California Energy Commission

Final Report Presentation

27 October 2021

Port of Los Angeles Advanced Yard Tractor Deployment and ECO-FRATIS Drayage Truck Efficiency Project

THE PORT OF LOS ANGELES

California Energy Commission Alternative and Renewable Fuels and Vehicle Technology Program

Final Report Presentation

City of Los Angeles Harbor Department: ARV-15-069

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Project Overview

CEC Funding $5,833,000
Project Partner Match Funds $2,808,007

ECO-FRATIS Drayage Truck Efficiency Project

Everport Terminal Services (Everport)

- 20 LNG yard tractors
- 5 battery-electric yard tractors

Cumulative Budget Expenditures

Project Budget Overview

Task No.	CEC Budget	Match Funding Budget	CEC Cumulative Expenditure	Match Cumulative Expenditure
1.0	$0	$0	$0	$0
2.0	$4,863,000	$0	$4,863,000	$0
3.0	$970,00	$434,007	$843,420.61	$454,264.81
4.0	$0	$2,374,000	$0	$3,481,232.69
Total	**$5,833,000**	**$2,808,007**	**$5,706,420.61**	**$3,935,497.50**

Project Purpose

To address high GHG and criteria and toxic pollutant emissions from on- and off-road vehicles that operate in and around the Port of Los Angeles.

Technologies demonstrated include:

- An Intelligent Transportation Systems and Technologies (ITS) project that integrated two established systems, FRATIS and Eco-Drive.
- Engines certified to the optional low-NOx standard (0.02 gm/bhp-hr) fueled by renewable liquefied natural gas (RNG).
- Zero-emission battery-electric yard tractors.

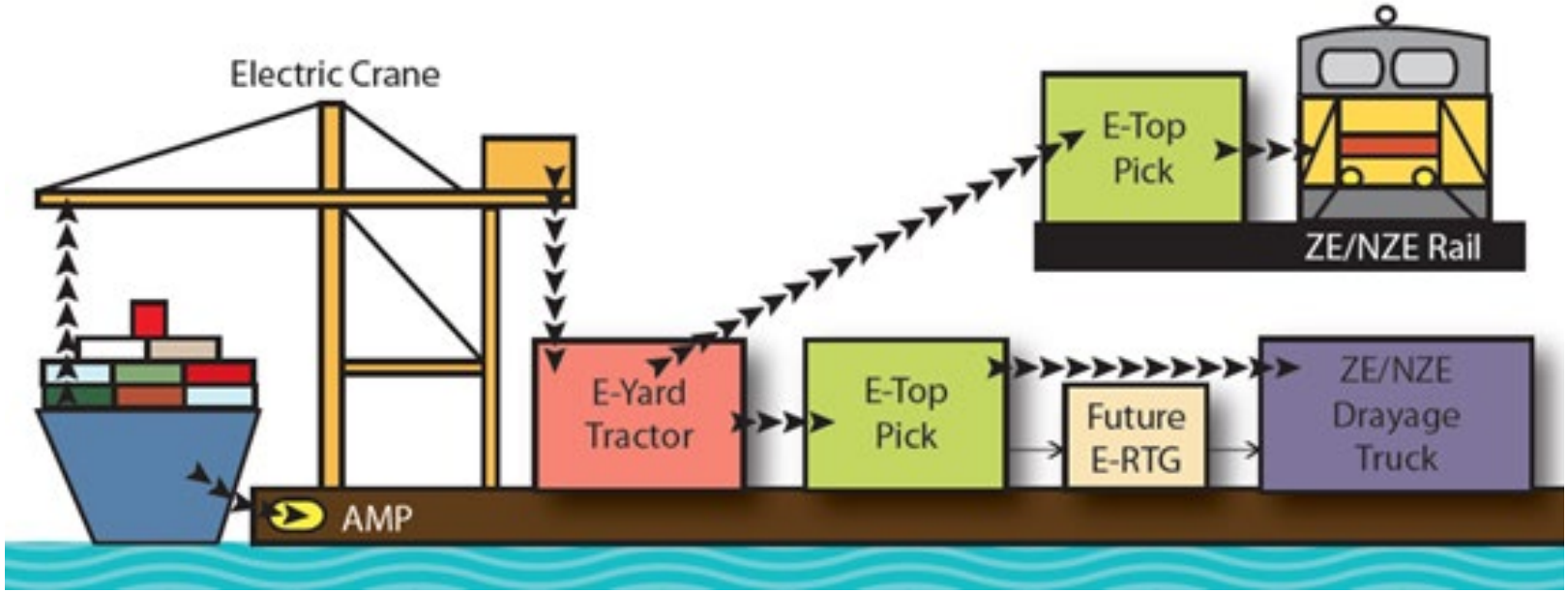
Project Goals and Objectives

Accelerate market acceptance of ITS, near zero-emission, and zero-emission technologies, while achieving measurable reductions in port equipment and diesel fuel consumption and emissions.

Specific measurable objectives include:

- Deployment of an integrated ITS system to reduce fuel consumption by trucks, reduce freight related emissions, increase driver productivity defined as number of orders/truck, reduce unproductive (bobtail) travel time, and decrease waiting time at marine terminals.
- Document displacement of petroleum diesel fuel, measured as amount of diesel gallons saved as a result of the ITS technology suite utilization.
- Design, build, and demonstrate 20 low-NOx (near-zero) emission and 5 zero-emission battery-electric yard tractors.
- Design, build, and demonstrate RNG fueling and electric charging infrastructure.
- Document significant reduction in GHG and criteria pollutant emissions.
- Document energy costs and the reduction in petroleum fuel consumption.

Zero-Emissions Pathway Concept



Advanced Yard Tractor Deployment Project Overview

This project was developed to aid marine terminal operators interested in adopting advanced cargo handling equipment technology to assess and overcome key obstacles that inhibit the deployment of advanced yard tractor technologies, including:

- Marine terminal operator uncertainty regarding advanced technology yard tractor performance. (Can it do the job?)
- Current "price premium", i.e., the incremental cost of alternative fuel and battery-electric vehicles as compared to conventionally-fueled vehicles.
- Lack of experience and knowledge in marine terminal industry regarding operation, refueling, and maintenance of advanced technology cargo handling equipment.

Advanced Yard Tractor Deployment Demonstration Fleet

Capacity Trucks RNG Yard Tractors

- Capacity planned, designed and fabricated 20 yard tractors equipped with Cummins 8.9L low-NOx RNG engine for demonstration at Everport.
- Designed to operate with range, lifting capacity, and maximum speed requirements comparable to diesel-powered terminal tractors, except for the change from diesel to RNG fuel.

BYD Battery-Electric Yard Tractors

- BYD planned, designed and fabricated 5 yard tractors equipped with BYD's battery-electric propulsion system.
- Designed to operate with range, lifting capacity, and maximum speed requirements comparable to diesel-powered terminal tractors, except for the accommodation for overnight charging.

Capacity: Design Challenges

- RNG storage tank required a 154-inch wheelbase.
- Fuel tank occupied all frame space on left side of truck, interfering with ingress/egress.
- Cooling system design, coolant and air pipe routing, fuel system mounting, fuel tank rub protection, and tailpipe support provisions required modifications.

BYD: Design Challenges

- Safety issue related to weight distribution at power take-off (PTO) ramp interfering with bomb cart at kingpin and area around 5th wheel, causing front wheels to lift off the ground.
- Safety issue related to door hydraulics, temporarily trapping operator inside cab.
- Structural issues with steel plate covering drive motor, exposing electrical cables, resulting in structural collapse of battery bank support.
- Additional safety modifications including 5th wheel support brackets, breakaway glad hands, and Emergency Exit stickers for front windshields.

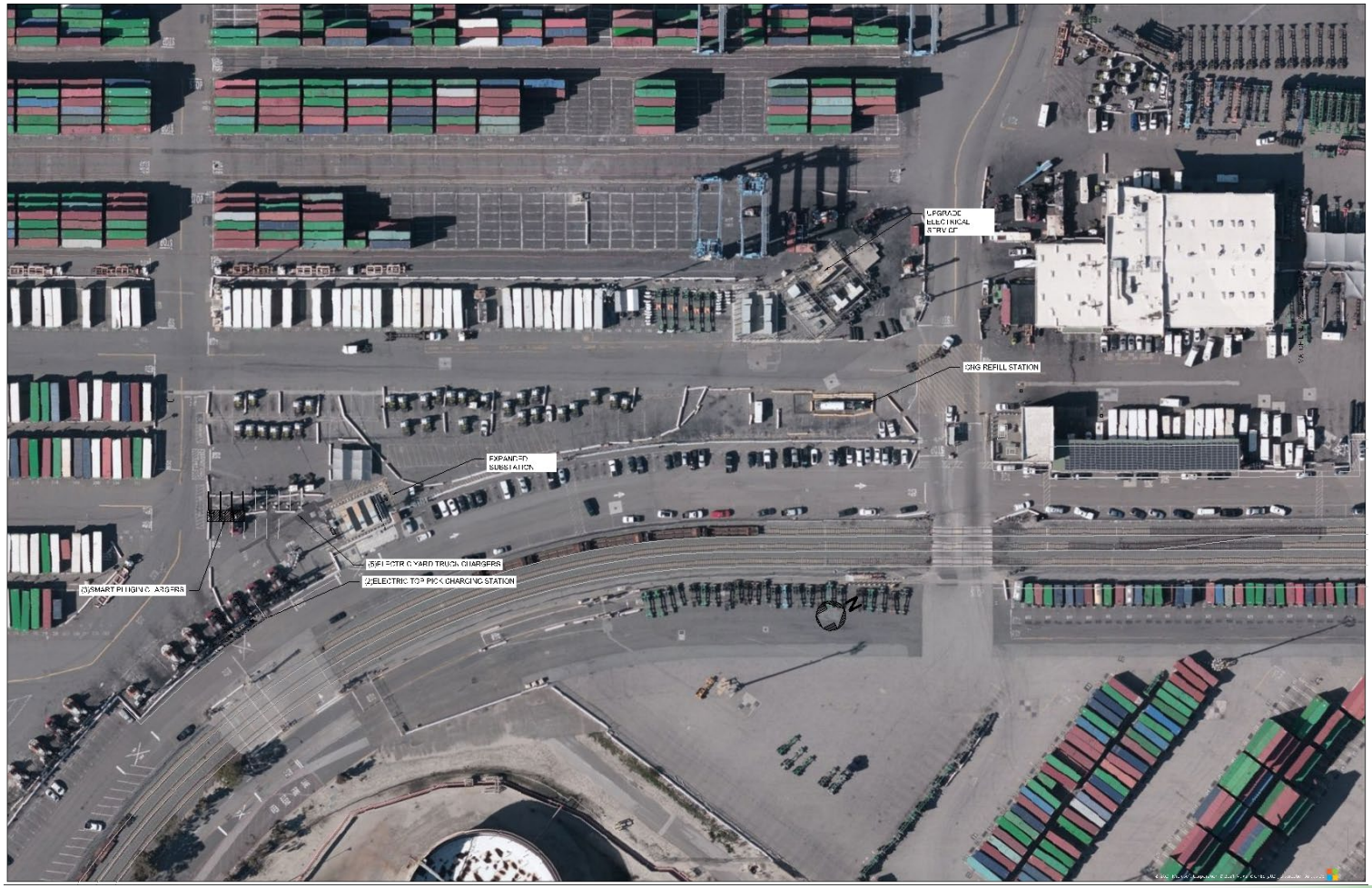
Note: This project demonstrated BYD's First-Generation battery-electric yard tractors. As of 2021, BYD is in production of Third-Generation yard tractors, which addresses many of these early design issues.

Infrastructure

Infrastructure for two alternative fuels was required to support demonstration fleet.

- Clean Energy Fuels provided RNG for Capacity low-NOx yard tractors.
- BYD and POLA coordinated installation of 5 BYD chargers to support battery-electric yard tractors.

Everport Terminal Construction Site Plan



RNG Yard Tractor Fueling Infrastructure

- Clean Energy designed and built a temporary fueling skid, referred to as the "Harpoon".
- Harpoon is an RNG storage tank mounted on a trailer chassis to allow movement to multiple locations.
- Harpoon includes all equipment: pumps, controls, electronics, and safety systems.
- Harpoon is designed with an integrated secondary containment for RNG spills, so that external secondary containment is not required.

RNG Yard Tractor Fueling Infrastructure Challenges

- Everport originally envisioned wet-hose fueling, but local permitting challenges did not allow it, leading to Harpoon design.
- Designed for movement, permitting restrictions required that the Harpoon remain stationary.
- All Harpoon components were third-party certified and Harpoon was used successfully at several other locations. Yet unit as a whole could not be permitted by LADBS. Significant effort undertaken by Clean Energy, at their cost, to certify Harpoon as a system.
- Significant costs incurred for site modifications such as berms, barriers and signage to satisfy other permitting requirements.

Battery-Electric Yard Tractor Charging Infrastructure

- Five BYD 100 kW high power 3-phase AC charging platform.
- Site location for the electric vehicle supply equipment (EVSE) was based on the facility's electrical power supply locations, yard operations, traffic flow, and safety considerations.
- BYD proprietary charging plug configuration.

Battery-Electric Yard Tractor Charging Infrastructure Challenges

- Challenges obtaining LADBS permit.
- Chargers and components not UL listed.
- BYD R&D made design changes to fulfill identified UL and other safety standard requirements, purchased all materials, provided labor, and hired contractors to perform charger modifications on-site.
- Chargers installed May 2018. Final permit issued February 27, 2020.

Capacity: Operational Experience

- Longer wheelbase design caused challenges with turning radius. Measurement: RNG 154”; battery-electric 114”; diesel 114”.
- Coriolis meter on Harpoon needed to be replaced. Repaired and operational in two weeks.
- Oil leaking into the coolant reservoir on some units. Repaired under warranty and pro-actively replaced on all twenty units.
- Modified all units with a redesigned fan shroud, fan blades, and stainless-steel oil coolers.
- Without wet-hose fueling, time intensive process taking 10-15 minutes per yard tractor (200-300 minutes to fuel entire fleet). Reduced operational duty-cycle.

BYD: Operational Experience

- Weight distribution causing front wheels to lift off ground when pulling a load of 52,365 lbs. Terminal sidelined the tractors.
- Air bag deployment and door hydraulics that trapped a longshoreman inside the cab, posing a serious safety issue and “red-tagging” all five units (i.e., removing them from service.
- Additional safety modifications requested. 5th wheel support brackets, installation of breakaway glad hands, and placement of Emergency Exit signage.
- Approach plate and integrity of structural assembly. Kingpin hitting metal as it extended, bending and cutting steel plate covering drive motor until it broke off entirely, exposing electrical cables, and in one case, resulting in structural collapse of battery bank support frame.

BYD: Operational Experience (cont.)

Weight Distribution / 5th Wheel

March 11, 2020

Upon deployment, issue with weight distribution causing front wheels to lift off ground when pulling a load of 52,365 lbs. Terminal sidelined the tractors.

Determination: PTO ramp was interfering with bomb cart and area around 5th wheel. 5th wheel resting height was slightly lower than side rail top surfaces, causing trailer's weight to partially rest on frame rail, triggering kingpin-5th wheel joint to seize.

Resolution: Reduce height of side rails by one inch to create a sufficient gap between bottom of trailer and top of frame rail. Replace top plate with a heavier-duty steel plate. Cut off a portion of beaver tail to reduce length.

Return to Service: June 8 - June 26, 2020.
Due to COVID-19 Stay at Home Orders, BYD's factory closed on March 20, 2020, began a staggered reopening on May 18, and resumed full operational status on June 8.

BYD: Operational Experience (cont.)

Door Hydraulics

August 6, 2020

An incident occurred involving air bag deployment and door hydraulics that trapped a longshoreman inside the cab, posing a serious safety issue and "red-tagging" all five units.

Determination: When air was depleted in cab air suspension, the cab position dropped too low, causing sliding door frame to sit on battery protective panel.

Resolution: Adding one 20 millimeter (mm) cab spacer and one 5mm cab spacer to cab support bracket, which created a 10 mm to 15 mm gap between door rail and battery protective panel.

Return to Service: November 2020 - March 2021.

BYD: Operational Experience (cont.)

Safety Modifications

September 2020

While the door hydraulics were being repaired, Everport requested additional safety modifications.

Determination: Retrofit units with safety modifications.

Resolution: Installation of 5th wheel support brackets, installation of breakaway glad hands, and placement of Emergency Exit signage and instructions on front windshield (these UTRs do not have usual side door emergency exit).

Return to Service: November 2020 - March 2021.
These modifications began late September 2020, but took some time to complete, due to lack of availability for 5th wheel support brackets and breakaway glad hands for all 5 vehicles. Lead-times were adversely impacted by COVID-19 pandemic.

BYD: Operational Experience (cont.)

Approach Plate Assembly and Wiring

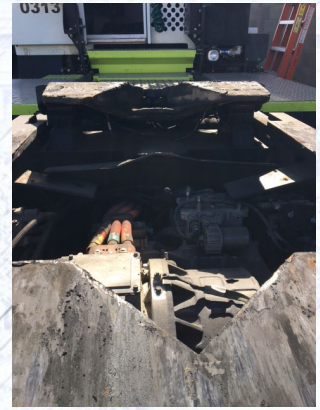
March 2021

Two units experienced issues with approach plate and integrity of structural assembly. Kingpin hitting metal as it extended, bending and cutting steel plate covering drive motor until it broke off entirely, exposing electrical cables, and in one case, resulting in structural collapse of battery bank support frame.

Determination: Ongoing.

Resolution: Ongoing.

Return to Service: All five units remain at BYD Lancaster facility.



Demonstration Results

- RNG yard tractor fleet accrued a total of 17,681 hours of operation.
- Battery-electric yard tractors accrued a total of 336 hours of operation.
- Challenges with battery-electric vehicle data loggers persisted until final month of demonstration.
- Lower than anticipated operational hours reduced expected outcomes.
- Review of RNG fuel purchase records indicated a disconnect between observed fuel economy during demonstration and actual fuel purchased by Everport for its RNG fleet.

Duty Cycles

The project objective was to demonstrate advanced technology yard tractors that would perform identically to a typical diesel-powered yard tractor. Range, lifting capacity, and maximum speed requirements were comparable to diesel-powered terminal tractors.

Specifically, the following minimum duty cycle performance metrics were targeted:

- One 8-hour shift (no opportunity charging/fueling assumed)
- Two 8-hour shifts with opportunity charging/fueling
- 70,000 freight load capacity (loaded container plus chassis)
- 25 mph at 0% grade
- Gradeability at vehicle launch: 20% grade at 81,000 GCW
- Gradeability at vehicle launch: 15% grade at 81,000 GCW

GHG and Criteria Pollutant Reductions for the RNG Yard Tractors

Scenario	CO2e (tons)	CO2e (metric tonnes)[5]	DPM (tons)	$PM_{2.5}$ (tons)	NOx (tons)	HC (tons)	SO_2 (tons)
Originally projected emission reductions (based on 1,816 hours operation per unit, 36,320 total fleet hours)	263	238	0.084	0.076	3.67	-7.49	0.023
Estimated emission reductions based on actual hours of operation (17,681 RNG yard tractor hours)	128	116	0.041	0.037	1.79	-3.65	0.011

1 short tonne = 0.907185 metric tons

GHG and Criteria Pollutant Reductions for the Zero-Emission Yard Tractors

Scenario	CO2e (tons)	CO2e (metric tonnes)	DPM (tons)	$PM_{2.5}$ (tons)	NOx (tons)	HC (tons)	SO_2 (tons)
Originally projected emission reductions (based on 1,816 hours of operation per unit, or 9,080 total fleet hours)	554	503	0.021	0.019	0.931	0.07	0.006
Estimated emission reductions based on actual hours of operation (336 zero-emission yard tractor hours)	21	19	0.0008	0.0007	0.0346	0.0025	0.0002

Diesel Fuel Displacement Calculation

Calculation Step	Value	Units
Diesel yard tractor fleet (865 units @ 1,816 hours each) total annual CO2e metric tonnes per POLA 2014 Emissions Inventory, Table 5.6	79,274	metric tonnes/year
Convert to short tons CO2e (1 short ton = 0.907185 metric tonne)	87,385.6	tons/year
Calculate tons CO2e per hour (divide total tons by 865 units and 1,816 hours)	0.0556	tons/hour of diesel operation
Convert to pounds per hour (multiply by 2,000 pounds per ton)	111.3	pounds/hour of diesel operation
Apply CO2e Emissions Coefficient for diesel (22.46 pounds of CO2e per gallon of diesel) to calculate the gallons per hour of a baseline diesel yard tractor.	4.95	diesel gallons/hour
Multiply gal/hr by 17,681 total RNG yard tractor hours of operation to estimate the reduction in diesel fuel consumption for the demonstration from the operation of 20 RNG yard tractors.	87,586	diesel gallons
Multiply gal/hr by 336 total battery-electric yard tractor hours of operation to estimate the reduction in diesel fuel consumption for the demonstration from the operation of five (5) battery-electric yard tractors.	1,668	diesel gallons
Total gallons displaced during this demonstration (sum the RNG and battery-electric diesel gallons displaced)	89,254	diesel gallons

Diesel Fuel – Baseline Fuel Cost Estimate

- Everport reported the weighted average price for diesel fuel purchased during the demonstration was $2.69 per gallon.
- EI-derived diesel fuel economy: 4.95 gallons/hour
- Hourly cost per diesel gallon consumed:
  - $2.69 /gal * 4.95 gal/hr = $13.32 / hour

RNG Estimated Equivalent Fuel Cost

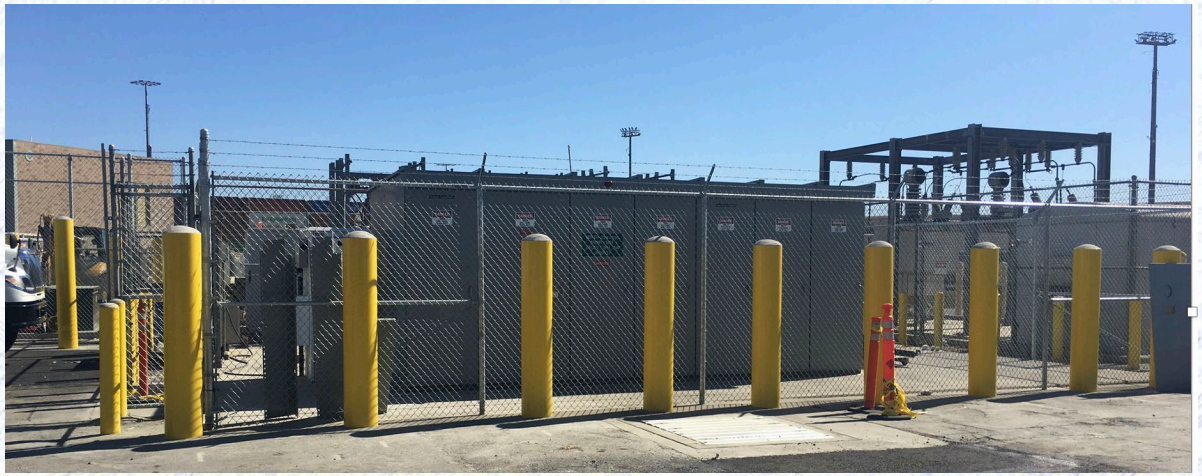
- Per Clean Energy invoices, Everport paid $507,239 for 134,966 DGE, or $3.76/DGE
- 22 units consumed RNG during this time, for a total of 18,475 hours of operation (17,681 hours for our project and 1,064 for the other 2 units).
- 134,966 DGE / 18,475 hours = 7.3 DGE / hour*

  * Based on internal fueling metrics, Capacity and Everport assert that actual fuel consumption at the unit is lower:

  - Capacity: 2.51 DGE / hour
  - Everport: 1.9 DGE / hour
- At $3.76 per DGE, the hourly cost to operate the RNG based on actual Clean Energy invoices was **$27.45 per operating hour**.
- Additionally, electricity to run the Harpoon averaged 483 kWh per month, costing a little over $100 per month.

Zero-Emission Estimated Equivalent Fuel Cost

- 336 hours of operation consumed 6,533 kWh of electricity during the limited battery-electric demonstration
- Everport utility invoices indicate an average of $0.21225 / kWh
- $ 0.21225 / kWh * 6,533 kWh = $1,386.63 for a total cost to operate 336 hours, or **$4.13 per operating hour**.



Operator Surveys

Operator surveys were conducted for RNG yard tractors. Nearly every survey category indicated RNG yard tractors as the same or better than diesel counterparts.

Positive approval for the following:

- Ten operators categorized decreased noise inside the cab as "better."
  - "Cleaner, quieter, nicer."
  - "Less fumes, ride quality."
- Ten operators categorized smoothness of shifting during acceleration as "better."
- Braking and ride comfort.

Areas for improvement include:

- Nine operators categorized maneuverability to be "worse" than diesel counterpart.
- Six operators commented on tripping hazard with cab entry and exit rating "worse."

As a result of so few operating hours for BYD units, operator surveys were not conducted for battery-electric units.

Lessons Learned

- Statewide training for inspection entities to familiarize and standardize requirements.
- Field certification of infrastructure is a time-consuming process. If possible, factory certify eligible components, as well as whole systems.
- There were also significant costs incurred for site modifications such as berms, barriers and signage to satisfy permitting requirements that were not considered in the original scope; future projects should plan for permitting requirements that will add unexpected project costs and schedule impacts.
- Equipment utilizing proprietary charging does not provide flexibility over time. Movement towards standardized charging is essential to equipment integration for continued operational use.
- OEMs familiar with producing equipment utilized in terminal operations are better prepared to produce advanced technology equipment for terminal operations.
- Appropriately integrated data collection tools provide more reliable robust data than manually reporting data, which is outside of a terminal's normal operations. Third-party data collection and analysis recommended.

Closing

The in-service demonstration of both the advanced yard tractor and ITS projects provided real-world operating experience with low- and zero-emission technology in yard tractors and advanced freight information system applications for drayage trucks. The objective of this project was to successfully demonstrate and enhance market acceptance of these advanced yard tractor technologies, as well as advanced freight information system applications for drayage trucks. The demonstration resulted in petroleum fuel reduction and significant GHG and criteria pollutant emissions reductions. Although the project experienced challenges, the team views these challenges as opportunities for investigation and development of advanced technology applications, providing positive advancement towards achieving petroleum consumption and emissions reduction goals.

Thank You!

Questions?