



Port of **LONG BEACH**
THE PORT OF CHOICE



THE PORT
OF LOS ANGELES



SAN PEDRO BAY PORTS
CLEAN AIR ACTION PLAN

2021 ANNUAL REPORT AND 2022 PRIORITIES
Technology Advancement Program

15 Years of Progress Moving Towards Zero Emissions

Acknowledgements

The Ports of Long Beach and Los Angeles wish to acknowledge our Advisory Committee for the ongoing guidance and support to the Technology Advancement Program. Specifically, the Ports thank the following Advisory Committee members:

- Francisco Donez, US Environmental Protection Agency, Region 9
- Nicholas Storelli, California Air Resources Board
- Marc Perry, California Energy Commission
- Joseph Impullitti, South Coast Air Quality Management District

In addition, the TAP appreciates the significant input to this report and support for the TAP provided by the following agency staff:

- Phil Barroca, South Coast Air Quality Management District
- Seungbum Ha, South Coast Air Quality Management District
- Patricia Kwon, South Coast Air Quality Management District
- Joseph Lopat, South Coast Air Quality Management District
- Mei Wang, South Coast Air Quality Management District

Table of Contents

1 INTRODUCTION..... 1

2 TECHNOLOGY ADVANCEMENT ACCOMPLISHMENTS IN 2021 5

3 PROGRESS TOWARD ZERO EMISSIONS 8

4 2022 TECHNOLOGY ADVANCEMENT PRIORITIES 10

5 2021 PROJECTS 11

5.1 Advanced Infrastructure Demonstration Project (Port of Los Angeles)..... 11

5.2 Advanced Yard Tractor Deployment and Eco-FRATIS Drayage Truck Efficiency Project (Port of Los Angeles)..... 13

5.3 Commercialization of POLB Off-Road Technology Demonstration Project (C-PORT) (Port of Long Beach)..... 15

5.4 Effenco Electric Active Stop-Start™ Technology Demonstration 16

5.5 Everport Advanced Cargo Handling Equipment Demonstration Project (Port of Los Angeles)..... 18

5.6 Nett Technologies Inc. BlueMAX™ NOVA 320e Harbor Craft Demonstration 19

5.7 Pasha Green Omni Terminal Demonstration Project (Port of Los Angeles) 21

5.8 Pasha Hawaii Ohana Class LNG-Powered Container Ships Project..... 22

5.9 Pasha Horizon C9 Vessel LNG Engine Repower Demonstration Project..... 23

5.10 Port Advanced Vehicle Electrification (PAVE) Project (Port of Long Beach) 24

5.11 South Coast AQMD Daimler Demonstration of Heavy-Duty Electric Trucks 25

5.12 South Coast AQMD Retrofit Technology Development – Water-in-Fuel Technology..... 27

5.13 South Coast AQMD Zero Emission Cargo Transport (ZECT) II Demonstration 29

5.14 Shore-to-Store Project (Port of Los Angeles) 31

5.15 Sustainable Terminals Accelerating Regional Transformation (START) Project (Port of Long Beach)..... 33

5.16 Zero-Emissions Terminal Equipment Transition Project (Port of Long Beach) 35

6 2021 TECHNOLOGY FUNDING 38

APPENDIX A: TECHNOLOGY ADVANCEMENT PROGRAM CONTACTS A-1

APPENDIX B: COMPLETED TAP PROJECTS..... B-1

List of Figures

Figure 1: Repowering RTGs to Zero Emissions 9
 Figure 2: Port of Los Angeles Zero-Emissions Pathway Concept.....12
 Figure 3: Taylor Battery-Electric Top Handler at LBCT (left) and SSA (right)16
 Figure 4: Installation of Effenco’s Stop-Start System.....17
 Figure 5: Taylor Battery-Electric Top Handler.....19
 Figure 6: Nett Technologies Demonstration Vessel.....20
 Figure 7: ShoreKat At-Berth Emissions Control System21
 Figure 8: Marine Vessel Pasha Horizon23
 Figure 9: Daimler Zero-Emission Class 8 Trucks26
 Figure 10: Demonstration Vessel MSC Anzu28
 Figure 11: Water-in-Fuel Emulsifier Emulsion Mixer and Booster Units.....29
 Figure 12: Complete Platform for WiF Installation on the Anzu Vessel.....29
 Figure 13: Hydrogen Fuel-Cell Class 8 Kenworth/Toyota Trucks31
 Figure 14: Zero-Emission Top Handler at Port of Oakland34
 Figure 15: Solar Station at Port of Stockton35

List of Tables

Table 1: 2021 Technology Advancement Project Snapshot 5
 Table 2: Advanced Infrastructure Demonstration Project Funding Partners12
 Table 3: Advanced Yard Tractor Deployment and Eco-FRATIS Drayage Truck Efficiency
 Funding Partners14
 Table 4: C-PORT Funding Partners15
 Table 5: Effenco Electric Active Stop-Start™ Technology Demonstration Project Funding
 Partners.....17
 Table 6: Everport Advanced Cargo Handling Equipment Demonstration Funding Partners18
 Table 7: Nett Technologies Inc. BlueMAX™ NOVA 320e Harbor Craft Demonstration.....20
 Table 8: Pasha Green Omni Terminal Demonstration Project Funding Partners21
 Table 9: Pasha Hawaii Ohana Class LNG-Powered Container Ships Project Funding Partners22
 Table 10: Pasha Hawaii Horizon Reliance LNG Conversion Project Funding Partners24
 Table 11: Daimler Zero-Emissions Truck Project Funding Partners26
 Table 12: MAN Energy Solutions USA Inc. Retrofit Technology Development Project28
 Table 13: South Coast AQMD ZECT II Demonstration Funding Partners30
 Table 14: Shore-to-Store Project Funding Partners.....32
 Table 15: START Project Funding Partners33
 Table 16: Zero-Emissions Terminal Transition Funding Partners36
 Table 17: Ports’ Technology Advancement Funding Investments as of December 31, 2021.....39

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.
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
DPM	diesel particulate matter
FRATIS	Freight Advanced Traveler Information Systems
EGR	exhaust gas recirculation
EVSE	electric vehicle support equipment
GHG	greenhouse gases
HP	horsepower
kW	kilowatt
kWh	kilowatt-hours
LNG	liquefied natural gas
MW	megawatt
NO _x	oxides of nitrogen
NZE	near zero-emission
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
SCR	selective catalytic reduction
SPS	Smart-Plug System
South Coast AQMD	South Coast Air Quality Management District
TAP	Technology Advancement Program
TEU	twenty-foot equivalent unit
USEPA	United States Environmental Protection Agency
ZE	zero emission
ZEV	zero emission vehicle

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. For more than 15 years, the Ports have made dramatic strides in reducing air emissions. Clean Air Action Plan (CAAP) programs have slashed pollution from heavy-duty trucks. Green leases and state regulations have curbed emissions from cargo-handling equipment and harbor craft. Accelerated shore power deployment through port lease requirements, the California At-Berth Regulation, and low-sulfur fuel regulations have led to significant drops in ship-related air pollution. In addition, local, state and federal grant funding has supported efforts to implement cleaner technologies at ports. Overall, between 2005 and 2020 port-related diesel particulate matter (DPM) emissions were reduced by 90%, nitrogen oxide (NO_x) emissions were reduced by 63% and sulfur oxide (SO_x) emissions were reduced by 97% at the Ports.

Still, there is much work to do. The most recent iteration of the CAAP, which was released in late 2017, calls for even more 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 do just that.

At the cornerstone of this effort is the Technology Advancement Program (TAP), which 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, which actively participate as members of the TAP Advisory Committee to evaluate technology projects, support the commercialization of these nascent technologies, and help leverage funds. More than a decade later, the TAP has undertaken more than 40 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, however, the Ports have needed to expand beyond the TAP, which has traditionally funded smaller scale, generally lower cost, stand-alone technology demonstrations applicable to the entire port complex. To that end, over the past few years, the Ports have made 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, trucks, 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 truck demonstrations.

These various approaches – 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 well over \$396 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.

Importantly, this Technology Advancement Report focuses only on pre-commercial technology advancement, which is one aspect of the CAAP. The Ports also invest heavily in the deployment of commercialized equipment and technologies, for example, by providing financial incentives for cleaner trucks and ships and by securing grants to help operators upgrade to cleaner commercially available equipment. These efforts are documented in the CAAP Quarterly Reports found at www.cleanairactionplan.org.

Significant Events in 2021

In 2021, the Ports continued to experience impacts from the COVID-19 pandemic but also faced new challenges resulting from global supply-chain disruptions and record levels of cargo throughput. Such impacts, described in more detail below, led to delays in some technology demonstration projects, but more importantly, highlighted the need for clean equipment and vehicles that can operate at never-before-seen activity levels and called even more attention to ship emissions, particularly at anchorage. In 2021, the California Air Resources Board (CARB) continued to work on regulations that could mandate cleaner harbor craft and drayage-truck fleets, and implementation began for the newly amended At-Berth Regulation, which will require as-yet-undeveloped technologies to control ship emissions during cargo loading and unloading.

These events create new demand on the TAP, but 2021 also presented new opportunities. First, the Governor's 2021-22 budget contained unprecedented levels of funding for clean technologies, specifically for heavy-duty, often port-related, equipment and vehicles. This funding will support the deployment of commercialized zero-emissions trucks and cargo-handling equipment as well as new technology demonstrations. Second, the federal government committed billions of dollars over the next five years in infrastructure and equipment programs designed to reduce climate change impacts and air pollution, among other goals, with much of these funds dedicated to seaports. Third, the Ports forged strong partnerships on technology advancement projects, leveraging resources across multiple agencies and organizations and demonstrating the value of large-scale collaborations that could shape the TAP's future. These events may impact the TAP for years to come and are described in more detail below.

Regulatory Activities

CARB continued to work on regulations for harbor craft and vehicle fleets (including drayage fleets), with workshops, technical studies, and Board hearings throughout 2021. These regulations have not been finalized, but nonetheless offer a glimpse into the presumed 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 has proposed 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, obviating the need for demonstrations of combustion platforms.

Further, the need to comply with the At-Berth Regulation still requires substantial new technology development over the next five years; the Ports and their partners may play an important role in helping these technologies come to fruition.

All of these regulations may shape TAP investments over the next few years.

COVID-Related Project Delays

The COVID pandemic, which began in March 2020, continued to impact several technology projects throughout 2021, although project partners became adept at working around COVID-related issues. Several demonstrations were either impacted or delayed for various reasons including:

- temporarily shutting down businesses and facilities that design and manufacture advanced technologies;
- travel restrictions prohibiting personnel from traveling to collaborate on projects and conduct in-person technical support, engineering, testing, and training protocols;
- restrictions on non-essential personnel boarding vessels or entering terminals, which is necessary to conduct emissions testing and to monitor the progress of demonstrations;
- difficulty acquiring necessary equipment parts from overseas; and
- COVID-related illnesses impacting the labor workforce in late 2021.

COVID-related impacts for individual projects are described in more detail in Section 5.

Supply Chain Disruption

Increased consumption of overseas products, coupled with labor and container shortages as well as pandemic-related work restrictions, resulted in unprecedented congestion levels at both Ports in 2021. The Ports responded with extended gate hours and other programs to clear cargo quickly from terminals. These actions led to high levels of operating activity; pushing terminal equipment and trucks to their performance limits. This congestion impacted a few TAP projects (see Section 5), 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 may shape future TAP demonstrations to ensure that clean equipment and vehicles can perform at the highest levels, under all conditions. Additionally, the large numbers of ships at anchorage further highlighted the importance of developing clean technologies to reduce ship emissions, an area in which the TAP is investing but could potentially expand upon.

Funding and Collaboration

After a lull in State grant funding, the trend reversed in 2021, resulting in record budgets for zero-emission equipment and vehicles, particularly in the freight sector. Over the next three years, the State plans to invest nearly \$4 billion to deploy zero-emission equipment, vehicles, and infrastructure, with \$2.3 billion allocated to CARB, which has traditionally been a significant source of technology advancement funds for the Ports. Much of this State funding is for commercialized zero-emission equipment and vehicles. With so many zero-emission trucks and pieces of equipment poised to enter the market as a result of State incentives, there is more opportunity than ever to identify performance gaps in these early-commercial vehicles and to target TAP resources toward solutions. Meanwhile, the TAP may be able to leverage State funds for new demonstrations of cleaner off-road equipment, including locomotives and ships. At the same time, the Ports can continue to expand on their partnerships, which in 2021 resulted in one of the largest regional collaborative projects to date: a large-scale pilot of zero-emission drayage trucks led by South Coast AQMD and supported by the Ports and a number of public and private agencies.

Looking Ahead

Even with the challenges of COVID and supply-chain disruptions, the Ports are committed to the goals set forth in the 2017 CAAP Update, particularly the push to transform terminal equipment to zero-emission technologies by 2030 and the truck fleet to zero-emission technologies by 2035. Commercialized zero-emission trucks are expected to arrive by 2024, but there are still gaps in charging and fueling infrastructure as well as a need for better understanding of large-scale zero-emission operations and performance requirements for vehicles and equipment that have been tested to their limits this past year. There is more work to be done on ocean-going vessel technologies and harbor craft in support of newly implemented and upcoming regulations. On the bright side, the technology pathways for trucks and cargo-handling equipment are becoming more clear. 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 for which the Ports' involvement is critical and on projects aligning with the CAAP's vision of a cleaner future. In time, as more clean technologies become commercialized, the role of the TAP may increasingly narrow, and at some point, may become irrelevant. 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 2021

In 2021, the Ports continued to implement technology advancement projects, the updates for which are documented herein. Major accomplishments in 2021 include:

- Completed the Advanced Yard Tractor Deployment and Eco-FRATIS Drayage Truck Efficiency Project (Section 5.2)
- Completed the Commercialization of POLB Off-Road Technology Demonstration Project (C-PORT) (Section 5.3)
- Closed out the Port Advanced Vehicle Electrification (PAVE) Project (Section 5.10)
- On April 21, 2021, the South Coast AQMD was awarded \$26.98 million for the California Joint Electric Truck Scaling Initiative (JETSII) project, which will deploy 100 zero-emission BETs that will be owned and operated by two major fleets that service the Ports (see Section 3).
- Launched studies to assess the feasibility of public charging and fueling in and near the port complex, including potential sites and business models. Each Port is conducting its own assessment.
- Continued to demonstrate pre-commercial zero- and near-zero emissions 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.
- Maintained an updated TAP website¹ to assure transparency and enhance communication of our technology results, as well as to provide resources for technology developers.

Table 1 provides an overview of active 2021 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 2021 and projected milestones for 2022.

Table 1: 2021 Technology Advancement Project Snapshot

Project Title	Project Description	Details	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, page 11	Zero Emission
Advanced Yard Tractor Deployment and Eco-FRATIS Drayage Truck Efficiency Project (Port of Los Angeles)	Completed in 2021. Demonstrate 20 yard tractors equipped with certified near-zero 0.02 gram/bhp-hr NOx engine and five zero-emission yard tractors. Also, demonstrate integration of intelligent transportation system technologies for on-road trucks.	Section 5.2, page 13	Zero- and Near-Zero Emission
Commercialization of POLB Off-Road Technology Demonstration Project (C-PORT, Port of Long Beach)	Completed in 2021. Demonstrate three battery-electric top handlers and a battery-electric yard tractor.	Section 5.3, page 15	Zero Emission

¹ <http://www.cleanairactionplan.org/technology-advancement-program/>

San Pedro Bay Ports Technology Advancement Report
2021 Annual Report and 2022 Priorities

Project Title	Project Description	Details	Technology
Effenco Electric Active Stop-Start™ Technology Demonstration	Evaluate effectiveness of Effenco’s Electric Active Stop-Start™ technology, a hybrid upgrade that automatically turns off the engine when a vehicle is stopped, providing electric power to vehicle systems such as transmission or HVAC without engine.	Section 5.4, page 16	Idle Reduction
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 5.5, page 18	Zero Emission
Nett Technologies Inc. BlueMAX™ NOVA 320e Harbor Craft Demonstration	Design, manufacture, and verify the BlueMAX™ NOVA 320e. This emissions control system consists of a combined active diesel particulate filter (ADPF) with upstream diesel oxidation catalyst (DOC) in front of a selective catalytic reduction (SCR) system with ammonia slip catalyst.	Section 5.6, page 19	Tier 4, Cleanest Available
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 5.7, page 22	Zero Emission and Other Platforms
Pasha Hawaii Ohana Class LNG-Powered Container Ships Project (Two New Builds)	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 5.8, page 22	LNG
Pasha Horizon C9 Vessel LNG Engine Repower Demonstration Project	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 5.9, page 23	LNG
Port Advanced Vehicle Electrification, PAVE Project (Port of Long Beach)	Closed out in 2021. Design, install, and deploy electrical fast-charging infrastructure to support battery-electric cargo handling equipment and battery storage.	Section 5.10, page 24	Zero Emission
South Coast AQMD Daimler Heavy-Duty Electric Trucks Demonstration	Develop and demonstrate 20 heavy-duty battery-electric trucks, ten of which will be deployed to serve the Ports.	Section 5.11, page 25	Zero Emission

San Pedro Bay Ports Technology Advancement Report
2021 Annual Report and 2022 Priorities

Project Title	Project Description	Details	Technology
South Coast AQMD Retrofit Technology Development - Water-in-Fuel Technology	Design, manufacture, and demonstrate ocean-going vessel Water in Fuel (WiF) retrofit technology on the MSC Anzu vessel. The technology is designed to achieve a 40% NOx reduction from Tier 2 engines at lower than 50% SMCR (Specified Maximum Continuous Rating) of the main engine.	Section 5.12, page 27	OGV Retrofit
South Coast AQMD Zero Emissions 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 5.13, page 29	Zero Emission
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 5.14, page 31	Zero Emission
Sustainable Terminals Accelerating Regional Transformation (START) Project (Port of Long Beach)	Demonstrate more than 100 pieces of zero-emissions terminal equipment and trucks at three California seaports, develop a near-zero emissions tugboat, deploy two ships with some of the cleanest available engines, and advance workforce development programs to support sustainable goods movement.	Section 5.15, page 33	Zero and Near-Zero Emission
Zero-Emissions Terminal Equipment Transition Project (Port of Long Beach)	Repower nine RTG cranes for full-electric power, demonstrate 12 zero-emissions yard tractors and two smart charging systems, and convert four LNG trucks to plug-in hybrid electric trucks with LNG range extender.	Section 5.16, page 35	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 continue their strong commitment to zero-emissions technology development and demonstration. In 2021, the Ports continued to lead or support 12 major zero- and near-zero emissions demonstration projects valued at over \$312 million in funding from the various project team members (including public and private match funding). Our efforts have made San Pedro Bay the hub of technology advancement for heavy-duty equipment with the world's highest concentration of zero-emissions trucks and terminal equipment in a single port complex.

The Ports and agency partners are actively managing projects with the following components:

- 114 new electric charging outlets
- 80 zero-emissions terminal equipment, including yard tractors, top handlers, rubber-tired gantry cranes (RTGs), and forklifts
- 37 zero-emissions drayage trucks (battery-electric and fuel cell)
- 20 near-zero emissions yard tractors
- 5 near-zero emissions drayage trucks
- 2 new hydrogen fueling stations

In addition to directly supporting zero-emissions technologies by funding demonstration projects and supportive efforts, such as the development of test protocols and charging standards, the TAP provides a forum for multiple agencies to work together and leverage resources toward our common goal. TAP supports zero-emissions 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.

As noted in Section 2, the Ports successfully pursued funding for a large-scale zero-emissions truck deployment. This effort culminated in the Joint Electric Truck Scaling Initiative (JETSI) Project, 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 is primarily funded by a \$26.9 million dollar grant received from a joint solicitation released by the CARB and the CEC to support large-scale deployments of on-road, ZE Class 8 drayage and regional haul trucks. Other funding partners include South Coast AQMD, Mobile Source Air Pollution Reduction Review Committee (or MSRC), Southern California Edison, and both Ports have committed to providing \$1.5 million each toward this project². Volvo Trucks North America and Daimler Truck North America will produce a combined 100 Class 8 battery-electric trucks for drayage and regional haul, which will be operated and maintained by two truck fleets, NFI (located in Ontario, CA) and Schneider (located in South El Monte, CA). To power the trucks, a total of 50 chargers will be provided and installed by NFI (34) and Schneider (16) at their respective sites. Notably, the chargers at NFI's Ontario facility will utilize renewable electricity generated through solar power, which is supported by five (5) megawatt hours (MWh) of battery energy storage.

² Final Board of Harbor Commissioners' approval anticipated in 2022.

Figure 1: Repowering RTGs to Zero Emissions



Nine diesel RTGs are being repowered at SSA, Pier J from diesel to full electric under the Zero Emissions Terminal Transition Project. See Section 5.16.

Specifically, the Ports are providing indirect support for South Coast AQMD's partnership with Volvo Group North America (Volvo) under a CARB grant, the Volvo Low Impact Green Heavy Transport Solutions (LIGHTS) Project. Under this project, Volvo and its project partners are demonstrating over 50 on- and off-road zero-emission trucks/equipment with associated infrastructure and solar power. The Ports are contributing expertise and in-kind labor.

The Ports are also facilitating demonstration fleet participation in South Coast AQMD's Zero-Emission Drayage Truck Demonstration Project under CARB's Greenhouse Gas Reduction Fund program. This project includes 42 demonstration trucks (zero-emission and plug-in hybrid technology) as well as supporting infrastructure.

In terms of direct support, the Ports have provided cost-share funds for South Coast AQMD's ZECT II project (Section 5.133) and allocated \$1 million each (total of \$2 million) to support South Coast AQMD's demonstration of Daimler heavy-duty electric trucks (Section 5.111).

4 2022 TECHNOLOGY ADVANCEMENT PRIORITIES

In 2022, the Ports must continue to support implementation of the 2017 CAAP Update, including a stronger focus on larger scale pilot demonstration projects that will assess the operational, maintenance, and environmental costs and benefits of zero- and near-zero emission vehicles and equipment in port applications.

Additionally, the Ports must continue to support the numerous demonstration projects already underway. These demonstration projects are in high gear, bringing early deployments of zero-emissions equipment and trucks and active charging infrastructure construction. The Ports already have learned so much from these projects and have begun to identify the gaps in understanding, which will shape future funding priorities. These projects are complicated and resource-intensive and have never before been attempted at this scale. The Ports must 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 2021, the Ports look forward to bringing more projects online to show in-use operation for a variety of zero-emission technologies and to identify areas of future investment.

Thus, in 2022, the Ports commit to the following technology advancement priorities:

- 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;
- Launch demonstrations to support promising technologies for ships;
- Explore concepts for terminal equipment charging and fueling infrastructure that provides for fast, safe electric charging and/or hydrogen refueling; and
- Consider new projects submitted under the TAP's ongoing Request for Information (RFI) review process³.
- Update the TAP Guidelines in order to prioritize projects aligned with presumed regulatory compliance pathways and those that enhance performance in early commercial vehicles and equipment.

³ The TAP RFI is available at: <https://cleanairactionplan.org/request-for-information-san-pedro-bay-ports-technology-advancement-program/>

5 2021 PROJECTS

This section provides additional detail for technology advancement projects that were active in 2021. 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)

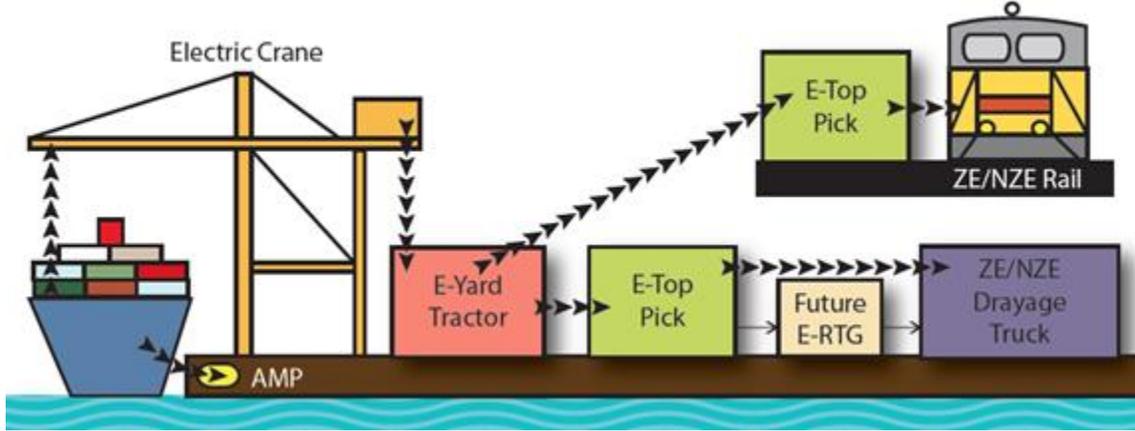
Project Description

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 (10-15 minute) 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 125kW 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, such as 30-minute lunch breaks or between-shift changes. Finally, a battery energy storage system (BESS) will be installed at the base charging stations 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, also referred to as the zero-emissions pathway, shown in Figure 2.

Figure 2: Port of Los Angeles Zero-Emissions Pathway Concept



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 2021

The prototype WAVE unit was constructed, validation tested, and pre-certified at the factory for UL compliance. The prototype was successfully integrated with the first BYD yard tractor. The second WAVE unit and integrated yard tractor were completed. By the end of 2021, the infrastructure was nearly complete for the Area #1 opportunity chargers and construction was in process for Area #2 chargers at the main corral.

Revised design concepts and engineering configurations were completed for the BESS that would meet the needs of terminal operations and interface with equipment specifications. Revisions were needed since original suppliers of the BESS ceased manufacturing.

2022 Milestones

The following activities are expected in 2022:

- Q1 final on-site field certification from UL for Area #1 WAVE chargers.
- Q1 delivery of the first integrated BYD yard tractor.
- Commissioning, training, and demonstration of the first two yard tractors and Area #1 opportunity chargers.
- Manufacturing and installation of the ten WAVE chargers and completion of the Area #2 charging corral infrastructure.
- Integration and delivery of the remaining nine yard tractors.
- Commissioning and demonstration of all ten yard tractors and 12 charging units.
- Infrastructure preparation for the BESS (expected delivery Q1 2023).

5.2 Advanced Yard Tractor Deployment and Eco-FRATIS Drayage Truck Efficiency Project (Port of Los Angeles)

Project Description

For this project, POLA demonstrated near-zero- and zero-emission cargo-handling equipment, as well as an intelligent transportation system (ITS) technology designed to improve on-road truck efficiency. The project included three major components:

- Demonstrate 20 yard tractors equipped with the Cummins Westport near-zero 0.02 gram/bhp-hr NOx engine. To further enhance project benefits, a temporary renewable natural gas (RNG) system is used to fuel these demonstration units.
- Demonstrate five yard tractors equipped with BYD's first-generation zero-emission propulsion technology.
- Demonstrate integration of intelligent transportation system technologies, called Eco-FRATIS. The base ITS system is already being demonstrated on trucks, but with this project, a suite of additional technologies including traffic signal control were added to further enhance efficiency benefits.

This project is related to the Everport Advanced Cargo-Handling Equipment Demonstration Project described in Section 5.5, which will demonstrate BYD's next-generation battery-electric yard tractors.

Project Partners & Budget

The project was funded in part by a \$5.83 million grant from CEC’s Low Carbon Transportation Greenhouse Gas Reduction Fund Investments. The overall project budget was \$8.64 million.

Table 3 summarizes the funding contributions.

Table 3: Advanced Yard Tractor Deployment and Eco-FRATIS Drayage Truck Efficiency Funding Partners

Project Partners	Contributions
California Energy Commission	\$5,833,000
OEMs and Demonstration Partners	\$2,808,007

Accomplishments During 2021

The 20-unit LNG low-NOx yard tractor demonstration was completed in 2020. Driver feedback was positive regarding the units’ capabilities, and other than minor warranty repairs, the fleet has been reliable. The units were operated one shift per day, due to the additional time it took to fuel each unit. At best during the demonstration, fueling took between 10 and 15 minutes per unit, which did not efficiently integrate with Everport’s operation to allow for these units to operate double shifts. Everport continues to utilize the low-NOx yard tractors in daily operations.

The five BYD yard tractors and associated EVSE continued to face technical challenges in 2021. The one-year demonstration of the BYD zero-emission units was conducted between March 2020 and March 2021. Subsequently, the units experienced a number of different issues that required return to BYD’s manufacturing facility in Lancaster, CA for trouble shooting, redesign and/or repair. Major issues included the door hydraulics design and ongoing issues with the fifth wheel design, which even after redesign to address an earlier fifth wheel weight distribution issue, continued to rub at the bombcart or chassis during tight maneuvers. Additionally, Everport requested a breakaway design for the glad hands, coupling devices that connect emergency air lines and electrical services from the yard tractor to the trailer, to address a safety concern. The units accumulated just over 350 hours of in-service operation during the demonstration, with many lessons learned that will be applied to POLA’s following project the Everport Advanced Cargo-Handling Equipment Demonstration Project discussed in Section 5.5.

The Eco-FRATIS demonstration was completed in 2020. In this effort, the project team integrated proven technologies designed to reduce traffic congestion, fuel consumption and emissions by improving the efficiencies of logistics, cargo movements, and driver behavior. The project was designed to improve mobility in and to/from the Ports of Los Angeles and Long Beach via reduced: truck trips, truck-miles travelled, truck-hours travelled, truck idling, which reduces emissions and fuel consumption. Overall, this project combined technologies that directly reduced tailpipe emissions with efficiency improvement strategies to provide an overall benefit to POLA operators and adjacent communities.

The Final Report was submitted to CEC for agency review and final invoices were paid; this project is complete.

5.3 Commercialization of POLB Off-Road Technology Demonstration Project (C-PORT) (Port of Long Beach)

Project Description

The Port of Long Beach C-PORT project, in partnership with SSA Marine and Long Beach Container Terminal (LBCT), demonstrated four pieces of zero-emission cargo-handling equipment. The demonstration included three battery-electric top handlers manufactured by Taylor Machine Works and BYD Motors, Inc. and a battery-electric yard tractor manufactured by Kalmar with TransPower. This project also includes an educational component by which Long Beach Unified School District students learned about the Port of Long Beach’s zero-emission technology efforts through a capstone research project.

Project Partners & Budget

The project is funded in part by a \$5.2 million grant from CARB’s California Climate Investments. The overall project budget is \$8.3 million. Table summarizes the funding contributions.

Table 4: C-PORT Funding Partners

Project Partners	Contributions
Port of Long Beach	\$1,332,386
California Air Resources Board	\$5,249,820
South Coast Air Quality Management District	\$350,000
OEMs and Demonstration Partners	\$1,199,882

Accomplishments in 2021

The C-PORT project demonstrated three battery-electric top handlers provided by Taylor Machine Works in partnership with technology provider, BYD. Two of the three top handlers were demonstrated at Pier J, SSA and the third top handler was demonstrated at Pier E, LBCT. Additionally, Kalmar in partnership with technology provider TransPower/Meritor built and delivered one battery-electric yard tractor, which was demonstrated at Pier E, LBCT.

Both LBCT and SSA are two terminals that operate differently from each other. LBCT is a mostly autonomous ZE terminal that used the demonstration units against rail-limited operations, whereas SSA is more of a typical seaport container terminal, requiring CHEs to operate entirely over two full shifts.

As a result of these grant efforts, terminal operators were able to obtain important lessons-learned from these projects. A final report is available on the Port of Long Beach website.

Figure 3 includes photos of battery-electric top handlers operating at two port terminals.

Figure 3: Taylor Battery-Electric Top Handler at LBCT (left) and SSA (right)



All deliverables under the CARB and AQMD agreements were achieved and the final report was accepted by CARB in August 2021.

5.4 Effenco Electric Active Stop-Start™ Technology Demonstration

Project Description

The objective of this project is to demonstrate Effenco's Active Stop-Start electric hybrid technology to reduce yard tractor emissions and evaluate viability for large-scale implementation. This project will retrofit six yard tractors at APM Terminals. In previous studies of Effenco's technology with New York City Department of Sanitation, engine run time was reduced by 39-52%, resulting in a 12-31% reduction in fuel consumption and related emissions. For this project, Effenco projects emission reductions ranging from 30-60% percent, depending on pollutant type. Effenco plans to seek an aftermarket parts exemption from CARB in order to be able to sell and install their system in California.

The Effenco technology is a hybrid upgrade that automatically turns off the combustion engine when the vehicle is immobile and provides electric power to vehicle systems such as transmission or HVAC when the engine is off, thus reducing the amount of vehicle engine run time. Along with the installation of the Start-Stop technology, Effenco's bi-directional telemetry systems will be installed to monitor the performance of the retrofit with the precision of capturing over 100 operating parameters every tenth of a second.

Project Partners & Budget

The Ports are contributing \$180,000 in co-funding to this project with a total project budget of \$625,163.

Table 5 summarizes the project funding contributions.

Table 5: Effenco Electric Active Stop-Start™ Technology Demonstration Project Funding Partners

Project Partners	Contributions
Port of Los Angeles	\$90,000
Port of Long Beach	\$90,000
Effenco	\$445,163

Accomplishments During 2021

In Q3 2021, CARB granted Effenco an experimental permit to test their Active Start-Stop electric hybrid technology on six yard tractors at APM Terminals. In Q4 2021, Effenco, the Pacific Crane Maintenance Company, and APM Terminals staff successfully installed the system on six demonstration units. After commissioning the system and conducting operator training the six-month demonstration commenced. Effenco continues to engage CARB on the aftermarket parts exemption process in order to receive approval to sell their system in California.

2022 Milestones

The following activities are expected in 2022:

- Complete the six-month demonstration.
- Complete data analysis and final report development.

Figure 4: Installation of Effenco’s Stop-Start System



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

Project Description

POLA’s Everport Advanced Cargo-Handling Equipment Demonstration Project will demonstrate three BYD electric yard tractors and two Taylor battery-electric top handlers. This project also will demonstrate the Cavotec SmartCharging System (SCS) for yard tractors. For this project, POLA is investing in new switchgear and the associated supporting infrastructure, since the terminal does not currently have enough energy capacity for this new equipment. This upgrade is being designed to allow for the eventual addition of up to 25 battery-electric yard tractors.

Project Partners & Budget

The project is being funded by a CEC Clean Transportation Program grant, formerly known as the Alternative and Renewable Fuel and Vehicle Technology Program, in the amount of \$4,524,000, with project cost share in the amount of \$2,238,331, for a total projected project cost of \$6,762,331. Table 6 summarizes the funding contributions.

Table 6: Everport Advanced Cargo Handling Equipment Demonstration Funding Partners

Project Partners	Contributions
Port of Los Angeles	\$1,071,428
California Energy Commission	\$4,524,000
OEMs and Demonstration Partners	\$1,166,903

Accomplishments in 2021

The zero-emission Taylor top handlers successfully completed 12-months of in-service demonstration and provided valuable lessons learned for future models. The top handlers functioned well, with positive feedback from the terminal and equipment operators. Cumulatively, both top handlers operated a total of 2,512 hours. Although the hours are less than anticipated, due to ongoing challenges with the EVSE and the onboard charger, utilization remains consistent and the terminal plans to continue using the equipment beyond the demonstration period. Figure 4 shows the Taylor zero-emission top handler in operation at Everport.

Challenges regarding adaptability of the charging interface between the Cavotec arm and funnel and the BYD charging platform resulted in several design modifications. Three modified SCSs were built, delivered to Everport, installed, and passed UL field certification in 2021. Three yard tractors were successfully integrated with the system, but needed to undergo additional factory modifications to the headache rack and beavertail.

Figure 5: Taylor Battery-Electric Top Handler



2022 Milestones

The following activities are expected in 2022:

- Completion of terminal redevelopment construction.
- Delivery of three fully modified next-generation BYD battery-electric yard tractors integrated with the Cavotec SCS.
- Commissioning, training, and demonstration of the yard tractors and SCS.

5.6 Nett Technologies Inc. BlueMAX™ NOVA 320e Harbor Craft Demonstration

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 (ADPF) with upstream diesel oxidation catalyst (DOC) in front of a selective catalytic reduction (SCR) 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 DPM, NO_x, and CO (with small increases in greenhouse gases due to the use of carbon fuel injection). This 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 (see Figure 5).

Project Partners & Budget

The Ports contributed \$500,000 in co-funding to this project with a total project budget of \$1,200,000. Table summarizes the project funding contributions.

Table 7: 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 During 2021

With design and fabrication complete in 2019, the project team proceeded with shipping the aftertreatment system to California in early 2020 for installation on the candidate vessel, the *Bass*. Due to COVID-19 travel restrictions, the Nett Technologies team was unable to travel to conduct the installation but was able to walk through the installation procedures with Pacific Tugboat personnel who completed the installation of the aftertreatment hardware. In 2021, the Nett Technologies team walked the Pacific Tugboat personnel through the procedures for activating the SCR system. Once the system was activated, the vessel was run for 75 hours to degreen the aftertreatment system and began accumulating the necessary durability demonstration hours. Accumulation of the durability demonstration hours will continue into 2022 and will be followed by the final emission testing.

2022 Milestones

The following activities are expected in 2022:

- Complete accumulation of the 1,000 durability demonstration hours. (expected early Q2)
- Conduct emission testing to achieve CARB verification of the BlueMAX™ NOVA 320e as installed in the *S.Bass* harbor craft.

Figure 6: Nett Technologies Demonstration Vessel



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

Project Description

This POLA demonstration project has several components including: two battery-electric yard tractors from BYD Motors; two battery-electric yard tractors and two battery-electric on-road trucks from TransPower, one battery electric Kalmar yard tractor, electrification of three 21-ton forklifts from TransPower; a microgrid with battery storage capability that is tied to a one megawatt rooftop solar array, and a land-based ship emissions capture and treatment system (ShoreKat) designed for criteria emissions reduction. The system is depicted in Figure 7, below.

Figure 7: 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. The overall project budget is \$26,602,400. Table summarizes the funding contributions.

Table 8: Pasha Green Omni Terminal Demonstration Project Funding Partners

Project Partners	Contributions
California Air Resources Board	\$14,510,400
OEMs and Demonstration Partners	\$12,092,000

Accomplishments in 2021

In 2021, the project agreement was modified to extend the project term to December 2023 to allow additional demonstration time and more time to install rooftop solar. The KalmarT2E+ yard tractor was commissioned and put into service and was used consistently and reliably in service. The Harbor Department submitted our first permit application to the Los Angeles Fire Department (LAFD) for the replacement of the fire suppression system in the battery storage system. TransPower contracted with third party engineer to evaluate and determine that the vehicles as modified by TransPower were safe for operation and the vehicles were placed in service.

2022 Milestones

The following activities are expected in 2022:

- Approval of LAFD permit for fire suppression system for battery storage
- The solar panels are expected to be installed on the warehouse.
- Harbor Department will complete the installation of a new fire suppression system to replace the one provided by BYD, and the battery storage system will be commissioned and begin demonstration.
- Final Report will be submitted to CARB.

5.8 Pasha Hawaii Ohana Class LNG-Powered Container Ships Project

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 vessel will be Tier III-certified marine diesel engines capable of burning heavy fuel oil (HFO), distillate fuel or LNG, but will be optimized for LNG.

Project Partners & Budget

Pasha budgeted over \$430M 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 9. TAP funding will support the initial repower design and documentation of the demonstration and emission reduction benefits.

Table 9: 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 2021

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. Challenges with the initiation of LNG system paperwork delayed the first LNG bunkering to 2022. Pasha received approval for the LNG fueling process for the ships, which will call at the Port of Long Beach, and continued work on obtaining the necessary permits.

2022 Milestones

The following activities are expected in 2022:

- The first new LNG vessel is expected to be delivered in the 2nd quarter of 2022.
- Data collection plan will be approved and emissions data collected from LNG-powered trip(s).
- The second new LNG vessel will be completed and delivered in the 3rd quarter 2022.

5.9 Pasha Horizon C9 Vessel LNG Engine Repower Demonstration Project

Project Description

Pasha Hawaii Holdings LLC (Pasha) will repower an existing OGV, M/V Horizon (see Figure 8), 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 high pressure in a 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 8: 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 10. TAP funding will support the initial repower design and documentation of the demonstration and emission reduction benefits.

Table 10: 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 2021

The design work was completed and the ship dry-docked to begin the engine repower in 4th quarter 2021. The anticipated repower schedule initially proposed has been heavily delayed by contract negotiations and the COVID-19 pandemic.

2021 Milestones

The following activities are expected in 2022:

- Data collection plan will be approved.
- The ship will be delivered into service in Q4 2022.

5.10 Port Advanced Vehicle Electrification (PAVE) Project (Port of Long Beach)

Project Description

The Port of Long Beach’s Port Advanced Vehicle Electrification (PAVE) Project, funded under a grant from the California Energy Commission (CEC), was originally planned to take place at Total Terminal International’s (TTI) facility at Pier T. The project also looked to develop a comprehensive port-wide Dynamic Energy Forecasting Tool in partnership with the Electric Power Research Institute (EPRI) to predict how much energy and supportive infrastructure seaports will need to deploy zero-emissions terminal equipment. However, in 2020, the project with TTI was unable to move forward due to significant changes in the scope of work that would have exceeded the original budget by \$6 million. As a result, TTI opted not to move forward with the project.

In June 2021, the Port of Long Beach submitted an updated scope of work, schedule of products, and budget to the CEC for a revised demonstration project with International Transportation Service (ITS) at Pier G. The new scope of work would have included demonstration of a battery-electric Kalmar yard tractor and an Autocar battery-electric yard tractor which would be fueled by Tritium chargers utilizing the ROCSYS mechanized connectors. The project would also have included battery storage and a microgrid controller. However, after careful review, the CEC determined the new project was not large enough compared to the original PAVE project. As a result, the PAVE project did not move forward as a comparable, large-scale infrastructure project and demonstration of equipment was determined infeasible at any container terminal within the time constraints of the grant funding.

Project Partners & Budget

The project was funded in part by an \$8,000,000 grant from CEC. Ultimately, these funds were returned to the CEC.

Accomplishments in 2021

In spite of the challenges described above, the team developed the Dynamic Energy Forecasting Tool (DEFT). DEFT is an open-source software tool for evaluating the financial and operational impacts of transitioning to zero-emission stevedoring operations. The Electric Power Research Institute was contracted as a subgrantee for its development.

5.11 South Coast AQMD Daimler Demonstration of Heavy-Duty Electric Trucks

Project Description

This project, being led by South Coast AQMD, manufactured and is now demonstrating 20 heavy-duty battery-electric trucks with Daimler Trucks North America (DTNA): 15 Class 8 eCascadia and five Class 6 eM2 trucks. The project includes three demonstration fleets: NFI Logistics (NFI), Penske Logistics and Penske Truck Leasing. NFI is demonstrating five Class 8 trucks and is the primary drayage operator/demonstrator. Penske Logistics also has five Class 8 trucks and is pulling freight as a logistics operator itself, while Penske Truck Leasing (PTL) is engaging customers in the use of the remaining five Class 8 trucks with companies such as US Foods, UPS and Black Horse Carriers. PTL is also engaging with customers, like Costco, on the use and demonstration of the five Class 6 eM2s. All vehicles are operating in real-world commercial fleet operations in one of the region's largest zero-emission port truck demonstrations. More information about this and other South Coast AQMD-led projects can be found at www.aqmd.gov/technology.

Regarding infrastructure, the project includes ten DC Fast Charge (DCFC) locations comprising 20 chargers, 30 plugs and a total of 2550 kW of electric power charging capacity. The majority of the 20 DCFC systems are 150 kW, four are 62.5 kW and one is 50 kW. Seven chargers and 1112.5 kW of charging is located in Chino (five @150 kW and one @62.5 kW at NFI and two @150 kW at Penske). The largest Penske location is in Ontario with three 150 kW chargers. This location will also demonstrate an 800 kWh / 300 kW Battery Energy Storage System (ESS). Other chargers are located in La Mirada, Anaheim, Temecula, Carson, and San Diego. Another and much smaller NFI station is located closer to the Ports in Wilmington. Finally, and a smaller station is operating at Velocity Vehicle Group (a Daimler dealer in Fontana).

Project Partners & Budget

The total project budget is \$31.3 million with funding contributions primarily from South Coast AQMD and DTNA, as well as the Ports and the Environmental Protection Agency Region 9.

Table 11 summarizes the funding contributions.

Table 11: Daimler Zero-Emissions Truck Project Funding Partners

Project Partners	Contributions
Port of Long Beach	\$1,000,000
Port of Los Angeles	\$1,000,000
South Coast Air Quality Management District	\$12,670,072
Daimler Trucks North America	\$15,670,072
Environmental Protection Agency Region 9	\$1,000,000

Accomplishments During 2021

It has now been 18 months since the first Class 8 eCascadia rolled out and one year since the first Class 6 eM2 rolled out. Overall, the demonstration units have accumulated over 600,000 miles and continue to be used by demonstration fleet partners daily. The Class 8 trucks are averaging 2.1 kWh/mile, with average loads around 36,000 pounds and peak loads up to 60,000 pounds. The Class 6 trucks are averaging 1.4 kWh/mile.

All infrastructure is now fully commissioned. There are 10 infrastructure sites in this project with a combined total power of 2.55 MW. Most of the charging equipment is rated at 150 kW, with some smaller units rated at 62.5kW, and 50 kW. Daimler experienced issues with the Siemens EVSE at the Penske Ontario site where the system was experiencing irreconcilable issues with the charger/vehicle interface and not being able to maintain a full vehicle charging session. Siemens decided to fully replace this infrastructure. The replaced system is showing normal performance and is allowing Penske to resume full operations from their largest site under this project. The Ontario site also includes an energy storage system (ESS) that is targeted to be commissioned in March 2021. This system consists of a 300 kW power system and 800 kWh of storage. The plan is for the ESS to demonstrate how battery storage can help address the utility costs associated with peak power and demand charges. Project trucks are depicted in Figure 9.

Figure 9: Daimler Zero-Emission Class 8 Trucks



2022 Milestones

The following activities are expected in 2022:

- Continue assessing the Energy Storage System at the Ontario site in addressing peak shaving and reducing electric operating costs through end of project Q2 2022.
- Continue the two-year demonstration, which is scheduled to be complete in Q2 2022.
- Collect and analyze vehicle operation data.
- Demonstration vehicles to continue operation with demonstration fleets NFI and Penske
- End of Project plans for the demonstration vehicles expected to include any or all of the following actions or activities:
 - Some vehicles will remain with the Innovation fleet customers until Pre-series units arrive
 - Some vehicles will transition to High Voltage training for DTNA dealer network, internal employees, others
 - Some vehicles will be donated possibly to technical schools and Fire departments for training opportunities
 - Some vehicles will be assessed for aging and wear of all high voltage components
 - Some vehicles will have battery packs removed and repurposed into “portable” stationary storage to explore a potentially more affordable way to add site resiliency and a method to avoid peak demand charges during the day.
 - Any remaining units/pieces/components will be recycled/scrapped.

5.12 South Coast AQMD Retrofit Technology Development – Water-in-Fuel Technology

Project Description

Led by South Coast AQMD, the objective of this project is to design, manufacture, and demonstrate ocean-going vessel retrofit technology. MAN Energy Solutions USA Inc. (MAN) will demonstrate a Water in Fuel (WiF) retrofit technology on the MSC Anzu vessel (Figure 9), equipped with MAN's 2-stroke Tier II engine. The demonstration project includes emissions testing necessary to obtain the CARB approval via an Executive Order (or equivalent) for this technology's application to other vessels.

The NOx reduction effect, which is based on a significant reduction in the peak combustion cylinder temperature due to the added water is highly dependent on a high-quality, stable emulsion. The mixing ratio will be subject to an optimization during the commissioning of the system and will be electronically controlled using a high precision fuel-flow-meter. The technology (Figure 10) is designed to achieve a 40% NOx reduction from Tier 2 engines at lower than 50% SMCR (Specified Maximum Continuous Rating) of the main engine. This retrofit technology targets OGV emissions as the vessel transits to and from port. Figure 11 shows the complete platform with WiF unit installed on the Anzu vessel.

Project Partners & Budget

The Ports contributed \$1 million in co-funding to this project with a total project budget of \$3.2 million. Table 12 summarizes the project funding contributions.

Table 12: MAN Energy Solutions USA Inc. Retrofit Technology Development Project

Project Partners	Contributions
Port of Long Beach	\$500,000
Port of Los Angeles	\$500,000
South Coast Air Quality Management District	\$2,000,000
MAN Energy Solutions USA Inc.	\$200,000

Accomplishments During 2021

This project is near completion. The WiF unit was developed, manufactured and installed on the MSC Anzu vessel. The installation is 99% complete. The emission measurement equipment is partially installed, with plans for the PM measurement system installation in early 2022. Due to the global port congestion and unpredictable vessel schedule changes, the WiF commissioning and emission testing schedules continue to evolve, but based on the latest vessel schedule, emission testing will be conducted in second quarter of 2022, and the project is expected to complete in in the third quarter of 2022.

2022 Milestones

The following activities are expected in 2022:

- MAN will complete the installation of WiF unit and emission measurement system.
- The vessel will be commissioned in one of the Asian ports in March or April 2022.
- The emission testing will be conducted in POLA or POLB between March and June 2022.
- The final project report will be submitted by October 2022.

Figure 10: Demonstration Vessel MSC Anzu



Figure 11: Water-in-Fuel Emulsifier Emulsion Mixer and Booster Units



Figure 12: Complete Platform for WiF Installation on the Anzu Vessel



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

Project Description

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

- Transportation Power, Inc. (TransPower) developed two battery electric trucks with hydrogen fuel cell range extenders.
- US Hybrid developed two battery electric trucks, 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 battery electric truck 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 emissions (all-electric) mode and in a 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 \$1,291,480 in co-funding to this project with a total project budget of \$20,141,960. Table 13 summarizes the project funding contributions.

Table 13: South Coast AQMD ZECT II Demonstration Funding Partners

Project Partners	Contributions
U.S. Department of Energy	\$9,725,000
OEMs	\$3,075,841
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 During 2021

During 2020, 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 2022.

2022 Milestones

The following activities are expected in 2022:

- Six project trucks completed demonstration service in 2021.
- The data collected from these six demonstration trucks will be analyzed for drive performance, efficiency, etc.
- Cummins will deploy its demonstration truck in Q2 2022, with final demonstration results expected in early 2024.

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

Project Description

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

- Ten zero-emissions hydrogen fuel-cell-electric Class 8 on-road trucks (Figure 13) on the Kenworth T680 platform are being 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 will be operated by Toyota Logistics Services (4), United Parcel Services (3), Total Transportation Services Inc. (2), and Southern Counties Express (1).
- Two hydrogen fueling stations (Figure 13) that fuel heavy-duty trucks will be constructed by Shell in Wilmington and Ontario, California. The new stations will join three additional stations located at Toyota facilities around Los Angeles to form an integrated, five-station heavy-duty hydrogen fueling network.
- Expanded use of zero-emissions technology in off-road and warehouse equipment, including the first two zero-emissions yard tractors and e-cranes to be operated at POH, as well as the expanded use of two zero-emission forklifts at Toyota’s port warehouse.

Figure 13: Hydrogen Fuel-Cell Class 8 Kenworth/Toyota Trucks



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 14 summarizes the funding contributions.

Table 14: 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 2021

All ten hydrogen trucks completed the build process and then proceeded through shakedown, reliability assessment, and local drive evaluation. The trucks’ fuel cell system evaluation and overall fault resolution were completed at the Toyota facility. The zero-emission trucks began successful in-service demonstration in 2021.

The Ontario hydrogen fueling station completed commissioning protocols and was online as of Q3 2021. There continued to be some challenges with on-going reliability; however, the Shell team worked diligently to address the issues.

The Wilmington hydrogen fueling station achieved mechanical completion, completed the punch list from the prestart-up safety review, activated power to the site, and continued working through commissioning activities. The system evacuated nitrogen and introduced hydrogen for circulation through the equipment, ground storage, and dispensers. The station passed HyStEP testing and is expected to be online Q2 2022.

POH completed the 480-volt infrastructure project to support the battery-electric yard tractors. The Kalmar yard tractors were delivered, with an additional battery bank box, necessary to ensure operational endurance through the complete duty shift. The charging infrastructure was electrified, the yard tractors commissioned, and operator training completed.

2022 Milestones

The following activities are expected in 2022:

- Completion of hydrogen fuel-cell truck demonstration.
- Hydrogen fueling station in Wilmington fully operational.
- Demonstration of ZE yard tractors at POH.
- Completion of ZE forklift demonstration at Toyota.
- Completion of POH’s 4160 service e-crane infrastructure project and begin demonstration of hybrid-electric Liebherr 420 cranes.

5.15 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-emissions supply chain in and around its Matson Navigation Co. Pier C terminal. The Sustainable Terminals Accelerating Regional Transformation (START) Project, expected to be completed in 2024, will demonstrate more than 100 pieces of zero-emissions 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-emissions 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; and
- Two publicly-accessible heavy-duty truck charging outlets.

Project Partners & Budget

The START Project is funded partly by a \$50 million grant from the California Climate Investments. The project includes \$52 million in matching funds from private and public partners, for a total cost of \$102 million. Table 15 summarizes the funding contributions.

Table 15: 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 2021

In 2021, production continued for the electric yard tractors, electric top handlers, and electric drayage trucks. Additionally, Port of Stockton deployed all of their heavy-duty forklifts and continued use of the rail-car mover for its port-run operations. Port of Oakland completed the infrastructure construction for the charging equipment to support the heavy-duty on-road trucks, and accepted delivery of the 10 electric drayage trucks. The two electric top handlers were also delivered and assembled and are awaiting completion of the charging infrastructure.

The second of two Tier III container ships was commissioned and made its first voyages to Long Beach and Oakland in January 2021. Centerline Logistics handed over the project to Northwest Tug Leasing, a subsidiary of Saltchuck Marine, who finalized the design package and put the package out for bid. Upon receiving the construction bid, Northwest Tug Leasing opted to pull out of the project citing exceedingly high costs (i.e., bids \$6 million higher than anticipated) and long lead time for vessel components that would threaten the ability to complete the project within the grant timelines.

Charging infrastructure designs for Pier C in Long Beach were completed and submitted to the City for permit review. Infrastructure for the drayage trucks and public charging stations were under construction and is expected to be completed in early 2022.

2022 Milestones

The following activities are expected in 2022:

- Completion of infrastructure and delivery of the heavy-duty trucks in Long Beach.
- Complete yard tractor charging infrastructure and begin demonstration.
- Completion of infrastructure and commissioning of the electric top handlers at the Port of Oakland.
- Complete emission testing of the Tier III vessels.
- Complete demonstration of the electric forklifts and railcar mover in Stockton. (Figure 14)

Figure 14: Zero-Emission Top Handler at Port of Oakland



Figure 15: Solar Station at Port of Stockton



5.16 Zero-Emissions Terminal Equipment Transition Project (Port of Long Beach)

Project Description

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

The project includes:

- Repowering nine RTG cranes to full-electric power at SSA Marine Terminal (SSA), Pier J, in what would be the nation's largest deployment of fully electric RTGs (eRTGs) at a single terminal.
- Developing and deploying a total of 12 BYD battery-electric yard tractors – seven at International Transportation Service (ITS) and five at Long Beach Container Terminal (LBCT) of which two yard tractors, one at each terminal, be charged via a robotic arm using the Cavotec Smart Plug System (SPS).
- Converting four LNG trucks to LNG plug-in hybrid electric trucks (PHET) trucks at TTSI with zero-emissions capability developed by US Hybrid.

Project Partners & Budget

The Port received \$9,755,000 in CEC funding, which is matched by over \$10 million in project partner funding, for a total project investment of over \$20 million. Table 16 summarizes the funding contributions.

Table 16: Zero-Emissions Terminal Transition Funding Partners

Project Partners	Contributions
Port of Long Beach	\$3,997,515
California Energy Commission	\$9,755,000
Southern California Edison	\$3,950,000
OEMs and Demonstration Partners	\$2,405,501

Accomplishments in 2021

eRTG Crane Demonstration – SSA, Pier J

By the end of 2021, six eRTGs have been commissioned and placed into revenue service at Pier J. Due to the high volume of cargo containers arriving at the terminal and the need to keep all existing RTG cranes working, the remaining three RTG cranes will not be converted until the first half of 2022. Data continues to be collected for those eRTG cranes in service.

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

All four LNG PHETs were placed into drayage service in 2021. Performance and operating metrics were collected as part of the demonstration. In order to operate these trucks in zero-emissions mode, the trucks’ on-board battery system would need to be charged. To charge the trucks, TTSI installed a Nuuve charging system at their San Pedro facility prior to their move to Carson in 2021. Unfortunately, TTSI was unable to operate the trucks out of their San Pedro facility since their entire operations including management were now based in Carson. Since the Nuuve charging station is not located in the same facility as the demonstration trucks, the trucks are unable to start their routes with a full charge. In other words, the project was unable to demonstrate plug-in capability and zero-emission operation so all trucks continue to operate in LNG hybrid mode. In the meantime, TTSI continues to seek support from funding programs aimed to provide infrastructure needed to power their chargers such as the Nuuve system for this demonstration as well as future trucks at their new Carson facility.

BYD Battery-Electric Yard Tractors Demonstration – ITS, Pier G

In September 2021, ITS completed their demonstration efforts and fulfilled their project objectives under this grant. Although the BYD battery-electric yard tractors were capable of completing a full shift at ITS, they were not able to complete their required two shifts on a single charge (opportunity charging at the terminal was also underutilized). In addition, the majority of miles accrued on the unit adapted for the Cavotec SPS was associated with vehicle testing and repositioning, and the project team saw limited use in actual revenue service. For these reasons, ITS made the decision to return the BYD electric yard tractors and EVSEs (i.e., charging equipment), including the Cavotec SPS, to the respective manufacturers. While the BYD units were not a good fit for their operations, ITS has committed to testing other zero-emission technology options for their yard tractor fleet.

BYD Battery-Electric Yard Tractors Demonstration – LBCT, Pier E

In 2021, LBCT operated one BYD unit under a trial run. It is expected that LBCT will authorize BYD to complete the final build of the remaining four BYD electric yard tractors in 2022. Minor issues related to both the truck and charging system experienced in 2021 have been addressed and since resolved by BYD.

2022 Milestones

The following activities are expected in 2022:

- Commission and demonstrate all nine eRTG cranes at SSA Pier J;
- Continue to demonstrate all four LNG PHETs and commission two Nuuve charge ports to allow the trucks to charge and enable operations in zero-emissions mode when driving around the port complex and surrounding communities; and
- Deliver and demonstrate all five BYD yard tractors at LBCT.

6 2021 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.

The Ports and agency stakeholder investments for all past and current technology advancement projects approved to date are shown in Table 17 below. In 2021, the TAP focused on executing its already full portfolio of technology advancement projects rather than launching new ones. That said, in 2021, the TAP did review several projects that include a wide range of technologies that will be considered for Board of Harbor Commissioners' approval in 2022. Technologies under review cover OGV emission reduction for both at-berth and in-transit applications, a zero-emission CHE and a locomotive demonstration, among others.

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.

Table 17: Ports' Technology Advancement Funding Investments as of December 31, 2021

Project Category	POLB	POLA	South Coast AQMD	CARB	CEC	USEPA / USDOE & Other Agencies	Total Port & Agency Stakeholder	OEMs & Demonstration Partners	Total Project Budget
<u>Ocean-Going Vessels</u>									
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
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
OGV Slide Valve Low-Load Emissions Evaluation	\$108,000	\$108,000					\$216,000		\$216,000
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
<u>Harbor Craft</u>									
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
<u>Cargo-Handling Equipment</u>									
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

San Pedro Bay Ports Technology Advancement Report
2021 Annual Report and 2022 Priorities

Project Category	POLB	POLA	South Coast AQMD	CARB	CEC	USEPA / USDOE & Other Agencies	Total Port & Agency Stakeholder	OEMs & Demonstrati on Partners	Total Project Budget
Effenco Rapid Deployment of Electric Active Stop-Start™ Technology for Zero-Emission Idling from Port Yard Tractors Project	\$90,000	\$90,000.00					\$180,000	\$445,163	\$625,163
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
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
<i>RYPOS Diesel Emissions Control (L2+)</i>	<i>\$64,668</i>	<i>\$64,668.42</i>					<i>\$129,336.84</i>		<i>\$129,337</i>
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	\$5,339,820			\$6,972,820	\$1,199,882	\$8,450,886
Everport Advanced CHE Demonstration (CEC Funded)		\$1,071,428			\$4,524,000		\$5,595,428.00	\$1,166,903	\$6,762,331
Pasha Green Omni Terminal Demonstration Project (CARB Funded)				\$14,510,400			\$14,510,400	\$12,092,000	\$26,602,400
Port of Long Beach Zero Emissions Terminal Equipment Transition Project (CEC Funded)	\$3,997,515				\$9,755,000	\$3,950,000	\$17,702,515	\$2,405,501	\$20,108,016
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/AQMD 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 Emissions 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 Emissions 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

San Pedro Bay Ports Technology Advancement Report
2021 Annual Report and 2022 Priorities

Project Category	POLB	POLA	South Coast AQMD	CARB	CEC	USEPA / USDOE & Other Agencies	Total Port & Agency Stakeholder	OEMs & Demonstrations on Partners	Total Project Budget
<i>International Rectifier Plug-In Hybrid Electric Class 8 Truck Conversion</i>	\$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 Emissions Cargo Transport Demonstration	\$37,500	\$37,500	\$75,000				\$150,000		\$150,000
<i>Vision Motor Corp. Hydrogen Fuel Cell Plug-In Hybrid Electric Truck</i>	\$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
<i>VeRail Near-Zero Locomotive Demonstration – Moving Towards Zero Emissions</i>	\$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)	\$19,020,387.92	\$29,254,905.92	\$25,924,228	\$113,527,286	\$36,150,887	\$24,217,064	\$248,004,758.84	\$148,046,641	\$396,051,388.84
Total Port TAP Investment	\$48,275,293.84								

*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 U.S. EPA West Coast Collaborative (pre-dating the TAP).
 ***Port, OEM and partner match will depend on the final scope of work; see Section 5.10 for additional detail.
Italics denote projects that were modified during implementation in a manner that changed 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

- Francisco Donez, USEPA Region 9 donez.francisco@epa.gov
- Nicholas Storelli, California Air Resources Board Nicholas.Storelli@arb.ca.gov
- Marc Perry, California Energy Commission Marc.Perry@energy.ca.gov
- Mei Wang, South Coast AQMD mwang@aqmd.gov

Technology Advancement Program Staff

Port of Long Beach

415 W. Ocean Blvd.
Long Beach, CA 90802

POLB Technology Advancement Program Staff

- Rose Szoke, POLB TAP Coordinator rose.szoke@polb.com
- Morgan Caswell, Manager, Air Quality Practices morgan.caswell@polb.com
- Leela Rao, Senior Environmental Specialist leela.rao@polb.com
- Jennifer Williams, Environmental Specialist Associate jennifer.williams@polb.com

Port of Los Angeles

425 S. Palos Verdes Street
San Pedro, CA 90731

POLA Technology Advancement Program Staff

- Jacob Goldberg, POLA TAP Coordinator jgoldberg@portla.org
- Teresa Pisano, Marine Environmental Manager, Air tpisano@pola.org
- Tim DeMoss, Environmental Affairs Officer, Air tdemoss@pola.org
- Lisa Wunder, Marine Environmental Manager lwunder@portla.org
- Christine Batikian, Environmental Specialist cbatikian@portla.org

Administrative & Technical Support Staff

- Ray Gorski, Starcrest Consulting Group, LLC rgorski@starcrestllc.com
- Lauren Dunlap, Starcrest Consulting Group, LLC ldunlap@starcrestllc.com

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. Foss Maritime Green Assist™ Hybrid Tugboat (2010)
14. Centerline Logistics (formerly Harley Marine) Electric Drive Tugboat Design (2020)
15. Hybrid Yard Tractor Development & Demonstration (2010)
16. Hybrid Yard Tractor Development & Demonstration – Beta Test (2011)
17. Johnson Matthey Locomotive DPF Demonstration (2014)
18. Liquefied Natural Gas Yard Tractor Demonstration (2007)
19. Long Beach Container Terminal Eco-Crane™ (2011)
20. Maersk OGV Energy Efficiency Measurement Demonstration Project (2019)
21. OGV Slide Valve Low-Load Emissions Evaluation (2013)
22. RYPOS Advanced Diesel Particulate Filter for Cargo-Handling Equipment (2012)
23. RYPOS Advanced Level 3+ Diesel Particulate Filter RTG Crane Demonstration (2014)
24. San Pedro Bay Ports Drayage Truck Demonstration of a Near-Zero Ultra-Low NOx Natural Gas Engine Operating on Renewable Natural Gas (2018)
25. South Coast AQMD Development of a Near-Zero Emissions Diesel Engine for On-Road HDVs (2020)
26. South Coast AQMD HDV In-Use Emissions Testing Program (2013)
27. SoCalGas CNG Drayage Truck Demonstration (2010)
28. TransPower Electric Drayage Infrastructure and Improvement (EDII) Project (2016)

29. TransPower Electric Drayage Pre-Commercial Truck Demonstration (2016)
30. US Hybrid On-Board Charger for Zero Emissions Cargo Transport Demonstration (2016)
31. VYCON REGEN® System for Rubber-Tired Gantry Cranes Testing & Verification (2007)
32. Westport GX LNG Engine Development (2010)