



SAN PEDRO BAY PORTS CLEAN AIR ACTION PLAN

2017 ANNUAL REPORT AND 2018 PRIORITIES Technology Advancement Program

11 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
AMT	automated manual transmission
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
ESS	energy storage subsystem
GHG	greenhouse gases
HP	horsepower
ICU	inverter charger unit
kW	kilowatt
kWh	kilowatt-hours
LBCT	Long Beach Container Terminal
LNG	liquefied natural gas
MW	megawatt
NO _x	oxides of nitrogen
OGV	ocean-going vessel
PCAS	power control and accessory system
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
SoCalGas	Southern California Gas Company
TAP	Technology Advancement Program
TEU	twenty-foot equivalents
WIFE	water-in-fuel emulsification
ZE	zero emissions
ZEV	zero emissions 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 11 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 2016 port-related diesel particulate matter (DPM) emissions were reduced by 87%, nitrogen oxide (NO_x) emissions were reduced by 56% 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 a TAP Advisory Committee that evaluates technology projects, supports the commercialization of these nascent technologies, and helps leverage funds.

More than a decade later, the TAP has undertaken over 30 projects spanning test cycle development, hybrid and alternative fuel technology demonstrations, and zero emissions (ZE) equipment operation.

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 over the next 3 to 5 years. The TAP will play a critical role in this effort.

Over the next few years, 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 poised to inject more than \$1 billion into clean vehicle and equipment deployments over the next 3 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 intend to use TAP as a means of leveraging other public and private funds for demonstration. In the next fiscal year, the state has earmarked \$140 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 2017

In 2017, 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 2017 include:

- Issued a competitive Request for Proposals entitled “Demonstration of Air Pollutant Emissions Reduction Technologies for Commercial Harbor Craft.” The RFP was released on July 27, 2017, with proposals due September 21, 2017. The evaluation panel recommended Nett Technologies to 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. The project must first be approved by the Boards of Harbor Commissioners and will begin in 2018 upon contract execution.
- 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 anticipated to be complete in the first quarter of 2018;
- Maintained an updated TAP website² to enhance transparency and improve communications of our technology results and to provide resources for technology developers;
- Finalized a testing protocol for zero and near-zero emissions yard tractor demonstrations, which is critical to ensure consistent evaluation of emerging technologies. The protocol can be found on the Ports’ TAP website³;
- Funded the following new TAP projects:
 - San Pedro Bay Ports Drayage Truck Demonstration of a Near-Zero Ultra-Low NOx Natural Gas Engine Operating on Renewable Natural Gas
 - Port of Los Angeles (POLA) funding support for SCAQMD’s project entitled “Development of an Ultra-Low Emissions Diesel Engine for On-Road Heavy-Duty Vehicles”
- 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 2017 TAP projects. Section 5 provides a detailed status update for each of these projects, including specific accomplishments in 2017 and projected milestones for 2018. 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.

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

³ <http://www.cleanairactionplan.org/documents/yard-tractor-test-protocol-final-draft.pdf>

Table 1: 2017 TAP Project Snapshot

Project Title	Project Description	Status	Zero or Near-Zero Emissions Project?
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).	Approved and initiated in 2017	Near-Zero
Development of an Ultra-Low 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).	Approved and initiated in 2017	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 VR21C4-df 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) (Section 5.5).	Ongoing	Near-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 this report, the Ports continue their strong commitment to zero emissions technology development and demonstration, where providing direct funds for technology development is just one aspect of the TAP's leadership on zero emissions. Achieving sustainable goods movement requires a collaborative, multi-agency effort with significant cooperation from private industry. The TAP plays a critical role in this effort. 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 a common goal. TAP supports zero emissions 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.

In addition to the projects listed in Table 1, in 2017 the TAP provided support to the following zero emissions projects:

- SCAQMD Zero Emissions Cargo Transport Project (ZECT I): SCAQMD contracted with U.S. DOE on behalf of the Southern California Zero Emissions Freight Movement Regional Collaborative to develop and demonstrate zero emissions Class 8 drayage trucks in real world drayage service. The current list of equipment for this program (11 in total) includes four battery-electric trucks and two compressed natural gas (CNG) plug-in hybrid trucks from TransPower, and two battery-electric trucks and three LNG plug-in hybrid trucks from US Hybrid. The scope of work supported by the Ports for this project is now complete. While the demonstration of the TAP-sponsored units was completed in September 2017, TransPower and TTSI (the operator) are working on a lease agreement to allow ongoing use of the units in revenue service.
- SCAQMD Zero Emissions Drayage Truck Demonstration Project: CARB's Air Quality and Low Carbon Transportation Investments Programs selected SCAQMD for a major zero emissions technology demonstration that includes 25 BYD battery-electric trucks, 12 TransPower/Peterbilt battery-electric trucks, four Kenworth CNG plug-in hybrid electric trucks and three Volvo diesel plug-in hybrid electric trucks. SCAQMD finalized contracts with the project partners in 2016 and the first project trucks are anticipated to be completed in the first quarter of 2018. The Ports are working with SCAQMD to site the demonstration vehicles with fleets that operate in local and regional goods movement service.
- SCAQMD Catenary Zero Emissions Goods Movement System Demonstration with Siemens Industry Inc. (Siemens) to develop and then conduct a 6-month demonstration of an overhead catenary system (OCS) using Siemens' eHighway wayside power technology for heavy-duty trucks. Please refer to Section 6.5 for additional detail regarding the status of this project.

4 2018 TAP PRIORITIES

TAP priorities for 2018 generally support implementation of the recently adopted CAAP 2017 Update, including a strong 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 2018 TAP Priorities

To better focus TAP resources and to signal our interest in specific technologies, the Ports have identified the following mobile source applications for TAP funding priority:

- Zero and near-zero emissions cargo-handling equipment
- Zero and near-zero emissions heavy-duty vehicles
- Harbor craft technologies
- At-berth ship technologies
- Locomotive technologies

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 2018, it is imperative for the Ports to begin planning for zero emissions, 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 2018, 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;
- Implement the harbor craft and ship at-berth emissions reduction projects; and
- Issue a Call for Projects, likely mid-year.

Support for Zero-Emissions Truck Pilot Deployment

The Ports plan to set aside up to \$1 million from the TAP to begin supporting the zero emissions truck pilot deployment. These funds may be used for the following activities in 2018:

- Funding for smaller single fleet demonstrations of five to seven zero emissions trucks to identify challenges and opportunities for the larger deployment.
- Develop a fleet characterization to identify those fleets or duty cycles in which a pilot deployment makes the most sense.
- Evaluate infrastructure needs, including charging standards and fast-charging.
- Request allocation of funds from each Port's Board of Harbor Commissioners to create a ready "bank" for cost-share that can leverage state and federal grant funds for projects that directly support TAP priorities.

Support for Other Technology Projects

The Ports also plan to set aside up to \$500,000 from the TAP to support one or more projects under an open Call for Projects, which may include emissions-reduction technologies for cargo-handling equipment, locomotives, and ships.

In addition, the Ports will continue to support the following TAP activities in 2018:

- Implement the harbor craft emissions-reduction project, which includes entering into a contract with the selected firm and beginning development.
- Implement the at-berth emissions-reduction project, which includes selection of one or more proposals and contracting and beginning development of the technology.
- Continue to support and fund the following TAP projects:
 - SCAQMD Zero Emissions Cargo Transport (ZECT II) Demonstration;
 - VeRail Near-Zero Emissions Locomotive Demonstration;
 - Maersk Ocean-Going Vessel Energy Efficiency Measurement Demonstration;
 - San Pedro Bay Ports Drayage Truck Demonstration of a Near-Zero Ultra-Low NOx Natural Gas Engine Operating on Renewable Natural Gas; and
 - Development of an Ultra-Low Emissions Diesel Engine for On-Road Heavy-Duty Vehicles.

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.

The AC also serves as the mechanism for member agencies and the Ports to reach consensus on the level of emissions reductions achieved by the candidate technologies undergoing evaluation and other technical issues. As an example, in 2017 the Ports focused on the need for test plan guidelines that could be used to evaluate zero emissions yard tractor technologies. This effort was coordinated by the Ports with CARB and SCAQMD support, resulting in the publication of the "Zero/Near-Zero Emissions Yard Tractor Testing & Demonstration Guidelines," which will be used for future evaluation of zero and near-zero emissions drayage truck technologies.

5 KEY PROJECTS IN 2017

This section provides more details on TAP projects that were active in 2017. For information on completed TAP projects, please access the Final Reports at the program website: <http://www.cleanairactionplan.org/technology-advancement-program/>.

5.1 Development of Yard Tractor Testing Protocol

In recognition of the need to have a consistent evaluation process for all agencies conducting yard tractor-related demonstration projects, in 2017 the TAP finalized test protocols for yard tractor demonstrations. The “Zero/Near-Zero Emissions Yard Tractor Testing & Demonstration Guidelines”⁴ were developed in partnership with the SCAQMD and CARB. The guidelines will support the technical evaluation, performance testing, and durability validation of electric, hybrid-electric, and other advanced technology yard tractors.

The intent of the testing and demonstration protocol is to provide a consistent set of guidelines to advanced technology equipment manufacturers and demonstration partners regarding port requirements and expectations as they pertain to equipment performance, operability, and durability. Without such consistency, it is difficult to compare technologies and/or verify that zero or near-zero emissions equipment meet the minimum performance standards required for yard tractor operations within the port environment.

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, a 2014 Freightliner Cascadia day-cab equipped with an ISX12G engine (0.2 gm/bhp-hr NOx) was 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, 2017⁵. During the demonstration, the truck is fueling exclusively with renewable natural gas for high mileage accumulation for a minimum of 6 months (and at least 150 revenue trips).

The demonstration vehicle is monitored using a Qualcomm device for GPS tracking to provide data that show viability of the technology on the drayage service cycle. Data collected include miles traveled, number of deliveries, and routes. The truck is operated by Heavy Lift Transfer, LLC and runs approximately 10,000 miles per month as it services the Ports. During the demonstration project, the truck is maintained by Cummins Cal Pacific. A 6-month operating report and a final report detailing the truck operations will be prepared at completion of the demonstration.

⁴<http://www.cleanairactionplan.org/documents/san-pedro-bay-ports-zeronear-zero-emissions-drayage-truck-testing-demonstration-guidelines.pdf>

⁵https://arb.ca.gov/msprog/onroad/cert/mdehdehdv/2018/cummins_hhdd-ub_a0210674_11d9_0d02-0d01_ng.pdf

Project Partners & Budget

The Ports are contributing \$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 1: Near-Zero Emissions Natural Gas Truck



Project Benefits

Successful demonstration of a pre-commercial, near-zero emissions heavy-duty truck engine under this project offers significant potential in reducing NOx emissions for trucks in drayage service. In addition, the use of REDEEM, Clean Energy’s 100% renewable natural gas, ensures significant GHG reductions from the demonstration unit. This project supports the Ports’ efforts in moving toward ever cleaner engine technologies.

Accomplishments During 2017

Contracts were signed on July 14, 2017, and a kick-off meeting was held on August 7, 2017. Data collection began in August 2017. Overall the truck has maintained regular operation, with few extended maintenance issues. Driver feedback is very positive, particularly with regard to the truck’s power and lack of odor (from diesel fuel).

2018 Milestones

Upon completion of the 6-month in-service demonstration in February, a 6-month operating report will be prepared and submitted detailing important statistics such as mileage, revenue service trips undertaken, and maintenance records. Additionally, a final report reviewing HLT’s qualitative impressions of the truck’s performance, such as driver feedback and overall fueling and maintenance requirements will be prepared at the completion of the demonstration.

5.3 Development of an Ultra-Low 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 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 2017

The POLA Board of Harbor Commissioners approved the project and funding agreement with SCAQMD on October 19, 2017. The contract was fully executed by both parties on December 14, 2017.

2018 Milestones

Below is a summary of key milestones planned for 2018:

- Execute agreement between SCAQMD and SwRI
- Project kick-off meeting
- Develop low NOx platform and calibration to regulatory cycle targets
- Begin testing aftertreatment technology approaches

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 vehicles have 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.

The Zero Emissions Cargo Transport II Project follows the SCAQMD's original ZECT project (ZECT I, Section 3). 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, five 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 both a natural gas and diesel engine platform, for a total of seven demonstration vehicles. The natural gas platform will also have the potential to connect to a catenary system via a pantograph-based technology developed by Siemens (see Section 3 for more information on the Siemens project). The diesel platform will employ a retrofit strategy, making the demonstrated technology applicable to the legacy fleet of drayage trucks, including some 10,000 diesel trucks currently serving the Ports.

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 \$20,142,319. 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	\$566,990
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 have 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 2017

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 fuel cells provided by Hydrogenics. 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 both variants.

In 2017, TransPower completed its first prototype truck, which underwent periodic road testing the third quarter of 2017. Revenue service for this truck has been delayed by the discovery of a design flaw in the mounting of the fuel cells and fuel tanks behind the cab; insufficient space was left for containers to swing freely while the truck is turning. To resolve this issue, the two trucks will be sent to a local truck body shop to have the frames extended.

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 2017, US Hybrid's FCe™80 fuel cell engine was integrated into the truck along with the air and fuel system. The engineering team also fit checked and installed the traction motor, customized drive shaft fuel cell cooling system, electric driven air compressor unit, and the electro-hydraulic steering. Additionally, the battery, auxiliary system housing, mounting, and high voltage and low voltage wiring harness were integrated. This truck was unveiled at the 2017 ACT Expo in Long Beach, California.

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 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.

In 2017, BAE finalized requirements documents, control laws, and interface documents with Kenworth. The design is still subject to minor revisions as needed because of any problems found during integration, but these will be reported under the integration tasks. Kenworth successfully implemented a change in motor design addressing the high voltage interlock which resolved a safety concern. Successful updates of the design of the high voltage routing and the cooling routing are complete. Continued software development for the truck controller represents the closing of the design phase. BAE performed a full range of tests on the AM Racing traction motor system (ACTM). The firmware was updated to optimize the performance and control. The test results showed successful results across a range of speeds and torque settings. For the battery energy storage system, updated software was installed and tested. BAE continues to work to resolve several remaining issues.

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 a zero emissions (all-electric) mode and in a conventional hybrid electric mode using CNG.

In 2017, the project experienced significant delays related to the pantograph integration planned with Siemens that may lead to changes in schedule and budget for the program. The major issues around the design and fabrication of an electric drive train capable of hauling an 80,000 lb. GVW tractor combination up a 6.5% grade at 35 mph have been addressed and hardware is in fabrication or in-house. At this point, the project remains on target to complete the vehicle (without the pantograph) and turn it over for extended testing early in 2018.

Hydrogenics – Hydrogenics, which replaced International Rectifier, 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 in early 2018, with the demonstration scheduled for the third quarter of 2018. The Port of Long Beach previously approved funding for another TAP project with International Rectifier, which was terminated in 2016 prior to completion, leaving \$157,500 in Port of Long Beach’s unspent funds. The Port of Long Beach anticipates recommitting that amount in unspent funds to Hydrogenics USA, Inc.

2018 Milestones

Project milestones planned for 2018 include:

- Hydrogen fueling support for these fuel cell trucks was delayed and SCAQMD is working to provide fueling so demonstration of the fuel cell trucks may begin.
- The TransPower and US Hybrid fuel cell trucks are expected to enter demonstration service in early 2018, as soon as hydrogen fueling is secured.
- CTE will continue the system design and validation work for its vehicle in preparation for demonstration testing in early 2018.
- GTI is moving forward despite delays associated with the Siemens pantograph. Like CTE, GTI will also continue the system design work for its vehicle, with in-service demonstration during 2018.
- Hydrogenics will begin design and development of its demonstration truck, with plans for a 2018 demonstration. The Port of Long Beach plans to request approval for funding to help support the Hydrogenics project in January 2018.

5.5 VeRail Near-Zero Emissions Locomotive Demonstration

Project Description

VeRail Technologies, Inc. (VeRail) is developing a natural gas locomotive that combines near-zero emissions locomotive engines with onboard CNG fuel storage. By converting an EMD SD40-2 locomotive, the VeRail VR21C4-nz locomotive will be equipped with four near-zero natural gas engine/generator modules (EnGens). This is a change to the original design presented in the 2016 TAP Annual Report, but supports the goals of the project more fully and incorporates many suggestions from Pacific Harbor Line (PHL) who runs the Ports’ rail switching operation.

For example, the new design has reduced the number of CNG storage tanks on the locomotive from 12 to just 3, while increasing the onboard fuel capacity by over 20%, from 1,200 to 1,450 diesel gallon equivalents (DGE). The higher capacity CNG fuel storage tanks actually operate at a lower pressure—3,600 psi, compared to 5,000 psi in the original design. This means the locomotive can be refueled faster and will require less compression energy to reach maximum fill pressure. This will reduce fuel costs and GHG emissions associated with electricity used to operate the natural gas compression equipment. The new design also incorporates a new VeRail high-visibility, crashworthy cab. The cab was designed to provide PHL operating crews more comfort and safety as compared to current six-axle locomotive cab designs at PHL. Perhaps most importantly, the new locomotive design also allows 2,100 HP of rechargeable batteries to be added to the locomotive for *full zero-emissions* rail operation at a later date.

Figure 2: Previous design VeRail VR21C4-df dual fuel (diesel and natural gas) Locomotive

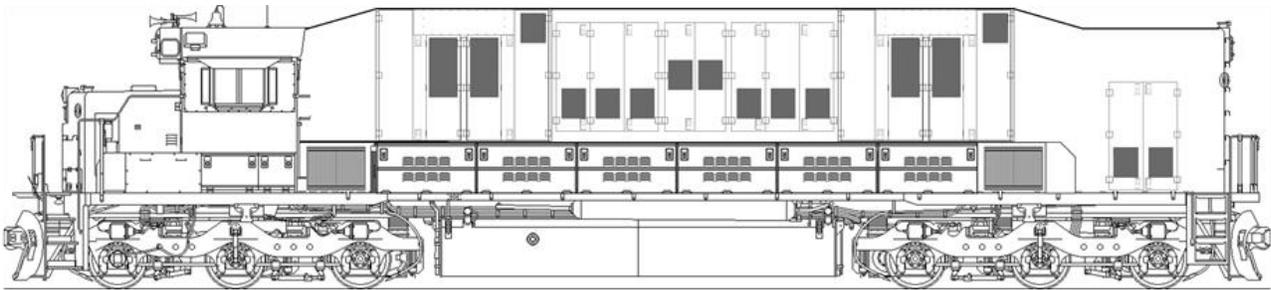


Figure 3: New Design VeRail VR21C4-nz Near-Zero Emissions Natural Gas (100%) Locomotive

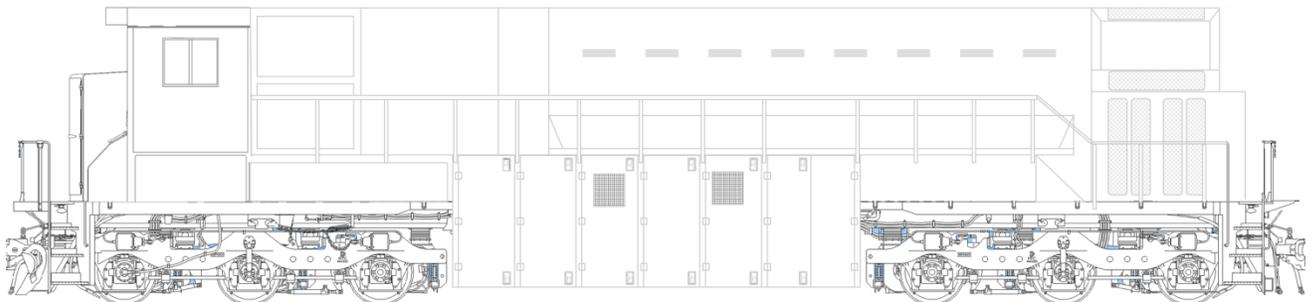
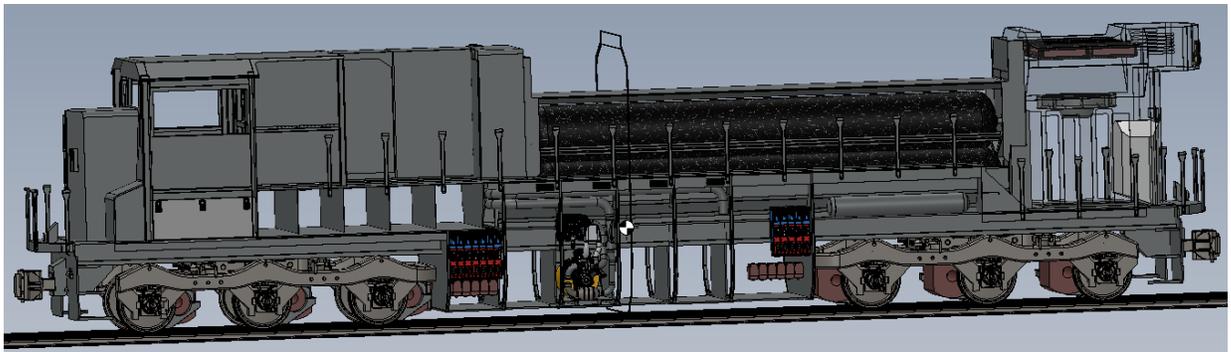


Figure 4: VeRail VR21C4-nz natural gas locomotive showing location of CNG tanks above the frame, four 600 HP near-zero emissions EnGens under the frame, and open space designed for future installation of a zero emissions battery system



Project Partners & Budget

The Ports are contributing \$600,000 (\$300,000 each) in co-funding to this project. The U.S. EPA and Southern California Gas Company have each committed \$500,000 to be administered by the SCAQMD. VeRail is providing \$3,100,000 in funding. Additionally, PHL is contributing in-kind, non-monetary support valued at approximately \$400,000. The total project budget is \$5,100,000. Table 5 summarizes the project funding contributions:

Table 5: VeRail Near-Zero Emissions Locomotive Demonstration Funding Partners

Project Partners	Contributions
VeRail Technologies, Inc.	\$3,100,000
Pacific Harbor Line (estimated value of in-kind support)	\$400,000
U.S. Environmental Protection Agency	\$500,000
Southern California Gas Company	\$500,000
Port of Long Beach	\$300,000
Port of Los Angeles	\$300,000

Project Benefits

The VeRail VR-series locomotive is the first locomotive designed specifically to meet CARB’s “Tier 5” and near-zero emissions levels. In April 2017, CARB officially petitioned the U.S. EPA for a new Tier 5 locomotive emissions standard requiring an 85% reduction in both NOx and PM below current EPA Tier 4 locomotive standards (e.g. NOx levels would be required to drop from the current 1.3 g/bhp-hr to just 0.2 g/bhp-hr). The VeRail VR-series locomotive is projected to provide over 90% reduction of NOx and PM, and a 22% reduction of GHG, thus being the first locomotive designed to fully meet the CARB petitioned EPA Tier 5 locomotive emissions standard. VeRail VR-series natural gas locomotives are projected to also meet near-zero emissions targets of 0.02 g/bhp-hr NOx for locomotives.

Accomplishments During 2017

During 2017, VeRail focused its efforts to redesign the locomotive to entirely eliminate the use of diesel fuel and support potential future addition of zero emissions batteries. The first VeRail engine was completed in 2017 and has been undergoing calibration in preparation for dynamometer testing. Mechanical engineering for the new high-RPM, high-horsepower VeRail generator (Phase 1 of the generator development) has been completed. The new three-tank CNG Tri-Pack design is completed and ready for review by the Federal Railway Administration (FRA). In December 2017, VeRail finalized registration with the U.S. EPA for certification of the natural gas engines and has been assigned manufacturer code VRT.

2018 Milestones

Integration of the core locomotive engine and generators (EnGens) including preliminary emissions testing is expected to occur in January 2018. That will be followed with dynamometer testing the engines under load, systems durability testing, building the new high-speed generators, procuring final EPA emissions certification on the engines (this process has already begun, and final systems integration. The locomotive is expected to be released for demonstration at PHL at the end of the third quarter 2018.

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) containerships calling at POLA and POLB to study ship efficiencies before and after major retrofits.

Figure 5: Georg Maersk Departing San Pedro Bay



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 will use the pre- and post-Radical Retrofit data from a minimum of four vessels to quantify energy and emissions improvements by operational mode. This will enable the results to be “apples-to-apples” comparison pre- and post-retrofit on a vessel basis and then compared to vessel results with the other vessel(s) in the same class.

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

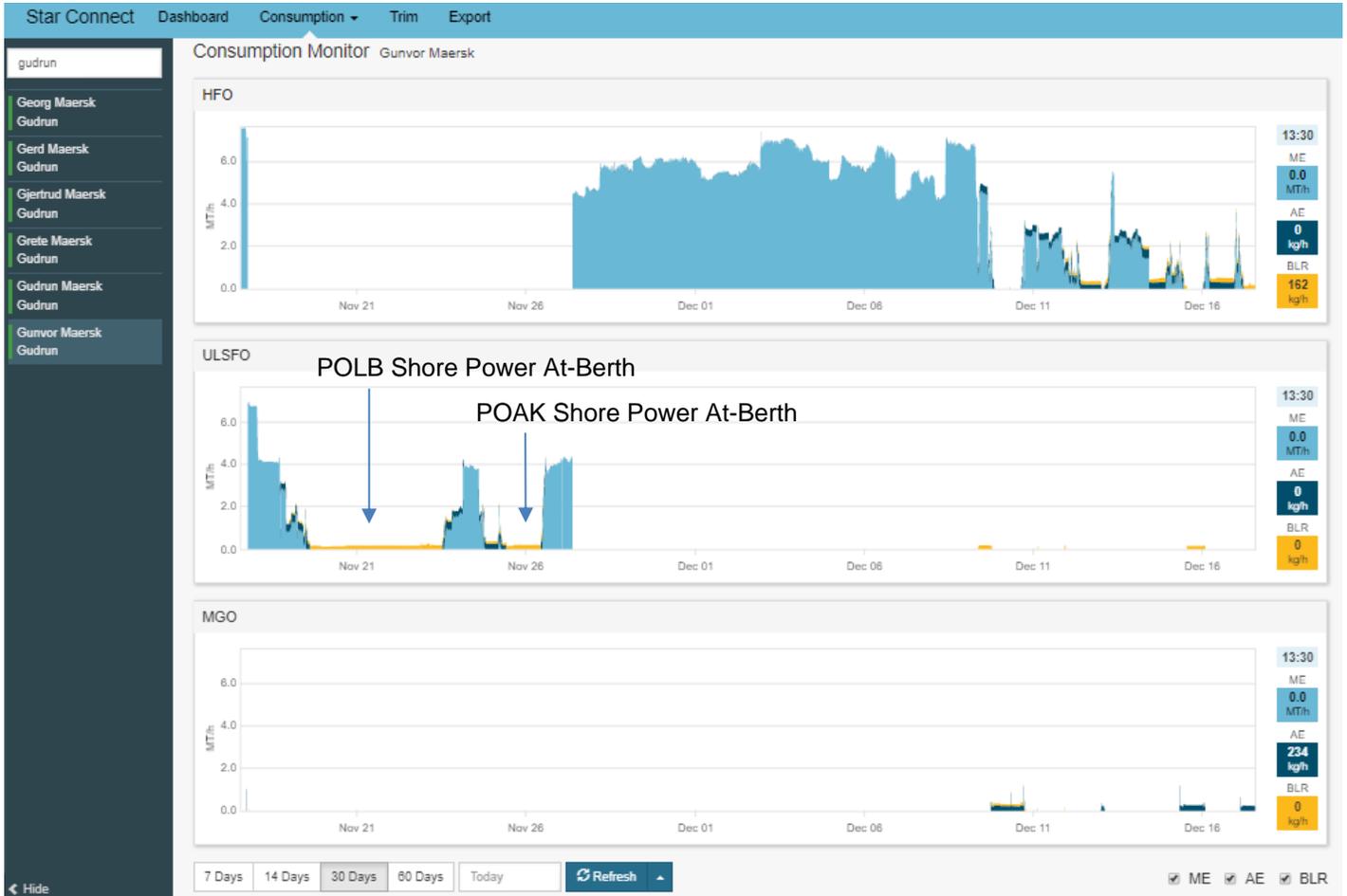
The key benefit of the project will be demonstration of the use of detailed, real-world data to quantify energy efficiencies and emissions improvements. Energy efficiency improvements are critical components of the California’s Sustainable Freight Action Plan and air quality strategies to bring the South 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, NO_x, and SO_x 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.

The following figure illustrates the *Guvnor Maersk's* fuel consumption rates by fuel type including a visit to Port of Long Beach and then a stop at Port of Oakland. Note that the yellow lines in the ULSFO figure indicates use of shore power.

Figure 6: *Guvnor Maersk* Example of Fuel Consumption by Fuel Type



Project Timeline Impacted by Global Cyberattack Event

Maersk Line experienced system wide disruption due to a global cyberattack event that occurred June 27, 2017. This disrupted access to StarConnect and other systems used to collect and transmit data for the project. Recovery and rebuilding of datasets continued through fourth quarter 2017.

Accomplishments During 2017

The following tasks were completed in 2017:

- Continued datasets collection from the fleet and associated pre-processing.
- Continued fleet rollout of Connected Vessel and CAMS/fuel flow meter data streams. Eleven of twelve ships were completed. The *Gunhilde Maersk* has the digital flowmeters and will complete the radical retrofit in dry dock in 2018.
- Continued the alignment of the collected datasets by vessel and pre-/post- Radical Retrofit and compare all appropriate datasets.
- Received the Duke University final report and recommendations related to the larger TAP project in April. This report was shared with the Ports in the June 2017 TAP project update.

2018 Milestones

It is anticipated that the following work will be conducted on the Maersk TAP Project during 2018:

- Completion of all 12 ships with CAMS/fuel flow meter data systems and radical retrofit of the final vessel.
- Select critical data elements to be used to quantify energy efficiency improvements and emissions. In addition, selected dataset elements will be defined and the sources of their output will be documented and evaluated for range of uncertainty.
- Develop approaches to quantify energy efficiency improvements, based on data elements selected, for both energy and fuel data streams.
- Develop data analysis procedures based on agreed quantification approach.
- Meet with Ports and TAP AC to review and obtain agreement on methods.
- Conduct 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 grant funding from other agencies to support demonstration projects being implemented by port tenants together with technology manufacturers. A brief summary of each project is provided below:

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. Unique to this project is the plan to use the Cavotec Automatic SmartCharging System for yard tractors. For this project, POLA will invest \$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. A project kick-off meeting is anticipated in early 2018.

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

The Port of Long Beach, in partnership with terminal operators and Southern California Edison, 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 with a total of \$1,677,176. The overall project scope includes:

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

The CEC agreement was fully executed on July 20, 2017. Port of Long Beach staff is working to finalize subrecipient agreements by the first quarter of 2018. Key milestones for 2018 include:

- Vehicle and equipment design
- Ordering vehicle and equipment components
- Building and integrating technology into demonstration vehicles and equipment
- Install electrical infrastructure and charging equipment

6.3 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 underway. Design and development of the electric and RNG-fueled yard tractors is underway. Infrastructure to support these units will be operational in March 2018, with delivery of the yard tractors spanning March through July 2018. The 1-year demonstration will begin in August 2018.

6.4 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 two forklifts and top handler 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 a greenhouse gas capture demonstration. 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. Accomplishments through 2016 include:

- Executed contracts between CARB and POLA; POLA and Pasha Stevedoring Terminal (PST); and PST with Burns & McDonnell (BMcD), BYD Company Limited (BYD), PermaCity, and TransPower.
- Completed roof retrofits at Berth 181 to accommodate solar photovoltaic (PV) system.
- Developed and submitted engineering designs for infrastructure upgrades to required agencies by BMcD.
- Initiated design and procurement of the ShoreKat emissions treatment system, that will include the demonstration of two additional treatment systems for greenhouse gas (GHG) emissions by Clean Air Engineering-Maritime.
- Designed and procured battery storage systems (BYD).
- Delivered two BYD electric yard tractors to PST.
- Procured base trucks from Navistar, base yard tractors from Cargotec, and externally-sourced subsystem components for Phase 1 vehicles by TransPower.

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 is winding down at the end of 2017. 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 is \$13,500,000. The demonstration covered 1 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 extends 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 will allow for seamless connection and detachment from the catenary power source. When entering the catenary system corridor, the pantograph system will verify the presence of catenary lines and allow the driver to raise the pantograph from within the cab of the truck. Upon leaving the catenary lane, the pantograph will automatically retract and the truck will switch to on-board power systems.

The system power supply was found to be encroaching upon a Southern California Gas Company pipeline so the demonstration was limited to 6 months in order to satisfy the utility's requirement to move it. Options for future deployments will be assessed once the final report on the demonstration results is reviewed and assessed. If there is no interest in continuing the demonstration system, it will be decommissioned.

7 2017 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 7. Two new projects were approved and funded by the TAP in 2017, both to demonstrate near-zero emissions drayage truck engines (diesel and renewable natural gas). 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 7, 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 7, but are noted within each project summary in Section 5.

Table 7 also contains technology projects funded by the Ports outside of the TAP budget that are summarized in Section 6.

Table 7: Ports' Technology Advancement Funding Investments through December 31, 2017

Project Category	Year Completed	POLB	POLA	AQMD	CARB	US EPA/ USDOE/ METRO	CEC	Total Port & Agency Stakeholder
Ocean-going Vessels								
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	ongoing		\$1,500,000*					\$1,500,000
Maersk OGV Energy Efficiency Measurement Demonstration	ongoing	\$500,000	\$500,000					\$1,000,000
Harbor Craft								
Foss Maritime Hybrid Tugboat	2010	\$500,000	\$889,920*		\$1,000,000			\$2,389,920
Cargo Handling Equipment and Port Terminal Projects								
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	\$32,334.21	\$32,334.21					\$64,668.42
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				\$14,500,000			\$14,500,000
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

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Table 7: Ports' Technology Advancement Funding Investments through December 31, 2017 (cont'd.)

Project Category	Year Completed	POLB	POLA	AQMD	CARB	US EPA/ USDOE/ METRO	CEC	Total Port & Agency Stakeholder
Container Drayage Trucks, Cont'd.								
<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			\$1,142,070	\$2,296,617	\$3,738,687
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	ongoing	\$37,500	\$37,500					\$75,000
Development of an Ultra-Low 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	\$566,990	\$566,990	\$2,400,000		\$9,725,000	\$2,400,000	\$15,658,980
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	ongoing	\$300,000	\$300,000			\$500,000		\$1,100,000
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)								
		\$9,621,671.71	\$11,576,812.71	\$8,961,406	\$17,054,806	\$13,872,200	\$23,784,617	\$85,371,513.42
Total Port TAP Investment								
		\$4,716,427.71	\$4,817,426.71					
Combined Ports' TAP Investment		\$9,533,834.42						

*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 2017.

APPENDIX A
Technology Advancement Program Advisory Committee Membership

- | | |
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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/completed-projects/>

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. SoCalGas CNG Drayage Truck Demonstration (2010)
21. SCAQMD HDV In-Use Emissions Testing Program (2013)
22. TransPower Electric Drayage Infrastructure and Improvement (EDII) Project (2016)
23. TransPower Electric Drayage Pre-Commercial Truck Demonstration (2016)
24. US Hybrid On-Board Charger for Zero Emissions Cargo Transport Demonstration (2016)
25. VYCON REGEN® System for Rubber-Tired Gantry Cranes Testing & Verification (2007)
26. Westport GX LNG Engine Development (2010)