



Port of LONG BEACH
THE PORT OF CHOICE



THE PORT
OF LOS ANGELES



SAN PEDRO BAY PORTS CLEAN AIR ACTION PLAN

2019 ANNUAL REPORT AND 2020 PRIORITIES Technology Advancement Program

13 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
DEF	diesel exhaust fluid
DOC	diesel oxidation catalyst
DOE	United States Department of Energy
DPF	diesel particulate filter
DPM	diesel particulate matter
FRATIS	Freight Advanced Traveler Information Systems
EGR	exhaust gas recirculation
EVSE	Electric Vehicle Support Equipment
GHG	greenhouse gases
HP	horsepower
kW	kilowatt
kWh	kilowatt-hours
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
South Coast AQMD	South Coast Air Quality Management District
TAP	Technology Advancement Program
TEU	twenty-foot equivalents
USEPA	United States Environmental Protection Agency
ZE	zero emission(s)
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. 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 2019 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%.

Still, there is much work to do. The most recent iteration of the CAAP (2017 CAAP Update) calls for even more aggressive strategies to reduce pollution and greenhouse gases and to ultimately transition to zero emissions over the next 20 years. Development and deployment of near-zero and zero-emissions technologies is critical to the success of these strategies, and the Ports have embarked on an unprecedented effort to do just that.

At the cornerstone of this effort is the Technology Advancement Program (TAP), which was initiated in 2007 to facilitate the development and demonstration of clean technologies to support the original CAAP goals. The TAP is a competitive funding program that relies heavily on partnerships with private industry and technology developers as well as strong relationships with regulatory agencies, which actively participate in the TAP Advisory Committee to evaluate technology projects, support the commercialization of these nascent technologies, and help leverage funds. More than a decade later, the TAP has undertaken more than 40 projects spanning test cycle development, hybrid and alternative fuel technology demonstrations, and zero emissions equipment deployment.

To achieve the scale of technology development needed for a zero-emissions transformation, however, the Ports have needed to expand beyond the TAP, which has traditionally funded smaller scale, generally lower cost, stand-alone technology demonstrations applicable to the entire port complex. To that end, over the past few years, the Ports have made significant investments in larger scale clean-equipment deployments at specific terminals and logistics centers, benefiting from local, state, and federal grant funds. These projects have allowed the Ports to test near-zero and zero-emissions technologies on a larger operational scale and to test multiple types of equipment – cargo-handling equipment, trucks, and ships – at a single location, replicating the real world. Lastly, the Ports have partnered with other agencies on technology demonstrations to maximize resources and to support regional efforts to reduce port-related emissions, even beyond port boundaries, such as truck demonstrations.

These various approaches – TAP, grant-funded demonstrations, and cost-sharing partnerships with other agencies – comprise the Ports' technology advancement portfolio, and this multi-pronged investment strategy has enabled the Ports to leverage dollars, engage more stakeholders, and diversify their technology projects. Since 2007, through these combined efforts, the Ports and their partners have invested over \$408 million in technology advancement. These efforts are summarized in Section 5 of this Technology Advancement Annual Report in order to showcase the breadth and scope of the increasing emphasis on clean technology development and implementation in port operations.

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, while continuing to nurture nascent ship 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.

Agency Partnerships

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

2 TECHNOLOGY ADVANCEMENT ACCOMPLISHMENTS IN 2019

In 2019, the Ports 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 2019 include:

- Funded two new TAP projects that were selected from the TAP's 2018 Call for Projects. These projects are detailed in Section 5 and listed below:
 - Effenco Electric Active Stop-Start™ Technology Demonstration (Section 5.4)
 - Harley Marine Electric Drive Tugboat Design (Section 5.6)
- Completed the Maersk Ocean-Going Vessel Energy Efficiency Measurement Demonstration Project. (Section 5.7)
- Completed technology feasibility assessments for drayage trucks and cargo-handling equipment as part of the 2017 CAAP Update; these assessments help identify future technology advancement needs and opportunities.¹
- Launched two new major zero-emissions projects: Port of Long Beach's START Project (Sustainable Terminals Accelerating Regional Transformation) and Port of Los Angeles's Shore-to-Store Project, both of which will develop and demonstrate dozens of pieces of zero-emissions cargo-handling equipment and trucks as well as cleanest-available ships and harbor craft.

¹ The feasibility assessments are available at www.cleanairactionplan.org.

- The Port of Long Beach completed the “Port Community Electric Vehicle Blueprint,” a comprehensive, stakeholder-driven pathway to achieving zero emissions. The plan identified barriers and solutions related to zero-emissions equipment development, infrastructure, financing, and workforce. The plan is available at www.polb.com/zeroemissions.
- Updated the TAP Guidelines to include a Request for Information (RFI) process by which technology developers can submit project concepts for consideration of TAP funding on an ongoing basis. The RFI form is available on the TAP Web site.
- Continued to refine the conceptual scope for a Large-Scale Zero-Emissions Pilot Truck Deployment, which aims to demonstrate 50-100 zero-emissions drayage trucks in a single deployment. In 2019, the Ports worked with stakeholders and funding agencies to identify initial concepts and potential costs. Additional work is expected in 2020.
- 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.
- Maintained an updated TAP website² to assure transparency and enhance communication of our technology results, as well as to provide resources for technology developers.

In addition to the above accomplishments, the VeRail project was closed out in 2019. The project, which intended to develop a near-zero emissions switcher locomotive capable of zero-emissions track miles, was withdrawn due to technological challenges. TAP funds were reallocated to other projects. For more details, see Section 5.16.

Table 1 provides an overview of active 2019 technology advancement projects, including those funded through the TAP, cost-sharing with other agencies, and large-scale grant-funded demonstrations. Section 5 provides a detailed status update for each of these projects, including specific accomplishments in 2019 and projected milestones for 2020.

Table 1: 2019 Technology Advancement Project Snapshot

Project Title	Project Description	Details	Technology
Advanced Infrastructure Demonstration Project (Port of Los Angeles)	Design and demonstrate inductive charging infrastructure to support opportunity charging for 10 battery-electric yard tractors.	Section 5.1, page 10	Zero Emissions
Advanced Yard Tractor Deployment and Eco-FRATIS Drayage Truck Efficiency Project (Port of Los Angeles)	Demonstrate 20 yard tractors equipped with certified near-zero 0.02 gram/bhp-hr NOx engine and five zero-emission yard tractors. Also, demonstrate integration of intelligent transportation system technologies for on-road trucks.	Section 5.2, page 12	Zero- and Near-Zero Emissions
Port of Long Beach Commercialization of POLB Off-Road Technology Demonstration Project (C-PORT)	Demonstrate three battery-electric top handlers, a hydrogen fuel cell yard tractor, and a battery-electric yard tractor.	Section 5.3, page 13	Zero Emissions

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

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Project Title	Project Description	Details	Technology
Effenco Electric Active Stop-Start™ Technology Demonstration	Initiated in 2019. Evaluate effectiveness of Effenco's Electric Active Stop-Start™ technology, a hybrid upgrade that automatically turns off the engine when a vehicle is stopped, providing electric power to vehicle systems such as transmission or HVAC without engine.	Section 5.4, page 15	Idle Reduction
Everport Advanced Cargo Handling Equipment Demonstration Project (Port of Los Angeles)	Develop and demonstrate three electric yard tractors and two battery-electric top handlers and smart charging system.	Section 5.5, page 16	Zero Emissions
Harley Marine Services (HMS) Electric Drive Tugboat Design	Initiated in 2019. Design and cost out an electric drive tugboat with multi-mission capabilities (ship assist, escort and rescue towing) with a 6,800 horse-power electric drive and a range of 2,400 nautical miles. The tugboat will have six Tier IV C32 diesel engines and two electric propulsion motors.	Section 5.6, page 17	Near-Zero Emissions
Maersk Ocean-Going Vessel Energy Efficiency Measurement Demonstration Project	Completed in 2019. Evaluate and quantify the benefits of energy efficiency improvements for ocean-going vessels using multiple new high-resolution data streams.	Section 5.7, page 18	Ship Efficiencies
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 5.8, page 20	Tier 4, Cleanest Available
Pasha Green Omni Terminal Demonstration Project (Port of Los Angeles)	Develop and demonstrate two battery-electric yard tractors; two battery-electric yard tractors and two battery-electric on-road trucks; three 21-ton electric repowered forklifts, a microgrid with battery storage capability tied to a rooftop solar array, and a land-based ship emissions capture and treatment system.	Section 5.9, page 22	Zero Emissions and Other Platforms
Port Advanced Vehicle Electrification, PAVE Project (Port of Long Beach)	Design, install, and deploy electrical fast-charging infrastructure to support battery-electric yard tractors, forklifts and battery storage.	Section 5.10, page 23	Zero Emissions
SCAQMD Daimler Heavy-Duty Electric Trucks Demonstration	Initiated in 2019. Led by SCAQMD. Develop and demonstrate 20 heavy-duty battery-electric trucks, ten of which will be deployed to serve the Ports.	Section 5.11, page 24	Zero Emissions

Project Title	Project Description	Details	Technology
SCAQMD Development of a Near-Zero Emissions Diesel Engine for On-Road Heavy-Duty Vehicles	Led by SCAQMD. Develop an ultra-low NOx (0.02 g/bhp-hr) emissions <i>diesel</i> engine for on-road heavy-duty vehicles.	Section 5.12, page 26	Near-Zero Emissions
SCAQMD Zero Emissions Cargo Transport (ZECT) II Demonstration	Led by SCAQMD. ZECT II encompasses the development of seven drayage trucks by five different contractors and includes PHEV, BEV and fuel cell technology.	Section 5.13, page 27	Zero Emissions
Shore-to-Store Project (Port of Los Angeles)	Initiated in 2019. Develop and demonstrate 10 hydrogen-fuel-celled Class 8 trucks, build two heavy-duty hydrogen fueling stations, and demonstrate two electric yard tractors at the Port of Hueneme and electric forklifts at Toyota warehouses.	Section 5.14, page 29	Zero Emissions
Sustainable Terminals Accelerating Regional Transformation (START) Project (Port of Long Beach)	Initiated in 2019. Demonstrate more than 100 pieces of zero-emissions terminal equipment and trucks at three California seaports, develop a near-zero emissions tugboat, deploy two ships with some of the cleanest available engines, and advance workforce development programs to support sustainable goods movement.	Section 5.15, page 31	Zero and Near-Zero Emissions
VeRail Near-Zero Emissions Locomotive Demonstration	Withdrawn in 2019. Develop a natural-gas locomotive capable of zero-emissions track miles, or a fully zero-emissions, battery-electric locomotive.	Section 5.16, page 33	Near-Zero Emissions
Zero-Emissions Terminal Equipment Transition Project (Port of Long Beach)	Repower nine RTG cranes for full-electric power, demonstrate 12 zero-emissions yard tractors and two smart charging systems, and convert four LNG trucks to plug-in hybrid electric trucks with LNG range extender.	Section 5.17, page 34	Zero and Near-Zero Emissions

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

3 PROGRESS TOWARD ZERO EMISSIONS

As summarized in Table 1 and detailed in Section 5, the Ports continue their strong commitment to zero-emissions technology development and demonstration. In 2019, the Ports led 12 major zero- and near-zero emissions demonstration projects valued at over \$313 million in funding from the various project team members (including public and private match funding). Our efforts have made San Pedro Bay the hub of technology advancement for heavy-duty equipment with the world's highest concentration of zero-emissions trucks and terminal equipment in a single port complex.

These TAP and agency projects include the following:

- 37 zero-emissions drayage trucks (battery-electric and fuel cell)
- 85 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
- 158 new electric charging outlets
- 2 new hydrogen fueling stations
- 1 near-zero emissions tugboat with Tier IV engines and an electric-drive system

In addition to directly supporting zero-emissions technologies by funding demonstration projects and supportive efforts, such as the development of test protocols and charging standards, the TAP provides a forum for multiple agencies to work together and leverage resources toward our common goal. TAP supports zero-emissions technology projects led by other agencies by providing technical expertise, facilitating partnerships with port operators, offering a test bed for port-related technologies, and writing support letters to help other agencies secure funding for these demonstration projects. This direct and indirect support is critically important to making zero emissions a reality.

Figure 1: Repowering RTGs to Zero Emissions



Nine diesel RTGs are being repowered from diesel to full electric under the Zero Emissions Terminal Transition Project. See Section 5.17.

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

The Ports also are facilitating demonstration fleet participation in SCAQMD's Zero-Emission Drayage Truck Demonstration Project under CARB's Greenhouse Gas Reduction Fund program.

In terms of direct support, the Ports have provided cost-share funds for SCAQMD's ZECT II project (Section 5.13) and recently allocated \$1 million each (total of \$2 million) to support SCAQMD's newly launched demonstration of Daimler heavy-duty electric trucks (Section 5.11).

4 2020 TECHNOLOGY ADVANCEMENT PRIORITIES

In 2020, the Ports must continue to support implementation of the 2017 CAAP Update, including a stronger focus on larger scale pilot demonstration projects that will assess the operational, maintenance, and environmental costs and benefits of zero- and near-zero emissions vehicles and equipment in port applications.

Additionally, the Ports must continue to support the numerous demonstration projects already underway. These demonstration projects are in high gear, bringing early deployments of zero-emissions equipment and trucks and active charging infrastructure construction. The Ports already have learned so much from these projects and have begun to identify the gaps in understanding, which will shape future funding priorities. These projects are complicated and resource-intensive and have never before been attempted at this scale. The Ports must prioritize the successful completion of these projects not only to meet grant deadlines and compliance requirements but also to expedite the path to zero emissions. In 2020, the Ports look forward to bringing more projects online to show in-use operation for a variety of zero-emissions technologies and to identify areas of future investment.

Thus, in 2020, the Ports commit to the following technology advancement priorities:

- Continue to execute the many grant-funded and TAP-funded demonstrations underway; complete the projects within grant deadlines; and pave the way for additional technology advancement based on lessons learned;
- Finalize plans for a pilot deployment of 50 to 100 zero emissions trucks;
- Allocate funding to support promising technology demonstrations for ships;
- Explore concepts for terminal equipment charging infrastructure that provides fast charging and/or does not require manual handling of high-voltage connection cables; and
- Consider new projects submitted under the TAP's ongoing RFI review process.

5 KEY PROJECTS IN 2019

This section provides additional detail for technology advancement projects that were active in 2019. These projects represent the full portfolio of technology investments, including projects funded and managed by both Ports through the TAP, projects funded by grants and managed by one Port (the lead port is indicated in parentheses), and projects led by other agencies for which the Ports have contributed cost-share funds.

For information on completed TAP projects, please access the Final Reports archived on the program website: <http://www.cleanairactionplan.org/technology-advancement-program/>. All completed TAP projects are listed in Appendix B. More information about SCAQMD-led projects can be found at www.aqmd.gov/technology.

5.1 Advanced Infrastructure Demonstration Project (Port of Los Angeles)

Project Description

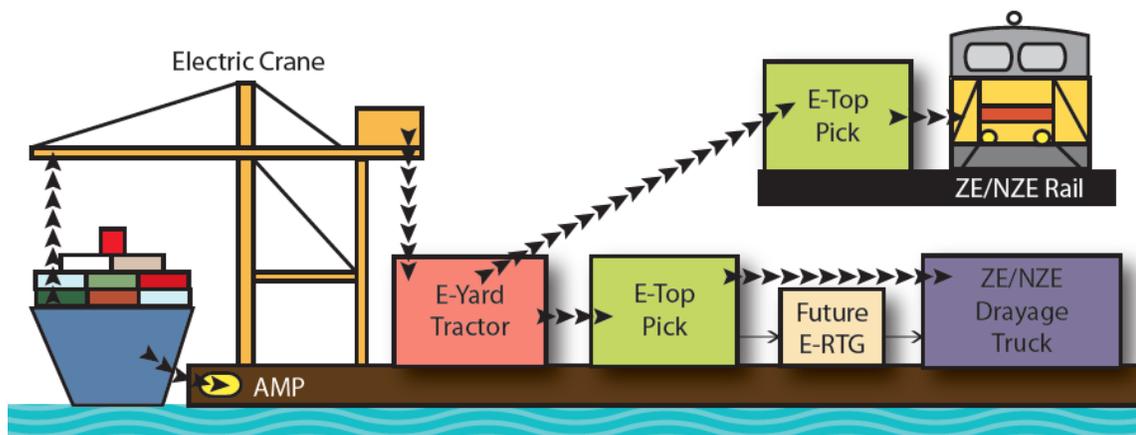
The Port of Los Angeles Zero Emission Freight Vehicle Advanced Infrastructure Demonstration (AID) will model elements of a system that could ultimately electrify a major container terminal at

the United States' busiest container port. The demonstration will take place at West Basin Container Terminal (WBCT), which had received grant funding to demonstrate 10 battery-electric yard tractors. The AID project, funded largely by a CEC grant, will enable POLA to support the design and development of advanced charging technology for the 10 yard tractors that would provide even better capability to complete two full 8-hour shifts each day, a proof of concept to install additional chargers and deploy more vehicles.

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

Ultimately, this project will not only demonstrate a series of prototype electrified equipment and charging mechanisms, but will showcase a model of how to fully realize the vision of a zero emission container terminal, also referred to as the zero-emissions pathway, shown in Figure 2.

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



Project Partners & Budget

This project is funded partly with a \$7.8 million CEC grant. Additionally, SCAQMD is contributing nearly \$1.8 million in the form of a Targeted Air Shed Grant to WBCT, and OEMs, demonstration partners, and POLA is contributing the balance. The total project cost is roughly \$11.3 million.

Table 2 summarizes the funding contributions.

Table 2: Advanced Infrastructure Demonstration Project Funding Partners

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

Accomplishments in 2019

The kick-off meeting was held in September 2019, and POLA’s Engineering group began to design the infrastructure to support the WAVE system. Design is expected to continue through 2020.

2020 Milestones

The following activities are expected in 2020:

- Design of the WAVE technology is expected to be complete by the end of 2020.
- Construction work will begin at WBCT to install the background infrastructure to support the WAVE systems.
- All equipment orders will be placed.

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

Project Description

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

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

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

Project Partners & Budget

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. Table 3 summarizes the funding contributions.

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

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

Accomplishments During 2019

The 20-unit LNG low-NOx yard tractor demonstration began November 1, 2019. Driver feedback has been positive about the units’ capabilities, and other than minor warranty repairs, the fleet has been reliable. Currently, the units are being operated one shift per day, due to the amount of time it takes to fuel each unit. Currently, fueling takes between 10 and 15 minutes per unit, which does not efficiently integrate with Everport’s operation to allow for double shifts.

The five BYD yard tractors and associated EVSE were delivered to Everport in 2019. In order to be permitted for use by the City of Los Angeles, the EVSE required third-party inspection and certification (i.e., UL listing). The lack of certification to UL standards is a common issue with these emerging technology charging platforms. After various improvements were made, the final EVSE design was approved in December 2019, and final permit approval is anticipated in January 2020, at which time the BYD units may initiate in-service demonstration. The one-year demonstration of the BYD zero-emission units is anticipated to begin February 2020.

The data collection test plan for the Eco-FRATIS demonstration was finalized in 2019, and a driver was selected to conduct the demonstration, which is expected to begin in 2020.

2020 Milestones

The following activities are expected in 2020:

- Approval of the EVSE is expected in Q1 2020.
- The zero-emissions yard tractor demonstration is expected to begin in early 2020, and demonstration of the near-zero emissions units will continue throughout the year.
- The Eco-FRATIS demonstration is expected to begin.

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

Project Description

The Port of Long Beach C-PORT project, in partnership with SSA Marine and Long Beach Container Terminal (LBCT), will demonstrate five zero-emissions cargo-handling vehicles. The demonstration will include three never-before-tested battery-electric top handlers manufactured by Taylor Machine Works and BYD Motors, Inc. and feature a unique, head-to-head comparison of a hydrogen fuel cell yard tractor manufactured by Chinese OEM Sinotruk versus a battery-

electric yard tractor manufactured by Kalmar with TransPower. This project also includes an educational component by which Long Beach Unified School District students learned about the Port of Long Beach’s zero-emissions efforts through a capstone research project.

Project Partners & Budget

The project is funded in part by a \$5.3 million grant from CARB’s California Climate Investments. The overall project budget is \$8.4 million. Table 4 summarizes the funding contributions.

Table 4: C-PORT Funding Partners

Project Partners	Contributions
Port of Long Beach	\$1,373,485
California Air Resources Board	\$5,339,820
South Coast Air Quality Management District	\$350,000
OEMs and Demonstration Partners	\$1,388,066

Accomplishments in 2019

The TransPower EVSE to support the Kalmar battery-electric yard tractor was commissioned in the second quarter of 2019, and there have been no issues. The Kalmar yard tractor was delivered shortly thereafter, and the demonstration began in July 2019. The terminal operator, LBCT, has reported being very pleased with the tractor.

Figure 3: Kalmar Battery-Electric Yard Tractor



The Taylor top handlers were delivered to SSA and LBCT, but the demonstration cannot begin until the EVSE have been fully commissioned. To date, two of the three BYD EVSE units have been commissioned. The Sinotruk hydrogen yard tractor project was halted in 2019 due to numerous technical, engineering, and safety issues.

In 2019, the Port of Long Beach and Long Beach Unified School District won a “Clean Air Award” from SCAQMD in the clean-air education and outreach category for the zero-emissions educational program developed as part of this technology-advancement project.

2020 Milestones

The following activities are expected in 2020:

- All three EVSE units for the top handlers are expected to be commissioned and operational in the first quarter of 2020.
- The demonstration of the yard tractor is expected to continue; demonstrations of the top handlers are expected to begin in early 2020.
- Development of the final report is expected to begin in late 2020.

5.4 Effenco Electric Active Stop-Start™ Technology Demonstration

Project Description

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

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

Project Partners & Budget

The Ports are contributing \$180,000 in co-funding to this project with a total project budget of \$625,163. Table 5 summarizes the project funding contributions.

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

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

Accomplishments During 2019

Installation of the system on the demonstration units began in late 2019 and Effenco began coordinating with CARB to start the verification process.

2020 Milestones

The following activities are expected in 2020:

- Complete installation of the Effenco Active Stop-Start technology in the yard tractors.
- Conduct the six-month demonstration.
- Complete the project.

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

Project Description

POLA’s Everport Advanced Cargo-Handling Equipment Demonstration Project will demonstrate three BYD electric yard tractors and two Taylor battery-electric top handlers. This project also will demonstrate the Cavotec SmartCharging System for yard tractors. For this project, POLA is investing in 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 addition of up to 25 battery-electric yard tractors.

Project Partners & Budget

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. Table 6 summarizes the funding contributions.

Table 6: Everport Advanced Cargo Handling Equipment Demonstration Funding Partners

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

Accomplishments in 2019

In October 2019, Taylor commissioned the two top handlers, and the Port of Los Angeles, Taylor, and Everport hosted a press event to display the units. The full demonstration is pending final third-party certification and approval of the EVSE. Because the Taylor top handlers use BYD charging equipment, which is not UL-listed (see Section 5.2 for more details). This project faces the same delays encountered in the Advanced Yard T tractor Deployment Project.

Figure 4: Taylor Battery-Electric Top Handler



POLA Engineering worked with Cavotec to develop the terminal infrastructure and SmartCharging systems for the yard tractors, and Everport will place the order for the three second-generation BYD battery-electric yard tractors as soon as it has some in-use experience with the first generation units they will demonstrate under the Advanced Yard Tractor Deployment Project (Section 5.2). The 12-month demonstrations for the yard tractors and top handlers will begin once the EVSE has been approved to operate.

2020 Milestones

The following activities are expected in 2020:

- Approval of the EVSE is expected in Q1 2020.
- Everport is expected to place the order for the second-generation BYD yard tractors pending the outcome of the first-generation demonstration described in Section 5.2.
- Yard tractor and top handler demonstrations will begin.

5.6 Harley Marine Electric Drive Tugboat Design

Project Description

For this project, Harley Marine Services (HMS) will design and cost an electric-drive tugboat that would have multi-mission capabilities (ship assist, escort and rescue towing) with a 6,800 horsepower electric drive and a range of 2,400 nautical miles. The tugboat will have six C32 diesel engines (Tier 4) and two electric propulsion motors. Compared to a tugboat constructed in 2018 that meets today's USEPA marine engine standards (Tier IV propulsion engines and Tier III auxiliary engines), NO_x, PM and ROG emissions from this electric drive tugboat design are projected to be reduced by 68%, 68%, and 70%, respectively. Reductions are projected to approach 90% for all pollutants when compared to a tug that meets 2013 emission standards. This project is a component of the larger START Project described in Section 5.15.

The goal of this project is to bring diesel electric technology into tugboat utility. Currently, there are no electric drive tugboats in North America. Key deliverables include the tugboat specifications, a complete design drawing package, projected emission and fuel consumption reductions, a minimum of two shipyard construction quotes, and a final project report.

It should be emphasized that TAP funding is limited to the design of the electric drive tug. Construction costs are expected to be covered by grants and HMS funding. The construction phase would also include comprehensive emissions testing to document emission reduction benefits. The overall cost to design and construct the electric drive tugboat is estimated to be \$18,000,000.

Project Partners & Budget

The Ports are contributing \$235,000 in co-funding to this project with a total project budget of \$599,000. Table 7 summarizes the project funding contributions:

Table 7: Harley Marine Electric Drive Tugboat Design Project Funding Partners

Project Partners	Contributions
Port of Los Angeles	\$117,500
Port of Long Beach	\$117,500
Harley Marine Services and Other Partners	\$364,000

Accomplishments During 2019

In 2019, Harley Marine completed preliminary design and began contract design, which is the step required in order to obtain bids for the new tugboat. The overall timeline for design was delayed in part due to changes in how the gross tonnage of vessels is calculated. As a result of these changes, the vessel as originally designed was significantly overweight. By working with different component suppliers, the designers were able to rearrange the vessel layout to achieve the target vessel weight. Once Harley Marine Services has secured cost estimates for building the tugboat, the TAP portion of the project will be deemed complete; however, construction and demonstration will continue as part of the START Project.

2020 Milestones

The following activities are expected in 2020:

- Complete contract design in First Quarter 2020
- Secure cost estimates for building the new tugboat
- Final Report for design portion of TAP project; construction and demonstration to take place under the START Project

5.7 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) was 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 were 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: Project Vessel “Gunhilde Maersk”



These ships are part of Maersk Line’s \$125 million Radical Retrofit Program (Radical Retrofit), which retrofitted 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 approximately 9,000+ TEUs (twenty-foot equivalent units) to approximately 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.

Project Partners & Budget

The overall Radical Retrofit budget is \$125 million dollars. Maersk Line has agreed to incorporate enhanced fuel flow monitors, to collect and process 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 8 summarizes the project funding contributions.

Table 8: 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

Accomplishments During 2019

The field work for Maersk’s Ocean-Going Vessel Energy Efficiency Measurement Demonstration Project was completed in 2018, with the Final Project report issued in 2019. This Final Report is available on the TAP website.³

As reported in previous annual reports, Maersk was hit by a system-wide cyber-attack in June 2017, which was extremely disruptive and tied up a substantial amount of the company’s resources for months. Furthermore, vessel data were not accessible for a significant amount of time as the company’s Information Technology group worked to reestablish the company’s systems and secure servers. This was a major unforeseen event that significantly impacted the project’s resources and timeline. The project did successfully advance the understanding of new detailed data collection systems and instrumentation being deployed on ships; identified challenges associated with data security, logistics, chain-of-custody; and identified significant uncertainties that need to be addressed as more detailed data streams come online. The lessons learned can help maximize the success of future TAP ship-related projects.

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

Project Description

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

Project Partners & Budget

The Ports contributed \$500,000 in co-funding to this project with a total project budget of \$1,200,000. Table 9 summarizes the project funding contributions.

Table 9: 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

³<https://cleanairactionplan.org/documents/maersk-ocean-going-vessel-energy-efficiency-measurement-demonstration-tap-project-final-report.pdf/>

Accomplishments During 2019

This project is well underway with design and fabrication complete in 2019. The design included completion of the dimensional assessment of the vessel, computer modelling and physical prototyping and design/system integration, which involved integrating the existing technology used in stationary applications to the marine environment and developing manufacturing blueprints. In 2019, Nett Technologies, Inc. also designed and developed prototypes and conducted in-house testing of the NOx and PM systems and urea delivery system. Lastly, in 2019, Nett Technologies, Inc. fabricated the system to prepare for installation in the coming year.

2020 Milestones

The following activities are expected in 2020:

- Install and commission the system into the demonstration vessel. This is tentatively set for mid-January 2020.
- Obtain CARB approval for all emissions testing procedures.
- Begin the demonstration of the BlueMAX™ NOVA 320e in the *S. Bass* harbor craft.

Figure 6: Nett Technologies Demonstration Vessel and BlueMAX NOVA System



Left: The demonstration vessel, *S. Bass*. **Right:** 3D model of the BlueMAX™ NOVA 320e

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

Project Description

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

Figure 7: ShoreKat At-Berth Emissions Control System



Project Partners & Budget

The project is funded in part by a \$14.5 million grant from CARB’s Assembly Bill 118 Air Quality Improvement Program and Low Carbon Transportation Greenhouse Gas Reduction Fund Investments. The overall project budget is \$26,602,400. Table 10 summarizes the funding contributions.

Table 10: Pasha Green Omni Terminal Demonstration Project Funding Partners

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

Accomplishments in 2019

In 2019, significant progress was made on this multi-faceted project. The demonstration began for the two TransPower yard tractors, both of which are in operation when ships are being offloaded. The BYD yard tractors were delivered in 2019, but demonstration cannot begin until the EVSE receives third-party certification, which is expected in early 2020. One of the three TransPower forklifts was delivered and in use in 2019, but required modifications, which took the unit out of service. The BYD battery storage system has been delivered but has not yet received

final permitting due to Los Angeles City Fire Department requirements for an enhanced fire suppression system and Los Angeles Department of Building and Safety Requirements for third party certification of the system. The ShoreKat at-berth emissions control system was operational in 2019, and the demonstration began.

2020 Milestones

The following activities are expected in 2020:

- The solar panels are expected to be installed on the warehouse and roof, which required significant upgrades in 2018 to support the heavy array.
- The two on-road trucks are expected to be delivered and begin demonstration.
- All three forklifts are expected to be delivered and begin demonstration.
- The BYD EVSE will receive approval, allowing the yard tractor demonstration to begin.
- The project team will develop a fire suppression solution, and the BYD battery storage system will be commissioned and begin demonstration.
- The ShoreKat system will continue demonstration.

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

Project Description

The Port of Long Beach’s Port Advanced Vehicle Electrification (PAVE) Project 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 following components:

- Design and construct charging outlets for almost 40 pieces of electrical terminal equipment at TTI,
- Four zero-emissions yard tractors will demonstrate the world’s first direct current fast-charging system for battery-electric yard hostlers in a rigorous, heavy-duty port environment in partnership with ChargePoint. Two additional zero-emissions yard tractors will demonstrate alternating current fast-charging.
- Deploy battery storage and energy management strategies in partnership with TransPower to minimize and better understand the grid impacts associated with widespread deployment of electric vehicles and equipment.
- Develop a comprehensive portwide Dynamic Energy Forecasting Tool to predict how much energy and supportive infrastructure seaports will need to support zero-emissions terminal equipment.

Project Partners & Budget

The project is funded in part by an \$8,000,000 grant from CEC and nearly \$1.4 million from SCAQMD in the form of a Targeted Air Shed Grant and Proposition 1B funds awarded to TTI. The total project budget is roughly \$16.7 million. Table 11 summarizes the funding contributions.

Table 11: PAVE Project Funding Partners

Project Partners	Contributions
Port of Long Beach	\$3,704,266

California Energy Commission	\$8,000,000
South Coast Air Quality Management District	\$1,372,500
OEMs and Demonstration Partners	\$3,658,646

Accomplishments in 2019

In 2019, the Port of Long Beach began design of the 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. In addition, Port staff in partnership with the Electric Power Research Institute finalized the specification for the Dynamic Energy Forecasting Tool (DEFT), which seeks to estimate the level of energy that infrastructure seaports will need to support zero-emissions terminal equipment. The team also began to draft the data collection test plan.

2020 Milestones

The following activities are expected in 2020:

- Complete the data collection test plan
- Advertise the project for competitive bidding with infrastructure scheduled to be installed by the end of the year
- Issue purchase orders for six battery-electric yard tractors
- Finalize the DEFT communication plan, which will outline the Ports strategy to share and validate the DEFT tool with other port stakeholders.

5.11 SCAQMD Daimler Demonstration of Heavy-Duty Electric Trucks

Project Description

This project, led by South Coast AQMD, will manufacture and demonstrate 20 heavy-duty battery-electric trucks with Daimler Trucks North America (DTNA): 15 Class 8 eCascadia and 5 Class 6 eM2 trucks. The project includes two demonstration fleets: NFI Logistics (NFI) and Penske Truck Leasing. NFI will operate 10 eCascadias from their Chino, CA warehouse and distribution center and are expected to shuttle cargo to and from the San Pedro Bay Ports. Penske Truck Leasing will demonstrate 5 eCascadias through their logistics operation and will select clients to demonstrate the five Class 6 eM2s. All vehicles will operate in real-world commercial fleet operations in what is one of the region’s largest zero-emission port truck demonstrations. More information about this and other South Coast AQMD-led projects can be found at www.aqmd.gov/technology.

Project Partners & Budget

The total project budget is \$31.3 million with funding contributions primarily from SCAQMD and Daimler, as well as the Ports and the Environmental Protection Agency Region 9. Table 12 summarizes the funding contributions.

Table 12: Daimler Zero-Emissions Truck Project Funding Partners

Project Partners	Contributions
Port of Long Beach	\$1,000,000
Port of Los Angeles	\$1,000,000

South Coast Air Quality Management District	\$12,670,072
Daimler Trucks North America	\$15,670,072
Environmental Protection Agency Region 9	\$1,000,000

Accomplishments During 2019

This project includes 20 zero-emission trucks with associated DC fast charge infrastructure. Fifteen units are Class 8 (eCascadia) and five are Class 6 (eM2). The Class 8 trucks are built on the Cascadia chassis and assembled at DTNA in Portland, OR. The Class 6 are built on the M2 chassis and are assembled by Agility Fuel Solutions in Fontana, CA. DTNA has completed and delivered all 15 Class 8 eCascadias to the two demonstration fleets in Southern California: ten to NFI and five to Penske Truck Leasing. Penske will deploy the eCascadias under their logistics arm with their own drivers. All five of the eM2s have been built by Agility Fuel Solutions and are undergoing commissioning exercises. All five eM2's will be deployed by Penske which has identified customers to demonstrate the five trucks for the two-year demonstration period. Penske, DTNA and Agility will remain engaged in the deployment, training, and customer feedback on the eM2.

Regarding infrastructure, the project includes ten DC Fast Charge (DCFC) locations comprising 20 chargers, 30 plugs and a total of 2550 kW of electric power charging capacity. The majority of DCFC systems will be 150 kW, three will be 62.5 kW and one 50 kW. Six of the stations are commissioned (five at Penske and one at NFI in Chino). The Penske Ontario location is now commissioned and is their largest @450 kW. NFI's largest is at their Chino location with 750 kW total power distributed over five DCFCs. Another and much smaller NFI station is planned closer to the Ports in Wilmington. Finally, a smaller station is planned to be installed at Velocity Vehicle Group (a Daimler dealer in Fontana). It should be noted that the Penske Ontario location will also feature the demonstration of a Battery Energy Storage System (ESS) and will help to show how and ESS can help manage electricity costs (by relying on stored power during peak rates).

The team procured data logging equipment and are currently tracking driver behavior, thermal system performance, battery health, state of charge, auxiliary load demands, etc. In addition, routine maintenance and unexpected repairs are also being tracked. The Penske e-Cascadia fleet has logged more than 30,000 miles, with an average energy economy of 1.980 kW-hr/mi, and the NFI trucks have logged more than 55,000 miles, with an average energy economy of 2.096 kW-hr/mi.

2020 Milestones

The following activities are expected in 2020:

- Continue the two-year demonstration, which is scheduled to be complete in Q4, 2021.
- Commission the remaining charging stations, which include two with NFI and one with Velocity Vehicle Group.
- Deployment of eM2s with Penske.
- Collection of vehicle data.

5.12 SCAQMD Development of a Near-Zero Emissions Diesel Engine for On-Road HDVs

Project Description

The objective of this project, which is led by SCAQMD, is 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. Development of technologies to achieve ultra-low NOx emissions from diesel engines for on-road heavy-duty vehicles will accelerate wide-scale deployment of much cleaner heavy-duty engines in the South Coast Air Basin. Under this project, technologies are being developed to ensure that the engines also may be fueled with renewable diesel fuels, helping to address the GHG emissions reduction needs throughout California. More information about this and other SCAQMD-led projects can be found at www.aqmd.gov/technology.

Project Partners & Budget

The Port of Los Angeles contributed \$287,500 in co-funding to this project with a total project budget of \$1 million. Table 13 summarizes the project funding contributions.

Table 13: 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

Accomplishments During 2019

The project objective is to achieve 0.02 gm/bhp-hr NOx from a diesel engine, while minimizing CO2 emissions. The project team now believes this goal is attainable for a commercial product, and the effort is now focused on fine-tuning the applied technologies to minimize NOx and CO2 emissions from clean diesel-fueled heavy-duty engines and demonstrate the new design in demonstration service. Below is a summary of key accomplishments this year:

- Evaluated a number of aftertreatment technologies at SwRI in the engine test lab, with three standing out as very promising for low-NOx diesel engines, including:
 - Cylinder deactivation, found to be one of the most effective options,
 - A light-off SCR that is close-coupled (located near the turbo charger on the engine under the hood), and
 - Heated dosing, where the diesel exhaust fluid (DEF) fluid is heated, which helps reduce emissions during low load engine operation.
- Preliminary tests results have been good and showed the potential to achieve low-NOx and reduced CO2 at the tailpipe.

2020 Milestones

The following activities are expected in 2020:

- Complete and submit project Final Report (expected April 2020)
- Finalize a project proposal and finalize partners and funding to integrate the design in a Class 8 heavy-duty truck in demonstration service, including real-world emissions testing.

5.13 SCAQMD Zero Emission Cargo Transport (ZECT) II Demonstration

Project Description

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

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 \$1,291,480 in co-funding to this project with a total project budget of \$20,141,960. Table 14 summarizes the project funding contributions.

Table 14: SCAQMD ZECT II Demonstration Funding Partners

Project Partners	Contributions
U.S. Department of Energy	\$9,725,000
OEMs	\$3,075,841
South Coast Air Quality Management District	\$2,400,000
California Energy Commission	\$2,400,000
L.A. Department of Water and Power	\$1,000,000
Port of Long Beach	\$724,490
Port of Los Angeles	\$566,990
Southern California Gas Company	\$250,000

Accomplishments During 2019

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

TransPower

- Transportation Power, Inc. (TransPower) developed two battery electric trucks with hydrogen fuel cell range extenders.
- During 2019, the first truck (“FC1”) and second truck (“FC2”) have been demonstrated at TTSL. The service went through interruptions due to mechanical failures and TransPower addressed the issues.
- Truck FC1’s battery pack is being upgraded in Transpower’s integration facility and FC2 has been reliable and has seen increasing use in service.

US Hybrid

- US Hybrid developed two battery electric trucks, each with an on-board hydrogen fuel cell generator.
- Both units, FC1 and FC2, began their demonstration at TTSL.
- FC1 has been reliable and increasing use in service.
- FC2 completed a hydrogen tank valve repair and US Hybrid plans to upgrade the fuel tank capacity from 25 kg to 35 kg to increase range to as much as 280 miles.

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 truck was deployed in February 2019, but service was interrupted due to failures. These issues have been addressed and the truck has accumulated over 10,000 miles including mileage from the test track and regular service.

GTI/BAE and Kenworth

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

- Kenworth addressed several issues encountered during testing at its test track in Washington state, and the truck completed the 200-mile roundtrip final test with no issues and was shipped to TTSI on Oct 5, 2019.
- The truck increased mileage in service and accumulated over 1,260 miles in November and December of 2019.

Hydrogenics

- Hydrogenics will develop and demonstrate a fuel cell range extended Class 8 truck.
- Hydrogenics was acquired by Cummins and is planning to deploy the truck in July 2020 with the support of Cummins.

2020 Milestones

The following activities are expected in 2020:

- All six project trucks plan to continue regular demonstration service in 2019.
- Hydrogenics will deploy its demonstration truck in July 2020.

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

Project Description

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

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

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



Project Partners & Budget

In late 2018, CARB awarded roughly \$41 million to POLA for the Zero- and Near Zero-Emission Freight Facilities (ZANZEFF) project. Project partners, including Toyota, Shell, Kenworth, SCAQMD, and Port of Hueneme (POH) are providing \$41,446,612 in match funding. Table 15 summarizes the funding contributions.

Table 15: Shore-to-Store Project Funding Partners

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

Accomplishments in 2019

Five of the hydrogen trucks completed assembly and began initial testing; in December 2019, one truck completed 68 miles of highway driving. Shell broke ground on its Ontario site in December 2019, and in Wilmington, permits have been submitted and bids for construction will be issued soon. Both stations are expected to begin operations in September 2020.

Hueneme moved forward on contracting for construction and is also conducting a mini-demonstration of both the BYD and Kalmar units, in order to allow operators to try out/compare existing yard tractors and decide which works best for their operations.

2020 Milestones

The following activities are expected in 2020:

- All of the hydrogen trucks will be on the road, and the demonstration will begin.
- The Port of Hueneme is expected to complete its mini-demonstration of yard tractors and place orders for equipment by the end of Q1 2020, and the full demonstration will begin by Q4 2020.
- The Shell stations in Ontario and Wilmington are expected to be operational by Q4 2020.

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

Project Description

In partnership with the Port of Stockton and Port of Oakland, the Port of Long Beach received a \$50 million CARB grant for a transformative demonstration of a near-zero and zero-emissions supply chain in and around its Matson Navigation Co. Pier C terminal. The Sustainable Terminals Accelerating Regional Transformation (START) Project, expected to be completed by 2022, will demonstrate more than 100 pieces of zero-emissions terminal equipment and trucks at three California seaports, develop a better-than-Tier IV emissions tugboat (see Section 5.6), deploy two ships with some of the cleanest available engines, and advance workforce development programs to support sustainable goods movement.

For this project, the Port of Oakland will deploy 10 electric trucks and 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 demonstrate:

- 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 in regular service on the West Coast
- An electric-drive tugboat by Harley Marine Services
- Five electric trucks at an off-dock container yard
- Two charging heavy-duty truck outlets.

Project Partners & Budget

The START Project is funded partly by a \$50 million grant from the California Climate Investments. The project includes \$52 million in matching funds from private and public partners, for a total cost of \$102 million. Table 16 summarizes the funding contributions.

Table 16: START Project Funding Partners

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

Accomplishments in 2019

In 2019, SSA Marine placed orders for the electric yard tractors, which will be manufactured by DINA and TransPower, and heavy-duty forklifts that will operate at SSA’s Port of Stockton terminal. Additionally, Port of Stockton ordered heavy-duty forklifts and the rail-car mover for its port-run operations. Port of Oakland began the infrastructure design for the charging equipment to support the heavy-duty on-road trucks, and manufacturing began on the 10 electric trucks that will be deployed to Oakland (Peterbilt and TransPower).

The first of two Tier 3 container ships was commissioned and made its first voyages to Long Beach and Oakland, thus beginning the demonstration for that project component, and Harley Marine Services completed preliminary design on the better-than-Tier IV emissions tugboat (see Section 5.6 for more details on the status of this project).

Charging infrastructure development in Long Beach has encountered delays due to the proposed EVSE not being UL-listed, which is a common problem for these emerging infrastructure technologies. The manufacturer is working to get the equipment appropriately certified, potentially as early as Q1 2020.

2020 Milestones

The following activities are expected in 2020:

- Delivery of the heavy-duty trucks in Long Beach and Oakland, pending charging infrastructure completion.
- Secure UL (or equivalent) certification for the EVSE in Long Beach, which allows infrastructure design and development to proceed, with infrastructure potentially being complete by Q4 2020.
- Commission and begin demonstration of the second Tier III vessel.
- Delivery of the remaining electric forklifts and the railcar mover in Stockton, with demonstration commencing potentially as early as Q3 2020.

5.16 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 have been 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. 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 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-emissions track mile operation, it also provided a pathway to address the challenges of FRA requirements. After much consideration, the project team agreed that it was best to migrate the project scope to a full 100% zero-emissions technology platform.

2019 Update

During 2019, VeRail focused its efforts to redesign the locomotive to entirely eliminate the use of diesel and CNG fuel and support the transition to zero-emissions battery technology. Ultimately, the technological and engineering challenges of this approach proved too difficult, and the project team made the decision to withdraw the project.

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

Project Description

The Port of Long Beach, in partnership with terminal operators and Southern California Edison (SCE), is demonstrating zero-emissions cargo-handling equipment projects throughout the Port. The project includes:

- Repower nine RTG cranes to full-electric power at SSA Marine Terminal, Pier J, in what would be the nation’s largest deployment of fully electric RTGs at a single terminal.
- Develop and deploy a total of six and four BYD battery-electric yard tractors at International Transportation Service (ITS), Pier G and Long Beach Container Terminal (LBCT), Pier E, respectively, where each terminal will demonstrate one battery-electric yard tractor designed to automatically charge using the Cavotec Smart Plug System (Figure 9) for a total of 12 demonstration vehicles.
- Convert four LNG trucks to plug-in hybrid electric trucks (PHET) LNG trucks at TTSI with zero-emissions capability in partnership with US Hybrid.
- Analyze the workforce development impacts of zero emissions with Long Beach City College.

Project Partners & Budget

The Port received \$9,755,000 in CEC funding, which is matched by over \$9.6 million in project partner funding, for a total project investment of \$19,370,948. Table 17 summarizes the funding contributions.

Table 17: Zero-Emissions Terminal Transition Funding Partners

Project Partners	Contributions
Port of Long Beach	\$3,345,609
California Energy Commission	\$9,755,000
Southern California Edison	\$3,950,000
OEMs and Demonstration Partners	\$2,320,339

Accomplishments in 2019

Plan, Design and Build the Retrofitted e-RTG’s

All civil work and electrical infrastructure construction were completed in 2019, including the energizing and commissioning of four new switchgears at SSA to support the RTG electrification. All required materials were delivered, and the first RTG began conversion to electric in December 2019.

The eRTG project is roughly four months behind schedule due to unforeseen electrical infrastructure needs. This included four switchgears that had not been accounted for but were needed to enable proper and safe connection from the equipment to the grid. In November 2019, the Port approved covering the cost of the four switchgears in order to move forward with this demonstration.

Figure 9: Cavotec Smart Charging System



Plan, Design and Build the Plug-In Hybrid Electric Trucks (PHET)

US Hybrid completed design and engineering for the plug-in hybrid electric trucks and completed the repower of one truck. This project is delayed because the project team decided to change the design of the trucks to accommodate on-board charging units. The on-board chargers make the trucks compatible with existing charging infrastructure at TTSI, thus eliminating the need for new charging infrastructure at the site.

The first repowered truck began preliminary on-road testing in October 2019 and has completed more than 250 miles without any issues. The first truck was laboratory tested at the University of California, Riverside Center for Environmental Research & Technology in November 2019 to obtain information to further fine-tune the truck. The remaining three trucks are at US Hybrid for build-outs.

Plan, Design and Build the Battery-Electric Yard Tractors

Construction was largely completed on the infrastructure to support the seven yard tractors at ITS and five yard tractors at LBCT, and the Cavotec Smart-Plug system units were delivered in June 2019. Testing of the Cavotec Smart-Plug units took place in September 2019 and encountered issues that prevented the yard tractors from charging; design work continued through 2019 to resolve the issues. BYD delivered a test unit yard tractor to LBCT in April 2019 and to ITS in June 2019.

The demonstration, however, cannot begin because the BYD manual charging units have not been certified and commissioned. For the ten BYD EVSEs, a third-party certification will be performed by TUV. TUV certification demonstrates that the EVSE conforms to the Underwriters Laboratory (UL) standards, which is a requirement of the Port. The same will also be done for the two Cavotec SPS units, only the third-party certification will be conducted by ETI. BYD will hold delivery of the remaining yard tractors until the EVSE has been commissioned.

Long Beach City College completed its workforce development report, which is available at www.polb.com/zeroemissions.

2020 Milestones

The following activities are expected in 2020:

- All RTGs will be converted to full electric, and the demonstration will begin.
- All of the PHETs will be delivered and the demonstration will begin Q1 2020.
- BYD EVSE are expected to receive approval, allowing yard tractors to charge.
- All yard tractors will be delivered, and the demonstration will begin.
- The Cavotec smart charging system is expected to resolve its design issues and begin the demonstration.

6 2019 TECHNOLOGY FUNDING

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

The Ports and agency stakeholder investments for all past and current technology advancement projects approved to date are shown in Table 18 below. Five new technology projects were approved and funded in 2019, including:

- Effenco Electric Active Stop-Start™ Technology Demonstration (Section 5.4)
- Harley Marine Electric Drive Tugboat Design (Section 5.6)
- SCAQMD Daimler Demonstration of Heavy-Duty Trucks (Section 5.11)

In addition, POLA initiated two new grant-funded projects, including:

- Advanced Infrastructure Demonstration Project (Section 5.1)
- Shore-to-Store Demonstration Project (Section 5.14)

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

Table 18: Ports' Technology Advancement Funding Investments as of December 31, 2019

Project Category	POLB	POLA	South Coast AQMD	CARB	CEC	US EPA / US DOE & Other Agencies	Total Port & Agency Stakeholder	OEMs & Demonstration Partners	Total Project Budget
<u>Ocean-Going Vessels</u>									
APL Singapore Slide Valve/WIFE	\$22,500	\$22,500		\$783,628			\$828,628	\$471,372	\$1,300,000
ACTI AMECS Emissions Testing	\$149,527	\$149,527	\$55,000				\$354,054	\$249,157	\$603,211
Bluefield Holdings Krystallon OGV Scrubber	\$825,000	\$825,000					\$1,650,000	\$1,740,000	\$3,390,000
OGV Slide Valve Low-Load Emissions Evaluation	\$108,000	\$108,000					\$216,000		\$216,000
ACTI At-Berth Emissions Reductions for Ships	\$703,388						\$703,388		\$703,388
Tri-Mer Mobile Emissions Treatment System (METS-1) At-Berth Emissions Reductions for Ships		\$1,500,000					\$1,500,000	\$9,500,000	\$11,000,000
Maersk OGV Energy Efficiency Measurement Demonstration (completed in 2019)	\$500,000	\$500,000					\$1,000,000	\$1,860,000	\$2,860,000
<u>Harbor Craft</u>									
Harley Marine Electric Drive Tugboat Design Project	\$117,500	\$117,500					\$235,000	\$364,000	\$599,000
Nett Technologies Inc. BlueMAXTM NOVA 320e	\$250,000	\$250,000					\$500,000	\$700,000	\$1,200,000
Foss Maritime Hybrid Tugboat	\$500,000	\$889,920		\$1,000,000			\$2,389,920	\$5,610,080	\$8,000,000
<u>Cargo Handling Equipment / Port Terminal Projects</u>									
LNG Yard Tractor	\$350,000	\$0				\$75,000**	\$425,000.00		\$425,000
Balqon Electric Terminal Tractor	\$0	\$263,500.00	\$263,500				\$527,000.00		\$527,000
Vycon RTG REGEN Flywheel	\$11,500	\$11,500.00	\$8,000				\$31,000.00		\$31,000
Balqon Lithium Battery Upgrade	\$0	\$400,000.00					\$400,000.00	\$540,000	\$940,000
Hybrid Yard Tractor	\$300,000	\$300,000.00				\$300,000**	\$900,000.00	\$300,000	\$1,200,000
LBCT Eco-Crane	\$42,468	\$42,467.50				\$130,130	\$215,065.00	\$265,065	\$480,130
Capacity Plug-In Hybrid Tractor	\$29,500	\$32,000.00					\$61,500.00		\$61,500
APT Emulsified Biodiesel	\$44,000	\$44,000.00					\$88,000.00	\$88,000	\$176,000
<i>RYPOS Diesel Emissions Control (L2+)</i>	<i>\$64,668</i>	<i>\$64,668.42</i>					<i>\$129,336.84</i>		<i>\$129,337</i>

San Pedro Bay Ports Technology Advancement Report
2019 Annual Report and 2020 Priorities

Project Category	POLB	POLA	South Coast AQMD	CARB	CEC	US EPA / US DOE & Other Agencies	Total Port & Agency Stakeholder	OEMs & Demonstration Partners	Total Project Budget
Hybrid Yard Tractor Development & Demonstration – Beta Test	\$13,000	\$13,000.00					\$26,000.00		\$26,000
RYPOS Adv. L3+ DPF – RTG Cranes	\$36,130	\$36,130.00					\$72,260.00	\$249,880	\$322,140
Port of Long Beach Zero Emissions Terminal Equipment Transition Project	\$3,345,609				\$9,755,000	\$3,950,000	\$17,050,609.24	\$2,320,339	\$19,370,948
Advanced Yard Tractor Deployment and Eco-FRATIS Drayage Truck Efficiency Project					\$5,833,000		\$5,833,000	\$2,808,007	\$8,641,007
Pasha Green Omni Terminal Demonstration Project				\$14,510,400			\$14,510,400	\$12,092,000	\$26,602,400
Everport Advanced CHE Demonstration		\$1,071,428.00			\$4,524,000		\$5,595,428.00	\$1,166,903	\$6,762,331
Commercialization of Off-Road Technology Demonstration	\$1,373,000		\$350,000	\$5,339,820			\$7,062,820	\$1,388,066.40	\$8,450,886.40
Port Advanced Vehicle Electrification	\$3,704,266		\$1,372,500		\$8,000,000		\$13,076,766	\$3,658,646	\$16,735,412
Sustainable Terminals Accelerating Regional Transformation	\$3,531,157		\$500,000	\$50,000,000		\$3,250,000	\$57,281,157	\$43,237,585	\$100,518,742
Effenco Rapid Deployment of Electric Active Stop-Start™ Technology for Zero-Emission Idling from Port Yard Tractors Project	\$90,000	\$90,000					\$180,000	\$445,163	\$625,163
Advanced Infrastructure Demonstration Project		\$392,500	\$442,750		\$7,842,270	\$1,344,750	\$10,022,270	\$1,326,885	\$11,349,155
Container Drayage Trucks									
Westport ISXLNG Engine	\$250,000	\$250,000	\$1,250,000		\$500,000		\$2,250,000	\$7,644,027	\$9,894,027
SoCalGas CNG Drayage Truck	\$111,577.50	\$111,577.50	\$421,250				\$644,405	\$1,355,595	\$2,000,000
<i>Vision Motor Corp. Hydrogen Fuel Cell Plug-In Hybrid Electric Truck</i>	\$95,625	\$95,625					\$191,250		\$191,250
US Hybrid On-Board Charger for Zero Emissions Cargo Transport Demonstration	\$37,500	\$37,500	\$75,000				\$150,000		\$150,000
TransPower Pre-Commercial Electric Drayage Truck Demonstration	\$150,000	\$150,000			\$2,296,617	\$1,192,184	\$3,788,801	\$655,000	\$4,443,801
TransPower Electric Drayage Infrastructure and Improvement	\$300,000	\$300,000					\$600,000	\$5,700,000	\$6,300,000
<i>International Rectifier Plug-In Hybrid Electric Class 8 Truck Conversion</i>	\$17,500	\$17,500					\$35,000	\$381,972	\$416,972
HLT San Pedro Bay Ports Drayage Truck Demonstration of a Near-Zero Ultra-Low NOx Natural Gas Engine Operating on Renewable Natural Gas	\$37,500	\$37,500					\$75,000	\$121,555	\$196,555
Development of a Near-Zero Emissions Diesel Engine for On-Road Heavy-Duty Vehicles		\$287,500	\$287,500	\$425,000			\$1,000,000		\$1,000,000

San Pedro Bay Ports Technology Advancement Report
2019 Annual Report and 2020 Priorities

Project Category	POLB	POLA	South Coast AQMD	CARB	CEC	US EPA / US DOE & Other Agencies	Total Port & Agency Stakeholder	OEMs & Demonstration Partners	Total Project Budget
SCAQMD Zero Emission Cargo Transport (ZECT) II	\$724,489.50	\$566,989.50	\$2,400,000		\$2,400,000	\$10,975,000	\$17,066,479	\$3,075,481	\$20,141,960
Develop and Demonstrate Catenary Zero Emissions Goods Movement System	\$2,000,000	\$4,000,000*	\$2,500,000		\$3,000,000	\$2,000,000	\$13,500,000		\$13,500,000
Daimler Truck North America/AQMD Battery-Electric Trucks Demonstration	\$1,000,000	\$1,000,000	\$12,670,072			\$1,000,000	\$15,670,072	\$15,670,072	\$31,340,144
Shore-to-Store Project		\$13,999,331	\$1,000,000	\$41,122,260			\$56,121,591	\$26,427,281	\$82,548,872
<u>Locomotives</u>									
Johnson Matthey DPF Locomotive Demonstration	\$75,000	\$75,000		\$346,178			\$496,178	\$196,178	\$692,356
<i>VeRail Near-Zero Locomotive Demonstration – Moving Towards Zero Emissions</i>	<i>\$25,000</i>	<i>\$25,000</i>					<i>\$50,000</i>		<i>\$50,000</i>
<u>Technology Advancement Support Efforts</u>									
Heavy-Duty Drayage Truck Duty Cycle Characterization	\$12,681	\$13,000					\$25,681		\$25,681
Development of Drayage Truck Chassis Dynamometer Test Cycle	\$12,000	\$11,466					\$23,466		\$23,466
AQMD HDV In-Use Emissions Testing Program	\$153,276	\$153,276	\$1,701,156				\$2,007,708		\$2,007,708
Total Investment (Includes Funding Outside TAP)	\$21,113,362.16	\$28,254,905.92	\$25,296,728	\$113,527,286	\$44,150,887	\$24,217,064	\$256,560,233.08	\$151,608,309.40	\$408,168,542.48
Total Port TAP Investment	\$49,368,268.08								

**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 CONTACTS

Technology Advancement Program Advisory Committee Membership

- | | |
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| ▪ Naveen Berry, South Coast AQMD | nberry@aqmd.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. Maersk OGV Energy Efficiency Measurement Demonstration Project (2019)
18. OGV Slide Valve Low-Load Emissions Evaluation (2013)
19. RYPOS Advanced Diesel Particulate Filter for Cargo-Handling Equipment (2012)
20. RYPOS Advanced Level 3+ Diesel Particulate Filter RTG Crane Demonstration (2014)
21. San Pedro Bay Ports Drayage Truck Demonstration of a Near-Zero Ultra-Low NOx Natural Gas Engine Operating on Renewable Natural Gas (2018)
22. SCAQMD HDV In-Use Emissions Testing Program (2013)
23. SoCalGas CNG Drayage Truck Demonstration (2010)
24. TransPower Electric Drayage Infrastructure and Improvement (EDII) Project (2016)
25. TransPower Electric Drayage Pre-Commercial Truck Demonstration (2016)
26. US Hybrid On-Board Charger for Zero Emissions Cargo Transport Demonstration (2016)
27. VYCON REGEN® System for Rubber-Tired Gantry Cranes Testing & Verification (2007)
28. Westport GX LNG Engine Development (2010)