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Port of LONG BEACH
THE GREEN PORT

THE PORT OF LOS ANGELES

SAN PEDRO BAY PORTS

CLEAN AIR ACTION PLAN

2023 ANNUAL REPORT AND 2024 PRIORITIES

Technology Advancement Program

17 Years of Progress Moving Towards Zero Emissions

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- Marc Perry, California Energy Commission
- Mei Wang, South Coast Air Quality Management District

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Acronyms & Abbreviations

AC	Advisory Committee or alternating current
ACTI	Advanced Cleanup Technologies Incorporated
AMECS	Advanced Maritime Emissions Control System
APL	Shipping line formerly known as American President Line
APT	Advanced Petroleum Technologies, Inc.
BET	battery electric truck
BEV	battery-electric vehicle
BMS	battery management system
CAAP	Clean Air Action Plan
CAMS	control alarm monitoring system
CARB	California Air Resources Board
CEC	California Energy Commission
CHE	cargo-handling equipment
CNG	compressed natural gas
CO_2	carbon dioxide
COVID-19	Coronavirus Disease 2019
DOC	diesel oxidation catalyst
DOE	United States Department of Energy
DPF	diesel particulate filter
EVSE	electric vehicle supply equipment
GHG	greenhouse gases
HP	horsepower
kW	kilowatt
kWh	kilowatt-hours
LNG	liquefied natural gas
MW	megawatt
NO_x	oxides of nitrogen
OGV	ocean-going vessel
PHEV	plug-in hybrid electric vehicle
POLA	Port of Los Angeles
POLB	Port of Long Beach
PM	particulate matter
RFI	Request for Information
RTG	rubber-tired gantry crane
SPS	Smart-Plug System
South Coast AQMD	South Coast Air Quality Management District
TAP	Technology Advancement Program
USEPA	United States Environmental Protection Agency
ZE	zero emission

1 INTRODUCTION

The Ports of Long Beach and Los Angeles (Ports) comprise one of the world's premier seaport complexes and are recognized as global leaders in environmental stewardship. The 2017 Clean Air Action Plan Update (CAAP), jointly approved by both Ports, calls for aggressive strategies to reduce pollution and greenhouse gases and to ultimately transition to zero emissions. Development and deployment of new technologies are critical to the success of these strategies, and the Ports, in partnership with numerous stakeholders, have embarked on an unprecedented effort to hasten this transformation.

The Technology Advancement Program (TAP), is at the cornerstone of this clean-air effort. The TAP was initiated in 2007 to facilitate the development and demonstration of clean technologies to support the original CAAP goals. The TAP is a funding program that relies heavily on partnerships with private industry and technology developers as well as strong relationships with regulatory agencies that actively participate as members of the TAP Advisory Committee to evaluate technology projects, support the commercialization of these nascent technologies, and help leverage funds. The TAP funds pilot testing and real-world demonstrations of emerging (i.e., pre-commercial) emission-reduction technologies for Port-specific mobile sources, including ocean-going vessels, locomotives, cargo handling equipment, harbor craft, and heavy-duty truck infrastructure, with a focus on zero-emission technologies. Since inception, the TAP has undertaken more than 50 projects spanning test cycle development, hybrid and alternative fuel technology demonstrations, and zero-emission equipment deployment.

To achieve the scale of technology development required for a zero-emission transformation, the Ports have expanded beyond the TAP, making significant investments in larger scale clean-equipment deployments at specific terminals and logistics centers, benefiting from local, state, and federal grant funds. These projects have allowed the Ports to test near-zero and zero-emission technologies on a larger operational scale and to test multiple types of equipment – cargo-handling equipment, locomotives, harbor craft, and ships – at a single location, replicating the real world. Lastly, the Ports have partnered with other agencies on technology demonstrations to maximize resources and to support regional efforts to reduce port-related emissions, even beyond port boundaries, such as drayage truck demonstrations.

These various approaches – the TAP, grant-funded demonstrations, and cost-sharing partnerships with other agencies – comprise the Ports' technology advancement portfolio, and this multi-pronged investment strategy has enabled the Ports to leverage dollars, engage more stakeholders, and diversify their technology projects. Since 2007, through these combined efforts, the Ports and their partners have invested just over $475 million in technology advancement. These efforts are summarized in Section 5 of this Technology Advancement Annual Report in order to showcase the breadth and scope of the increasing emphasis on clean technology development and implementation in port operations.

This TAP Annual Report focuses only on pre-commercial technology advancement, which is one aspect of the CAAP. For additional detail regarding the Ports' significant investments to deploy commercialized equipment and technologies, please refer to the CAAP Progress Reports found at *www.cleanairactionplan.org.*

Significant Events in 2023

In 2023, the Ports continued to recover from the COVID-19 pandemic. Technology demonstration projects that had been delayed during the pandemic resumed and some were completed. The global supply-chain disruptions and record cargo volumes from the year prior began to ease in 2022, returning the Ports to a steady state of higher, but manageable, activity. Rising cargo volumes have stressed terminal equipment and trucks to their performance limits, highlighting the need to rethink the performance expectations of zero-emission equipment; equipment that was adequate pre-disruption now needs to run for longer hours at a higher use intensity, which changes the technology performance expectations. These new expectations are shaping future TAP demonstrations to ensure that clean equipment and vehicles can perform at the highest levels, under all conditions.

Meanwhile, in 2023, the California Air Resources Board (CARB) began to mandate cleaner harbor craft and drayage-truck fleets. These regulations provide a clear path forward for port operators. The Ports can focus on technologies likely to be acceptable under these new regulations and forgo projects unlikely to align with CARB's vision. For harbor craft, CARB is requiring Tier 4 engines with diesel particulate filters as a near term requirement with bonus credit for zero-emission vessels; anything less than these technology platforms is not a good investment of TAP funds. Likewise, CARB has clearly signaled its intent to require zero-emission drayage trucks with promulgation of the Advanced Clean Fleets Regulation, obviating the need for demonstrations of combustion platforms. Conversely, the need to comply with the At-Berth Regulation, which went into effect in 2021, still requires substantial new technology development over the next five years. As such, the Ports and their partners may play an important role in helping these technologies come to fruition.

In 2023, the State and Federal governments continued prioritize funding for port infrastructure and clean technologies, including investment in heavy-duty, port-related equipment and vehicles. This funding will support the deployment of commercialized zero-emission trucks and cargo-handling equipment as well as new technology demonstrations. For example, the California State Transportation Agency awarded nearly $1.2 billion in grant funding in 2023 under its Port Freight and Infrastructure Program. With zero-emission equipment poised to enter the market as a result of State mandates, there is opportunity to identify performance gaps in early commercial cargo-handling equipment and to target TAP resources toward solutions. However, State incentives have begun to wane with implications for limiting future funds available for technology advancement. Looking ahead, there may be a greater reliance on federal programs for the deployment of commercialized technologies and technology advancement projects. Meanwhile, the TAP may be able to leverage funds for new demonstrations of cleaner off-road equipment, including locomotives and ships.

Looking Ahead

The Ports are committed to the goals set forth in the 2017 CAAP Update, particularly the push to transition terminal equipment to zero-emission technologies by 2030 and the truck fleet to zero-emission technologies by 2035. The volume of commercialized zero-emission trucks servicing the Ports is expected to increase in 2024, but there are still gaps in charging and hydrogen fueling infrastructure as well as a need for better understanding of large-scale zero-emission operations and performance requirements for vehicles and equipment. There is more work to be done on ocean-going vessel technologies and harbor craft in support of newly implemented and upcoming regulations. On a positive note, the technology pathways for trucks and cargo-handling equipment are becoming clearer. Given the significant levels of State and Federal funding available in the near term, and the collaborative framework already in place, the TAP can focus its resources on projects aligned with the CAAP's vision. In time, as more clean technologies become commercialized, the role of the TAP may increasingly narrow, and at some point, may no longer be necessary. At that point, the Ports can shift resources away from technology advancement and toward implementation.

Agency Partnerships

Project selection is supported by the TAP Advisory Committee (AC), comprised of the South Coast AQMD, California Air Resources Board (CARB), California Energy Commission (CEC), and United States Environmental Protection Agency (USEPA), Region 9. A list of current AC members is included in Appendix A. The AC serves in an advisory capacity to Port staff for screening, evaluating, and recommending projects that merit further development or demonstration. In addition, the AC members provide information as it pertains to co-funding from their agencies that could be used to move projects toward implementation.

2 TECHNOLOGY ADVANCEMENT ACCOMPLISHMENTS IN 2023

In 2023, the Ports continued to implement technology advancement projects, the updates for which are documented herein. Major accomplishments in 2023 include:

- Completed the Port of Los Angeles Everport Advanced Cargo Handling Equipment Demonstration Project (Section 5.3)
- Completed the Nett Technologies Inc. BlueMAX™ NOVA 320e Harbor Craft Demonstration (Section 5.4)
- Completed the Port of Los Angeles Shore to Store Demonstration Project (Section 5.12)
- Completed the Port of Long Beach Zero-Emission Terminal Equipment Transition Project (Section 5.15)
- Initiated the Crowley Electric Tug Project (Section 5.2)
- Initiated the Pacific Harbor Line Zero-Emission Locomotive Demonstration (Section 5.5)
- Initiated the SSA Marine H2 Fuel Cell Top Handler Development and Demonstration Project (Section 5.9)
- Initiated the South Coast AQMD Ocean-Going Vessel Low-Pressure Exhaust Gas Recirculation Retrofit (LP-EGR), Polar Bear Pilot Vessel Conversion (Section 5.11)
- Continued to demonstrate pre-commercial zero-emission equipment and vehicles throughout each port by leveraging port and tenant resources with state and federal funding. These ongoing demonstrations are providing valuable project data and "lessons learned" to inform deployment once these technologies have been commercialized.
- Finalized the 2021 Update to the CAAP Feasibility Assessment for Drayage Trucks[1].
- Updated the TAP Guidelines to reflect new regulations that drive the Ports and their tenants toward zero-emission operation.
- Updated the TAP website[2] to assure transparency and enhance communication of technology results, as well as to provide resources for any parties including Port stakeholders interested in the TAP.

Table 1 provides an overview of active 2023 technology advancement projects, including those funded through the TAP, cost-sharing with other agencies, and large-scale grant-funded demonstrations. Section 5 provides a detailed status update for each of these projects, including specific accomplishments in 2023 and projected milestones for 2024 Projects presented in bold font indicate completion in 2023.

Table 1: 2023 Technology Advancement Project Snapshot

Project Title	Project Description	Section	Technology
Advanced Infrastructure Demonstration Project (Port of Los Angeles)	Design and demonstrate inductive charging infrastructure to support opportunity charging for 10 battery-electric yard tractors.	Section 5.1	Zero Emission
Crowley Electric Tug Project (Port of Long Beach)	Design and build a battery-plug-in hybrid tugboat capable of 90 tons bollard pull for ship assist and harbor work. A key deliverable of this project is for this tug to be approved by CARB as a Zero-Emission	Section 5.2	Zero-Emission Capable

[1] *https://cleanairactionplan.org/strategies/trucks/*
[2] *http://www.cleanairactionplan.org/technology-advancement-program/*

Project Title	Project Description	Section	Technology
	Advanced Technology (ZEAT) tug under the recently amended Commercial Harbor Craft (CHC) regulation. This will require the vessel to be capable of providing a minimum of 3% of vessel power required for main propulsion and auxiliary power operation with zero tailpipe emissions when averaged over a calendar year.		
Everport Advanced Cargo Handling Equipment Demonstration Project (Port of Los Angeles)	**Develop and demonstrate three battery-electric yard tractors powered by a smart charging system and two battery-electric top handlers.**	**Section 5.3**	**Zero Emission**
Nett Technologies Inc. BlueMAX™ NOVA 320e Harbor Craft Demonstration (Port of Long Beach)	**Design, manufacture, and verify the BlueMAX™ NOVA 320e. This emissions control system consists of a combined active diesel particulate filter with upstream diesel oxidation catalyst (DOC) in front of a selective catalytic reduction system with ammonia slip catalyst.**	**Section 5.4**	**Tier 4, Cleanest Available**
Pacific Harbor Line Zero-Emission Switcher Locomotive Demonstration Project (Port of Long Beach)	Design and demonstrate a zero-emission switcher locomotive and associated charging infrastructure.	Section 5.5	Zero Emission
Pasha Green Omni Terminal Demonstration Project (Port of Los Angeles)	**Develop and demonstrate two battery-electric yard tractors and two battery-electric on-road trucks; three 21-ton electric repowered forklifts; a microgrid with battery storage capability tied to a rooftop solar array; and a land-based ship emissions capture and treatment system.**	**Section 5.6**	**Zero Emission and Other Platforms**
Pasha Hawaii Ohana Class LNG-Powered Container Ships Project – Two New Builds (Port of Los Angeles)	Design and build two Ohana class vessels powered with internal combustion dual-fuel (LNG & diesel) propulsion technology to facilitate the primary use of cleaner burning LNG. AMP capability included. These propulsion engines will meet Tier III standards.	Section 5.7	LNG
Pasha Horizon C9 Vessel LNG Engine Repower Demonstration Project (Port of Los Angeles)	Repower one C9 class vessel from steam turbine power to internal combustion dual-fuel (LNG & diesel) technology to facilitate the primary use of cleaner burning LNG and provide a significant engine efficiency increase. AMP capability will also be included in this repower. These propulsion engines will meet Tier III standards.	Section 5.8	LNG
SSA Marine H2 Fuel Cell Top Handler Development and Demonstration Project (Port of Long Beach)	Design, manufacture, and demonstrate two hybrid hydrogen fuel cell top handlers.	Section 5.9	Zero Emission

Project Title	Project Description	Section	Technology
South Coast AQMD Zero-Emission Cargo Transport (ZECT) II Demonstration	ZECT II encompasses the development of seven drayage trucks by five different contractors and includes PHEV, BEV and fuel cell technology.	Section 5.10	Zero Emission
South Coast AQMD Ocean-Going Vessel Low-Pressure Exhaust Gas Recirculation Retrofit (LP-EGR), Polar Bear Pilot Vessel Conversion	Retrofit two OGVs with emissions reduction technology including (1) Low-Pressure Exhaust Gas Recirculation, and (2) multiple fuel flexible injection platform with a gas supply system.	Section 5.11	OGV Retrofit
Shore-to-Store Project (Port of Los Angeles)	**Develop and demonstrate 10 hydrogen-fuel-cell Class 8 trucks, build two heavy-duty hydrogen fueling stations, and demonstrate two electric yard tractors at the Port of Hueneme and electric forklifts at Toyota warehouses.**	**Section 5.12**	**Zero Emission**
Sustainable Terminals Accelerating Regional Transformation (START) Project (Port of Long Beach)	Demonstrate more than 100 pieces of zero-emission terminal equipment and trucks at three California seaports, develop a battery-hybrid electric tugboat, deploy two ships with some of the cleanest available engines, and advance workforce development programs to support sustainable goods movement.	Section 5.13	Zero and Near-Zero Emission
Toyota Tsusho Hydrogen Top Handler and Mobile Hydrogen Refueler Project (Port of Los Angeles)	Demonstrate the repower of a diesel top handler and develop and deploy a “mobile” hydrogen refueler to support the demonstration.	Section 5.14	Zero Emission
Zero-Emission Terminal Equipment Transition Project (Port of Long Beach)	**Repower nine RTG cranes for full-electric power, demonstrate 12 zero-emission yard tractors and two smart charging systems, and convert four LNG trucks to plug-in hybrid electric trucks with LNG range extender.**	**Section 5.15**	**Zero and Near-Zero Emission**

Please access additional information for completed TAP projects at the program website: *http://www.cleanairactionplan.org/technology-advancement-program/*

3 PROGRESS TOWARD ZERO EMISSIONS

As summarized in Table 1 and detailed in Section 5, the Ports continued their strong commitment to zero-emission technology development and demonstration. In 2023, the Ports led or supported 16 major zero-emission demonstration projects valued at just over $365 million in funding from the various project team members (including public and private match funding). These efforts have made San Pedro Bay Ports the hub of technology advancement for heavy-duty equipment with the world's highest concentration of zero-emission trucks and terminal equipment in a single port complex. This report covers major zero-emission technology projects undertaken and funded by the Ports to date, including:

- 116 new electric charging outlets
- 81 zero-emission terminal equipment, including yard tractors, top handlers, rubber-tired gantry cranes (RTGs), and forklifts
- 37 zero-emission drayage trucks (battery-electric and fuel cell)
- Hydrogen fueling infrastructure to support the above projects:
    - 2 new hydrogen fueling stations
    - 1 portable hydrogen fueler

In addition to directly supporting zero-emission technologies by funding demonstration projects, the TAP provides a forum for multiple agencies to work together and leverage resources toward a common goal. The TAP supports zero-emission technology projects led by other agencies by providing technical expertise, facilitating partnerships with port operators, offering a test bed for port-related technologies, and writing support letters to help other agencies secure funding for these demonstration projects. This direct and indirect support is critically important to making "zero emissions" a reality. An example of this support outside the traditional TAP structure is the use of the Ports' Clean Truck Fund fees for the Joint Electric Truck Scaling Initiative (JETSI) Project, which is being led by South Coast AQMD. The JETSI Project supports the development and demonstration of zero-emission, battery-electric truck technologies and infrastructure, as well as solar and energy storage technologies to enable development and demonstration of microgrids. The JETSI project directly supports the Ports' Clean Air Action Plan 2017 Update, which established a goal for zero-emissions drayage trucks entering and exiting the Ports by 2035. Further, the mayors of Long Beach and Los Angeles committed the San Pedro Bay Ports to participating in a large-scale zero-emission truck project such as this in their 2017 joint declaration. As stated in the declaration, the intent of a 50-100 truck deployment would be to test zero emissions drayage trucks at scale in order to encourage the production of vehicles, demonstrate feasibility, and provide meaningful data in real world port operations. The Ports' respective Boards of Harbor Commissioners approved the combined funding request of $3 million in 2022.

The Ports are funding other zero-emission initiatives. More information on this may be found in the CAAP Progress Reports found at *www.cleanairactionplan.org.* For more detailed information regarding in-use zero-emission technology deployed throughout the San Pedro Bay Ports, please refer to each Port's respective Emissions Inventory[3].

[3] POLA Emissions Inventory: *https://www.portoflosangeles.org/environment/air-quality/air-emissions-inventory* and POLB Emissions Inventory: *https://polb.com/environment/air/#emissions-inventory*

4 2024 TECHNOLOGY ADVANCEMENT PRIORITIES

2024 will continue the Ports' commitment towards implementation of the 2017 CAAP Update, which includes advancing harbor craft projects, demonstrating innovative fueling and charging technologies, showcasing the feasibility of alternatively fueled vessels as well as demonstrations focused on zero-emission cargo handling equipment, in particular, those powered using hydrogen fuel cell technology. In addition, technology investments that have a stronger focus on the operational, maintenance, and environmental costs and benefits of zero-emission vehicles and equipment in port applications are sought. As zero-emission vehicles and equipment become commercialized and more widely available for purchase, they will no longer qualify as TAP projects. At that point, the Ports must direct TAP resources to the areas in greatest need of technology development.

Additionally, the Ports must continue to support the numerous demonstration projects already underway. The Ports have learned from these projects and continue to identify gaps in understanding, which will shape future funding priorities. The Ports will continue to prioritize the successful completion of these projects not only to meet grant deadlines and compliance requirements but also to expedite the path to zero emissions. In 2024, the Ports look forward to bringing more projects online to showcase in-use operation for a variety of zero-emission technologies and to identify areas of future investment.

Thus, in 2024, the Ports commit to the following technology advancement priorities:

- Consider new projects submitted under the TAP's ongoing Request for Information (RFI) review process[4] with a particular focus on ships, harbor craft, and locomotives source categories.
- Continue to demonstrate zero-emission technologies for cargo-handling equipment.
- Explore concepts for innovative terminal equipment charging and fueling infrastructure that provide for fast, safe electric charging and/or hydrogen refueling.
- Continue to execute the many grant-funded and TAP-funded demonstrations underway; complete the projects within grant deadlines; and pave the way for additional technology advancement based on lessons learned.
- The Ports will continue to monitor and apply to Federal grant programs to fund major emission reduction grant programs and projects to support port tenants. The Ports will support tenants in their efforts to implement zero-emission technology by providing guidance and application leadership, as needed, to a number of state and federal funding programs including but not limited to the Diesel Emission Reduction Act, Port Infrastructure Development Program, etc.

[4] The TAP RFI is available at: *https://cleanairactionplan.org/request-for-information-san-pedro-bay-ports-technology-advancement-program/*

5 2023 PROJECTS

This section provides additional detail for technology advancement projects that were new or active in 2022. These projects represent the full portfolio of technology investments, including projects funded and managed by both Ports through the TAP, projects funded by grants and managed by one Port (the lead port is indicated in parentheses), and projects led by other agencies for which the Ports have contributed cost-share funds.

For information on completed TAP projects, please access the Final Reports archived on the program website: *https://cleanairactionplan.org/technology-advancement-program/reports/.*

5.1 Advanced Infrastructure Demonstration Project (Port of Los Angeles)

Project Description

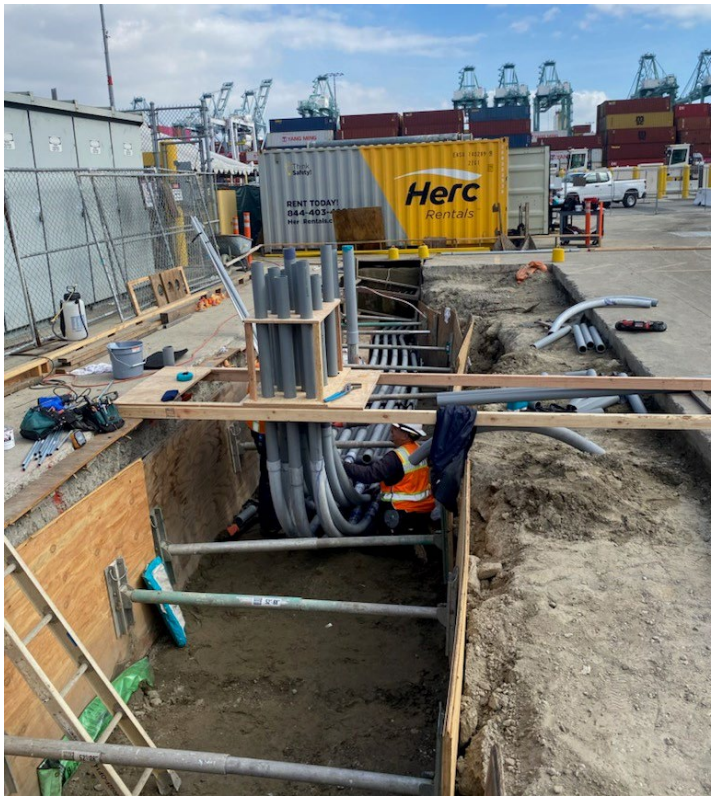
The Port of Los Angeles Zero-Emission Freight Vehicle Advanced Infrastructure Demonstration (AID) will model elements of a system that could ultimately electrify a major container terminal at the United States' busiest container port. The demonstration will take place at West Basin Container Terminal (WBCT), which received grant funding to demonstrate 10 battery-electric yard tractors. The AID project, funded largely by a CEC grant, will enable POLA to support the design and development of advanced charging technology for the 10 yard tractors providing even better capability to complete two full 8-hour shifts each day, a proof of concept to install additional chargers and deploy more vehicles.

For this project, POLA is partnering with Wireless Advanced Vehicle Electrification, LLC (WAVE) to design and demonstrate inductive charging technology to support each of the 10 yard tractors at WBCT's equipment corral, as well as two opportunity charging stations at the central break location where the yard tractors can obtain a quick top-off mid-shift. WAVE's wireless charging pads allow completely hands-free connection for equipment to charge without a physical connection to the power source (i.e., charging with no plug). Each 250-kilowatt (kW) system can charge two trucks at up to 125 kW each. WAVE will install five systems at WBCT's equipment corral to charge 10 next-generation BYD battery-electric yard tractors while off-duty. Additionally, to increase runtime for the electric yard tractors, an opportunity charging station will be installed at a centrally located break facility on WBCT's terminal to charge two yard tractors whenever there is a break opportunity for a top-off mid-shift, such as 30-minute lunch breaks or even 10-15 minute breaks (Figure 1). Finally, a battery energy storage system (BESS) will be installed at the base charging stations at the main equipment corral to minimize peak-demand charges that could result from a sudden influx of 10 high-power yard tractors all charging off the electrical grid simultaneously (Figure 2).

Ultimately, this project will not only demonstrate a series of prototype electrified equipment and charging mechanisms but will showcase a model of how to fully realize the vision of a zero-emission container terminal.

Figure 1: Two Commissioned WAVE Opportunity Charging Pads and a BYD Battery-Electric Yard Tractor

Figure 2: Infrastructure Construction at the Main Equipment Corral: Substation Power Distribution 3-Inch Conduit Placement



Project Partners & Budget
This project is funded by a $7.8 million CEC grant. The yard tractors will be purchased with supporting funds from South Coast AQMD in the form of a USEPA Targeted Air Shed Grant and with additional funds from OEMs, demonstration partners, and POLA. The total project cost is projected to be $11.3 million. Table 2 summarizes the funding contributions.

Table 2: Advanced Infrastructure Demonstration Project Funding Partners

Project Partners	Contributions
Port of Los Angeles	$392,500
California Energy Commission	$7,842,270
US Environmental Protection Agency	$1,344,750
South Coast Air Quality Management District	$442,750
OEMs and Demonstration Partners	$1,326,885

Accomplishments in 2023
WAVE completed manufacture and delivery of all charging gear. Manual door retrofit materials were received by BYD for all 10 yard tractors. Six yard tractors were integrated, retrofitted, and delivered to WBCT in Q4. Four of the yard tractors began operational duty and utilized the two opportunity chargers near the break area. The WAVE gear at the main equipment corral passed UL inspection in Q1. Due to extended lead-times for the transformer, switchgear, and BESS construction at the main equipment corral stopped in Q1 and resumed in Q4.

2024 Milestones
The following activities are expected in 2024:

- Installation and integration of transformer, switchgear, and BESS at the main equipment corral (Q2 2024).
- Integration, modification, and delivery of the remaining four yard tractors (Q2 2024).
- Complete infrastructure construction for the main charging corral (likely Q2 2024).
- Energize and commission charging at the main equipment corral (likely Q2 2024).
- Commission and demonstrate all 10 yard tractors, 12 charging units, and BESS for 12 months (likely Q2 2024 – Q3 2025).

5.2 Crowley Electric Tug Project (Port of Long Beach)

Project Description
Crowley Marine Services (Crowley) has designed a zero-emission capable tugboat to replace an older Tier 2 engine-equipped tug. Upon completion of the building process, the tugboat will be demonstrated at the San Pedro Bay Ports and is expected to have the ability to exert a force equivalent to 90 tons when conducting ship assist and harbor work. The battery system, with a proposed 3,400 kW-hr of energy available in normal working conditions, will serve as the primary power source, supplemented by onboard diesel generators as needed.

A charging station at Crowley's berth at the Port of Los Angeles will enable the hybrid tugboat to attain a minimum of 30% zero-emission operation, and charging station expansion throughout the Ports would further increase zero-emission operation. Achieving the 30% threshold would align the tugboat with the California Air Resources Board's designation as a Zero Emission Advanced Technology (ZEAT) harbor craft. Ultimately, this project is part of a broader goal to significantly reduce criteria and greenhouse gas emissions from the harbor craft source category, recognizing their substantial contribution to these environmental concerns.

Project Partners & Budget

The estimated project budget for the vessel alone is over $37.6 million. Crowley will contribute over $15 million, and the Ports will co-fund the demonstration to provide a total of $1.5 million. The California Air Resources Board, the Environmental Protection Agency, and the California State Transportation Agency will contribute the remaining amount. Table 3 summarizes the funding contributions from the project partners.

Table 3: Zero-Emission Hybrid Tugboat Demonstration Partners

Project Partners	Contributions
Port of Long Beach	$750,000
Port of Los Angeles	$750,000
South Coast Air Quality Management District	$1,500,000
California Air Resources Board	$2,940,000
U. S. Environmental Protection Agency	$6,000,000
California State Transportation Agency (POLB Grant)	$10,000,000
Crowley	$15,705,000

Accomplishments in 2023

Crowley worked towards completion of the bid package and building funding support for the project. Ports staff worked with their respective Boards of Harbor Commissioners toward project approval and the contract agreement between the Port of Long Beach and Crowley was finalized on October 18, 2023. After receiving bids from shipyards, Crowley selected their shipyard for construction of the vessel and entered into negotiations with the shipyard to solidify contract terms.

2024 Milestones

The following activities are expected in 2024:

- Port of Los Angeles to receive Board approval for project and execute Cost Share Agreement with Port of Long Beach
- Execute contracts for additional awarded grant funds
- Project kick-off meeting
- Sign contract with selected the shipyard
- Start of tugboat construction

5.3 Everport Advanced Cargo Handling Equipment Demonstration Project (Port of Los Angeles)

Project Description

In 2023, POLA's Everport Advanced Cargo-Handling Equipment Demonstration Project completed demonstration of two Taylor battery-electric top handlers and three BYD Motors battery-electric yard tractors integrated with the Cavotec Smart Plug-In System (SPS). To support this project, POLA invested in terminal reconstruction including new switchgear and the associated electrical infrastructure. Prior to the infrastructure redevelopment, the terminal did not have enough energy capacity to support the EV equipment. The upgrade was designed to allow for the potential addition of several more battery-electric yard tractors to Everport's fleet.

Project Partners & Budget

The project was funded by a CEC Clean Transportation Program grant of just over $4.5 million. The project cost share commitment is $3 million, for a total projected project cost of just over $7.5 million. Table 4 summarizes the funding contributions.

Table 4: Everport Advanced CHE Demonstration Funding Partners

Project Partners	Contributions
Port of Los Angeles	$2,096,210
California Energy Commission	$4,524,000
OEMs and Demonstration Partners	$905,413

Accomplishments in 2023

As background, the zero-emission Taylor top handlers successfully completed 12-months of in-service demonstration in 2021 and provided valuable lessons learned for future models. The top handlers continued to be utilized in daily operations during 2023.

Three BYD battery-electric yard tractors integrated with SPS charging began demonstration in May 2022, following commissioning and training activities. Challenges regarding adaptability of the charging interface between the Cavotec arm and funnel and the BYD charging platform resulted in several design modifications prior to demonstration. The project team found the BYD demonstration to be challenging, due to issues that arose during the demonstration. These issues included the need for several modifications and repairs before the yard tractors could be effectively deployed. Challenges with the AC/DC charging platform alterations, modifications to the funnel box housing, and the height differential in the charging funnel installation resulted in engineering redesigns for both the yard tractors and the SPS. Nonetheless, the Port believes the project was a success based on the important lessons learned throughout the demonstration. The most important project outcome was continued product improvement towards developing battery-electric yard tractors capable of meeting the rigorous demands of marine terminal operations. Notwithstanding the issues encountered, when operational, the units worked side-by-side with conventional diesel-fueled models, with the demanding requirements of a port terminal operation (Figure 3).

Figure 3: BYD Battery-Electric Yard Tractors Engaged with Cavotec Smart Plug-In System

The SPS chargers were connected to a temporary power source in September 2021 and switched to the new permanent power from the substation in March 2022. The infrastructure redevelopment construction project was completed in August 2022.

The project Final Report was submitted to CEC in November 2023 and this project is now complete.

5.4 Nett Technologies Inc. Harbor Craft Demonstration (Port of Long Beach)

Project Description

The objective of this project is to design, manufacture, and verify the BlueMAX™ NOVA 320e retrofit emission control system, which consists of a combined active diesel particulate filter with upstream diesel oxidation catalyst (DOC) in front of a selective catalytic reduction system with ammonia slip catalyst, as a retrofit to reduce emissions of eligible harbor craft. The BlueMAX™ NOVA 320e technology is fully developed, CARB-verified and commercialized for stationary engine applications, where it achieves reductions of 85 to 99 percent in diesel particulate matter, NOx, and CO (with small increases in greenhouse gases due to the use of carbon fuel injection). The overall goal of this project is to “marinize” the retrofit system for use in a tugboat application in a manner that requires minimal operator involvement. Pacific Tugboat Service is the demonstration partner and will be using its *S.Bass* harbor craft for this project.

Project Partners & Budget
The Ports contributed $500,000 in co-funding to this project with a total project budget of $1.2 million. Table 5 summarizes the project funding contributions.

Table 5: Nett Technologies Inc. BlueMAX™ NOVA 320e Harbor Craft Demonstration

Project Partners	Contributions
Port of Long Beach	$250,000
Port of Los Angeles	$250,000
Nett Technologies Inc. and Pacific Tugboat Service	$700,000

Accomplishments in 2023
Design and fabrication of the aftertreatment system was completed in 2019, with installation and system activation completed in 2020 and 2021. In 2022 the aftertreatment system began accumulating the necessary durability demonstration hours. By the end of 2022, about half of the needed 1000 hours of durability demonstration had been accumulated and so the contract with Nett Technologies was extended to allow for additional time to complete the durability hour accumulation and conduct final emissions testing. Durability testing continued at a slow pace in early 2023. Upon further investigation, Nett Technologies found that a bypass switch had been installed on the vessel due to intermittent electrical issues between the system and the vessel. As a result, although the vessel had been in use, the emission control system was not consistently being utilized, resulting in slow accumulation of durability hours. Because installation of a bypass switch is not allowed by the CARB verification procedures, CARB requested that the verification be halted while issues with the system were addressed. Unfortunately, because the demonstration vessel was scheduled to undergo an engine repower in mid-2023 there was insufficient time to remedy the issues and restart the durability hour accumulation. In addition, the aftertreatment system would not be compatible with the new engines that were procured for the repower. As a result, the demonstration was concluded without completing the demonstration or receiving verification of the aftertreatment system.

5.5 Pacific Harbor Line Zero-Emission Locomotive Demonstration (Port of Long Beach)

Project Description
Pacific Harbor Line (PHL) submitted a project concept to design, manufacture and demonstrate a battery charging system to support PHL's demonstration of a zero-emission, battery-electric switching locomotive at the Ports. In 2023, the project was approved by the Ports' respective Board of Harbor Commissioners. The battery charging system was installed at PHL's locomotive shop located on Port of Los Angeles property.

PHL provides rail transportation, maintenance and dispatching services to the Ports using the cleanest diesel-electric locomotive fleet in California. PHL operates 59 track-miles and 18 route-miles within the Ports with a current fleet of mostly Tier 3 diesel-electric locomotives. The zero-emission switcher locomotive leased for this demonstration was purpose-built for this project and is being funded entirely by Progress Rail. The locomotive has a nameplate rating (or total battery energy storage capacity) of 2.4 megawatt-hours, with six alternating current traction motors, enabling it to function for most of a day. The battery charging system is needed to maximize the ZE locomotive's available time for operation within the Ports. In order to minimize the time required to recharge batteries, the charging system was installed on a track at PHL's locomotive shop and is connected to the electrical grid of the Los Angeles Department of Water and Power (LADWP). Because this ZE locomotive is comparable in power to one of PHL's six-motor diesel-electric locomotives, it will be able to perform comparable work moving trains and switching rail cars. When commissioned, the battery charging system was used to power the locomotive.

Project Partners & Budget

PHL is partnering with Progress Rail, a major global rail providing locomotives and associated infrastructure under parent company Caterpillar, Inc. Other project team members include contractor Dynalectric-Los Angeles (a division of KDC, Inc.), who oversaw the site planning, site modifications, and installation of the battery charging system at PHL's locomotive shop. Another contractor, TK1SC, signed off on all of the engine drawings and documents used in the permitting process required by the Los Angeles Department of Water and Power. Table 6 summarizes the project funding contributions. The Ports are contributing over $845,000, which is matched by just over $3.5 million, for a total project cost of just over $4.38 million.

Table 6: PHL ZE Locomotive Project Funding Partners

Project Partners	Contributions
Port of Long Beach	$422,695
Port of Los Angeles	$422,695
OEMs and Demonstration Partners	$3,538,264

Accomplishments in 2023

In 2023, the project was approved by the Ports' respective Board of Harbor Commissioners. The battery charging system was installed in October 2023 (Figure 4). Testing and commissioning was completed in November 2023. Both the battery charging system and locomotive were placed in service December 2023 where the unit is currently performing rail services for a 12-month demonstration.

2024 Milestones

The following activities are expected in 2024:

- Completion of the in-use demonstration of the battery charging system.
- Completion and submittal of the final report.

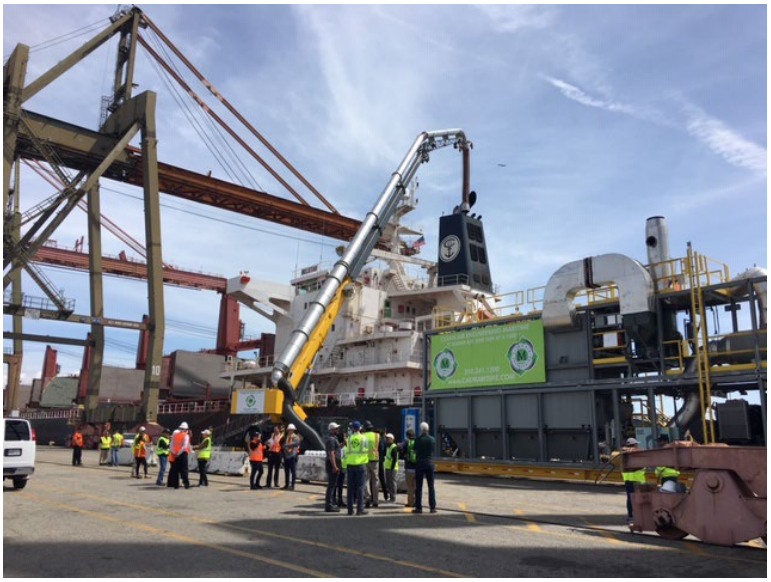
Figure 4: PHL Locomotive Charging System Under Construction

5.6 Pasha Green Omni Terminal Demonstration Project (Port of Los Angeles)

Project Description

This POLA demonstration project has several components including: two battery-electric Generation 1 yard tractors from BYD Motors, two battery-electric Kalmar yard tractors repowered by TransPower, one commercially available battery electric Kalmar T2E+ yard tractor, two Navistar International repowered battery-electric on-road trucks from TransPower, electrification repower of three 21-ton forklifts from TransPower, and associated chargers(two BYD 100-kW and seven TransPower 70-kW chargers). The project also includes a microgrid with battery storage capability that is tied to a one megawatt rooftop solar array, and the ShoreKat--a land-based ship emissions capture and control system (ECCS) designed for criteria emissions reduction. The system is depicted in Figure 5.

Figure 5: ShoreKat At-Berth Emissions Control System



Project Partners & Budget

The project is funded in part by a $14.5 million grant from CARB's Assembly Bill 118 Air Quality Improvement Program and Low Carbon Transportation Greenhouse Gas Reduction Fund Investments. POLA contributed nearly $6.4 million, bringing the overall project budget is nearly $33 million. Table 7 summarizes the funding contributions.

Table 7: Pasha Green Omni Terminal Demonstration Project Funding Partners

Project Partners	Contributions
Port of Los Angeles	$6,358,613
California Air Resources Board	$14,510,400
OEMs and Demonstration Partners	$12,092,000

Project Updates and Accomplishments in 2023

The demonstration project that began in 2016 was planned to be completed within a three-year period; however, delays in equipment development, agency approvals, and contract negotiations combined with safety and reliability issues limited the full demonstration of the equipment and microgrid infrastructure and extended the demonstration period until December 2023. A final report was prepared and submitted to the California Air Resources Board documenting the results of the demonstration.

The Green Omni Terminal Project provided valuable lessons learned for the deployment of zero-emission and near-zero-emission technologies, including EVs, electric CHE, and the ShoreKat ECCS at a multi-modal facility. Pasha served as a test facility for the commercialization of zero-emission technologies that move high-tonnage break bulk and containerized cargo. Through the demonstration, the project provided valuable information on the process of obtaining the proper authorizations to operate battery-electric CHE and vehicles safely and legally, as well as the deployment of supporting charging infrastructure. While the overall demonstration duration was generally less than the two-year target due to delays in deployment of equipment, the process of placing the infrastructure and equipment in service and iteratively modifying, upgrading, and

repairing the equipment to achieve operational utility provided valuable data and insights on the reliability and commercial readiness of each of the technologies. Lessons learned from this project have informed follow-on projects being implemented at POLA, as well as other California and U.S. ports. Additionally, configuration, operational, and safety issues have been shared with Original Equipment Manufacturers, resulting in improvements in commercially available, yard tractors, forklifts, and on-road trucks. This grant demonstration is complete.

5.7 Pasha Hawaii Ohana Class LNG-Powered Container Ships Project (Port of Los Angeles)

Project Description

The objective of this project is to build two new vessels that operate using diesel or liquefied natural gas (LNG). These new vessels will replace two existing vessels that currently operate on inefficient steam turbine engines; two existing vessels will be decommissioned as part of this effort to ensure they no longer operate. The new vessels will be AMP capable (to allow use of shore power) and include automatic stop start technology. The new vessels are Tier III-certified marine diesel engines capable of burning heavy fuel oil (HFO), distillate fuel or LNG, and are optimized for LNG.

Project Partners & Budget

Pasha budgeted over $430 million to cover the majority of project costs associated with the design and construction of the two new LNG vessels for this demonstration project. The Ports are contributing $500,000 to this project as shown in Table 8. TAP funding will support the initial design and documentation of the demonstration and emission reduction benefits.

Table 8: Pasha Hawaii Ohana Class LNG-Powered Container Ships Project Funding Partners

Project Partners	Contributions
Port of Los Angeles	$250,000
Port of Long Beach	$250,000

Accomplishments in 2023

The contract agreements were finalized in late 2020 and design work was completed. Construction of the first vessel was slower than anticipated due to restrictions related to the COVID-19 pandemic. The first vessel, the George III, was delivered to Pasha and began service in August 2022. The second new LNG vessel (“Janet Marie”) was delivered in the July quarter of 2023. Pasha received approval for the LNG fueling process and obtained all necessary permits, and has been successfully bunkering the LNG vessels as they call on a roughly weekly basis since August 2022. The ships bunker approximately 320,000 gal of LNG per fueling event, with the goal of operating entirely on LNG. The delivered vessels have a friendly competition between the crews to see which can maintain a longer run entirely on LNG before needing to switch to diesel for supply or maintenance reasons.

2024 Milestones
The following activities are expected in 2024:

- The data collection plan will be approved and emissions data collected from LNG-powered trip(s).
- The final report will be submitted and the project completed.

5.8 Pasha Horizon C9 Vessel LNG Engine Repower Demonstration Project (Port of Los Angeles)

Project Description
Pasha Hawaii Holdings LLC (Pasha) will repower an existing OGV, M/V Horizon (Figure 6), to operate on liquefied natural gas (LNG). Pasha's repowered vessel will call at the Ports of Los Angeles and Long Beach as part of the demonstration.

The existing baseline engine burns heavy fuel oil (HFO) but in a high pressure, closed cylinder to generate steam and turn a turbine. The repower from steam turbine power to internal combustion LNG technology will facilitate the use of cleaner burning LNG and provide a significant engine efficiency increase. AMP capability will also be included in this repower design. At the conclusion of the repower, all engines will meet Tier III emission standards. While the engine can burn HFO when LNG is not available, the propulsion system will be optimized for LNG fueling.

Figure 6: Marine Vessel Pasha Horizon

Project Partners & Budget
Pasha budgeted $41.5M to cover the majority of project costs associated with this repower demonstration project. The Ports are contributing $500,000 to this project as shown in Table 9. TAP funding will support the initial repower design and documentation of the demonstration and emission reduction benefits.

Table 9: Pasha Hawaii Horizon Reliance LNG Conversion Project Funding Partners

Project Partners	Contributions
Port of Los Angeles	$250,000
Port of Long Beach	$250,000

Accomplishments in 2023
The design work was completed and the ship dry-docked to begin the engine repower in 4th quarter 2021. The repower process has been slow, due to shipyard closures for health concerns (COVID; Heat), and test failures for the new engine block. Modifications have been made throughout 2022, and initial MGO trials were completed in December 2023. Despite the setbacks the vessel is on schedule to be deployed in January 2024.

2024 Milestones
The following activities are expected in 2024:

- The data collection plan will be approved for emissions testing.
- The ship will be delivered and placed into service in Q1 2024.
- The final report will be submitted and the project completed.

5.9 SSA Marine H2 Fuel Cell Top Handler Development and Demonstration Project (Port of Long Beach)

Project Description
SSA Marine (SSA), in collaboration with Taylor Machine Works (Taylor), will design, manufacture, and demonstrate two zero-emission top handlers powered by liquid hydrogen that will be stored onboard in two 35 kg tanks subcooled to -250°F. These top handlers will utilize hydrogen fuel cell technology to recharge the batteries for zero-emission operation. The technology will be fuel cell dominant with batteries on board to assist the fuel cell during heavy power use and to capture regen power, which will enable SSA to operate for over 16 hours. The field demonstration will evaluate equipment performance, operational time, mileage, energy consumption and customer issues related to the equipment. The 12-month demonstration will take place at SSA's Matson facility at the Port of Long Beach's Pier C following the commission of the top handlers.

It is anticipated that liquid hydrogen will be delivered weekly to the terminal where fuel will be stored at the terminal at a dedicated site in two 700 kg tanks. Since no onsite compression is required, no major infrastructure at the terminal would be needed.

In 2019, SSA and Taylor demonstrated two first-generation ("Gen 1") battery-electric top handlers (Figure 7), similar technology to the hybrid top handlers; however, the "Gen 1" equipment relied solely on a battery pack charged from the grid. This grid-based design had limited capabilities, unable to complete SSA's daily duty cycle of two 8-hour shifts on a single charge. The goal with this hybrid fuel cell top handler demonstration is to improve the design of the "Gen 1" equipment, making it meet operational demands, eliminate range anxiety, and operate free of the electrical grid.

Figure 7: Taylor "Gen 1" Battery-Electric Top Handler

Project Partners & Budget

The budget of this project is nearly $6.5 million. SSA and partners will provide nearly $4.3 million, and the Ports will each provide nearly $1.1 million. Taylor and a hydrogen fuel supplier will contribute the remaining amount. Table 10 summarizes the funding contributions from the project partners.

Table 10: Hybrid Hydrogen Fuel Cell Top Handler Demonstration Partners

Project Partners	Contributions
Port of Long Beach	$1,095,500
Port of Los Angeles	$1,095,500
SSA, Taylor and partners	$4,291,295

Accomplishments in 2023

In 2023, the project was approved by the Ports' respective Board of Harbor Commissioners. A project kick-off meeting was held shortly after to discuss next steps for the project.

2024 Milestones

The following activities are expected in 2024:

- Construction of hydrogen fuel cell top handlers for delivery in 2025.
- Selection of hydrogen fuel supplier.

5.10 South Coast AQMD Zero-Emission Cargo Transport (ZECT) II Demonstration

Project Description

This project is to accelerate deployment of zero-emission cargo transport (ZECT) technologies to reduce harmful diesel emissions, petroleum consumption and greenhouse gases (GHG) in surrounding communities along the goods movement corridors that are impacted by air pollution from heavy diesel traffic. ZECT II includes development and demonstration of seven drayage trucks by five different contractors, as follows:

- Transportation Power, Inc. (TransPower) developed two BETs with hydrogen fuel cell range extenders.
- US Hybrid developed two BETs, each with an on-board hydrogen fuel cell generator.
- Under project management by the Center for Transportation and the Environment (CTE), BAE Systems developed a BET with hydrogen fuel cell range extender.
- Under project management by the Gas Technology Institute (GTI), BAE Systems and Kenworth developed one battery electric hybrid truck with a CNG range extender. The truck can operate in zero-emission (all-electric) mode and in conventional hybrid electric mode using CNG.
- Hydrogenics (a Cummins Inc. Company) will develop and demonstrate a fuel cell range extended Class 8 truck.

Project Partners & Budget

The Ports are contributing nearly $1.3 million in co-funding to this project with a total project budget of just over $20 million. Table 11 summarizes the project funding contributions.

Table 11: South Coast AQMD ZECT II Demonstration Funding Partners

Project Partners	Contributions
US Department of Energy	$9,725,000
OEMs	$3,075,481
South Coast Air Quality Management District	$2,400,000
California Energy Commission	$2,400,000
L.A. Department of Water and Power	$1,000,000
▪ Port of Long Beach	$724,490
▪ Port of Los Angeles	$566,990
Southern California Gas Company	$250,000

Accomplishments in 2023

Six of the demonstration trucks continued their in-service demonstration at TTSI. Throughout the demonstration, the battery and fuel-cell-dominant fuel cell trucks have demonstrated a range of 150-200 miles, with an average fuel consumption rate of 6-8 mi/kilogram of hydrogen (fuel consumption varies by duty cycle, load, etc.). Operator feedback has been positive and TTSI is working with the truck developers to negotiate continued use upon completion of the demonstration.

For the Cummins (formerly Hydrogenics) truck, the project was delayed due to the acquisition of Hydrogenics by Cummins, Inc. and the desire to implement a new power train design. Cummins received US DOE approval for this redesign, which is underway. This truck will begin its demonstration service in Q2 2024.

2024 Milestones

The following activities are expected in 2024:

- The data collected from the six demonstration trucks will be consolidated to provide the conclusion of drive performance, efficiency, etc.
- Cummins will deploy its demonstration truck in Q2 2024, with final demonstration results expected by Q2 2025.

5.11 South Coast AQMD Ocean-Going Vessel Low-Pressure Exhaust Gas Recirculation Retrofit (LP-EGR), Polar Bear Pilot Vessel Conversion

Project Description

For this project, Wärtsilä will retrofit two Mediterranean Shipping Company (MSC) International Maritime Organization (IMO) Tier II ocean-going vessels (OGV). The first vessel (either MSC Shuba or MSC Shiya) will be retrofit with a Low-Pressure Exhaust Gas Recirculation (LP-EGR). EGR is the process where a portion of the exhaust gases (about 30-40%) is redirected to the intake side of the engine and subsequently re-enters the cylinders. The recirculated exhaust gases reduce the oxygen (O2) content and increase the concentration of carbon dioxide in the incoming air. As a result, peak combustion temperature reduces significantly due to reduced O2 in the combustion air, reducing NOx formation. The installation of a patent-pending particulate filter at the exhaust of a SOx scrubber is included in the design to protect the EGR cooler and provide an estimated 90% PM reduction. The retrofit will have a small footprint that will require less integration and changes to the vessel infrastructure. A short installation time can also be expected.

The second vessel, MSC Topaz, will be retrofit with a multiple fuel flexible injection platform with a gas supply system. The vessel will initially operate as a dual-fuel (diesel-LNG), but it will be capable of running multiple fuel types with minor modifications. To meet IMO target of reducing GHG emissions, the promising alternative fuels for shipping include LPG, methanol, biofuel, hydrogen, and ammonia. Upgrading a ship requires huge investment, both ship owners and technology developers are opting for the most flexible fuel options so the decision can be made for the near-term and long-term based on the viable alternatives. The system is designed to be retrofit into Wartsila and WindGD two-stroke low-speed engines installed on container vessels, bulk carriers, or tankers, however, in principle, it could be done on other brands of electronically controlled engines, making it a solution that can be deployed across the majority of vessels operating today. Some “Off-the-Shelf” items for the gas supply system will be used to make the retrofit more adaptable. This retrofit does not require major changes to the existing engine and the patent-protected technology significantly reduces methane slip.

The Low-Pressure Exhaust Gas Recirculation retrofit is expected to achieve at least 75% NOx and 90% PM emission reduction from a Tier II vessel. The multiple fuel flexible injection retrofit is expected to achieve 70% NOx, PM, and 25% CO2 emission reductions from a Tier II vessel. The projection of total emission reductions from both vessels is 124 tons/year of NOx, and at least 70% PM reduction. The actual PM reductions will need to be measured during the emission verification tests since there are no PM test results from these baseline engines for these two vessels.

Project Partners & Budget

The total cost for the Wartsila Retrofit Technology Development – LPEGR and Multi-Fuel Injection System projects is estimated at just over $20.2 million. Table 12 summarizes the project funding contributions.

Table 12: OGV Low-Pressure Exhaust Gas Recirculation Retrofit & Polar Bear Pilot Vessel Conversion Project Funding Partners

Project Partners	Contributions
Port of Long Beach	$300,000
Port of Los Angeles	$300,000
South Coast AQMD	$300,000
USEPA	$10,874,000
OEMs and Demonstration Partners	$8,456,700

Accomplishments in 2023

The MSC Topaz vessel engine cylinder bore size was reduced to improve fuel efficiency. Two laboratory engine tests were conducted to verify MSC Topaz's new engine rating, including a sea trail. Two engine emissions measurements were also conducted. The results show 13% reduction in fuel usage and 33% NOx emission reductions from the cylinder bore size reductions. The development of the injection system and control arrangement for the upgraded engine has started. The design was submitted to classification for formal approval.

General arrangement drawing of the fuel supply system, location in rooms, and interconnecting piping was completed. The fuel supply system was produced but during the testing, some leakage from the fuel injection system was detected, and the improved fuel injection system was designed and ordered. A boil-off gas compressor and cryogenic valves were also ordered. The fuel tanks for the LPG, LNG and NH3 fuel are being produced. The tanks delivery date was delayed to January 2024. The tanks are built to carry both LNG and ammonia (Figures 8, 9 & 10).

2024 Milestones

The following activities are expected in 2024:

- Obtain Classification Approvals
- Engine Conversion
- Auxiliary Engine and Boil-off Gas Management System Installation
- LP-EGR system Engineering and Design
- Field Testing

Figure 8: Longitudinal Cross Section of Retrofit Impacted Area with Fuel Release Dispersion Model

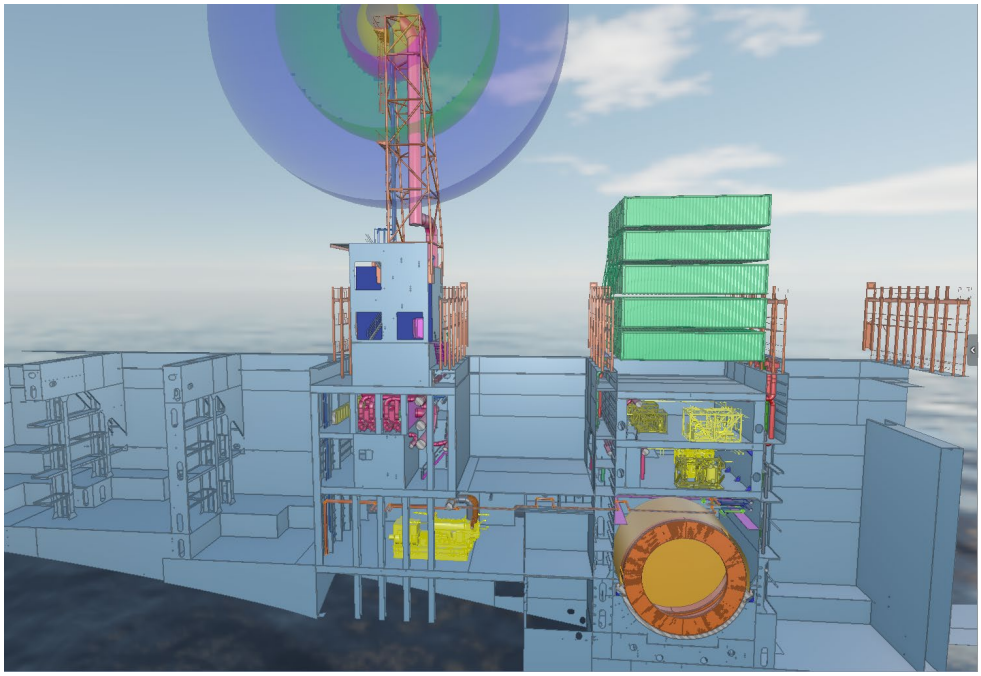
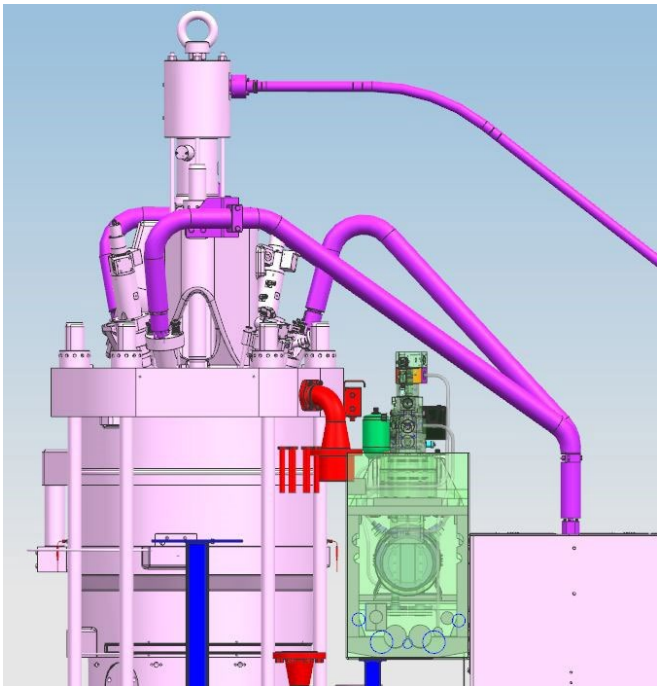


Figure 9: Tank Manufacturing Status

Figure 10: Fuel Injection Diagram



5.12 Shore-to-Store Project (Port of Los Angeles)

Project Description
This project features one of the region's largest demonstrations of zero-emission hydrogen-fueled on-road trucks, including new fueling infrastructure, and zero-emission cargo-handling equipment at a smaller seaport. This project consists of three main components:

- Ten zero-emission hydrogen fuel-cell-electric Class 8 on-road trucks on the Kenworth T680 platform were developed through a collaboration between Kenworth and Toyota to move cargo from the Los Angeles ports throughout the Los Angeles basin, as well as ultimately to inland locations such as Riverside County, the Port of Hueneme (POH), and eventually to Merced. The trucks were operated by Toyota Logistics Services (4), United Parcel Services (3), Total Transportation Services Inc. (2), and Southern Counties Express (1). (Figure 11)
- Two hydrogen fueling stations that fuel heavy-duty trucks were constructed by Shell in Wilmington and Ontario, California. The new stations joined two additional stations located at Toyota facilities around Los Angeles to form an integrated, four-station heavy-duty hydrogen fueling network.
- Expanded use of zero-emission technology in off-road and warehouse equipment, including the first two zero-emission yard tractors (Figure 12) and e-cranes to be operated at the Port of Hueneme, as well as the expanded use of two zero-emission forklifts at Toyota's port warehouse.

Figure 11: Hydrogen Fuel-Cell Class 8 Kenworth/Toyota Trucks at the Shell Hydrogen Fuel Station near the Port of Los Angeles

Figure 12: Kalmar Electric Yard Tractor at the Port of Hueneme

Project Partners & Budget

In late 2018, CARB awarded $41.1 million to POLA for the Zero- and Near Zero-Emission Freight Facilities (ZANZEFF) project. Project partners, including Toyota, Shell, Kenworth, South Coast AQMD, and POH are providing $41.4 million in match funding. Table 13 summarizes the funding contributions.

Table 13: Shore-to-Store Project Funding Partners

Project Partners	Contributions
Port of Los Angeles	$13,999,331
California Air Resources Board	$41,122,260
South Coast Air Quality Management District	$1,000,000
OEMs and Demonstration Partners	$26,427,281

Accomplishments in 2023

In 2022, the Ontario and Wilmington hydrogen fueling stations were successfully commissioned and all ten hydrogen fuel cell electric trucks (FCEV) completed in-service demonstration with 21,650 miles of operational data collected and analyzed. The FCEV Ocean trucks were able to perform drayage operation with similar average fuel economy as the conventional vehicles in the baseline fleets despite spending a larger portion of their driving on urban and congested roadways. The demonstration not only showed viability for Class 8 FCEVs in drayage operations of these distances and provided the immediate benefit of reducing direct localized emissions, it also showed that the first-generation technology used in these vehicles is equivalent to the fuel economy performance of conventional Class 8 diesel trucks.

POH completed the demonstration of two Kalmar battery-electric yard tractors in January 2023. The equipment performed reliably for the expected operational duty-cycle though a major conclusion of the demonstration was the need to maximize opportunity charging. Onboard telematics data were utilized to characterize operation of the electric terminal tractors for the 12-month demonstration (January 24, 2022, to January 25, 2023). Combined, the two units operated 183 days during the data collection period, traveling almost 2,750 miles. The electric tractors were typically used 1–2 days per week and exhibited very consistent schedules corresponding to the operators' work schedule and break periods. The yard tractors were able to operate for two shifts per day, with opportunity charges throughout. The electric tractors spend less than 25% of their operational time driving, while more than 75% of the time is spent in "idle" or accessory-only mode. However, in terms of energy consumption, 75% is spent driving the tractor and 25% is spent idling. The electric tractors consumed 3.7 kWh/mi, which is much lower than the baseline tractors' equivalent energy consumption rate of 13.9 kWh/mi (2.7 mpg), highlighting the energy efficiency benefit of the electric powertrain for this type of vehicle operation.

Eight months of forklift operations were evaluated. In general, the units were used 1 to 3 hours per day each, with the electric units generally being used more than the propane (baseline) units. The electric units provided equivalent performance to the baseline units.

Port staff worked with CARB staff throughout early 2023 toward completion of the project Final Report, including compliance with ADA formatting requirements. The Report was submitted to the California Air Resources Board in May 2023.

5.13 Sustainable Terminals Accelerating Regional Transformation (START) Project (Port of Long Beach)

Project Description

In partnership with the Port of Stockton and Port of Oakland, the Port of Long Beach received a $50 million CARB grant for a transformative demonstration of a near-zero and zero-emission supply chain in and around its Matson Navigation Co. Pier C terminal. The Sustainable Terminals Accelerating Regional Transformation (START) Project will demonstrate more than 100 pieces of zero-emission terminal equipment and trucks at three California seaports, deploy two ships with some of the cleanest available engines, and advance workforce development programs to support sustainable goods movement.

For this project, the Port of Oakland will deploy 10 electric trucks and seven pieces of terminal equipment. The Port of Stockton will deploy more than 40 electric forklifts and an electric railcar mover with a 56 hp range-extender engine (Kohler KDI 1903TCR) that will be operated on renewable diesel. At the Port of Long Beach, the START Project will demonstrate:

- 33 zero-emission yard tractors at Pier C — one of the largest deployments of such equipment at a single marine terminal;
- Two container ships with Tier 3 engines, which will be the cleanest container ships to call in regular service on the West Coast;
- Five electric trucks at an off-dock container yard;
- Two publicly-accessible heavy-duty truck charging outlets; and
- One zero-emission capable plug-in hybrid tugboat.

Project Partners & Budget

The START Project is funded partly by a $50 million grant from the California Climate Investments. The project includes over $50.5 million in matching funds from private and public partners, for a total cost of over $100.5 million. Table 14 summarizes the funding contributions.

Table 14: START Project Funding Partners

Project Partners	Contributions
Port of Long Beach	$3,531,157
California Air Resources Board	$50,000,000
South Coast Air Quality Management District	$500,000
Port of Oakland and Port of Stockton	$3,250,000
OEMs and Demonstration Partners	$43,237,585

Accomplishments in 2023

In 2023, the charging infrastructure for the electric yard tractors at the Port of Long Beach (Figure 13) was completed and the charging infrastructure for the electric yard tractors at the Port of Oakland began. Due to lengthy permitting delays, the infrastructure at the Port of Oakland is not expected to be complete until Q2 2024. Commissioning of the yard tractors began in 2023, but numerous issues with the vehicles, as well as the charging stations, prevented official commencement of the demonstration. Nine of the ten drayage trucks at the Port of Oakland completed their demonstration period; the tenth vehicle entered service just prior to Shippers Transport Express terminating drayage service at that location. In December 2023 the drayage trucks were delivered at the Port of Long Beach Shippers Transport location. Interoperability issues were discovered between the trucks and the charging stations, preventing the vehicles from being commissioned. The electric top handlers operating at Shippers Transport Express in Oakland completed their demonstration and will continue in service under the facility's new operations.

Both Tier III container ships continued operations and emissions testing of the auxiliary engines was completed on each vessel. Emissions testing of the baseline vessel was also completed. A shipyard to construct the Crowley zero-emission capable plug-in hybrid tugboat was identified and Port of Long Beach staff worked with Crowley and funding agencies to secure additional funding for the project, in addition to approving a TAP award.

2024 Milestones

The following activities are expected in 2024:

- Commissioning and demonstration of the heavy-duty drayage trucks in Long Beach.
- Commissioning of the yard tractors and begin demonstration.
- Receiving final approval for TAP funds to support the Crowley project.
- Finalize data collection results and data reports for the electric forklifts and ocean going vessels.

Figure 13: Zero-Emission Yard Tractors and Chargers at Port of Long Beach

5.14 Toyota Tsusho Hydrogen Top Handler and Mobile Hydrogen Refueler Project (Port of Los Angeles)

Project Description

Toyota Tsusho America, Inc. (Toyota Tsusho) will demonstrate the repower of a diesel top handler from conventional fuel to zero-emission technology. The engine of the diesel top handler was repowered with a hydrogen fuel cell powered propulsion system with by US Hybrid. This portion of the project has progressed through a series of steps. Initially, the diesel-powered top handler's performance baseline was determined to provide a benchmark for future comparison. Engineering drawings and simulation models were produced to conceptualize the fuel cell system integration into the top handler after the diesel powertrain was removed. The top handler repower (Figure 14) is complete and the equipment was delivered to Fenix Marine Services (FMS) terminal from US Hybrid. The project demonstration is scheduled to commence later than anticipated due to a shipping delay of top handler components for fueling. The demonstration will take place at Fenix Marine Services (FMS) marine terminal at the Port of Los Angeles (POLA) over twelve months with an extended period of six months to accommodate for the delayed shipping period. The goal with the repowered top handler is for it to function as efficiently as the original and conduct a heavier duty cycle at a rail yard. A successful demonstration of the hydrogen top handler will prove the feasibility of fuel-cell-powered cargo handling equipment and may be the impetus to the advancement of the heavy-duty hydrogen fuel cell market. In addition to technological advancement, this project helps shape the field of alternative marine fuel usage at the San Pedro Bay Ports.

Along with repowering the top handler, Toyota Tsusho will develop and deploy a mobile hydrogen refueler (Figure 15). Nine separate cylinders, 27.57kg of hydrogen each are placed on a fixed truck chassis with a design capacity of 930bar 247.5 kilogram (kg) of hydrogen. A total of 9-cylinder tanks (27.5kg/ cylinder) of liquid hydrogen to are mounted on the mobile refueler caddie (Figure 16). The refueler will deliver hydrogen fuel at a rate of approximately 2 kg/minute. Once safety approvals and permits are obtained, the mobile refueler will fuel the repowered top handler. Longer term, the team hopes to develop experience and approvals to conduct hydrogen fueling in a manner similar to wet-hose fueling of diesel equipment that is current practice.

Figure 14: Toyota Tsusho Repowered Hydrogen Top Handler

Figure 15: "ONE H2" Mobile Refueler

Figure 16: "ONE H2" Hydrogen Cartridge

Project Partners & Budget
The City of Los Angeles Harbor Department and the Port of Long Beach are sharing costs associated with the project in the amount of $430,000 each, for a total of $860,000. This TAP funding is matched by over $2.8 million from Toyota Tsusho. Additional support is provided by project partners US Hybrid and FMS. The total project cost is estimated at just over $4.8 million. Table 15 summarizes the funding contributions from the project partners.

Table 15: Hydrogen Top Handler and Mobile Hydrogen Refueler Project Funding Partners

Project Partners	Contributions
Port of Long Beach	$430,000
Harbor Department	$430,000
Toyota Tsusho	$2,822,568
US Hybrid	$276,477
Fenix Marine Services	$887,000

Accomplishments in 2023
Toyota Tsusho worked towards reinstatement of lapsed special approvals from the City of Los Angeles Harbor Department for their demonstration project. The contract agreements were finalized in late November 2022. The completion of assembly for the top handler and mobile refueler components occurred in November 2023. Operational testing and demonstration of the delivered hydrogen fuel cell-powered top handler commenced in December 2023.

2024 Milestones

The following activities are expected in 2024:

- A project final report.
- Operational testing and demonstration of the hydrogen fuel cell-powered top handler.
- Testing of "wet fueling" using the mobile refueler for the fuel cell top handler.
- Completion of assembly for the mobile refueler scheduled for delivery and demonstration.
- Reassembly of the top handler at the Fenix on site.
- Delivery of the complete hydrogen mobile refueler to FMS.
- Renewal of hydrogen fueling safety approvals and permits.

5.15 Zero-Emission Terminal Equipment Transition Project (Port of Long Beach)

Project Description
The Port of Long Beach, in partnership with terminal operators and technology manufacturers, demonstrated zero-emission cargo-handling equipment projects at three container terminals. In addition, the Port partnered with Total Transportation Services, Inc. (TTSI) to demonstrate near-zero-emission heavy-duty trucks, which service the San Pedro Bay Ports.

The project involved:

- Repowering nine RTG cranes to full-electric power at SSA Marine Terminal (SSA), Pier J.
- Developing and deploying 12 BYD battery-electric yard tractors – seven at International Transportation Service (ITS) and five at Long Beach Container Terminal (LBCT). Of the total yard tractors at ITS and LBCT, one yard tractor for each terminal was modified to operate with the Cavotec Smart Plug System (SPS), a mechanized charger.
- Converting four LNG trucks to LNG plug-in hybrid electric trucks (PHET) trucks at TTSI with zero-emission capability developed by US Hybrid.

Project Partners & Budget

The Port received $9.755 million in CEC funding, which was matched by over $10 million in project partner funding, for a total project investment of nearly $19 million. The total amount of CEC funding was reduced to $8,610,000 upon the return of funds that was originally allocated for the BYD demonstration at LBCT. Table 16 summarizes the funding contributions.

Table 16: Zero-Emission Terminal Transition Project Funding Partners

Project Partners	Contributions
Port of Long Beach	$3,997,515
California Energy Commission	$8,610,000
Southern California Edison	$3,950,000
OEMs and Demonstration Partners	$2,405,501

Accomplishments in 2023

eRTG Crane Demonstration – SSA, Pier J

This demonstration undertook a groundbreaking conversion project in collaboration with SSA and Cavotec to transform nine (9) conventional rubber-tired gantry (RTG) cranes into grid-powered electric RTG (eRTG) cranes. The project aimed to reduce emissions and enhance operational efficiency. The conversion process involved retrofitting RTG cranes with various essential components, including a cable reel system, a guidance system, and a battery container to support off-grid operations.

This demonstration concluded in 2022. The eRTG cranes at SSA are still in operation today and have been performing well.

Hybrid LNG Plug-In Hybrid Electric Trucks (PHET) Demonstration – TTSI/US Hybrid

This demonstration aimed to accelerate the transition and commercialization of zero-emissions (ZE) on-road drayage trucks by demonstrating four LNG PHETs that were converted by US Hybrid from older LNG trucks provided by TTSI. The LNG PHETs faced challenges with proprietary charging station interfaces, hindering their intended zero-emission operations. In addition, operational shifts in 2021 led to a move to Carson, California; however, there was insufficient electrical infrastructure at the site to power the newly acquired Nuvve chargers. This was needed to demonstrate charging capability and zero-emission mode.

The revenue service demonstration was intended to assess truck performance over 12 months. One of the main issues encountered in this demonstration was the recurrent engine coolant and radiator failures within months of deployment. This resulted in frequent downtime, and eventually, all four trucks were removed from revenue service in June 2022 due to engine failures. Driver feedback indicated that the LNG PHETs could handle the demands of Port drayage effectively but the frequent engine cooling system and radiator failures raised concerns. Cummins, the engine manufacturer, identified pressure cracks in the engines and proposed a costly reconstruction in 2023. Cummins suggested potential causes, such as poor engine oil management and excessive idling, though both reasons were disputed. It was suspected that the remaining three LNG PHETs may have had similar engine issues. Discussions between US Hybrid, TTSI, and Cummins regarding responsibility for the engine failures did not yield a commitment from Cummins to entirely cover the repair of the engines as was hoped.

While on-board chargers performed as designed, the charging stations could not be assessed due to compatibility issues and the trucks' ongoing engine problems. The project demonstrated promising capabilities of LNG PHETs in Port drayage operations but was plagued by recurring engine failures, challenges with charger compatibility, and uncertain repair costs. As a result, the project concluded in 2023 and a pivot was made to instead focus on the data analysis.

BYD Battery-Electric Yard Tractors Demonstration

This project revolved around the demonstration of 12 BYD Model 8Y electric yard tractors at two Port terminals, ITS and LBCT. This number was later reduced to eight battery-electric yard tractors, 7 of which were delivered to ITS and one to LBCT. The final four battery-electric yard tractors were not delivered to LBCT due to complications with the engineering design and build.

The demonstration at ITS concluded in 2021 with ITS electing to return all EVSEs and electric yard tractors. In early 2022, LBCT continued testing one BYD battery-electric yard tractor at their terminal with minor setbacks due to terminal staffing and charging issues. BYD was given approval to complete the final build of the remaining four electric yard tractor. However, after failing to build and deliver the remaining tractors due to the lack of engineering and manufacturing resources in place for the redesign and manufacturing, BYD was unable to commit to a delivery schedule that would fit within the remaining time of the grant. The BYD demonstration at LBCT officially concluded in the 3rd quarter of 2022, and the remaining funds were returned to the CEC. In 2023, LBCT started the process to return the one BYD battery-electric yard tractor and four charging equipment.

Final Report/Meeting in 2023

The Port submitted their final invoice to the CEC on March 30 prior to the June 30, 2023 liquidation, and completed all grant obligations prior to the December 31, 2023 deadline. A final report for this project was submitted to the CEC for formal publication on December 5, 2023. A final presentation was provided to the CEC at the December 4, 2023 final meeting, and the grant is now considered “complete”.

6 2023 TECHNOLOGY FUNDING

The Ports contribute funding to technology investments through several mechanisms as identified in the TAP Guidelines. The TAP is supported by both Ports and funding for each demonstration is subject to approval by each Port's Board of Harbor Commissioners, or is received via a competitive grant basis, by participating agencies. These include but are not limited to the South Coast AQMD, CARB, USEPA, and CEC. Project co-funding is also contributed by the Ports and project partners as either cash or in-kind contributions, or a combination of both.

Contributions from participating agencies other than the Ports are typically made on a project-by-project basis. It should be noted that TAP contractors are required to provide a minimum of 50% co-funding in the form of cash and/or in-kind contributions to each project. In order to meet the stringent agency match funding requirements, the Ports may utilize the project costs from a related or synergistic project to leverage additional grant funds to expand technology development and demonstration.

The Ports and agency stakeholder investments for all past and current technology advancement projects approved to date are shown in Table 17 below. In 2023, the TAP focused on continuing to execute its portfolio of technology advancement projects while launching four new projects.

Table 17: Ports' Technology Advancement Funding Investments as of December 31, 2023

Project Category	POLB	POLA	South Coast AQMD	CARB	CEC	USEPA & Other Agencies	Total Port & Agency Stakeholder	OEMs & Demonstration Partners	Total Project Budget
Ocean-Going Vessels									
ACTI AMECS Emissions Testing	$149,527	$149,527	$55,000				$354,054	$249,157	$603,211
ACTI At-Berth Emissions Reductions for Ships	$703,388						$703,388		$703,388
APL Singapore Slide Valve/WiFE	$22,500	$22,500		$783,628			$828,628	$471,372	$1,300,000
Bluefield Holdings Krystallon OGV Scrubber	$825,000	$825,000					$1,650,000	$1,740,000	$3,390,000
Maersk OGV Energy Efficiency Measurement Demonstration	$500,000	$500,000					$1,000,000	$1,860,000	$2,860,000
Maersk OGV Slide Valve Low-Load Emissions Evaluation	$108,000	$108,000					$216,000		$216,000
MAN Energy Solutions USA Inc. Water-in-Fuel Technology Demonstration for Ocean-Going Vessels	$500,000	$500,000	$2,000,000				$3,000,000	$200,000	$3,200,000
Pasha Hawaii Ohana Class LNG Powered Container Ships (Two) Project	$250,000	$250,000					$500,000	*	$500,000
Pasha Horizon C9 Vessel LNG Engine Repower Demonstration Project	$250,000	$250,000					$500,000	*	$500,000
Tri-Mer Mobile Emissions Treatment System (METS-1) At-Berth Emissions Reductions for Ships		$1,500,000					$1,500,000	$9,500,000	$11,000,000
South Coast AQMD Ocean-Going Vessel Low-Pressure Exhaust Gas Recirculation Retrofit (LP-EGR), Polar Bear Pilot Vessel Conversion	**$300,000**	**$300,000**	**$300,000**			**$10,874,000**	**$11,774,000**	**$8,456,700**	**$20,230,700**
Harbor Craft									
Centerline Logistics (formerly Harley Marine) Electric Drive Tugboat Design Project	$117,500	$117,500					$235,000	$364,000	$599,000
Crowley Electric Tug Project	**$10,750,000*** **	**$750,000**	**$1,500,000**	**$2,940,000**		**$6,000,000**	**$21,940,000**	**$15,705,000**	**$37,645,000**
Foss Maritime Hybrid Tugboat	$500,000	$889,920		$1,000,000			$2,389,920	$5,610,080	$8,000,000
Nett Technologies Inc. BlueMAX™ NOVA 320e	$250,000	$250,000					$500,000	$700,000	$1,200,000
Cargo-Handling Equipment									
APT Emulsified Biodiesel	$44,000	$44,000.00					$88,000.00	$88,000	$176,000
Balqon Electric Terminal Tractor		$263,500.00	$263,500				$527,000.00		$527,000
Balqon Lithium Battery Upgrade		$400,000.00					$400,000.00	$540,000	$940,000
Capacity Plug-In Hybrid Tractor	$29,500	$32,000.00					$61,500.00		$61,500

Project Category	POLB	POLA	South Coast AQMD	CARB	CEC	USEPA & Other Agencies	Total Port & Agency Stakeholder	OEMs & Demonstration Partners	Total Project Budget
Effenco Rapid Deployment of Electric Active Stop-Start™ Technology for Zero-Emission Idling from Port Yard Tractors Project	*$71,775*	*$71,775*					*$143,550*		*$143,550*
Hybrid Yard Tractor*	$300,000	$300,000.00				$300,000	$900,000.00	$300,000	$1,200,000
Hybrid Yard Tractor Development & Demonstration – Beta Test	$13,000	$13,000.00					$26,000.00		$26,000
Hydrogen Top Handler and Mobile Hydrogen Refueler Project	$430,000	$430,000					$860,000	$3,986,045	$4,846,045
LBCT Eco-Crane	$42,468	$42,467.50				$130,130	$215,065.00	$265,065	$480,130
LNG Yard Tractor*	$350,000					$75,000	$425,000.00		$425,000
RYPOS Advanced L3+ DPF – RTG Cranes	$36,130	$36,130.00					$72,260.00	$249,880	$322,140
RYPOS Diesel Emissions Control (L2+)	*$64,668.42*	*$64,668.42*					*$129,336.84*		*$129,337.84*
SSA Marine H2 Fuel Cell Top Handler Development and Demonstration Project	**$1,095,500**	**$1,095,500**					**$2,191,000**	**$4,291,295**	**$6,482,295**
Vycon RTG REGEN Flywheel	$11,500	$11,500.00	$8,000				$31,000.00		$31,000
Advanced Infrastructure Demonstration Project (AID Project; CEC Funded)		$392,500	$442,750		$7,842,270	$1,344,750	$10,022,270	$1,326,885	$11,349,155
Advanced Yard Tractor Deployment and Eco-FRATIS Drayage Truck Efficiency Project (CEC Funded)					$5,833,000		$5,833,000	$2,808,007	$8,641,007
Commercialization of Off-Road Technology Demonstration (C-PORT Project; CARB Funded)	$1,332,386		$350,000	$5,249,820			$6,932,206	$1,199,882	$8,132,088
Everport Advanced CHE Demonstration (CEC Funded)		$2,096,210			$4,524,000		$6,620,210	$905,413	$7,525,623
Pasha Green Omni Terminal Demonstration Project (CARB Funded)		$6,358,613		$14,510,400			$20,869,013	$12,092,000	$32,961,013
Port of Long Beach Zero-Emission Terminal Equipment Transition Project (CEC Funded)	$3,997,515				$8,610,000	$3,950,000	$16,557,515	$2,405,501	$18,963,016
Sustainable Terminals Accelerating Regional Transformation (START Project; CARB Funded)	$3,531,157		$500,000	$50,000,000		$3,250,000	$57,281,157	$43,237,585	$100,518,742
Container Drayage Trucks									
Daimler Truck North America/SCAQMD Battery-Electric Trucks Demonstration	$1,000,000	$1,000,000	$12,670,072			$1,000,000	$15,670,072	$15,670,072	$31,340,144
Develop and Demonstrate Catenary Zero-Emission Goods Movement System	$2,000,000	$4,000,000	$2,500,000		$3,000,000	$2,000,000	$13,500,000		$13,500,000
Development of a Near-Zero Emission Diesel Engine for On-Road Heavy-Duty Vehicles		$287,500	$287,500	$425,000			$1,000,000		$1,000,000
HLT San Pedro Bay Ports Drayage Truck Demonstration of a Near-Zero Ultra-Low	$37,500	$37,500					$75,000	$121,555	$196,555

Project Category	POLB	POLA	South Coast AQMD	CARB	CEC	USEPA & Other Agencies	Total Port & Agency Stakeholder	OEMs & Demonstration Partners	Total Project Budget
NOx Natural Gas Engine Operating on Renewable Natural Gas									
International Rectifier Plug-In Hybrid Electric Class 8 Truck Conversion	*$17,500*	*$17,500*					*$35,000*	$381,972	$416,972
SoCalGas CNG Drayage Truck	$111,577.50	$111,577.50	$421,250				$644,405	$1,355,595	$2,000,000
South Coast AQMD Zero-Emission Cargo Transport (ZECT) II	$724,489.50	$566,989.50	$2,400,000		$2,400,000	$10,975,000	$17,066,479	$3,075,481	$20,141,960
TransPower Pre-Commercial Electric Drayage Truck Demonstration	$150,000	$150,000			$2,296,617	$1,192,184	$3,788,801	$655,000	$4,443,801
TransPower Electric Drayage Infrastructure and Improvement	$300,000	$300,000					$600,000	$5,700,000	$6,300,000
US Hybrid On-Board Charger for Zero-Emission Cargo Transport Demonstration	$37,500	$37,500	$75,000				$150,000		$150,000
Vision Motor Corp. Hydrogen Fuel Cell Plug-In Hybrid Electric Truck	*$95,625*	*$95,625*					*$191,250*		*$191,250*
Westport ISX LNG Engine	$250,000	$250,000	$1,250,000		$500,000		$2,250,000	$7,644,027	$9,894,027
Shore-to-Store Project (CARB Funded)		$13,999,331	$1,000,000	$41,122,260			$56,121,591	$26,427,281	$82,548,872
Locomotives									
Johnson Matthey DPF Locomotive Demonstration	$75,000	$75,000		$346,178			$496,178	$196,178	$692,356
Pacific Harbor Line Zero-Emission Locomotive Demonstration	**$422,695**	**$422,695**					**$845,390**	**$3,538,264**	**$4,383,654**
VeRail Near-Zero Locomotive Demonstration – Moving Towards Zero Emissions	*$25,000*	*$25,000*					*$50,000*		*$50,000*
Technology Advancement Support Efforts									
AQMD HDV In-Use Emissions Testing Program	$153,276	$153,276	$1,701,156				$2,007,708		$2,007,708
Development of Drayage Truck Chassis Dynamometer Test Cycle	$12,000	$11,466					$23,466		$23,466
Heavy-Duty Drayage Truck Duty Cycle Characterization	$12,681	$13,000					$25,681		$25,681
Total Investment (Includes Funding Outside TAP)	$32,000,357.92	$39,618,270.92	$27,724,228	$116,377,286	$35,005,887	$41,091,064	$291,817,093.84	$183,317,292	$475,134,385.84
Total Port TAP Investment	**$71,618,628.84**								

*Denotes Pasha projects costs for the LNG Repower project are ~$41.5M; project costs for the two-vessel LNG new-build project are $430.3M.
**Denotes EPA-grant funding contribution from the USEPA West Coast Collaborative (pre-dating the TAP).
*** Includes $10,000,000 in CalSTA Port Freight and Infrastructure Program FY2023 funds awarded to POLB.
"**Bold**" denotes projects new this reporting year
"*Italics*" denote projects that were modified during implementation in a manner that changed from the original budget.
"Shaded" areas denote grant projects that were awarded State funding.

APPENDIX A: TECHNOLOGY ADVANCEMENT PROGRAM CONTACTS

Technology Advancement Program Advisory Committee Membership

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APPENDIX B: COMPLETED TAP PROJECTS

The following TAP projects are complete and additional information is available online at the Clean Air Action Plan' TAP website: *https://cleanairactionplan.org/technology-advancement-program/reports/*

1. ACTI Advanced Maritime Emissions Control System (AMECS) Project (2008)
2. Advanced Yard Tractor Deployment and Eco-FRATIS Drayage Truck Efficiency Project (2021)
3. APL Singapore Slide Valve & Water-In-Fuel Emulsion Demonstration Program (2009)
4. Alternative Petroleum Technologies' Emulsified Biodiesel (2011)
5. Balqon E-30 Electric Terminal Tractor Development & Demonstration Project (2009)
6. Balqon Lithium-Ion Battery Demonstration (2011)
7. Bluefield Holdings Krystallon Ocean-Going Vessel Scrubber (2013)
8. Capacity Plug-In Hybrid Electric Terminal Tractor (2010)
9. Characterization of Drayage Truck Duty-Cycles (2011)
10. Commercialization of POLB Off-Road Technology Demonstration Project (C-PORT) (2021)
11. Development of a Drayage Truck Chassis Dynamometer Test Cycle (2011)
12. Development of On-Road Drayage Truck Testing Protocol (2016)
13. Effenco Electric Active Stop-StartTM Technology Demonstration (2022)
14. Foss Maritime Green Assist™ Hybrid Tugboat (2010)
15. Centerline Logistics (formerly Harley Marine) Electric Drive Tugboat Design (2020)
16. Hybrid Yard Tractor Development & Demonstration (2010)
17. Hybrid Yard Tractor Development & Demonstration – Beta Test (2011)
18. Johnson Matthey Locomotive DPF Demonstration (2014)
19. Liquefied Natural Gas Yard Tractor Demonstration (2007)
20. Long Beach Container Terminal Eco-Crane™ (2011)
21. Maersk OGV Energy Efficiency Measurement Demonstration Project (2019)
22. OGV Slide Valve Low-Load Emissions Evaluation (2013)
23. RYPOS Advanced Diesel Particulate Filter for Cargo-Handling Equipment (2012)
24. RYPOS Advanced Level 3+ Diesel Particulate Filter RTG Crane Demonstration (2014)
25. San Pedro Bay Ports Drayage Truck Demonstration of a Near-Zero Ultra-Low NOx Natural Gas Engine Operating on Renewable Natural Gas (2018)
26. South Coast AQMD Daimler Demonstration of Heavy-Duty Electric Trucks (2022)
27. South Coast AQMD Development of a Near-Zero Emission Diesel Engine for On-Road HDVs (2020)
28. South Coast AQMD HDV In-Use Emissions Testing Program (2013)

29. South Coast AQMD Water-in-Fuel Retrofit Technology Demonstration (2022)
30. SoCalGas CNG Drayage Truck Demonstration (2010)
31. TransPower Electric Drayage Infrastructure and Improvement (EDII) Project (2016)
32. TransPower Electric Drayage Pre-Commercial Truck Demonstration (2016)
33. US Hybrid On-Board Charger for Zero-Emission Cargo Transport Demonstration (2016)
34. VYCON REGEN® System for Rubber-Tired Gantry Cranes Testing & Verification (2007)
35. Westport GX LNG Engine Development (2010)