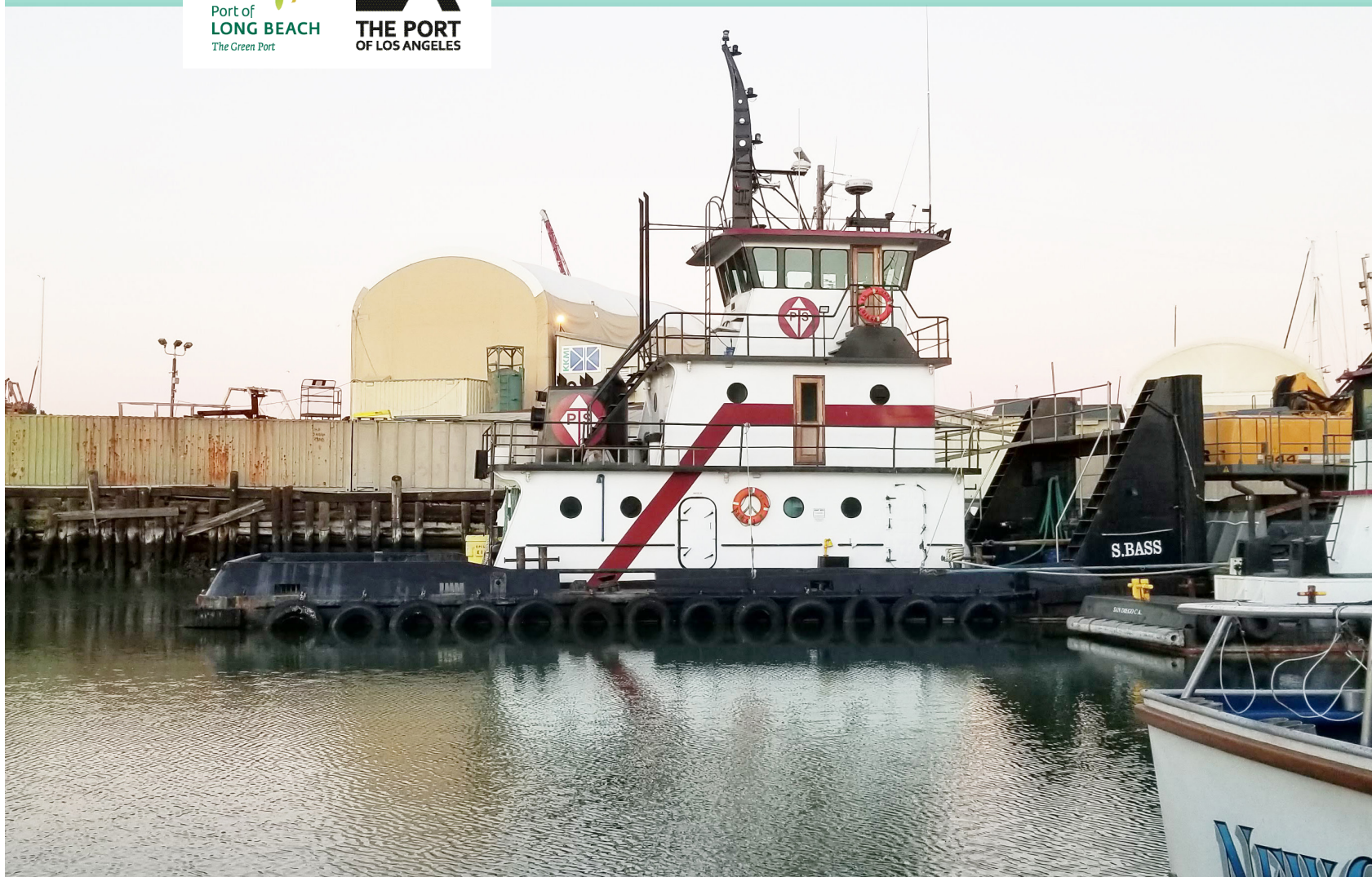


MARCH 2019



SAN PEDRO BAY PORTS **CLEAN AIR ACTION PLAN**

2018 ANNUAL REPORT AND 2019 PRIORITIES Technology Advancement Program

12 Years of Progress Moving Towards Zero Emissions

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Acronyms & Abbreviations

AC	Advisory Committee or alternating current
ACTI	Advanced Cleanup Technologies Incorporated
Ah	ampere-hour
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
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
EPA	United States Environmental Protection Agency
GHG	greenhouse gases
HP	horsepower
kW	kilowatt
kWh	kilowatt-hours
LBCT	Long Beach Container Terminal
LNG	liquefied natural gas
MW	megawatt
NO _x	oxides of nitrogen
NZE	near zero-emissions
OGV	ocean-going vessel
PHEV	plug-in hybrid electric vehicle
PHL	Pacific Harbor Line
POLA	Port of Los Angeles
POLB	Port of Long Beach
PM	particulate matter
RR	radical retrofit
RTG	rubber-tired gantry crane
SCAQMD	South Coast Air Quality Management District
TAP	Technology Advancement Program
TEU	twenty-foot equivalents
ZE	zero emission(s)
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. The Ports also serve as a principal economic engine for Southern California, moving \$300 billion in trade each year and supporting more than 800,000 jobs in Southern California. The latest economic forecasts indicate that the demand for containerized cargo moving through the Southern California region will continue to increase by the year 2035. The Ports recognize that their ability to accommodate projected growth in trade will depend upon their ability to address adverse environmental impacts that result from such trade.

Over the past 12 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 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 2017 port-related diesel particulate matter (DPM) emissions were reduced by 87%, nitrogen oxide (NO_x) emissions were reduced by 58% and sulfur oxide (SO_x) emissions were reduced by 97%.

In November 2017, the Ports adopted the latest iteration of the CAAP (2017 CAAP Update¹), which calls for even more aggressive strategies to reduce pollution and greenhouse gases and to ultimately transition to zero emissions over the next 20 years. Critical to the success of these strategies is the development and deployment of near-zero and zero emissions technologies.

The Technology Advancement Program, or TAP, was initiated in 2007 to facilitate the development and demonstration of clean technologies to support CAAP goals. The TAP is a competitive funding program that relies heavily on partnerships with private industry and technology developers as well as strong relationships with regulatory agencies, including the U.S. Environmental Protection Agency (USEPA), California Air Resources Board (CARB), California Energy Commission (CEC) and the South Coast Air Quality Management District (SCAQMD), which actively participate in the TAP Advisory Committee that evaluates technology projects, support the commercialization of these nascent technologies, and help leverage funds. A list of current AC members is included in Appendix A.

More than a decade later, the TAP has undertaken over 40 projects spanning test cycle development, hybrid and alternative fuel technology demonstrations, and zero emissions (ZE) equipment deployment.

The Ports, however, do not limit their technology advancement efforts to the TAP itself. Over the past year, the Ports and their project partners have launched a number of new technology demonstrations as a result of grant funding awards from federal, state and local agencies. These new efforts are summarized in Section 6 of this TAP Annual Report in order to showcase the breadth and scope of the increasing emphasis on clean technology development and implementation in port operations.

¹ <http://www.cleanairactionplan.org/news/2017-clean-air-action-plan-update-released/>

Looking Ahead

Adoption of the 2017 CAAP Update represented a huge leap forward for the Ports. The plan sets ambitious goals to transform the truck fleet to zero emissions by 2035 and the terminal equipment to zero emissions by 2030, as well as interim targets for near-zero emissions deployment if no feasible zero-emissions technologies exist. Specifically, the Ports committed to a pilot demonstration of 50 to 100 trucks in a single fleet or duty cycle to assess the challenges and opportunities associated with a full transition to zero emissions. In support of these goals, the Ports must act expeditiously to develop, demonstrate, and deploy zero emissions technologies and infrastructure over the next three to five years. The TAP will play a critical role in this effort.

Working through the highly successful TAP model of collaboration among the Ports, regulatory agencies, and operators, the Ports will seek to identify new and immediate opportunities for zero emissions truck and terminal equipment development and demonstrations while continuing to nurture nascent at-berth and harbor craft emissions-reduction technologies.

Achieving verification or state approval of these technologies will be key; the state and federal government is injecting more than \$1 billion into clean vehicle and equipment deployments over the next three years, largely for verified and commercialized technologies. Programs such as TAP, with heavy involvement from the regulatory agencies, can help facilitate and expedite verification and commercialization, allowing our operators to access these substantial levels of funding as quickly as possible.

At the same time, the Ports will continue to use TAP as a means of leveraging other public and private funds for demonstration of cleaner technologies. In the next fiscal year, the state has earmarked \$55 million for zero and near-zero emissions technology demonstration grants and for purchases of vehicles and equipment on the cusp of full commercialization. These grants require significant match funds, in some cases as high as 50%. Working with our regional partners, such as SCAQMD, the Ports can use TAP funds to help offset match requirements, thus supporting technology development even if these projects are not directly administered by the Ports.

2 TAP ACCOMPLISHMENTS IN 2018

In 2018, the TAP continued to support technology advancement with a particular focus on zero emissions vehicle demonstrations and development of supporting infrastructure (i.e., charging equipment). Major accomplishments in 2018 include:

- Issued the TAP's first Call for Projects, which resulted in 18 project concepts, nine of which were invited to submit full project proposals. Eight proposals were received and four are being recommended to the Boards of Harbor Commissioners by port staff for funding in early 2019.
- Issued a competitive Request for Proposals entitled "Land or Barge-Based Ocean-Going Vessel At-Berth Exhaust Emissions Capture & Treatment Systems: In-Use Demonstration at the San Pedro Bay Ports." Proposal evaluation is underway.
- Maintained an updated TAP website² to assure transparency and enhance communication of our technology results, as well as to provide resources for technology developers.

² <http://www.cleanairactionplan.org/technology-advancement-program/>

- Funded a new TAP project entitled “Nett Technologies Inc. BlueMAX™ NOVA 320e Harbor Craft Demonstration” as a result of the TAP’s RFP for harbor craft emission reduction technologies.
- Completed the San Pedro Bay Ports Drayage Truck Demonstration of a Near-Zero Ultra-Low NOx Natural Gas Engine Operating on Renewable Natural Gas.
- Developed a conceptual scope for a Large-Scale Zero-Emission Pilot Truck Deployment, which aims to demonstrate 50-100 zero-emission drayage trucks in a single deployment. In 2018, the Ports conducted a survey of trucking companies to gauge interest in the pilot demonstration and held a working group meeting of truck operators, manufacturers and funding agencies to review initial concepts. The Ports anticipate refining these concepts in early 2019.
- Continued to demonstrate zero and near-zero emissions equipment and vehicles throughout each port by leveraging port and tenant resources with state and federal funding.

Table 1 provides an overview of 2018 TAP projects. Section 5 provides a detailed status update for each of these projects, including specific accomplishments in 2018 and projected milestones for 2019. Additionally, Section 6 summarizes advanced technology projects underway that complement the TAP efforts to accelerate commercialization of zero and near-zero emissions equipment and vehicles.

Figure 1: Project Truck from the Near-Zero Emissions Demonstration (Section 5.2)



Table 1: 2018 TAP Project Snapshot

Project Title	Project Description	Status	Zero or Near-Zero Emissions Project?
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 5.1).	Approved and initiated in 2018	Not Applicable
San Pedro Bay Ports Drayage Truck Demonstration of a Near-Zero Ultra-Low NOx Natural Gas Engine Operating on Renewable Natural Gas	Demonstration of pre-commercial 12 liter near-zero ultra-low NOx CNG engine that will be certified to the optional low NOx standard of 0.02 g/bhp-hr. The truck fuels exclusively with Renewable Natural Gas (Section 5.2).	Completed in 2018	Near-Zero
Development of a Near-Zero Emissions Diesel Engine for On-Road Heavy-Duty Vehicles	Develop an ultra-low NOx (0.02 g/bhp-hr) emissions <i>diesel</i> engine for on-road heavy-duty vehicles (Section 5.3).	Ongoing	Near-Zero
SCAQMD 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 5.4).	Ongoing	Zero
VeRail Near-Zero Emissions Locomotive Demonstration - Moving Towards Zero Emissions	The VeRail switcher locomotive will be equipped with two near-zero natural gas power modules and two 600 hp diesel back-up Tier 4 gen-sets (only for peak power needs) as well as zero-emission capability to operation a full 8-hour shift without the need to charge (Section 5.5).	Ongoing	Zero
Maersk Ocean-Going Vessel Energy Efficiency Measurement Demonstration Project	Evaluate and quantify the benefits of energy efficiency improvements for ocean-going vessels using multiple new high-resolution data streams (Section 5.6).	Ongoing	Not Applicable

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 throughout Sections 5 and 6, the Ports continue their strong commitment to zero emissions technology development and demonstration. In 2018, the Ports led eight major zero and near-zero emissions demonstration projects valued at nearly \$175 million in funding from the various project team members (including public and private match funding). Our efforts have made San Pedro Bay the epicenter of technology advancement for heavy-duty equipment with the world's most dense concentration of zero-emissions trucks and terminal equipment in a single port complex.

These TAP and agency projects include the following:

- 7 zero-emissions drayage trucks
- 81 zero-emissions terminal equipment, including yard tractors, top handlers, rubber-tired gantry cranes, and forklifts
- 5 near-zero emissions drayage trucks
- 20 near-zero emissions yard tractors
- 152 new electric charging outlets

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-emission technology projects led by other agencies by providing technical expertise, facilitating partnerships with port operators, offering a test bed for port-related technologies, and writing support letters to help other agencies secure funding for these demonstration projects. This direct and indirect support is critically important to making zero emissions a reality.

Specifically, the Ports are supporting SCAQMD's new partnership with Volvo Group North America (Volvo) under a recently awarded CARB grant, the Volvo Low Impact Green Heavy Transport Solutions (LIGHTS) Project. Under this project, Volvo and its project partners will develop and demonstrate over 50 on- and off-road zero-emission truck and equipment with associated infrastructure and solar power. The Ports also allocated \$2 million each (total of \$4 million) to support SCAQMD's deployment of near-zero natural gas trucks in 2019 and are facilitating demonstration fleet participation in SCAQMD's Zero-Emission Drayage Truck Demonstration Project under CARB's Greenhouse Gas Reduction Fund program.

4 2019 TAP PRIORITIES

TAP priorities for 2019 will continue to support implementation of the CAAP 2017 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 vehicles and equipment in port applications.

4.1 2019 TAP Priorities

On an annual basis, the Ports define funding priorities for the upcoming calendar year including the specific solicitations planned for release and the amount of funding allotted to these projects. This approach enables the Ports to plan more effectively the TAP's annual budget, to signal the TAP's immediate needs for technology development, and to leverage funding sources from other agencies.

In 2019, the Ports will continue planning for zero emission technologies, specifically focusing on the pilot deployment of 50 to 100 zero emissions trucks. The Ports will need to identify fleets or duty cycles most appropriate for this type of deployment, to continue to invest in the development and demonstration of zero emissions trucks, and to ensure the charging or fueling infrastructure is in place to support these trucks. At the same time, the Ports must continue to advance other emission-reduction technologies, including those for terminal equipment, harbor craft, and ships at berth.

To that end, in 2019, the TAP commits to the following priorities:

- Allocate funding in the amount of up to \$500,000 per Port to support the pilot deployment of 50 to 100 zero emissions trucks;
- Initiate four new projects selected as a result of the TAP 2018 Call for Projects;
- Allocate up to \$300,000 to support promising technology demonstrations for ships; and
- Explore concepts for terminal equipment charging infrastructure that provides fast charging and/or does not require manual handling of high-voltage connection cables.

In 2018, our demonstration projects kicked into 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 begun to identify the gaps in understanding, which will shape future TAP funding priorities. In 2019, 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.

4.2 Agency Partnerships

Project selection is supported by the TAP Advisory Committee (AC). 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 potentially be used to move projects toward implementation.

5 KEY PROJECTS IN 2018

This section provides additional detail for TAP projects that were active in 2018. For information on completed TAP projects, please access the Final Reports archived on the program website:

<http://www.cleanairactionplan.org/technology-advancement-program/>. All completed TAP projects are listed in Appendix B.

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

Project Description

The objective of this TAP 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. 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 their *S.Bass* harbor craft for this project.

This project was proposed in response to the TAP’s Request for Proposals (RFP) entitled “Demonstration of Air Pollutant Emission Reduction Technologies for Commercial Harbor Craft,” released mid-2017 and selected by an Evaluation Panel consisting of TAP Advisory Committee members and staff from each Port using the scoring detailed in the RFP.

Project Partners & Budget

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

Table 1: 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

Project Benefits

Successful verification of this tugboat retrofit technology is anticipated to provide an 85 to 99 percent reduction in DPM, NOx, and CO. These estimates are based on performance of the technology in the stationary prime generator application. It should be noted that a small increase in greenhouse gases is expected due to the use of fuel carbon injection for the system (up to 2.5%).

Accomplishments During 2018

The POLB Board of Harbor Commissioners approved the project and funding agreement with Nett Technologies on July 9, 2018. The cost share agreement was fully executed by both

parties on July 31, 2018. The project kick-off meeting was conducted on August 16, 2018, after which the following efforts were initiated through December 2018:

- Began the contract engineering phase, which includes drafting and gathering necessary data and analysis to support the Preliminary Verification Application (PVA). This effort includes project management work and communicating with CARB regarding PVA submittal requirements, as well as an Experimental Permit application, which is required before the engines may be retrofit. The PVA shall be sent to CARB after the dimensional analysis is complete and in coordination with CARB staff.
- Began the initial dimensional assessment of the vessel, computer modelling and prototyping (i.e., physical prototype fit testing), which is critically important for ensuring the system will fit into the available vessel space.
- Manufactured the data loggers, which were sent to Pacific Tugboat Services for duty cycle analysis.
- Requested University of California at Riverside to participate in field testing.

2019 Milestones

Project milestones planned for 2019 include:

- Completion of prototype in-house testing.
- Complete the design and system integration of the BlueMAX™ NOVA 320e into the demonstration vessel.
- Install and commission the system into the demonstration vessel.
- Obtain CARB approval for the PVA and implement the associated emissions testing procedures, including a minimum of 75 hours of de-greening prior to emissions testing.
- Initiate the in-use demonstration of the BlueMAX™ NOVA 320e in the *S. Bass* harbor craft.

Figure 2: Project Vessel “S. Bass”



5.2 San Pedro Bay Ports Drayage Truck Demonstration of a Near-Zero Ultra-Low NOx Natural Gas Engine Operating on Renewable Natural Gas

Project Description

The objective of this TAP project was to demonstrate the operation of a near-zero natural gas engine in drayage truck service. For this project, Heavy Load Transfer, LLC (HLT) procured a 2014 Freightliner Cascadia day-cab equipped with an ISX12G engine (0.2 gm/bhp-hr NOx). This truck was then repowered with a pre-commercial 12-liter (400 HP and 1,450 lb.-ft. torque) near-zero ultra-low NOx (0.02 gm/bhp-hr) CNG engine that was certified to CARB's optional low NOx level of 0.02 g/bhp-hr on December 22, 2017³.

Project Partners & Budget

The Ports contributed \$75,000 in co-funding to this project with a total project budget of \$196,555. Table 2 summarizes the project funding contributions:

Table 2: Near-Zero Ultra-Low NOx Natural Gas Engine Demonstration Funding Partners

Project Partners	Contributions
Port of Long Beach	\$37,500
Port of Los Angeles	\$37,500
Heavy Load Transfer, LLC, Clean Energy, Cummins Cal Pacific	\$121,555

Figure 3 Near-Zero Emissions (NZE) Natural Gas Truck



³https://arb.ca.gov/msprog/onroad/cert/mdehdehdv/2018/cummins_hhdd-ub_a0210674_11d9_0d02-0d01_ng.pdf

Project Benefits

Successful demonstration of this pre-commercial, near-zero emissions heavy-duty truck engine proved the technology meets operational expectations while significantly reducing NOx emissions for trucks in drayage service. In addition, the use of Redeem™, Clean Energy's 100% renewable natural gas, resulted in significant greenhouse gas emission reductions from the demonstration unit. This project supports the Ports' efforts in moving toward ever cleaner engine technologies.

Accomplishments During 2018

The project demonstration began on July 10, 2017, concluded on February 5, 2018 and a final report was approved and published in May 2018⁴. During the demonstration, the project truck fueled exclusively at Clean Energy's liquefied natural gas (LNG) station, which dispenses renewable natural gas, marketed as Redeem™. This fuel is made entirely from organic waste and according to Clean Energy, is up to 70% cleaner than diesel. The truck was monitored during the demonstration to provide data that document viability of the technology on the drayage service cycle. Results of the six-month demonstration are highlighted below:

- 532 Port-related moves (revenue trips)
- 1,181.9 total engine hours
- 18,490 miles travelled
- 3,045 LNG gallons consumed

Cummins Cal Pacific was called to service the demonstration engine twice during the six-month period. The first call was to address a check engine light and the second call was for engine control calibration. All other maintenance during the demonstration consisted of routine maintenance and repairs, including BIT Inspections, fuses, wiper blades, battery replacement, mud flaps, etc.

Overall, the truck maintained regular operation, with no major maintenance issues. Driver feedback was very positive, particularly with regard to the truck's power and lack of odor (from diesel fuel). The 12-liter, low-NOx (near-zero) LNG engine met all duty cycles encountered during the demonstration and was a favorite among drivers for its improved power compared to smaller natural gas fueled truck engines as well as the diesel trucks in the fleet. Travel around the terminal and over the local bridges, even with full loads averaging 38,000 pounds, was easily accomplished with this newly certified low-NOx engine.

5.3 Development of a Near-Zero Emissions Diesel Engine for On-Road Heavy-Duty Vehicles

Project Description

The objective of this project is to use lessons learned from the successful 13-liter heavy-duty diesel engine demonstration project to advance engine and aftertreatment technologies in current heavy-duty diesel engines to achieve NOx emission levels that are at least 90% lower than 2010 heavy-duty NOx emissions standards. Southwest Research Institute (SwRI) will: (1) identify specific diesel engines, test cycles, and aftertreatment technologies, (2) characterize the baseline emission performance of the engine, (3) determine engine characteristics for cold starts, hot starts, normal operation and low-load, low-temperature operation, and (4) define

⁴ <http://www.cleanairactionplan.org/documents/hlt-demonstration-final-report-5-14-18.pdf/>

possible engine control strategies. Based on the engine performance and engine control strategies, SwRI will select technology pathways for screening and final engine system development. Once developed, the engine will be tested using both the Federal Test Procedure for emissions certification and non-certification test cycles representative of real-world use in different vocations that are prevalent in the air basin. The use of vocational specific test cycles will provide additional insights towards the engine's real-life emissions reduction potential.

Project Partners & Budget

The Port of Los Angeles is contributing \$287,500 in co-funding to this project with a total project budget of \$1 million. Table 3 summarizes the project funding contributions:

**Table 3: Ultra-Low Emissions Diesel Engine Development Project
Funding Partners**

Project Partners	Contributions
Port of Los Angeles	\$287,500
California Air Resources Board	\$425,000
South Coast Air Quality Management District	\$287,500

Project Benefits

Development of an ultra-low NOx emissions diesel engine for on-road heavy-duty vehicles will accelerate wide-scale deployment of much cleaner heavy-duty engines in the South Coast Air Basin by significantly reducing criteria pollutant emissions from diesel-fueled trucks. This engine also can be fueled with renewable diesel fuels, helping to address the GHG emissions reduction needs throughout California.

Accomplishments During 2018

Below is a summary of key accomplishments this year:

- SCAQMD executed the project agreement with SwRI;
- SCAQMD conducted the project kick-off meeting on June 26, 2018;
- Installed the project engine in the test cell for "shake down". Shake down encompasses all the work necessary to prepare for the test series planned for this project;
- SwRI began conducting a variety of test profiles to establish emissions from different engine design configurations with the goal to meet ultra-low NOx emission levels;
- SwRI added several key components to the engine including cylinder deactivation hardware; and
- Aftertreatment technologies were down selected

2019 Milestones

Key milestones planned for 2019 include the following:

- Baseline testing will begin in January 2019;
- Engine control algorithms will be refined;
- Test aftertreatments will be selected;

- Engine testing on previously developed low load profiles will be conducted;
- Preliminary results are anticipated to be available for project team review in early 2019; and
- Complete and submit project Final Report.

5.4 SCAQMD Zero Emissions Cargo Transport (ZECT) II Demonstration

Project Description

The I-710 and CA-60 highways are major transportation corridors in the Southern California region, which are used daily by heavy-duty drayage trucks that transport the cargo from the Ports to the inland transportation terminals. These terminals, which include stores/warehouses and inland-railways, are anywhere from 5 to 50 miles in distance from the Ports. The operation of these drayage trucks has a significant impact on the air quality in this region and impacts the quality of life in the communities near these corridors and the Ports. ZECT II encompasses the development of seven drayage trucks by five different contractors via two main components:

- Development and demonstration of zero emissions fuel cell range extended electric drayage trucks; and
- Development and demonstration of hybrid electric drayage trucks for goods movement operations between the Ports near dock rail yards and warehouses.

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.

For this project, six electric drayage trucks will be demonstrated with a range of fuel cell sizes and battery capacities. In addition, plug-in hybrid technologies will be demonstrated on a natural gas platform, for a total of seven demonstration vehicles.

These advanced technology trucks will operate along major drayage truck corridors including the Terminal Island Freeway, a primary corridor for port cargo travelling between Port of Los Angeles and Port of Long Beach terminals and the Intermodal Container Transfer Facility, a near-dock rail facility.

Project Partners & Budget

The Ports are contributing \$1,291,479 in co-funding to this project with a total project budget of \$20,141,960. In 2018, the Port of Long Beach Board of Harbor Commissioners approved an additional \$157,500 in TAP funding using TAP funds that were returned from a withdrawn project. Table 4 summarizes the project funding contributions:

**Table 4: SCAQMD Zero Emissions Cargo Transport (ZECT) II Demonstration
Funding Partners**

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

Project Benefits

The battery-electric trucks equipped with fuel cell range extenders will emit zero emissions. The hybrid-electric trucks are expected to operate at near-zero emissions levels. This project supports the Ports' efforts in moving toward zero emissions technologies.

Accomplishments During 2018

The following is a short description of each of the project vehicles and technologies followed by a status update:

TransPower – Transportation Power, Inc. (TransPower) is developing two battery electric trucks with hydrogen fuel cell range extenders. The preliminary technical concept for the proposed fuel cell range extender project is to use TransPower's proven ElecTruck™ drive system as a foundation and add a small fuel cell provided by Hydrogenics and on-board hydrogen storage. The project will result in the manufacturing and deployment of two demonstration trucks, one with a 30 kW fuel cell and one with a 60 kW fuel cell, enabling a direct comparison of the two sizes.

During 2018, the 30kW prototype truck ("FC1") was in limited service at TTSL with over 3,700 kilometers accumulated to date. Mileage accumulation has been slower than planned due to several technical issues including a drive train fault, hydrogen fuel valve leaks and a failed hydrogen sensor.

An interesting outcome of the demonstration is that the project team learned that if the drivers cannot complete their delivery as a result of a truck failure, they do not get paid. The project team discussed this with TTSL and worked out a plan to ensure the drivers are paid if the truck has a breakdown. TransPower assigned a technician to ride "right seat" to the driver so that if any failures occur during deliveries, the fault could be immediately addressed, and the delivery could be completed.

The second truck ("FC2") is in the commissioning phase and is anticipated to deploy in demonstration service in early 2019.

US Hybrid – US Hybrid is developing two battery electric trucks, each with an onboard hydrogen fuel cell generator. The trucks will be powered by a lithium-ion battery with an 80 kW hydrogen fuel cell generator in charge sustaining mode, eliminating the need for charging.

In 2018, US Hybrid also deployed its first truck to TTSL, but soon after US Hybrid detected that the vehicle's manifolds showed evidence of corrosion that penetrated the coating, which was due to supplier quality issues. To address this, the FCE80 power plant was sent to US Hybrid for manifold upgrades. During this upgrade, US Hybrid noticed that the cooling system had evidence of rust and debris particulates, which may be due to not fully flushing or aging of the old radiator (this is a repowered 2012 truck). New cooling lines and re-flushing the system was conducted to ensure that there are no debris/containment issues going forward.

CTE/BAE and Kenworth – Under project management by the Center for Transportation and the Environment (CTE), BAE Systems is developing a battery electric truck with hydrogen fuel cell range extender. The power output of the electric drive train is comparable to that of a Class 8 truck engine. AC traction motors will be mounted one on each rear drive axle and the electric drive train in the architecture is set up to be fully redundant. The vehicle will operate primarily from the batteries, engaging the fuel cell system only when the batteries reach a specified state of charge. BAE anticipates that the 30 kilogram (kg) of hydrogen (25 kg usable) will provide approximately 112 miles of range between fuel fills.

This truck is currently being tested on Kenworth's test track in Washington state and has accumulated more than 12,000 miles primarily from track testing and some operation on the open road. In late 2018, the truck experienced faults related to power steering, transmission, and the fuel cell engine that caused significant downtime. The truck was shipped to Kenworth's engineering center for diagnosis and repair, and Ballard was on-site for all fuel cell diagnostic and repair activity. Several software upgrades were implemented to continue optimizing performance. Near the end of 2018, the truck was being repackaged to be sent back to Paccar Technical Center (PTC) with the goal of achieving 40 fault-free hours of continuous operation before being shipped to the demonstration site.

GTI/BAE and Kenworth – Under project management by the Gas Technology Institute (GTI), BAE Systems will develop one battery electric hybrid truck with CNG range extender and optional catenary capability. The truck will operate in zero emissions (all-electric) mode and in a conventional hybrid electric mode using CNG.

During testing at Kenworth's test track in Washington, several issues were encountered, and the truck was returned to Kenworth R&D for vehicle tear down and inspection. The electric motor supplier completed the tear down, component and assembly analysis, and determined that the rotor assembly had not been properly torqued and was moving when introduced to extreme loads and operating conditions. The motors were reassembled with high strength fasteners, properly torqued, and returned to Kenworth for testing, which is ongoing.

Hydrogenics – Hydrogenics will develop and demonstrate a fuel cell range extended Class 8 truck. Hydrogenics is currently working with Daimler's VVG dealership group on the development of a fuel cell range extended truck under a separate CEC project. For ZECT II, a second unit will be built; this unit is anticipated to begin production and subsequent demonstration as soon as the first truck is in service.

2019 Milestones

Project milestones planned for 2019 include:

- While hydrogen fueling support for these fuel cell trucks was secured in 2018, the project team determined additional supply is needed; additional hydrogen fuel will be arranged to meet all demonstration needs.
- All project trucks are expected to achieve regular demonstration service in 2019.
- Hydrogenics will begin design and development of its demonstration truck in 2019.

5.5 VeRail Near-Zero Emissions Locomotive Demonstration

Project Description

VeRail Technologies, Inc. (VeRail) originally planned to develop a natural gas locomotive that combined near-zero emissions locomotive engines with onboard CNG fuel storage for use as a Pacific Harbor Line (PHL) switcher locomotive. By converting an EMD SD40-2 locomotive, the VeRail VR21C4-nz locomotive would be equipped with four near-zero natural gas engine/generator modules (EnGens). The design also allowed 2,100 HP of rechargeable batteries to be added to the locomotive for *full zero-emissions* rail operation at a later date.

Project Scope Revisions for 2018

Early in 2018, VeRail developed its engineering package for consideration by the Federal Railroad Administration (FRA). The results of FRA's preliminary review indicated to VeRail that the requirements associated with carrying CNG onboard a locomotive would be a significant challenge to address and were not fully anticipated as part of the original design. Concurrently, the Port of Los Angeles was awarded funding under CARB's Fiscal Year 2016-17 Off-Road Advanced Technology Demonstration Projects Program for the "Port of Los Angeles Zero-Emission Track-Miles Locomotive Demonstration." This funding expanded the project beyond near-zero emission technology to include a 1,820 kW-hr battery bank to supply enough energy to allow a typical eight hour shift without charging.

This CARB funding not only facilitated the expansion of the VeRail project to include capability for zero-emission track mile operation, it also provided a pathway to address the challenges of FRA requirements that emerged this year. After much consideration, the project team agreed that it was best to migrate the project scope to a full 100% zero-emission technology platform. The balance of the year was focused on working amongst the team to approve the new scope and follow-up with necessary documentation and approvals.

Project Partners & Budget

The Ports are contributing \$503,321 (\$303,321 POLA; \$200,000 POLB) in co-funding to this project. The SCAQMD will also be providing \$300,000. VeRail is providing \$3,100,000 in funding and in in-kind contributions. Additionally, PHL is contributing in-kind, non-monetary support valued at approximately \$230,000 in operation and maintenance of the locomotive. The CARB grant will provide \$2,768,860. Table 5 summarizes the project funding contributions that are/will be contracted as part of the zero emission demonstration:

**Table 5: VeRail Zero Emissions Locomotive Demonstration
Funding Partners**

Project Partners	Contributions
VeRail Technologies, Inc.	\$3,100,000
Pacific Harbor Line (estimated value of in-kind support)	\$230,000
South Coast Air Quality Management District	\$300,000
Port of Long Beach	\$200,000
Port of Los Angeles	\$303,321
California Air Resources Board	\$2,768,860

Project Benefits

With the scope revision to 100% zero-emission capability, the VeRail locomotive will reduce all criteria and GHG exhaust emissions by 100 percent.

Accomplishments During 2018

During 2018, VeRail focused its efforts to redesign the locomotive to entirely eliminate the use of diesel and CHG fuel and support the transition to zero-emission battery technology. The charging infrastructure was installed at PHL's facility.

2019 Milestones

In 2019, the project will focus on implementing its new iteration, now known as the Port of Los Angeles Zero-Emission Track-Miles Locomotive Demonstration. Key milestones in the coming year include:

- Locomotive design and systems integration,
- Charging system power supply connection, and
- Initiate the demonstration and begin data collection.

5.6 Maersk Ocean-Going Vessel Energy Efficiency Measurement Demonstration Project

Project Description

The objective of the Maersk Ocean-Going Vessel Energy Efficiency Measurement Demonstration Project (Maersk TAP Project) is to evaluate and quantify the benefits of energy efficiency improvements for ocean-going vessels. During this demonstration, detailed high frequency operational energy and fuel data are being collected onboard two classes of 9,000 twenty-foot equivalents (TEU) containerhips calling at POLA and POLB to study ship efficiencies before and after major retrofits.

Figure 4: Project Vessel “Gunhilde Maersk”



These ships are part of Maersk Line’s \$125 million Radical Retrofit Program (Radical Retrofit), which will retrofit existing vessels with multiple energy efficiency technologies, such as redesigning the bulbous bow of each vessel, replacing existing propellers with more efficient models, adding propeller boss cap fins to reduce the inefficiencies associated with the shearing of water at the end of the propeller, and “derating” the main engines to make them more efficient at lower speeds.

In addition to the propulsion-related retrofits highlight above, the retrofit program includes raising the bridge to increase each ship’s capacity from about 9,000+ TEUs (twenty-foot equivalent units) to about 11,000+ TEUs. This allows the Maersk Line G-Class ships to carry more containers per vessel while decreasing their environmental impact per container moved. It should be noted that the ships calling the San Pedro Bay Ports are already equipped with shore-power capabilities.

The Maersk TAP Project will have access to continuously recorded data showing how much energy each engine uses in conjunction with speed, engine power, weather, operational mode, and other operational variables through the use of the ship’s engine management systems and newly installed mass flow meters to capture key performance data. The Maersk TAP Project was originally scoped to use the pre- and post-Radical Retrofit data from four vessels to quantify energy and emissions improvements by operational mode. As a result of an unprecedented cyberattack affecting Maersk’s worldwide operations, the scope and methodology for this project was revised as discussed below.

Project Partners & Budget

The overall Radical Retrofit budget is \$125 million dollars. Maersk Line has agreed to incorporate the enhanced fuel flow monitors, to collect and process all project data, and to provide its in-house operational and technical expert resources for this TAP project. The Ports

are contributing a combined \$1 million for real-time tracking systems to quantify vessel emissions while ships are at sea and at-berth. Table 6 summarizes the project funding contributions:

Table 6: Maersk Ocean-Going Vessel Energy Efficiency Measurement Demonstration Funding Partners

Project Partners	Contributions
Maersk Line	\$1,860,000
Port of Long Beach	\$ 500,000
Port of Los Angeles	\$ 500,000

Project Benefits

The key benefit of the project will be demonstration of the use of detailed, real-world data to quantify energy efficiencies and emissions improvements. Energy efficiency improvements are critical components of California's Sustainable Freight Action Plan and air quality strategies to bring the South Coast Air Basin into air quality standards attainment. Currently, the regulatory community has not defined an approach to quantifying efficiency improvements from ocean-going vessels; the Maersk TAP Project is the first opportunity to develop such a quantification methodology and demonstration.

From an emissions standpoint, the Maersk Radical Retrofit (RR) is expected to reduce fuel consumption by 2,000 to 3,000 metric tonnes per year, with a total annual reduction of 10,000 tonnes of fuel for the four vessels evaluated in this project. This reduces the GHG emissions of these four vessels by an estimated 31,140 tonnes of CO₂ per year. DPM, NOx, and SOx are also reduced as a result of lower engine loads and the associated reduced fuel consumption.

In addition, an increase in carrying capacity will reduce the carbon footprint per container transported in line with globally accepted measurement of CO₂ reductions from liner shipping activities. The planned capacity boost on each of these 9,000+ TEU vessels increases capacity by about 9%, thereby reducing fuel consumption and emissions produced per container by about 8% at full capacity utilization.

Project Scope and Timeline Adversely Impacted by Global Cyberattack Event

Maersk Line experienced system wide disruption due to a global cyberattack⁵ event that occurred June 27, 2017. This disrupted access to the Maersk network and StarConnect and other systems used to collect and transmit data for the project, as well as availability of technical personnel and resources supporting the project. Recovery continued for several months.

Accomplishments During 2018

The Radical Retrofits were completed on all twelve vessels as originally planned, with the final vessel dry docked in Spring 2018. Detailed high frequency operational energy and fuel data are limited or fragmented for most vessels prior to the Radical Retrofits. Data availability is summarized in Figure 5 below.

⁵ <https://www.wired.com/story/notpetya-cyberattack-ukraine-russia-code-crashed-the-world/>

Figure 5: Project Data Availability Matrix (as of Fall 2018)

Vessel Name	Vessel Class	Pre-Radical Retrofit			Post-Radical Retrofit			
		MSPS w/GIS	CAMS	Consumption	MSPS w/GIS	CAMS	Consumption	Near Real-Time
Gudrun Maersk	Gudrun	X			X	X	X	
Grete Maersk	Gudrun	X			X	X	X	
Gerd Maersk	Gudrun	X			X	X	X	24 hrs
Gunvor Maersk	Gudrun	X			X	X	X	
Georg Maersk	Gudrun	X			X	X	X	
Gjertrud Maersk	Gudrun	X			X	X	X	
Guthorm Maersk	Gerner	X			X	X	X	
Gerda Maersk	Gerner	X		4 months 0 CA trips	X	X	X	
Gunde Maersk	Gerner	X			X	X	X	
Gustav Maersk	Gerner	X		5.5 months 1 CA trip	X	X	X	
Gerner Maersk	Gerner	X			X	X	X	
Gunhilde Maersk *	Gerner	X		13 months 0 CA trips	n/a	n/a	n/a	n/a

Based on the above data availability, the project team worked together with the Ports on a plan to proceed with the project goals as much as possible in light of the limited data. The new plan used available pre/post RR data for Gerda (~4 months), Gustav (~5.5 months; 1 California trip), and Gunhilde (~13 months) focusing on fuel consumption. This was substantiated with MSPS pre/post RR to evaluate fuel efficiency benefits. Energy efficiency improvements were to be determined using both control alarm monitoring system (CAMS) and fuel consumption datasets.

Fortunately, limited fuel consumption data and MSPS data were available for the Gerda, Gustav, and Gunhilde and these data were recompiled, and analysis started at the end of 2018. The draft analysis of the G-Class and recommendations on emissions inventory improvements based on the G-Class analysis are anticipated to be submitted to the Ports in Spring 2019 with a final report scheduled for June 2019.

In light of these data limitations, Maersk evaluated other ship classes which had been through similar retrofits. They found that the Emma Class has substantial pre/post RR data including CAMS, fuel consumption data, and MSPS. Maersk is evaluating the feasibility of using the Emma Class as a Phase 2 effort, which would build on the findings of the G-Class, apply the Emma Class dataset, and confirm or improve the approach used for the G-Class.

2019 Milestones

It is anticipated that the following work will be conducted on the Maersk TAP Project during 2019:

- Complete full data analysis and quality assurance reviews.
- Prepare draft technical documentation and presentation material.
- Present Ports and TAP AC draft documentation and results from analysis.
- Finalize project report.

6 ADDITIONAL PORT TECHNOLOGY ADVANCEMENT INVESTMENTS

In addition to the above initiatives, there are a number of other technology development efforts being supported by the Ports that are outside of the TAP itself. These projects include direct port investment, as well as projects in which the Ports have received significant grant funding from partner agencies to support demonstration projects being implemented by port tenants together with technology manufacturers. An overview of the funding commitments is provided in Table 7 and a brief update for each project is provided further below. For each Port \$1, nearly \$7.75 in agency and OEM/demonstration partner funding is supporting the below projects.

Table 7: Overview of Additional Port Technology Advancement Investments

Project Category/Title	POLB	POLA	Agency Partner Funding	OEMs/DEMO Partner	Total Project Budget
Everport Advanced Cargo Handling Equipment Demonstration		\$1,071,428	\$4,524,000	\$1,166,903	\$6,762,331
Advanced Yard Tractor Deployment and Eco-FRATIS Drayage Truck Efficiency Project			\$5,833,000	\$2,808,007	\$8,641,007
Port of Long Beach Zero-Emissions Terminal Equipment Transition Project (CEC-17)	\$1,677,176		\$9,755,000	\$2,320,339	\$13,752,515
Pasha Green Omni Terminal Demonstration Project			\$14,510,400	\$12,092,000	\$26,602,400
Overhead Catenary Zero Emissions Trucks	\$2,000,000	\$4,000,000	\$7,500,000		\$13,500,000
Commercialization of POLB Off-Road Technology Demonstration Project (C-PORT)	\$1,225,484		\$5,689,820	\$1,388,066	\$8,303,370
Port Advanced Vehicle Electrification (PAVE)	\$3,704,266		\$2,195,000	\$3,658,646	\$9,557,912
Sustainable Terminals Accelerating Regional Transportation (START) (aka CARB ZANZEFF)	\$7,796,157		\$53,750,000	\$39,377,612	\$100,923,769
TOTAL:	\$16,403,083	\$5,071,428	\$103,757,220	\$62,811,573	\$188,043,304

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

The 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 Automatic SmartCharging System for yard tractors. For this project, POLA is investing \$2 million (cash and in-kind) to support the purchase and installation of a new switchgear and the associated infrastructure to support this project, since the terminal does not currently have enough capacity for this new equipment. This upgrade is being designed to allow for the eventual additional of up to an additional 25 battery-electric yard tractors. The project is being funded by a 2017 CEC grant in the amount of \$4,524,000, with project cost share in the amount of \$2,238,331, for a total project cost of \$6,762,331. In 2018,

Taylor began design and manufacture of the top handlers and is working with BYD on charger technology that will be used for these units. POLA Engineering is working with Cavotec to develop the terminal infrastructure and once final connection design is finalized, BYD will begin manufacture of these 2nd generation battery-electric yard tractors.

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

This project, which began in early 2017, includes three major components:

- Demonstration of 20 yard tractors that will be equipped (for the first time in this off-road yard tractor application) with the Cummins Westport near-zero 0.02 gram/bhp-hr NOx engine. To further enhance project benefits, a temporary renewable natural gas (RNG) fueling system will be utilized for the demonstration.
- Demonstration of five yard tractors that will be equipped with BYD's zero emissions propulsion technology.
- Demonstrate integration of intelligent transportation system (ITS) 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 are added to further enhance efficiency benefits.

The project is funded in part by a \$5.83 million grant from CEC's Low Carbon Transportation Greenhouse Gas Reduction Fund Investments. The overall project budget is \$8.64 million. Contracts with the subrecipients were executed in mid-2017 and the project is well underway. Highlights from 2018 include:

- Design and development of the BYD battery-electric yard tractors is complete and BYD is working with Everport to finalize the design. Design issues were identified in prototype units being commissioned for POLA's Green Omni Terminal Demonstration Project (Section 6.4); these issues will be resolved before Everport accepts delivery of the BYD units for this project:
 - The 5th wheel connection between the tractor and the trailer was redesigned to improve the fit. Another 5th wheel issue was identified that will be addressed in the next generation design – conventional diesel yard tractors allow the trailers to be raised and lowered while the tractor while mobile. During initial commissioning of this design, it was discovered that the BYD unit must be stationary for trailers to be moved up and down. This design need will be addressed in future designs.
 - Operation of the tractor in reverse was not acceptable to Everport (the tractor was not slowing down when the accelerator pedal was released when in reverse). BYD is implementing software programming changes to address this concern, which should be resolved in early 2019.
- Design of the low-NOx RNG-fueled yard tractors is complete, and manufacturing is underway for all 20 units, with the final unit scheduled for delivery mid-2019.
- Infrastructure to support these units encountered issues related to third-party certification requirements (i.e., UL listing) which are expected to be resolved in early 2019.
- The one-year demonstration is anticipated to begin May 2019.

6.3 Port of Long Beach Zero-Emissions Terminal Equipment Transition Project

The Port of Long Beach, in partnership with terminal operators and Southern California Edison (SCE), will be demonstrating and deploying projects for zero emissions cargo-handling equipment. The Port received \$9,755,000 in CEC funding, which is matched by POLB (\$1,677,176) and project partners (\$2,320,339) for a total project investment of \$13,752,515. The overall project scope includes:

- Repower nine RTG cranes for full-electric power at SSA Marine Terminal, Pier J.
- Demonstrate 12 zero emissions BYD yard tractors and an automated smart charging system at ITS and LBCT.
- Convert four LNG trucks to plug-in hybrid electric trucks (PHET) with LNG range extender at TTSI (with US Hybrid as the technology provider).
- Support workforce training programs through Long Beach City College for these technologies.
- Outreach activities that include education for disadvantaged communities.

The CEC agreement was fully executed on July 20, 2017. Subgrant agreements were executed in 2018. Port of Long Beach staff has finalized all subrecipient agreements. Key milestones for 2019 include:

- Completed the data collection test plan for all demonstration projects
- Delivered all LNG trucks for conversion to LNG-PHETs
- Completed design of the LNG-PHET
- Completed infrastructure design for the BYD demonstration
- Completed design of the Cavotec smart charger
- Long Beach City College completed a draft final report of the workforce gap analysis
- Commenced integration of the new natural gas engines into the first truck for the US Hybrid/TTSI demonstration
- Commenced construction work at SSA Pier J for the 9 electric RTG demonstration which includes SCE upgrades and civil work

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

This demonstration project has several components including: two battery-electric yard trucks from BYD Motors; two battery-electric yard trucks and two battery-electric on-road trucks from TransPower, electrification of three 21-ton forklifts from TransPower; a micro grid 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 that will include the demonstration of two greenhouse gas capture technologies. 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. Major accomplishments in 2018 and plans for 2019 include:

- Completed roof and warehouse retrofits at Berth 180-181 to accommodate solar photovoltaic (PV) system. For this aspect of the project, Pasha incurred unplanned costs to update the warehouse and roof to meet codes to accommodate this project.

- Designed and procured battery storage systems from BYD. These are battery storage systems, where solar power will feed 2.5 megawatts of energy that can be used to charge vehicles or for peak shaving. The systems are at Pasha and must meet UL standards before being put into use. These are the first battery storage systems seeking certification within the City of Los Angeles. The BYD team continues to work towards final certification in early 2019.
- Received two electric yard tractors and two on-road trucks from TransPower in June 2018.
- Installed charging stations for the TransPower equipment and received third-party certification for chargers in July 2018. These systems require different charging configurations, so a coding system was devised by Pasha to ensure correct connection. Demonstration of these units will begin in first quarter 2019.
- Delivered two BYD electric yard tractors to Pasha second quarter 2019. Operational issues were identified for the 5th wheel and reverse operation. These issues are discussed above in Section 6.2 and are expected to be addressed by BYD early 2019.
- Installed BYD chargers and anticipating certification of BYD charging stations for BYD yard tractors in second quarter 2019.
- The first repowered zero-emission high-tonnage forklift will be delivered by the end of first quarter 2019. The second and third units will be delivered by second quarter 2019.
- Tri-Mer and Clean Air Engineering Maritime delivered the main treatment portion of the ShoreKat crane and capture system in January 2018. It will be assembled and commissioned on a custom trailer to allow for the safe movement of the treatment system on the terminal in first quarter 2019. The trailer was ordered in May and arrived in late 2018. Due to the weight of the assembled system, the team is evaluating ways to move it around the terminal. The unit may be used against a ship in first quarter 2019.

6.5 Overhead Catenary for Zero Emissions Trucks

SCAQMD's project with Siemens Industry Inc. (Siemens) to conduct a demonstration of an overhead catenary system (OCS) using Siemens' eHighway wayside power technology for heavy-duty trucks ended in 2018. SCAQMD and its agency partners funded this project in the amount of \$7,500,000. POLB contributed \$2 million and POLA committed \$4 million from the China Shipping Mitigation Fund to this project. The overall project budget was \$13,500,000. The demonstration covered one mile of catenary power lines in both directions along Alameda Street in the City of Carson with three catenary accessible trucks from Volvo and TransPower. The trucks demonstrated a variety of architectures including diesel hybrid, CNG hybrid, and battery electric. The hybrid drive system extended the operating range of the truck beyond the all-electric range of the catenary system, enabling the truck to perform regional drayage operations and bridge gaps in catenary infrastructure as it is deployed on a regional level. The Siemens' pantograph system was designed to allow for seamless connection and detachment from the catenary power source. When entering the catenary system corridor, the pantograph system verifies the presence of catenary lines and allows the driver to raise the pantograph from within the cab of the truck. Upon leaving the catenary lane, the pantograph automatically retracts and the truck switches to on-board power systems. The Alameda Street demonstration was agreed by the project team to be a successful proof of concept in a representative operating environment; however, important risks were identified for future consideration, including the uncertainty related to installation of catenary infrastructure (i.e., utility interface, coordination/permits with local jurisdictions) and the uncertainty if fleet operators would adopt the technology.

Figure 6: Demonstration of the Overhead Catenary System



As part of this project, a detailed total cost of ownership study was conducted that studied the technology under two scenarios: Alameda Street and I-710. This study concluded that with sufficient penetration (zero-emission miles), catenary technology can be more cost effective than diesel plug-in hybrid electric vehicle operation due to battery costs of the PHEVs and associated cost of fast chargers and overnight chargers. All final reports associated with this project are available on the TAP website for additional detail.

A major issue encountered for this project was that the system power supply was found to be encroaching upon a Southern California Gas Company pipeline. As a result, the demonstration was limited to six months in order to satisfy the utility's requirement to move it after this time.

Due to the interference of the system's power supply and the local gas pipeline, the system will be decommissioned. The Port of Long Beach has paid all funds committed to the project and the Port of Los Angeles will release final payment when the catenary system is decommissioned in 2019.

6.6 Commercialization of POLB Off-Road Technology Demonstration Project (C-PORT)

The C-PORT project, in partnership with SSA Marine and Long Beach Container Terminal, will demonstrate five zero-emissions cargo handling vehicles. The demonstration will include three never-before-tested battery-electric top handlers and feature a unique, head-to-head comparison of a hydrogen fuel cell yard truck versus a battery-electric yard truck.

The project is funded in part by a \$5.3 million grant from CARB's California Climate Investments, a statewide initiative that puts billions of Cap-and-Trade dollars to work reducing greenhouse gas emissions, strengthening the economy and improving public health and the

environment. The overall project budget is \$8.3 million. Contracts with the subrecipients were executed in 2018 and the project is underway. Infrastructure to support these units will be operational beginning in Q2 2019, with equipment deployment scheduled for mid-2019. The demonstration is scheduled for completion by early 2020.

6.7 Port Advanced Vehicle Electrification (PAVE) Project

The Port of Long Beach's Port Advanced Vehicle Electrification (PAVE) Project will design, install, and deploy electrical charging infrastructure, including electrical conduit, wires, switchboards, transformers, and switchgears, to support battery-electric yard tractors and forklifts at Total Terminals International's facility at Pier T. The PAVE Project includes the world's first heavy-duty, off-road direct current fast-charging system for battery electric yard hostlers. The project also includes support for workforce development by promoting electric vehicle infrastructure training programs and a development of a comprehensive portwide Dynamic Energy Forecasting Tool to predict how much energy and supportive infrastructure seaports will need to support zero-emissions terminal equipment.

The project is funded in part by nearly \$1.4 million from SCAQMD and an \$800,000 grant from CEC's ARFVTP, and has an overall project budget of over \$9.55 million. Contracts with the project team were executed in 2018 and the project is underway. The project is scheduled for completion by March 2022.

6.8 Sustainable Terminals Accelerating Regional Transportation (START) Project

In partnership with the Ports of Stockton and 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 funding for Sustainable Terminals Accelerating Regional Transformation (START) Project will demonstrate more than 100 pieces of zero-emissions terminal equipment and trucks at three California seaports, develop a zero-emissions tugboat, deploy two ships with some of the cleanest available engines, and advance workforce development programs to support sustainable goods movement. The START Project is part of California Climate Investments, a statewide initiative that puts billions of cap-and-trade dollars to work reducing greenhouse gas emissions, strengthening the economy and improving public health and the environment — particularly in disadvantaged communities. The project will be completed by June 2021 and includes \$52 million in matching funds from private and public partners, for a total cost of \$102 million.

For this project, the Port of Oakland will deploy 10 electric trucks and six pieces of terminal equipment. The Port of Stockton will deploy more than 40 electric forklifts. At the Port of Long Beach, the START Project will fund:

- 33 zero-emissions yard tractors and one zero-emissions top handler 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 on the West Coast
- An electric-drive tugboat
- Five electric trucks at an off-dock container yard
- Two charging heavy-duty truck outlets, the first publicly accessible outlets of their kind in Southern California.

In 2018, the Port of Long Beach executed the grant agreement. In 2019, the Port plans to complete infrastructure design and to begin design and engineering on the equipment and to conduct baseline emissions testing on a tugboat and Tier 2 container ship. Additionally, the first of the two Tier 3 vessels is expected to arrive for emissions testing and demonstration in late 2019.

7 2018 TAP BUDGET AND TECHNOLOGY FUNDING

The TAP is supported by both Ports at an annual level of up to \$1,500,000 from each Port (up to \$3 million total). Additional funding is contributed on an ad-hoc basis by participating agencies, including but not limited to the SCAQMD, CARB, U.S. EPA, and CEC. Project co-funding is also contributed by the project proponent as either cash or in-kind contribution, or a combination of both.

The Ports and agency stakeholder investments for all past and current TAP projects approved to date are shown in Table 8. One new project was approved and funded by the TAP in 2018, the development and demonstration of harbor craft retrofit technology. Contributions from participating agencies other than the Ports are typically made on a project-by-project basis. In addition to the funding amounts reflected in Table 8, 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. Required match contributions are not included in Table 8 but are noted within each project summary in Section 5.

Table 8 also contains technology projects funded by the Ports outside of the TAP budget that are summarized in Section 6.

Table 8: Ports' Technology Advancement Funding Investments through December 31, 2018

Project Category	Year Completed	POLB	POLA	AQMD	CARB	US EPA/ USDOE/ Other Agencies	CEC	Total Port & Agency Stakeholder
<u>Ocean-going Vessels</u>								
APL Singapore Slide Valve/WIFE	2009	\$22,500	\$22,500		\$783,628			\$828,628
ACTI AMECS Emissions Testing	2008	\$149,527	\$149,527	\$55,000				\$354,054
Bluefield Holdings Krystallon OGV Scrubber	2013	\$825,000	\$825,000					\$1,650,000
OGV Slide Valve Low-Load Emissions Evaluation	2013	\$108,000	\$108,000					\$216,000
ACTI At-Berth Emissions Reductions for Ships	2015	\$703,388						\$703,388
Tri-Mer Mobile Emissions Treatment System (METS-1) At-Berth Emissions Reductions for Ships	2015		\$1,500,000					\$1,500,000
Maersk OGV Energy Efficiency Measurement Demonstration	ongoing	\$500,000	\$500,000					\$1,000,000
<u>Harbor Craft</u>								
Nett Technologies Inc. BlueMAX™ NOVA 320e	ongoing	\$250,000	\$250,000					\$500,000
Foss Maritime Hybrid Tugboat	2010	\$500,000	\$889,920*		\$1,000,000			\$2,389,920
<u>Cargo Handling Equipment and Port Terminal Projects</u>								
LNG Yard Tractor	2007	\$350,000				\$75,000**		\$425,000
Balqon Electric Terminal Tractor	2009		\$263,500	\$263,500				\$527,000
Vycon RTG REGEN Flywheel	2007	\$11,500	\$11,500	\$8,000				\$31,000
Balqon Lithium Battery Upgrade	2011		\$400,000					\$400,000
Hybrid Yard Tractor	2010	\$300,000*	\$300,000*			\$300,000**		\$900,000
LBCT Eco-Crane	2011	\$42,467.50	\$42,467.50			\$130,130		\$215,065
Capacity Plug-In Hybrid Tractor	2010	\$29,500*	\$32,000*					\$61,500
APT Emulsified Biodiesel	2011	\$44,000	\$44,000					\$88,000
<i>RYPOS Diesel Emissions Control (L2+)</i>	2012	\$64,668.42	\$64,668.42					\$129,336.84
Hybrid Yard Tractor Development & Demonstration – Beta Test	2011	\$13,000*	\$13,000*					\$26,000
RYPOS Adv. L3+ DPF – RTG Cranes	2014	\$36,130	\$36,130					\$72,260
Port of Long Beach Zero Emissions Terminal Equipment Transition Project	ongoing	\$1,677,176*					\$9,755,000	\$11,432,176
Advanced Yard Tractor Deployment and Eco-FRATIS Drayage Truck Efficiency Project	ongoing						\$5,833,000	\$5,833,000
Green Omni Terminal Demonstration Project	ongoing				\$14,510,400			\$14,510,400
Everport Advanced CHE Demonstration	ongoing		\$1,071,428				\$4,524,000	\$5,595,428
Commercialization of Off-Road Technology Demonstration	ongoing	\$1,225,484.09*		\$350,000	\$5,339,820			\$6,915,304.09
Port Advanced Vehicle Electrification	ongoing	\$3,704,266*		\$1,395,000			\$800,000	\$5,899,266
Sustainable Terminals Accelerating Regional Transportation	ongoing	\$7,796,157*		\$500,000	\$50,000,000			\$61,546,157

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Table 8: Ports' Technology Advancement Funding Investments through December 31, 2018 (cont'd.)

Project Category	Year Completed	POLB	POLA	AQMD	CARB	US EPA/ USDOE/ Other Agencies	CEC	Total Port & Agency Stakeholder
Container Drayage Trucks								
Westport ISX LNG Engine	2010	\$250,000	\$250,000	\$1,250,000			\$500,000	\$2,250,000
SoCalGas CNG Drayage Truck	2010	\$111,577.50	\$111,577.50	\$421,250				\$644,405
<i>Vision Motor Corp. Hydrogen Fuel Cell Plug-In Hybrid Electric Truck</i>	2012	\$95,625	\$95,625					\$191,250
US Hybrid On-Board Charger for Zero Emissions Cargo Transport Demonstration	2016	\$37,500	\$37,500	\$75,000				\$150,000
TransPower Pre-Commercial Electric Drayage Truck Demonstration	2016	\$150,000	\$150,000			\$1,192,184	\$2,296,617	\$3,788,801
TransPower Electric Drayage Infrastructure and Improvement	2016	\$300,000	\$300,000					\$600,000
<i>International Rectifier Plug-In Hybrid Electric Class 8 Truck Conversion</i>	2016	\$17,500	\$17,500					\$35,000
HLT San Pedro Bay Ports Drayage Truck Demonstration of a Near-Zero Ultra-Low NOx Natural Gas Engine Operating on Renewable Natural Gas	2018	\$37,500	\$37,500					\$75,000
Development of a Near-Zero Emissions Diesel Engine for On-Road Heavy-Duty Vehicles	ongoing		\$287,500	\$287,500	\$425,000			\$1,000,000
SCAQMD Zero Emissions Cargo Transport (ZECT) II	ongoing	\$724,489.50	\$566,990	\$2,400,000		\$10,975,000	\$2,400,000	\$17,066,479
Develop and Demonstrate Catenary Zero Emissions Goods Movement System	ongoing	\$2,000,000*	\$4,000,000*	\$2,500,000		\$2,000,000	\$3,000,000	\$13,500,000
Locomotives								
Johnson Matthey DPF Locomotive Demonstration	2014	\$75,000	\$75,000		\$346,178			\$496,178
VeRail Near-Zero Locomotive Demonstration – Moving Towards Zero Emissions	ongoing	\$200,000	\$303,321	\$300,000	\$2,768,860			\$3,572,181
Technology Advancement Support Efforts								
Heavy-Duty Drayage Truck Duty Cycle Characterization	2011	\$12,681*	\$13,000*					\$25,681
Development of Drayage Truck Chassis Dynamometer Test Cycle	2011	\$12,000*	\$11,466*					\$23,466
AQMD HDV In-Use Emissions Testing Program	2015	\$153,276	\$153,276	\$1,701,156				\$2,007,708
Total Investment (Includes Funding Outside TAP)		\$22,529,913.01	\$12,933,895.92	\$11,506,406	\$75,173,886	\$17,992,314	\$29,108,617	\$169,175,031.93
Total Port TAP Investment		\$5,056,260.92	\$6,603,081.92					
Combined Ports' TAP Investment		\$11,659,342.84						

*This funding amount is a non-TAP, Port funding contribution to the project.

**Denotes EPA-grant funding contribution from the U.S. EPA West Coast Collaborative (pre-dating the TAP).

"*Italics*" denotes projects that were modified during implementation in a manner that changed the original budget; **Blue** denotes projects or project elements that were introduced in 2018.

APPENDIX A

Technology Advancement Program Advisory Committee Membership

- | | |
|---|-----------------------------|
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| ▪ John Lee, California Air Resources Board | jlee@arb.ca.gov |
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Appendix B: Completed TAP Projects

The following TAP projects are completed and additional information is available online at the Clean Air Action Plan' TAP website: <http://www.cleanairactionplan.org/technology-advancement-program/final-reports/>

1. ACTI Advanced Maritime Emissions Control System (AMECS) Project (2008)
2. APL Singapore Slide Valve & Water-In-Fuel Emulsion Demonstration Program (2009)
3. Alternative Petroleum Technologies' Emulsified Biodiesel (2011)
4. Balqon E-30 Electric Terminal Tractor Development & Demonstration Project (2009)
5. Balqon Lithium-Ion Battery Demonstration (2011)
6. Bluefield Holdings Krystallon Ocean-Going Vessel Scrubber (2013)
7. Capacity Plug-In Hybrid Electric Terminal Tractor (2010)
8. Characterization of Drayage Truck Duty-Cycles (2011)
9. Development of a Drayage Truck Chassis Dynamometer Test Cycle (2011)
10. Development of On-Road Drayage Truck Testing Protocol (2016)
11. Foss Maritime Green Assist™ Hybrid Tugboat (2010)
12. Hybrid Yard Tractor Development & Demonstration (2010)
13. Hybrid Yard Tractor Development & Demonstration – Beta Test (2011)
14. Johnson Matthey Locomotive DPF Demonstration (2014)
15. Liquefied Natural Gas Yard Tractor Demonstration (2007)
16. Long Beach Container Terminal Eco-Crane™ (2011)
17. OGV Slide Valve Low-Load Emissions Evaluation (2013)
18. RYPOS Advanced Diesel Particulate Filter for Cargo-Handling Equipment (2012)
19. RYPOS Advanced Level 3+ Diesel Particulate Filter RTG Crane Demonstration (2014)
20. San Pedro Bay Ports Drayage Truck Demonstration of a Near-Zero Ultra-Low NOx Natural Gas Engine Operating on Renewable Natural Gas (2018)
21. SCAQMD HDV In-Use Emissions Testing Program (2013)
22. SoCalGas CNG Drayage Truck Demonstration (2010)
23. TransPower Electric Drayage Infrastructure and Improvement (EDII) Project (2016)
24. TransPower Electric Drayage Pre-Commercial Truck Demonstration (2016)
25. US Hybrid On-Board Charger for Zero Emissions Cargo Transport Demonstration (2016)
26. VYCON REGEN® System for Rubber-Tired Gantry Cranes Testing & Verification (2007)
27. Westport GX LNG Engine Development (2010)