantalla **'Ready to drive'** (Listo para manejar) después de 30 segundos.
4. Para comenzar a manejar seleccione **'Drive' (D)** o **'Reverse' (R)** en el panel de control de cambios. (Ver pic 2)

Pic

Pic 2

Pic 3

SECUENCIA DE APAGADO:

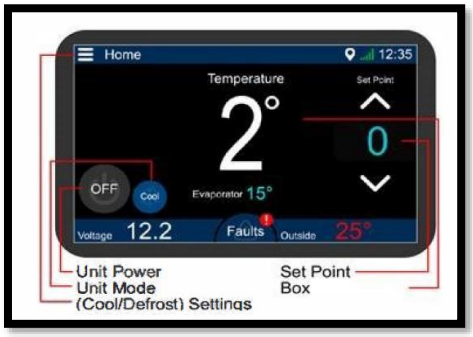
1. Detenga el vehículo por completo y mientras presiona el pedal de freno presione **'Neutral' (N)** en el panel de control de cambios. (Ver pic 2)
2. Presione el freno de mano. (Ver pic 3)
3. Si la unidad de refrigeración estuvo encendida durante el uso del camión entonces deberá apagarse presionando el botón OFF en la pantalla de la refrigeración. (Ver pic 4)
4. Coloque los interruptores **'Master'** e **'Ignition'** en la posición de encendido '**OFF'** (Ver pic 5)

CARGAR:

SECUENCIA PARA INICIAR CARGA:

1. Los interruptores **'Master'** e **'Ignition'** debe estar en la posición de apagado **'OFF'** (Ver pic 5) ***NOTA: Si va a cargar el camión después de manejar por favor de esperar un minuto después de la secuen_ cia de apagado antes de iniciar con la secuencia de carga.***
2. Conecte la pistola de carga en el enchufe del camión.
3. En la pantalla principal se podrá ver **'State of Charge'**, esto significa que la sesión de carga ha comenzado.

Pic 4



DETENER LA CARGA:

1. Para detener la sesión de carga presione por 5 segundos el botón Con el símbolo del **'Rayo'** en el panel de control de cambios (Ver pic 2)
2. Espere por 1 o 2 minutos a que el sistema del camión se apague completamente.
3. Desconecte la pistola de carga del camión y regrésela a su lugar en el cargador.

Pic 5