MAY 2025

Port of LONG BEACH
THE GREEN PORT

THE PORT OF LOS ANGELES

SAN PEDRO BAY PORTS

CLEAN AIR ACTION PLAN

2024 ANNUAL REPORT AND 2025 PRIORITIES

Technology Advancement Program

18 Years of Progress Moving Towards Zero Emissions

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- 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
AMP	Alternative Maritime Power
APL	Shipping line formerly known as American President Line
APT	Advanced Petroleum Technologies, Inc.
BET	battery-electric truck
CAAP	Clean Air Action Plan
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
DPF	diesel particulate filter
GHG	greenhouse gases
H2	Hydrogen
kW	kilowatt
LNG	liquefied natural gas
NO_x	oxides of nitrogen
OEM	Original Equipment Manufacturer
OGV	ocean-going vessel
POLA	Port of Los Angeles
POLB	Port of Long Beach
PM	particulate matter
RFI	Request for Information
RTG	rubber-tired gantry crane
South Coast AQMD	South Coast Air Quality Management District
USDOE	United States Department of Energy
TAP	Technology Advancement Program
TEU	Twenty-Foot Equivalent
USEPA	United States Environmental Protection Agency
ZE	zero emission

1 INTRODUCTION

The Ports of Long Beach and Los Angeles (Ports or San Pedro Bay 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 emission technologies. 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 public-private partnerships as well as strong relationships with regulatory agencies that actively participate as members of the TAP Advisory Committee (AC) 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 (CHE), harbor craft, and heavy-duty truck infrastructure, with a focus on zero-emission technologies. Since its inception, the TAP has undertaken more than 50 projects spanning test cycle development, zero-emission, 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 to make 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.

The Ports' technology advancement portfolio is comprised of the TAP, grant-funded demonstrations, and cost-sharing partnerships with other agencies. 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 over $431 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 the pre-commercial technology advancement aspect of the CAAP. For additional detail regarding the Ports' significant investments to deploy commercialized equipment and technologies, please refer to the CAAP Annual Progress Reports found at *www.cleanairactionplan.org.*

Looking Ahead

In 2024, the San Pedro Bay Ports moved historic cargo volumes - 10.3 million twenty-foot equivalents (TEUs) at the Port of Los Angeles and 9.6 million TEUs at the Port of Long Beach. This throughput represents a nearly 20% increase in container volume over the prior year (2023), and reflects the potential for busier operations at the nation's largest seaport complex. As a result, operational requirements for CHE are evolving and performance expectations are likely to increase for zero-emission technologies. Current and future TAP demonstrations will need to take into account the level of cargo throughput at the time of testing when evaluating performance in order to ensure that zero-emission equipment and vehicles can perform at the highest levels, under all conditions.

The Ports have invested substantial energy and capital into the ambitious 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 2025. However, given size of the drayage truck fleet serving the San Pedro Bay Ports – roughly 20,000 trucks – it will take time and substantial incentives to move the needle. Further, there are still significant gaps in charging and hydrogen fueling infrastructure for vehicles and equipment. More information on the state of technology and progress towards the CAAP goals will be described in detail in the San Pedro Bay Ports 2024 Feasibility Assessments for Drayage Trucks and Cargo Handling Equipment. Draft assessments are expected to be released to the public in the second quarter of 2025 for review and comment.

There is more work to be done on ocean-going vessel technologies and harbor craft in support of newly implemented and upcoming regulations. Notably, the technology pathways for cargo-handling equipment are becoming clearer. Given the significant levels of state and federal funding received by the Ports to date, 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. In the meantime, the Ports project that state and federal grant funding will be less than in recent years due to limited budgets and will therefore continue to focus on ensuring that TAP projects directly support CAAP goals.

Agency Partnerships

Project selection is supported by the TAP Advisory Committee (AC), comprised of the South Coast Air Quality Management District, California Air Resources Board, California Energy Commission (CEC), and the 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.

Technology Advancement Program
Advisory Committee

2 TECHNOLOGY ADVANCEMENT PROGRAM ACCOMPLISHMENTS IN 2024

In 2024, the Ports continued to implement technology advancement projects, the updates for which are documented herein. Major accomplishments in 2024 include:

- Initiated the AERAS Capture and Control Non-Regulated Vessel Demonstration (Section 5.2)
- Completed the Pacific Harbor Line Zero-Emission Locomotive Demonstration (Section 5.4)
- Completed the Pasha Hawaii Ohana Class Liquefied Natural Gas (LNG)-Powered Container Ships Project – Two New Builds (Section 5.5)
- Completed the Pasha Horizon C9 Vessel LNG Engine Repower Demonstration Project (Section 5.6)
- Completed the South Coast AQMD Zero-Emission Cargo Transport (ZECT) II Demonstration (Section 5.9)
- Completed the Toyota Tsusho Hydrogen Top Handler and Mobile Hydrogen Refueler Project (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.
- Initiated the 2024 Update to the CAAP Feasibility Assessments for Drayage Trucks and Cargo Handling Equipment.

Table 1 provides an overview of active 2024 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 2024 and projected milestones for 2025. Projects presented in bold font indicate completion or close out in 2024.

Table 1: 2024 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
AERAS Capture and Control Non-Regulated Vessel Demonstration (Port of Los Angeles)	Construct a capture-and-control system for testing on non-regulated vessel types (i.e., RoRo, Bulk).	Section 5.2	Capture & Control
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.**	**Section 5.3**	**Zero-Emission Capable**
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 5.4**	**Zero Emission**

Project Title	Project Description	Section	Technology
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. Alternative Marine Power (AMP) capability included. These propulsion engines will meet Tier III standards.**	**Section 5.5**	**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 5.6**	**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 5.7**	**Zero Emission**
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 plug-in hybrid, battery-electric and fuel cell technology.**	**Section 5.8**	**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 5.9	OGV Retrofit
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 5.10	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 5.11**	**Zero Emission**

Please access additional information for completed TAP projects at the program website: https://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 2024, the Ports continued to lead or support seven major zero-emission demonstration projects. The Ports will continue to prioritize the successful completion of the demonstration projects already underway, but also to expedite the path to zero emissions. The Ports have learned from these projects and continue to identify gaps in understanding, which will help shape future funding priorities. These efforts have made San Pedro Bay Ports a hub of technology advancement zero-emission trucks and terminal equipment.

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 (BET) 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.

The Ports are funding other zero-emission initiatives. More information on these may be found in the CAAP Annual 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[1].

[1] 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 2025 TECHNOLOGY ADVANCEMENT PRIORITIES

In 2025, the Ports will continue to prioritize the successful completion of current demonstration projects in progress to not only meet grant deadlines and compliance requirements, but also to expedite the path to zero emissions. The Ports have learned from these projects and continue to identify gaps in understanding, which will help shape future funding priorities.

Implementation of the 2017 CAAP Update will progress as the Ports seek additional opportunities to advance clean harbor craft projects, demonstrate innovative fueling and charging technologies, showcase the feasibility of alternatively fueled vessels, and test zero-emission terminal equipment. 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 will be 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. 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 2025, the Ports commit to the following technology advancement priorities:

- Consider new projects submitted under the TAP's ongoing Request for Information (RFI) review process[2] 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 alternative 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 grant programs, where allowable, 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.

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

5 2024 PROJECTS

This section provides additional detail for technology advancement projects that were active in 2024. These projects represent the current portfolio of technology investments, including projects funded and managed by both Ports through the TAP, projects funded by grants and managed by one Port, 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 and associated charging infrastructure. The AID project, funded largely by a CEC grant, will enable the Port of Los Angeles (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 (Figure 1). 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 2). 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. 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: Ten WAVE Charging Pads at the Main Equipment Corral will be Integrated with the BESS to Support the Battery-Electric Yard Tractors

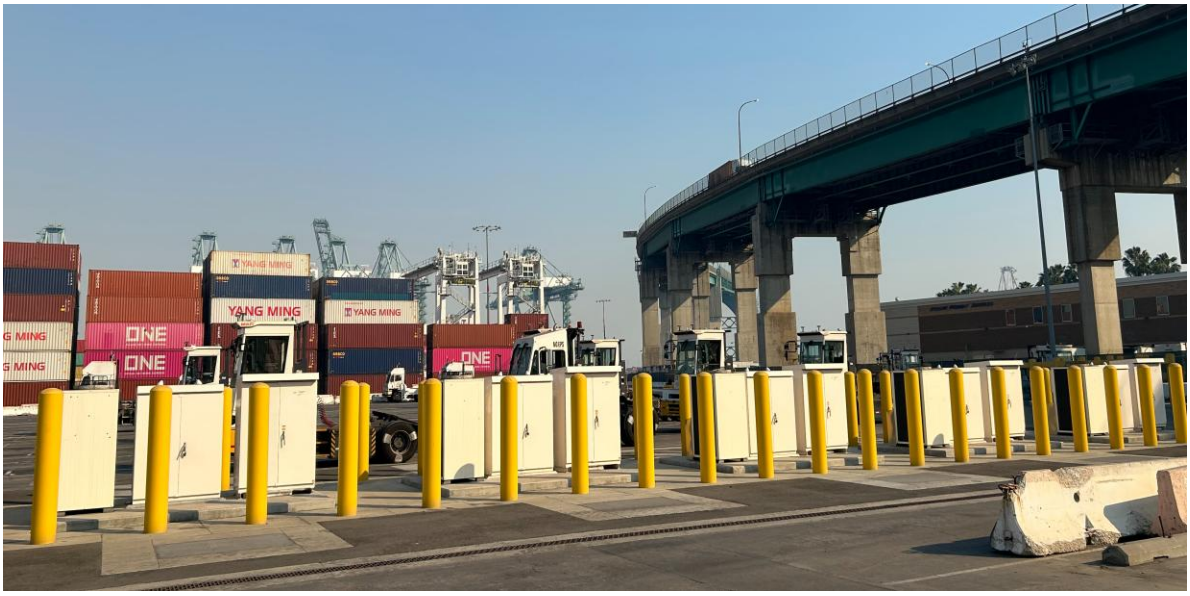

Figure 2: Two Commissioned WAVE Opportunity Charging Pads and a BYD Battery-Electric Yard Tractor

Project Partners & Budget

This project is funded by a $7.8 million CEC grant. The yard tractors were 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
U.S. Environmental Protection Agency	$1,344,750
South Coast Air Quality Management District	$442,750
OEMs and Demonstration Partners	$1,326,885

Accomplishments in 2024
The transformer, switchgear, and BESS were delivered and installed at the main equipment corral and the WAVE gear was temporarily energized to support commissioning activities. All 10 yard tractors were integrated, retrofitted, and delivered to WBCT. Two of the BYD yard tractors performed some operational duty and utilized the two WAVE opportunity chargers near the break area.

2025 Milestones
The following activities are expected in 2025:

- Integrate and commission the BESS.
- Finalize Los Angeles Department of Building and Safety (LADBS) permit approval for the main equipment corral.
- Energize and commission the main equipment corral.
- Yard tractor software updates and minor repairs completed.
- 10 yard tractors commissioned and in-service.
- Data collection challenges resolved.
- Deploy and demonstrate 10 yard tractors, 12 charging units, and the BESS for 12 months.

5.2 AERAS RoRo At-Berth Emissions Control Project (Port of Los Angeles)

Project Description
AERAS Technologies, LLC (AERAS) will design, develop, and test an emissions control system for Roll-On/Roll-Off (RoRo) vessels with the intent of obtaining certification from the California Air Resources Board (CARB) as a "CARB-Approved Emissions Control Strategy" (CAECS). CAECS are defined and certified by CARB under their At-Berth Emissions Control Regulation (At-Berth Regulation). AERAS will use their AERAS-1 system for this project. The demonstration of the system will occur primarily at the Port of Los Angeles and may be demonstrated at the Port of Long Beach as well.

RoRo vessels present unique challenges including long-length horizontal ducting requirements to account for RoRo stack locations, connection modifications to deal with obstructions, filtration and spark-arrest technologies, attachment modifications and crew transport arrangements to work on vessels that have unique waterside mooring and entrance points. The successful completion of the project will substantially decrease pollutants emitted from RoRo vessels while at berth, providing important benefits to the local community and introduce a new compliance pathway for vessels subject to CARB's At Berth Regulation.

The AERAS system is designed to remove 90% of oxides of nitrogen (NOx) and diesel particulates from marine diesel engines, has already been approved by CARB, and is presently servicing vessels in the San Pedro Bay Ports.

Project Partners & Budget
AERAS and the project team have a combined 60+ years of experience in engineering of environmental solutions. The project team includes Harbor Industrial Inc./Innovative Engineering and Maintenance for equipment assembly, fabrication and integration, P2S Inc. for engineering, and Pacific Tugboat Service for operating and barge construction support. American Marine Corporation will provide waterside operational labor and provisioning support.

Table 3 summarizes the funding contributions.

Table 3: AERAS Capture and Control Non-Regulated Vessel Demonstration Project Funding Partners

Project Partners	Contributions
Port of Los Angeles	$750,000
AERAS Technologies	$5.5M “in-kind”

Accomplishments in 2024
During the initial design phase, the Project Team completed design adjustments to AERAS-1 to meet the unique physical characteristics of RoRo vessels. Activities to support this effort included:

- Coordination with vessel demonstration partners to finalize operational parameters and constraints.
- Design of RoRo-specific connection hood(s) to optimize emission capture from a variety of RoRo exhaust stack configurations. Investigation and selection of mooring equipment to efficiently moor to the unique water-side architecture of RoRo vessels and to safely transfer crew from the AERAS-1 barge to RoRo vessels.
- Prepared and submitted the Demonstration Test Plan for CARB review and approval, which was received in December 2024. The Test Plan identifies the testing hours, data collection, and reporting necessary to successfully document AERAS-1 as a CAECS for RoRo vessels.

2025 Milestones
The following activities are expected in 2025:

- Naval architect analysis to ensure safe reach of the AERAS boom and connection.
- Modifications to the AERAS-1 barge and ductwork system as necessary to meet naval architect's direction.
- Manufacture of RoRo-specific capture hood(s) connections.
- Conduct a connection demonstration without emission capture to ensure safe vessel coordination and attachment of the AERAS capture hood to RoRo vessel stacks.
- Commissioning to establish operational parameters include exhaust temperature, flow rate, and vessel generator loads.
- Durability testing to demonstrate that AERAS-1 is capable of consistently treating emissions from RoRo vessels.

- Third-party testing to independently document emission capture rate and treatment efficiency of AERAS-1 on RoRo vessels.
- Compile demonstration and third-party test data for submittal to CARB.

5.3 Crowley Electric Tug Project (Port of Long Beach)

Project Description
Crowley Marine Services (Crowley) planned the design of a zero-emission capable tugboat to replace an older Tier 2 engine-equipped tug. Upon completion of the building process, the tugboat was to be demonstrated at the San Pedro Bay Ports. A charging station at Crowley's berth at the Port of Los Angeles would have enabled the hybrid tugboat to attain a minimum of 30% zero-emission operation.

Project Partners & Budget
The estimated project budget for the vessel alone is well over $37.6 million. Crowley originally planned to contribute over $15 million, and the Ports approved $1.5 million in co-funding for the demonstration. The California Air Resources Board, the Environmental Protection Agency, and the California State Transportation Agency awarded additional funding to to the Port of Long Beach (POLB) to cover the balance of project costs. Table 4 summarizes the funding contributions that were planned for each project partner.

Table 4: 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

2024 Update
In 2024, Crowley partnered with Baydelta to create a new joint venture to perform additional technical and commercial evaluations of this project's multiple grant agreements, vessel construction, and operations. For this joint venture, both companies planned to contribute capital and shared in the project risk.

Given the complexity of the technology of a vessel of this kind and open questions regarding the charging station and more, Crowley and Baydelta subsequently provided notice to the project partners that they are unable to commit to advancing this project on the timeline requested by the project partners. The Ports are working to assess the potential to reprogram funds to a similar hybrid tug project in 2025.

5.4 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 the operation of a zero-emission, battery-electric switching locomotive at the Ports. The design of the charging station began in 2021, with manufacturing completed in 2023 at the Progress Rail Facility in Sete Lagoas, Brazil. In 2023, the project received approval from the respective Board of Harbor Commissioners. The battery charging system was installed at PHL's locomotive shop, located on Port of Los Angeles property, in October 2023.

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 primarily consisting of Tier 3 diesel-electric locomotives. The zero-emission switcher locomotive, leased for this demonstration, was purpose-built for the project and is fully funded by Progress Rail. The locomotive has a nameplate rating of 2.4 megawatt-hours (its total battery energy storage capacity), with six alternating current traction motors, enabling it to operate for most of the day.

The battery charging system is crucial to maximizing the zero-emission locomotive's operational time within the Ports. To minimize recharging time, 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). This ZE locomotive, comparable in power to one of PHL's six-motor diesel-electric locomotives, will be able to perform similar tasks such as moving trains and switching rail cars. Upon commissioning, the battery charging system was used to power the locomotive.

Project Partners & Budget

PHL partnered with Progress Rail, a major global provider of locomotives and associated infrastructure under its parent company, Caterpillar, Inc. Other project team members included contractor Dynalectric-Los Angeles (a division of KDC, Inc.), which oversaw site planning, site modifications, and the installation of the battery charging system at PHL's locomotive shop. Another contractor, TK1SC, signed off on all engine drawings and documents required for the permitting process with the LADWP. Table 5 summarizes the project funding contributions. The Ports contributed over $845,000, which was matched by just over $3.5 million, bringing the total project cost to just over $4.38 million.

Table 5: 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

Project *Status - Completed*

The battery-electric locomotive and charger were officially placed into service in December 2023. During the one-year demonstration, which concluded in December 2024, it was found that the locomotive typically required recharging after one or two shifts, unlike diesel locomotives that

can operate for several days. This necessitated more complex work planning and limited the locomotive's operational locations. However, the future installation of additional chargers is expected to alleviate these challenges.

Operator feedback indicated that, after gaining experience, many operators preferred the battery-electric locomotive due to its reduced noise, strong pulling power, and comfort. Although charging was initially unfamiliar, it became a non-issue once crews received proper training. Charging times ranged from 1 to 4 hours, depending on battery depletion, and the locomotive could complete one heavy-duty (10-12 hours) or two light-duty (5-7 hours) cycles before needing to recharge.

Several lessons were learned during the demonstration. Initial delays were caused by software updates and supply chain issues for replacement parts, but these challenges have been resolved. Key areas for improvement included providing more initial training for crews and ensuring a greater supply of spare parts. Looking ahead, PHL plans to continue using the battery-electric locomotive and charger (Figure 3) through May 2025 and is negotiating an extension of the lease through 2026. Additionally, PHL was awarded a Federal Railway Administration grant to purchase five battery-electric locomotives and two charging stations, reinforcing its commitment to zero-emission technology.

Figure 3: PHL Locomotive Charging System Under Construction

5.5 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 6. TAP funding will support the initial design and documentation of the demonstration and emission reduction benefits.

Table 6: 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
Pasha	$430M “in-kind”

Projec*t Status - Completed*

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.

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

Project Description

Pasha Hawaii Holdings LLC (Pasha) will repower an existing ocean-going vessels (OGV), M/V Horizon (Figure 4), to operate on LNG. Pasha’s repowered vessel will call at the San Pedro Bay Ports 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 4: 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 7. TAP funding will support the initial repower design and documentation of the demonstration and emission reduction benefits.

Table 7: Pasha Hawaii Horizon Reliance LNG Conversion Project Funding Partners

Project Partners	Contributions
Port of Los Angeles	$250,000
Port of Long Beach	$250,000
Pasha	$41.5M “in-kind”

Project *Status - Completed*

Using LNG as a primary fuel source has proven to be a technologically viable solution to a low emission container shipping. As Pasha Hawaii continues to operate M/V George II, the technology will become even more reliable over time. As vessel crew knowledge and expertise in operating and maintaining LNG fueled vessels continues to grow, the viability of this new technology will be enhanced. The project was completed in 2024 the project management submitted their final report on January 15, 2024.

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

Project Description

The objective of this project, in partnership with SSA Marine (SSA) and Taylor Machine Works (Taylor) was to design, manufacture, and demonstrate two zero-emission top handlers powered by liquid hydrogen that would be stored onboard in two 35 kg tanks subcooled to -250˚F.

The new build top handlers would be fuel cell dominant with batteries on board to assist the fuel cell during heavy power use and to capture regen power, which would enable SSA to operate for over 16 hours, satisfying SSA's daily duty cycle of two 8-hour shifts. The liquid hydrogen would have been delivered by truck weekly to a dedicated site on terminal where fuel was to be stored in two 700 kg tanks. Since no onsite compression would have been required for liquid hydrogen storage, no major infrastructure at the terminal was needed.

The project was cut short during the design stage and the project was closed out ahead of schedule in 2024, with SSA and Taylor agreeing that this project posed too many risks due to an immature hydrogen market.

Background

In 2019, SSA and Taylor demonstrated two first-generation ("Gen 1") battery-electric top handlers, 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, notably the inability 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 was to improve the design of the "Gen 1" equipment, enabling it to meet operational demands, eliminate range anxiety, and operate free of the electrical grid.

Project Status- Withdrawn

Taylor encountered multiple challenges during the initial design phase which impaired their ability to complete final design. The main issues Taylor outlined involved the availability, safety, and storage of liquid hydrogen fuel, uncertainty of the supply chain of third-party fuel cell integrators, which both resulted in the inability to produce a top handler that would have successful software integration related to its components (hybrid powertrains, fuel cell controls, hybrid battery power delivery management, and hydrogen safety systems controls), and its ability to match the current demand load.

For the hydrogen fuel cell top handler to complete the daily duty cycle, a minimum of 80kg of hydrogen is require for each 8-hour shift. The current supply chain for mobile vehicles relies entirely on compressed gaseous hydrogen for onboard fuel storage. However, the fuel storage technology, which accommodates hydrogen gas pressures of 350 bar and 700 bar, is unable to store the required 80 kg of hydrogen. Space restrictions and this energy need called for the use of the highest energy density technically possible, which could be achieved by liquid hydrogen.

However, liquid hydrogen does not currently have a fully developed supply chain for fueling technology or storage tanks on mobile container handling equipment. The development of onboard liquid hydrogen systems is still required, which will lengthen the overall timeline due to critical research and development. Furthermore, the use of liquid hydrogen presents distinct safety challenges for both mobile equipment and storage, as well as during fueling, all of which must be addressed in the design and testing processes. Additionally, specialized training will be necessary for the workforce that will be fueling, operating, and maintaining this equipment.

Lessons Learned
When this project launched in 2021, it was anticipated that the market for hydrogen fuel cell CHE and the broader hydrogen fuel ecosystem would rapidly develop. However, as of today, hydrogen-powered CHE remains in the pre-commercial phase and is not yet ready for large-scale deployment by marine terminal operators.

Although the project was withdrawn, the initial design highlighted the technical and economic challenges hindering the full maturation of the hydrogen marketplace and impeding its commercialization. These findings will help inform future demonstrations of innovative liquid hydrogen technology.

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

Project Description
This project goal was to accelerate the 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 impacted by air pollution from heavy diesel traffic. ZECT II planned to develop and demonstrate seven (7) drayage trucks by five different contractors. Six (6) of the trucks were successfully demonstrated, with the seventh unit withdrawing from the program as discussed below:

- Transportation Power, Inc. (TransPower) developed two (2) BETs with hydrogen fuel cell range extenders.
- US Hybrid developed two (2) 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 one (1) BET with a hydrogen fuel cell range extender.
- Under project management by the Gas Technology Institute (GTI), BAE Systems and Kenworth developed one (1) battery-electric hybrid truck with a compressed natural gas (CNG) range extender. The truck can operate in zero-emission (all-electric) mode and conventional hybrid electric mode using CNG.
- International Rectifier (IR) was to develop and demonstrate one (1) fuel cell range extended Class 8 truck., but IR withdrew in 2016, and subsequent efforts were unable to find a suitable replacement.

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 8 summarizes the project funding contributions.

Table 8: South Coast AQMD ZECT II Demonstration Funding Partners

Project Partners	Contributions
United States 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	$566,990
▪ Port of Los Angeles	$566,990
Southern California Gas Company	$250,000

Project *Status - Completed*
This project was completed and the required agreement closeout documentation was submitted to the United States Department of Energy (USDOE) by the December 31, 2024 due date.

Between 2014 – 2024, six ZECT II zero-emission fuel cell drayage truck platforms, including fuel cell range extenders and CNG hybrid trucks, were successfully designed, developed, integrated, built, tested, and demonstrated with drayage fleet operators in transportation corridors within areas of the South Coast AQMD jurisdiction. Portable hydrogen refueling was deployed to support the fuel cell vehicles. The project had real-time improvement with on-going debugging and optimizations while the vehicles were under demonstration. All platforms demonstrated sufficient or excess power, torque, and energy to support 82,000lbs Gross Vehicle Weight Rating and grade ability to perform their daily duty cycles, with a range of 150-200 miles and an average fuel consumption rate of 6-8 mi/kilogram of hydrogen (fuel consumption varies by duty cycle, load, etc.). Collectively, the trucks drove over 23,000 miles during their respective demonstration phases.

International Rectifier was to develop a plug-in diesel hybrid-electric Class 8 drayage truck, and ultra-fast chargers for use in or near POLA and POLB. In late 2016, International Rectifier (IR) announced that it was being acquired by Infineon Technologies AG. After the acquisition, the new ownership declined to continue developing the truck. During the project, South Coast AQMD and the USDOE explored the opportunity to work with another manufacturer for this last unit, but ultimately were unable to find a replacement.

The ZECT II project was built upon the success of prior truck demonstration projects, such as the ZECT I project. ZECT I enabled vendors, like US Hybrid, to progress in electric powertrain technology. Demonstration projects like ZECT I and ZECT II provide many lessons that future projects can learn from, including but not limited to, vehicle performance or maintenance. Although most challenges were expected, vendors such as TransPower and US Hybrid were able to address issues related to data collection and new technology improvement issues.

Overall, the ZECT II was deemed a successful project since six of the planned seven ZECT II platforms, including fuel cell range extended and CNG hybrid trucks, were successfully designed, built, tested, and demonstrated with drayage fleet operators in transportation corridors within the South Coast AQMD. Some of these platforms further led to commercial products that are on the market today. Portable hydrogen refueling was deployed to support the fuel cell vehicles. The

project had real-time improvement with on-going debugging and optimizations while the vehicles were under demonstration. All platforms demonstrated sufficient or excess power, torque, and gradeability to transport most payloads.

Figure 5: ZECT II Zero-Emission Demonstration Truck

Source: South Coast Air Quality Management District

Figure 6: Hybrid Electric Cargo Transport (HECT) Truck

Source: South Coast Air Quality Management District

5.9 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 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% particulate matter (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 retrofitted 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 LNG 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 retrofitted 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 LP-EGR 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 9 summarizes the project funding contributions.

Table 9: 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 2024
The LP-EGR system has been developed and lab-tested. After performing the full assessment, it was determined that additional clearances are needed for the system installation and will require an adjustment in the design. The redesign is expected to be completed in early 2025 and to be further tested. In 2023, the MSC Topaz vessel engine cylinder bore size was reduced to improve fuel efficiency resulting in a 13% reduction in fuel usage and 33% NOx emission reduction. In 2024, LNG and ammonia fuel systems were incorporated in the design which required additional safety considerations. These changes include adding space for alternative fuel injectors, changes to the fuel tank materials, deep well pumps and adding a boil-off gas recovery system. Additional work is being done to assess the risk migration measurement in the event of a fuel leakage. These new changes require additional design changes, resulting in the delay of the milestone dates into 2025.

2025 Milestones
The following activities are expected in 2025:

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

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

- 33 zero-emission yard tractors at Pier C;
- 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 10 summarizes the funding contributions.

Table 10: 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 2024

In 2024, the electric yard tractor demonstration at the Port of Long Beach began. Due to uncertainty as to how the electric vehicles and infrastructure would perform, the terminal opted to begin with deploying only a portion of the fleet. As mechanical and interoperability issues persisted, only 6-12 yard tractors were operated at a time, slowing the overall demonstration. The Port of Oakland work on the infrastructure is proceeding slowly, with commissioning not expected to be complete until second quarter (Q2) 2025. The Port of Oakland completed their drayage truck and top handler demonstrations. At the Port of Long Beach Shippers Transport location, the drayage truck demonstration kicked off, although mechanical issues with the trucks and infrastructure slowed completion of the demonstration, which is expected to be completed in Q2 2025. The two public charging stations installed under this grant at the joint Ports' Terminal Access Center continued to operate well overall, with increasing usage by the growing number of battery-electric drayage trucks serving the Ports (Figure 5).

Both Tier III container ships continued operations and emissions testing was completed in 2023, with analysis of the samples continuing throughout 2024. Citing economic constraints, Crowley ceased work on development of their zero-emission capable plug-in hybrid tugboat. The Port of Long Beach has been working with another tugboat operator to take over the project.

2025 Milestones

The following activities are expected in 2025:

- Complete demonstration of the heavy-duty drayage trucks in Long Beach.
- Complete demonstration of the yard tractors.

- Incorporate replacement tugboat operator into the grant and proceed with execution of the shipyard contract.
- Finalize data reports for the ocean going vessels, drayage trucks, and yard tractors.

Figure 7: Zero-Emission Drayage Trucks Charging at Port of Long Beach

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

Project Description

Toyota Tsusho America, Inc. (Toyota Tsusho) demonstrated a repowered diesel top handler from conventional fuel to zero-emission hydrogen fuel cell technology. The top handler was repowered with a hydrogen fuel cell-powered propulsion system by US Hybrid. Initially, the diesel-powered top handler's performance baseline was measured 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 6) is complete and the equipment was delivered to Fenix Marine Services (FMS) terminal from US Hybrid. The demonstration took place at FMS marine terminal at POLA over 12 months with an extended period of six months to accommodate for shipping delays. The project goal was to demonstrate that the repowered top handler could function as efficiently as the diesel baseline in the heavier rail yard duty cycle. The successful operation of the hydrogen top handler demonstrated the feasibility of fuel-cell-powered CHE for a full shift in the container yard and may complete two full shifts on the rail yard with its recent upgraded capacity. This project has evidenced an impetus to the advancement of the heavy-duty hydrogen fuel cell market and has had notable usage promotion from cargo handling equipment (CHE) customers. In addition to technological advancement, this project has shaped the field of alternative marine fuel usage at the San Pedro Bay Ports. More specifically, this project improved the processing of hydrogen special permitting, clarity of safety expectations for training purposes and translation of regulatory language for field application in the context of heavy-duty port complexes located in the city of Los Angeles.

Along with repowering the top handler, Toyota Tsusho developed and deployed a mobile hydrogen refueler (Figure 7). Nine separate cylinders, 27.57 kg of hydrogen each are placed on a fixed truck chassis with a design capacity of 930bar 247.5 kg of hydrogen. A total of 9-cylinder tanks (27.5 kg/cylinder) of liquid hydrogen are mounted on the mobile refueler caddie (Figure 8). The refueler delivered hydrogen fuel at a rate of approximately 2 kg/minute. safety approvals and a special permit were obtained from Los Angeles Fire Department (LAFD), the mobile refueler successfully fueled the repowered top handler and Yesen terminal rubber-tired gantry (RTG) crane. These fueling occurrences validated the operators experience and secured the necessary approvals to conduct hydrogen fueling in a manner similar to wet-hose fueling of diesel equipment that is current practice.

Figure 8: Toyota Tsusho Repowered Hydrogen Top Handler

Figure 9: "ONE H2" Mobile Refueler

Figure 10: "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 11 summarizes the funding contributions from the project partners.

Table 11: H2 Top Handler and Mobile H2 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

Project *Status - Completed*

Toyota Tsusho extended their special approvals from the City of Los Angeles Harbor Department for their demonstration project. 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 and continued during 2024. The final upgrade to the top handler occurred late December and is planned to be recommissioned during first quarter (Q1) 2025. The mobile refueler was delivered during March 2024 and successfully demonstrated fueling at two terminals. A final report was delivered to the Ports summarizing the completed elements of the project.

While the project was officially closed out in 2024, the project team plans to conduct the following activities in 2025:

Mobile refueling operation and potential expansion for varied CHE use cases

- Additional operational testing and demonstration of the upgraded version of the hydrogen fuel cell-powered top handler will be gathered outside of the scope of this TAP project.
- Testing of "wet fueling" using the mobile refueler for the upgraded fuel cell top handler.

6 2024 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 12 below. In 2024, the TAP focused on continuing to execute its portfolio of technology advancement projects while reviewing concepts for potential new projects.

Table 12: Ports' Technology Advancement Funding Investments as of December 31, 2024

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
AERAS RoRo At-Berth Emissions Control Project		$750,000					$750,000	*	$750,000
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
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*
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 NOx Natural Gas Engine Operating on Renewable Natural Gas	$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
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	$566,989.50	$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)	$19,997,357.92	$38,522,770.92	$26,224,228	$113,437,286	$35,005,887	$35,091,064	$268,278,593.84	$163,320,997	$431,599,590.84
Total Port TAP Investment	**$58,520,128.84**								

* Denotes that the AERAS project team contributed ~$5.5 million in in-kind cost share for this project.
**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.
"**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

- Victoria Robbins, USEPA Region 9 — Robbins.Victoria@epa.gov
- Nicholas Storelli, California Air Resources Board — Nicholas.Storelli@arb.ca.gov
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APPENDIX B: COMPLETED TAP PROJECTS

The following TAP projects are complete. 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. Pacific Harbor Line Zero-Emission Locomotive Demonstration (2023)
24. Pasha Green Omni Terminal Demonstration Project (2024)
25. Pasha Hawaii Ohana Class LNG-Powered Container Ships Project (2024)
26. Pasha Horizon C9 Vessel LNG Engine Repower Demonstration Project (2024)
27. RYPOS Advanced Diesel Particulate Filter for Cargo-Handling Equipment (2012)
28. RYPOS Advanced Level 3+ Diesel Particulate Filter RTG Crane Demonstration (2014)
29. San Pedro Bay Ports Drayage Truck Demonstration of a Near-Zero Ultra-Low NOx Natural Gas Engine Operating on Renewable Natural Gas (2018)

30. South Coast AQMD Daimler Demonstration of Heavy-Duty Electric Trucks (2022)
31. South Coast AQMD Development of a Near-Zero Emission Diesel Engine for On-Road HDVs (2020)
32. South Coast AQMD HDV In-Use Emissions Testing Program (2013)
33. South Coast AQMD Water-in-Fuel Retrofit Technology Demonstration (2022)
34. South Coast AQMD Zero-Emission Cargo Transport (ZECT) II Demonstration (2024)
35. SoCalGas CNG Drayage Truck Demonstration (2010)
36. TransPower Electric Drayage Infrastructure and Improvement (EDII) Project (2016)
37. TransPower Electric Drayage Pre-Commercial Truck Demonstration (2016)
38. US Hybrid On-Board Charger for Zero-Emission Cargo Transport Demonstration (2016)
39. VYCON REGEN® System for Rubber-Tired Gantry Cranes Testing & Verification (2007)
40. Westport GX LNG Engine Development (2010)