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Port of LONG BEACH
The Green Port

THE PORT OF LOS ANGELES

SAN PEDRO BAY PORTS

CLEAN AIR ACTION PLAN

2016 ANNUAL REPORT AND 2017 PRIORITIES

Technology Advancement Program

10 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 ten 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 2015, port-related diesel particulate matter (DPM) emissions were reduced by 84 percent, nitrogen oxide (NO_x) emissions were reduced by 50 percent and sulfur oxide (SO_x) emissions were reduced by 97 percent.

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 US Environmental Protection Agency (USEPA), California Air Resources Board (CARB), California Energy Commission (CEC) and the South Coast Air Quality Management District (SCAQMD), which participate actively in a TAP Advisory Committee that evaluates technology projects, supports the commercialization of these nascent technologies, and helps leverage funds.

At the time of the TAP's adoption, there was a scarcity of funding for low-emission port vehicles and equipment. TAP filled an important role by providing funding and working to leverage outside agency resources to support clean port technologies. More broadly, the TAP helped signal interest and priority for additional investment in port-specific technology development and demonstration. Ten years later, the TAP has undertaken over 30 projects spanning test cycle development, hybrid and alternative fuel technology demonstrations, and zero-emissions (ZE) equipment operation.

Looking Ahead

In 2016, significant new goods movement initiatives prompted the Ports to re-evaluate the TAP to ensure alignment with our goals and to maintain our history of success.

First, the State – in a joint effort between CARB, CEC, and the California Department of Transportation – adopted the Sustainable Freight Action Plan, which offers comprehensive strategies to push the goods movement sector toward zero emissions, to improve freight efficiency, and to manage energy resources. Second, the Ports released a draft update to the Clean Air Action Plan with aggressive new strategies for zero-emissions trucks and terminal equipment, cleaner ships, freight efficiency, and energy. The document also proposed a new emissions reduction target for greenhouse gases (GHG), a first for the Ports, which calls for cutting GHGs

80% below 1990 levels by 2050. The CAAP 2017 Update is anticipated to be brought to both Boards of Harbor Commissioners for approval in 2017.

Third, over the last five years, a significant amount of funding has been directed to emerging technology development and demonstration in the goods movement sector. Agencies such as USEPA, CARB, and CEC have invested over $55 million in port-related demonstrations over the past few years, and Port projects have been awarded over $35 million from such funding opportunities to support zero- and near-zero emissions equipment and vehicle development and demonstration. The increase in available funding has reduced reliance on TAP funds but the growing number of port-related technology demonstrations has necessitated new testing protocols, duty cycle reports, and a focus on infrastructure to support the commercialization of this equipment. As advanced technologies move toward commercialization, the equipment and vehicles are potentially eligible for the federal Diesel Emission Reduction Act and the state incentive programs such as the Carl Moyer Program, Proposition 1B Goods Movement Emission Reduction Program, and Hybrid Vehicle Incentive Program that offset the higher cost of zero- and near-zero emissions equipment and vehicles.

In short, the landscape for emerging technologies that operate in and around ports has changed since the TAP's inception, and the TAP must adapt to fully realize the opportunities ahead. Moving forward, the Ports plan to retain the TAP's highly successful structure and implement improvements to ensure the most effective use of dollars and to align more fully with the CAAP 2017 Update's focus on zero emissions, greenhouse gas reductions, and energy. These changes are described more fully in Section 4.

2. TAP ACCOMPLISHMENTS IN 2016

In 2016, the TAP continued to support technology advancement, with a particular focus on zero emission vehicle demonstrations and development of supporting infrastructure (i.e., charging equipment).

Major accomplishments in 2016 include:

- Updated the TAP Guidelines to set funding priorities, to target high-need technologies, and to align with the Sustainable Freight Action Plan and draft CAAP 2017 Update, as described in Section 4;
- Finalized multi-agency testing protocols for zero- and near-zero emissions on-road truck demonstrations, which is critical in ensuring consistent evaluation of emerging technologies;
- Redesigned the TAP website to enhance transparency and improve communications of our technology results and to provide resources for technology developers;
- Funded new TAP projects to demonstrate energy-efficiency in ships and to test a near-zero emissions locomotive; and
- Continued to demonstrate zero- and near-zero emissions equipment and vehicles. Table 1 provides an overview of 2016 TAP projects. Additionally, Section 6 provides detailed status updates for each of these projects, including specific accomplishments in 2016 and projected milestones for 2017.

Table 1: 2016 TAP Project Snapshot

Project Title	Project Description	Status	Zero-Emission Project?
US Hybrid On-Board Charger for Zero Emission Cargo Transport (ZECT I) Demonstration	Upgrade to on-board charging for two project trucks. (Section 6.3)	Completed in 2016	Yes
TransPower Electric Drayage Pre-Commercial Trucks Demonstration (EDPCD)	Develop and demonstrate a ZE drive system for heavy-duty trucks for drayage service deployment. (Section 6.4)	Completed in 2016	Yes
TransPower Electric Drayage Infrastructure and Improvement (EDII)	Improved electrical charging at existing sites and improve the advanced battery management system for the EDPCD project vehicles. (Section 6.5)	Completed in 2016	Yes
SCAQMD Zero Emission 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 6.6)	Ongoing	Yes, and near-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 6.7)	Approved and initiated in 2016	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 6.8)	Approved and initiated in 2016	No

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 described in Table 1, the Ports have demonstrated our commitment to zero-emissions technology development. In 2016, four of the six active TAP projects were focused on zero emissions – the most of any TAP funding year – in an effort to significantly accelerate the commercialization of these clean vehicles and equipment.

Additionally, the Ports – outside of the TAP – have supported zero-emissions technology development directly by contributing funds to projects such as SCAQMD's overhead catenary demonstration, described in Section 7.

But 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 2016, 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-Emission Freight Movement Regional Collaborative to develop and demonstrate zero emission 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 CNG plug-in hybrid trucks from TransPower, and two battery-electric trucks and three LNG plug-in hybrid trucks from US Hybrid. The Ports wrote support letters to help SCAQMD secure these funds and worked with SCAQMD on a testing protocol for on-road drayage trucks. More directly, the Ports provided funds to augment the charging capabilities of the US Hybrid trucks (Section 6.3).

- SCAQMD Zero-Emission Drayage Truck Demonstration Project: CARB's Air Quality and Low Carbon Transportation Investments Programs selected SCAQMD for a major zero-emission technology demonstration that includes 25 BYD battery-electric trucks, 12 TransPower/Peterbilt battery-electric trucks, four Kenworth CNG plug-in hybrid electric trucks and two 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 Fall 2017.

4. TAP CHANGES FOR 2017

The TAP seeks to accelerate the commercial availability of new, clean technologies for port equipment in order to move towards an emissions-free port. The TAP is focused on testing and evaluating the performance of emerging technologies through in-service demonstrations. The TAP's goal is to nurture nascent emission-reduction technologies so they can be commercialized and deployed portwide. Funding demonstration projects is one aspect of this effort. Additionally, the TAP supports commercialization by developing testing protocols, contributing to technology research, and leading efforts to standardize design specifications for infrastructure and equipment.

Unlike other regional and state technology advancement programs, the Ports' TAP objective is to focus on clean technologies specifically for maritime-related mobile sources that operate in and around ports.

Moving into 2017, in light of the need to focus on greenhouse gas reductions, to address emissions from traditionally stubborn sources such as ships and harbor craft, and to maximize use of port dollars, the Ports plan to make the following improvements to the TAP implementation process:

- Shift to proactive solicitations in order to target specific high-need technologies;
- Identify new funding priorities for mobile source applications; and
- Cultivate new partnerships to support a broader approach to technology development.

These changes will expand the TAP's ability to leverage outside agency resources by aligning with State policy and will allow the Ports to direct resources to support technology development where there is the greatest need. The TAP, which has been focused mainly on technologies with criteria pollutant reductions, will evolve to include technologies and approaches with the potential to reduce GHGs in order to help us meet our greenhouse gas reduction target. The draft CAAP 2017 Update is designed to support the Ports' commitment to two overarching goals that cut across the categories of clean vehicles and equipment technology, freight infrastructure, freight efficiency, and energy resource planning: (1) technology advancement and (2) advocacy. The TAP is a key component to the Ports' new CAAP strategy.

4.1. Changes to the Solicitation Process

The TAP is a competitive funding program that uses several approaches to identify and support potential projects. Traditionally, the TAP has relied on unsolicited proposals from technology developers, which are then evaluated by the TAP Advisory Committee. This process has served us well; however, the Ports face significant environmental challenges that require a more targeted approach for identifying promising technologies in high-need areas.

To that end, in 2016, the Ports revised the TAP guidelines to include a new emphasis on port-initiated projects and proactive solicitations (i.e., Requests for Proposals), in order to stimulate technology development in high-need applications. Additionally, the TAP may issue RFPs for emerging infrastructure solutions to support cleaner vehicles and equipment and for technologies or operational efficiency strategies that result in less fuel consumption and thus fewer GHG and other pollutant emissions. Although the TAP will continue to

accept unsolicited proposals, it will do so only at certain times of the year under a Call for Projects, which is intended to streamline the proposal review process.

Additional information on this new approach can be found in the 2017 TAP Guidelines at *http://www.cleanairactionplan.org/technology-advancement-program/.*

4.2. 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- or near-zero emissions cargo-handling equipment
- Harbor craft technologies
- At-berth ship technologies
- Locomotive technologies
- Near-zero and zero-emissions heavy-duty vehicles

On an annual basis, the Ports will 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 more proactive 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.

4.3. New 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 emission reductions achieved by the candidate technologies undergoing evaluation and other technical issues. As an example, in 2016, the Ports focused on the need for test plan guidelines that could be used to evaluate zero emission truck technologies. This effort was coordinated by the Ports with CARB and SCAQMD support, resulting in the publication of the "Zero/Near-Zero Emissions Drayage Truck Testing & Demonstration Guidelines," which will be used for future evaluation of zero and near-zero emission drayage truck technologies.

In 2016, the Ports added a new agency to the TAP AC – the California Energy Commission – in recognition of this agency's critical support of alternative fuels technology demonstrations and expertise in zero emissions, advanced mobile source technologies, energy resources management, and alternative fuels infrastructure.

5. TAP PRIORITIES FOR 2017

In 2017, the TAP plans to support the following efforts:

- Fully implement the new TAP Guidelines for Proposals, which will include establishing a schedule for solicitations, as well as monitoring state and federal grant funding programs in order to align timing with anticipated program opportunities;
- Issue a Call for Projects[1];
- Finalize testing protocols for cargo-handling equipment;
- Develop a performance report of existing zero emission yard tractors to track in-service operation and to document any problems that were encountered and resolution status;
- 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

Additionally, in 2017, the Ports intend to release solicitations for two high-priority technology needs:

- At-Berth Emission Reduction Technology for Non-Regulated Vessels
- Harbor Craft Emission Reduction Technologies

At-Berth Emission Reduction Technology for Non-Regulated Vessels

By 2020, CARB's At-Berth Regulation will require 80% of covered vessels to use shore power or an approved alternative means to reduce emissions to levels equivalent to those achieved by shore power. Currently, vessels such as tankers, auto carriers, bulk ships, and general cargo are not included in the At-Berth Regulation, even though they contribute to the Ports' emissions. To address these emissions, the TAP will place a high priority on funding the development and demonstration of non-regulated vessel emissions reduction technology. This category is budgeted for up to $1,000,000 from the TAP.

Harbor Craft Emission Reduction Technologies

Harbor craft – tugboats, crew boats, and barges – are a rising source of emissions for the Ports. Under state regulation, most of the boats now have Tier 2 engines, but these engines are not as clean as the newer Tier 3 and Tier 4 engines, and there is no requirement for harbor craft operators to upgrade. Low-cost retrofit technologies that bring an engine from Tier 2 to Tier 3 or Tier 4 could provide substantial emissions benefits. Additionally, advancements in alternative fuels and zero-emissions vessels make harbor craft an attractive option for investment. This category is budgeted for up to $500,000 from the TAP.

[1] Visit TAP website for updated information regarding Call for Projects schedule at: http://www.cleanairactionplan.org/technology-advancement-program/

6. KEY PROJECTS IN 2016

This section provides more details on TAP projects that were active in 2016. For information on completed TAP projects, please access the Final Reports at the program website: *http://www.cleanairactionplan.org/technology-advancement-program/.*

6.1. International Rectifier Plug-In Hybrid Electric Class 8 Truck Conversion

The goal of this project with International Rectifier (IR) was to convert a conventional Class 8 drayage truck into a plug-in hybrid electric vehicle (PHEV). The Ports approved $350,000 in TAP funding for the project in 2013, which was matched with $381,972 from International Rectifier.

As discussed in the 2015 TAP Annual Report, IR was acquired by Infineon Technologies. As a result of the merger, Infineon has decided to not pursue the business being developed by IR's Advanced Development Group as it relates to the PHEV project. As a result, Infineon elected to terminate the TAP project in June 2016. The first (and only) task of IR's scope of work, Finalization of Test and Demonstration Plan, was completed in 2014 and payment of $35,000 from the ports was made. There has been no other TAP payment made since then, and the balance of $315,000 was returned to the Ports for reprogramming to other TAP projects.

6.2. Development of On-Road Drayage Truck Testing Protocol

In recognition of the need to have a consistent evaluation process for all agencies conducting truck-related demonstration projects, in 2016, the TAP finalized test protocols for on-road heavy-duty truck demonstrations. The "Zero/Near-Zero Emissions Drayage Truck Testing & Demonstration Guidelines"[2] were developed in partnership with the SCAQMD and the CARB. The guidelines will support the technical evaluation, performance testing, and durability validation of electric, hybrid-electric, and other advanced technology trucks intended to dray shipping containers from port marine terminals to destinations within the region.

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

A similar testing and demonstration protocol for cargo handling equipment was initiated in late-2016 and is anticipated to be published by mid-2017.

[2] http://www.cleanairactionplan.org/documents/san-pedro-bay-ports-zeronear-zero-emissions-drayage-truck-testing-demonstration-guidelines.pdf

6.3. US Hybrid On-Board Charger for Zero Emission Cargo Transport Demonstration

Project Description

In 2016, the Ports completed a $75,000 project with US Hybrid to augment the charging capabilities of two battery-electric trucks being developed and tested under a separate project led by SCAQMD. US Hybrid, which offers comprehensive engineering and integration expertise in powertrain and power conversion systems for medium- and heavy-duty electric, hybrid, and fuel cell vehicles, was selected by SCAQMD to develop and demonstrate two battery-electric zero-emissions Class 8 trucks under the 2012 Department of Energy Zero Emissions Cargo Transport (DOE ZECT I) grant. Originally, US Hybrid had planned to charge the trucks using off-board chargers. However, based on feedback from fleet operators and the available electric-vehicle charging infrastructure for heavy-duty trucks at the demonstration sites, US Hybrid upgraded its electric trucks with on-board chargers for this project. This change offered streamlined charging logistics and cost savings for fleet operators and ensured compatibility between the US Hybrid charging platform and platforms used by other zero-emission truck manufacturers.

US Hybrid designed, developed, and integrated two 60 kW 3-phase on-board chargers into two Class 8 battery electric drayage trucks. The 60kW charger is an enhancement to the existing 6.6 kW Level II on-board charger, giving the truck dual plug capability for fast- or slow-charging. The on-board chargers are now compatible with the charging infrastructure at Total Transportation Services, Inc. (TTSI), where the trucks are in demonstration service.

Project Partners & Budget

The Ports contributed $75,000 in TAP funding to this project with a total project budget of $150,000. Table 2 summarizes the project funding contributions:

Table 2: US Hybrid On-Board Charger for Zero Emission Cargo Transport Demonstration Funding Partners

Project Partners	Contributions
Port of Long Beach	$37,500
Port of Los Angeles	$37,500
SCAQMD	$75,000
TOTAL	$150,000

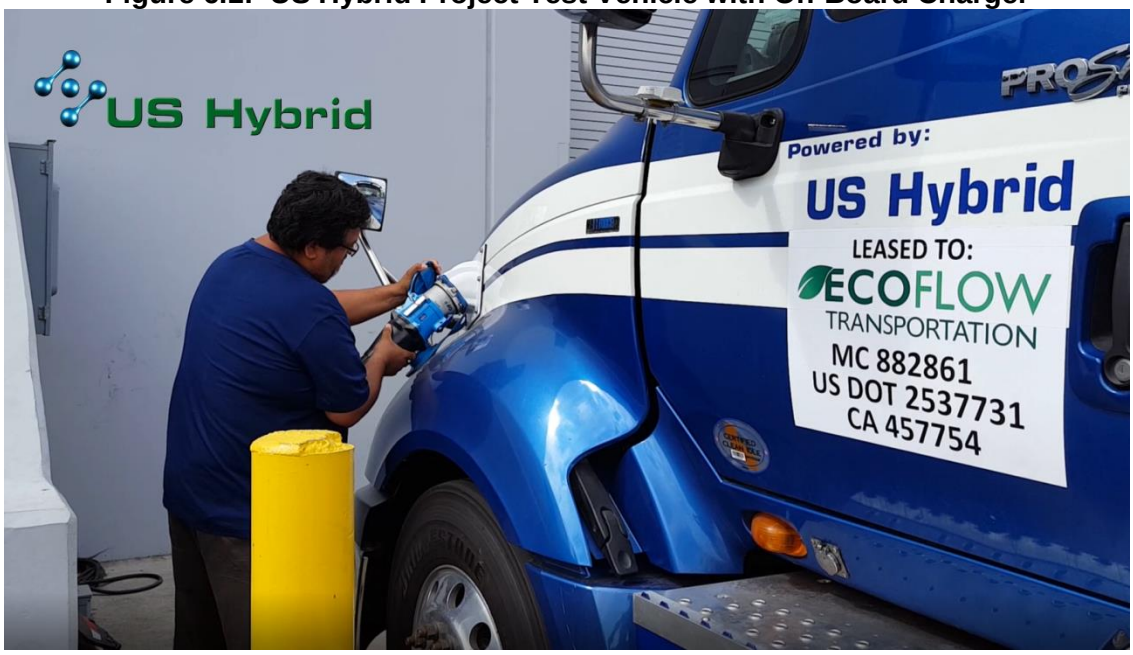
Project Benefits

This project supports the TAP's interest in standardizing charging methods for zero-emission vehicles and equipment and in priming technologies for commercialization by taking operator acceptance into account.

Accomplishments During 2016

US Hybrid successfully integrated the on-board chargers in the two trucks and submitted a final report documenting the project activity and results. Under the SCAQMD's ZECT I project, a demonstration of these trucks is underway. The 24-month demonstration, which includes ongoing monitoring of the on-board chargers, is expected to be completed in early 2018.

Figure 6.1: US Hybrid Project Test Vehicle with On-Board Charger



6.4. TransPower Electric Drayage Pre-Commercial Truck Demonstration (EDPCD)

Project Description

The objective of this TAP project was to develop and demonstrate a zero-emission battery-electric drive system for heavy-duty trucks for drayage service deployment. Under this project, TransPower's ElecTruck™ electric propulsion system was integrated into seven Navistar International ProStar trucks. This TAP project is a subset of the Zero-Emission Cargo Transport (ZECT I) Demonstration that is funded by the California Energy Commission, U.S. Department of Energy, South Coast Air Quality Management District and TransPower. Please see Section 3 for a brief summary of this larger scale project.

The TransPower's ElecTruck™ electric propulsion system offers technological innovations in several key areas, including:

- Power conversion: an advanced "Inverter-Charger Unit" (ICU) that combines the functions of the vehicle inverter, which controls the drive motors, and the battery charger, and regulates recharging of the vehicle battery pack, to facilitate battery recharging;
- Energy storage: high-energy battery modules using lithium-ion cells and an advanced battery management system (BMS) used to monitor each individual

battery cell and extend the life of the battery subsystem by enabling the replacement of failing cells;
- Main propulsion: an Automated Manual Transmission (AMT) that delivers torque from electric drive motors to the vehicle's wheels more efficiently than competing transmission technologies; and
- Vehicle control: a proprietary vehicle control system enabling the development of algorithms that will optimize vehicle efficiency, maximize battery life, and protect key components such as batteries and power electronics from excessive temperatures, voltage spikes, or current surges.

The TransPower's ElecTruck™ includes a newly redesigned power control and accessory subsystem (PCAS) that incorporates most of the truck's control elements into a single integrated structure which greatly facilitates the installation of PCAS subsystems including the ICUs, Central Control Modules and major components of electrically-driven accessory subsystem. In addition, the electric trucks include the latest improved Motor Drive Subsystem with the AMT and the Energy Storage Subsystem (ESS) featuring more efficient 300 ampere-hour (Ah) battery cells, consolidated energy storage system with improved access to components, and improved battery management system. The projected vehicle and performance specifications for the TransPower's electric-battery trucks were met and included the following:

- Vehicle Chassis: Navistar International ProStar Class 8 Chassis
- Drive System: TransPower's ElecTruck™ electric propulsion system
- Range: 70 to 100 miles at average load of 65,000 total gross vehicle weight rating
- Top Speed: 65 mph at level ground; 28 mph at 6% grade @ 80,000 pounds gross combined vehicle weight
- Capacity: 80,000 pounds maximum gross vehicle weight
- Acceleration: Achieve 30 mph in 16 seconds fully loaded; 60 mph in 70 Seconds fully loaded
- Battery Charging Time: 3 hours with single 70 kW charger (baseline configuration)

In addition to the above innovations and features, other major enhancements and improvements have also been (or are being) incorporated into the design and operation of electric trucks. Specifically, TransPower's new 311 KWh ESS based on the more energy dense cylindrical "KAM" batteries (to be incorporated into EDD1 upgrade) is expected to be more energy efficient than the 215 kWh ESS which are in existing Electric Drayage Demonstration (EDD) trucks, potentially increasing the operating range to 120 to 150 miles. In addition, the newer trucks (EDD5 to EDD7) are equipped with one ICU and one new inverter (instead of two ICUs used in EDD1 to EDD4) for cost savings, since one ICU can adequately supply power to charge the truck's batteries.

Project Partners & Budget

The Ports are contributing $300,000 in co-funding to this project with a total project budget of $4,443,801. Table 3 summarizes the project funding contributions:

Table 3: TransPower Electric Drayage Trucks Demonstration Funding Partners

Project Partners	Contributions
Port of Long Beach	$150,000
Port of Los Angeles	$150,000
TransPower	$655,000
U. S. Department of Energy	$1,142,070
California Energy Commission	$2,296,167

Project Benefits

Tailpipe criteria air pollutants, toxics air pollutants, and greenhouse gas emissions are completely eliminated in zero-emission trucks. Successful demonstration of zero-emission heavy-duty trucks under this project offers significant potential in reducing/eliminating emissions for trucks in drayage service. This project supports the Ports' efforts in moving toward zero-emission technologies.

Accomplishments During 2016

All seven EDD trucks were completely integrated, placed in service, or returned to TransPower for upgrades in 2016. These EDD trucks are designated as EDD1 to EDD7. Recent developments for each truck are summarized below:

- EDD1, originally featuring the Flux BMS and the larger 700 Ah cells is going through a major ESS upgrade after accumulating about 3,900 zero emission miles operating mainly at SA Recycling carrying metal parts and scrap. EDD1 is currently out of service as it is upgraded with the more efficient cylindrical "KAM" 90 Ah battery cells and TransPower's new BMS. The new batteries have 60% higher energy density (compared to batteries in other EDD trucks) and are expected to increase the operating range to more than 100 miles. Despite some delays in procuring and drive testing EDD1, the new upgrades are expected to be completed in early 2017.
- EDD2 and EDD5 to EDD7 trucks featured TransPower's upgraded BMS and the more efficient 300 Ah cells.
- EDD3 and EDD4 included the 300 Ah cells and the original Flux BMS.
- EDD5 to EDD7 also featured the improved power conversion system (one ICU and one inverter compared to two ICUs in prior EDD configurations).
- EDD6 and EDD7 also incorporated the new Jing-Jin Electric electric motor (which exhibited lower power output requiring further testing).

The trucks are in use at locations listed in Table 4.

Table 4: Status of TransPower EDD Trucks as of December 31, 2016

Electric Truck ID No.	Zero Emission Miles	Operating Location and Usage
EDD1	3,889	At TransPower pending upgrade
EDD2	9,804	Three Rivers Trucking; up to 8 turns per day, 5 days per week, and 20-80 miles per day
EDD3	9,628	Cal Cartage; up to 5 turns per day, 4-5 days per week, and 30-50 miles per day
EDD4	10,954	National Retail Transportation; moving IKEA containers, up to 2 turns per day, 4-5 days per week, 50-65 miles per day, and carrying containers up to 51,000 pounds (about 80,000 GCW)
EDD5	1,043	Knight Transportation; pending extensive efficiency and load testing by Southern California Edison
EDD6	466	Pasha; light break-bulk service
EDD7	2,034	Port of San Diego, BAE Systems; undergoing reliability improvements at TransPower before being put into service at POLA

2017 Milestones

While this TAP project is now completed, EDD1 to EDD7 trucks are expected to continue operating in 2017, demonstrating their durability and accumulating additional zero-emission miles while featuring new enhancements (e.g., more efficient battery storage system, improved charging capacity).

Figure 6.2: EDD6 at SA Recycling

Figure 6.3: EDD3 at Cal Cartage

6.5. TransPower Electric Drayage Infrastructure and Improvement (EDII) Project

Project Description

In tandem with the Electric Drayage Pre-Commercial Demonstration (EDPCD) Project (see Section 6.4), TransPower worked with the Ports of Long Beach and Los Angeles on this Electric Drayage Infrastructure and Improvement (EDII) Project, in partnership with Navistar, Total Transportation Services, Inc. (TTSI), SA Recycling, and CALSTART. The EDII project builds on the successes of the EDPCD Project that received grant funds from a variety of sources including an earlier TAP grant awarded in 2013.

The EDPCD project gained broader support than originally anticipated, expanding from the initial five to now seven trucks, creating the need for this EDII project. The EDII project improved electrical charging at existing sites and the advanced battery management system for the project vehicles. In addition, this project initiated a manufacturing engineering process to reduce the cost of manufacturing components and to enable TransPower to develop and implement failure modes and effects analyses and diagnostic capabilities similar to those used by established vehicle manufacturers. This is designed to help improve the overall reliability of TransPower's ElecTruck™ system.

Project Partners & Budget

The Ports each contributed $300,000 in co-funding to this project with a total project budget of $600,000. The combined EDPCD/EDII project has a total budget of approximately $5.7 million and capabilities that exceed those targeted by the initial program. Table 5 summarizes the project funding contributions:

Table 5: TransPower Electric Drayage Infrastructure and Improvement (EDII) Demonstration Funding Partners

Project Partners	Contributions
Port of Long Beach	$300,000
Port of Los Angeles	$300,000
TransPower	Match funding provided under TransPower's EDPCD project, summarized in Section 6.4

Project Benefits

The EDII project supports the seven zero emission trucks from the EDPCD project, which will result in the day-to-day use of zero emission drayage trucks throughout the Ports. The tasks in the EDII Project will result in establishment of capabilities beyond those targeted in the initial EDPCD project. This includes incremental improvements in the management of the vehicle batteries to be recharged using specially-designed infrastructure, to initiate the manufacturing/engineering process to achieve cost-effective production of future electric trucks, and to improve overall vehicle reliability through improved diagnostics.

Figure 6.4: EDII Wall-mounted Electric Vehicles Support Equipment

Accomplishments During 2016

The project was completed in 2016, however, TransPower is continuing to work with their fleet operator partners California Cartage Company, National Retail Trucking, Knight Transportation, Three Rivers Trucking, and Pasha. These partners are operating the project vehicles and providing critical real-world operational data for the fleets and TransPower.

The following EDII project tasks were completed:

- Upgraded and installed battery charging infrastructure at fleet operator sites;
- Developed and demonstrated a next generation battery management system (BMS);
- Completed a manufacturing engineering process that evaluated new manufacturing methods aimed at reducing the costs of manufacturing key ElecTruck™ drive system components and subsystems; and
- Implemented improved failure analyses and diagnostics capabilities to enhance vehicle reliability.

TAP funds were applied toward the cost of installing enhanced electrical charging infrastructure for the seven EDPCD/EDII trucks. In addition to the completed installation of all charging infrastructure, the enhancements improved vehicle battery management, such as aiming to reduce electric vehicle down time by 50%, employing a new technology such as a touchscreen diagnostic interface, and making the battery management system more robust. In addition, manufacturing engineering was undertaken to move toward more cost-effective production of future electric trucks, and enhance overall vehicle reliability through improved diagnostics. Figure 6.4 depicts the EDII charging infrastructure.

6.6. SCAQMD Zero Emission 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, 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 Emission 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-emission 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 emission 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. 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 7 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.

The following is a short description of each of the project vehicles and technologies:

Center for Transportation and the Environment (CTE) - Under project management by CTE, BAE Systems will develop 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.

Transportation Power, Inc. (TransPower) - TransPower will develop 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, one of the world's leading suppliers of hydrogen fuel cells. The proposed 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.

US Hybrid - US Hybrid will develop 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.

Gas Technology Institute (GTI) - Under project management by GTI, contractor 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.

International Rectifier (IR) - IR was to develop one plug-in hybrid-electric truck (PHEV) and an ultra-fast charger (UFC) for use in or near the ports. Toward the end of 2015, IR was acquired by Infineon Technologies and in 2016 the company withdrew from the project as discussed in Section 6.1. SCAQMD is expected to finalize and confirm a replacement project for International Rectifier with another technology developer, Hydrogenics. The SCAQMD Board approved Hydrogenics as the replacement technology provider in October 2016, but the US Department of Energy must also approve this change. Approval is expected in early 2017.

Project Partners & Budget

The Ports are contributing $1,133,979 in co-funding to this project with a total project budget of $19,984,820. Table 6 summarizes the project funding contributions:

Table 6: SCAQMD Zero Emission Cargo Transport (ZECT) II Demonstration Funding Partners

Project Partners	Contributions
US 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 emission levels. This project supports the Ports' efforts in moving toward zero-emission technologies.

Accomplishments During 2016
TransPower and US Hybrid have both made strides in the design and integration of the vehicle components, respectively. The CTE/Kenworth and GTI/BAE Systems vehicles have made considerable progress to provide a more advanced level of technology readiness in their designs although their development timelines are more extensive.

2017 Milestones
Project milestones planned for 2017 include:

- Both TransPower and US Hybrid are expected to have a vehicle ready for testing and demonstration by 2nd quarter 2017.
- CTE will continue the system design work for its vehicle and secure a hydrogen fuel supply as well as finalize contracts needed for the project by 3rd quarter 2017.
- GTI is moving forward despite delays associated with the Siemens pantograph. Like CTE, GTI will also continue the system design work for its vehicle.
- SCAQMD is expected to finalize and confirm a replacement project for International Rectifier with another technology developer, Hydrogenics. The SCAQMD Board approved Hydrogenics as the replacement technology provider in October 2016, but the US Department of Energy must also approve this change. Approval is expected in early 2017.

6.7. VeRail Near-Zero Emissions Locomotive Demonstration

Project Description

VeRail Technologies, Inc. (VeRail) is developing a dual-fueled locomotive that combines near-zero emissions locomotive engines with onboard compressed natural gas (CNG) fuel storage. By converting an EMD SD40 locomotive, the VeRail VR21C4-df locomotive will be equipped with two (2) near-zero natural gas power modules and two (2) 600 hp diesel back-up Tier 4 gen-sets. The diesel gen-sets will only be used to meet peak power requirements and to provide a safety back-up should the natural gas system malfunction. The VeRail locomotive is specifically designed to meet current operating requirements for switching locomotive activities; the VR214-df will undergo a one-year demonstration in Pacific Harbor Line (PHL) operations for at least 3,000 hours as required by CARB for verification that the locomotive achieves EPA Tier 4 switcher locomotive engine emission standards and CARB near-zero emission requirements. The one-year demonstration will further validate the locomotive's in-use performance, durability, and reliability.

Figure 6.5: VeRail VR21C4-df dual fuel (diesel and natural gas) Locomotive

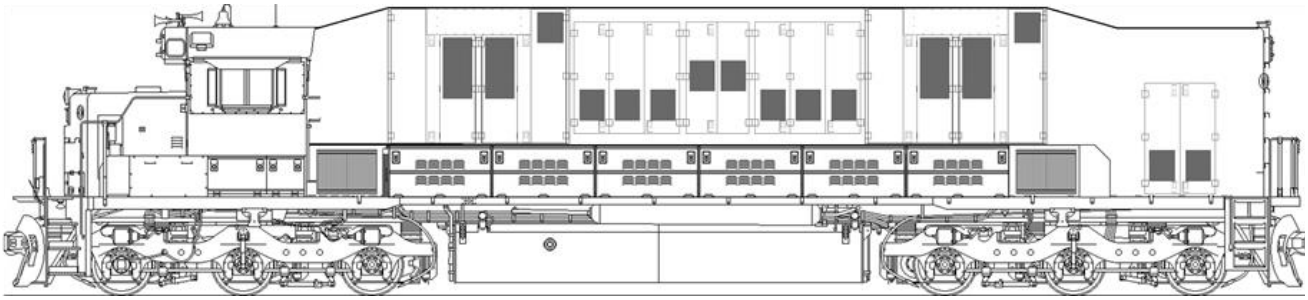
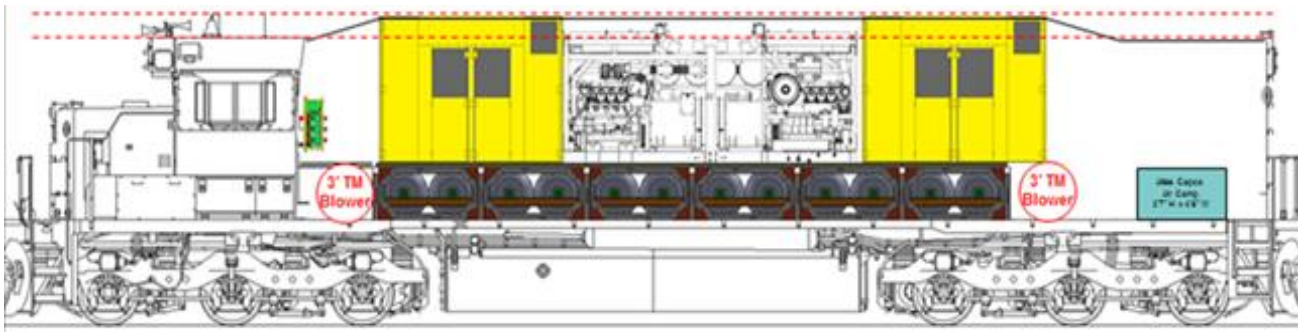


Figure 6.6: VeRail VR21C4-df dual fuel locomotive showing location of CNG tanks above the frame, dual 1,200 HP near-zero emissions natural gas Power Modules (in yellow), and twin 600 HP Tier 4 diesel gensets (between the natural gas Power Modules).



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 roughly $400,000. The total project budget is $5,100,000. Table 7 summarizes the project funding contributions:

Table 7: 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 4+" and near-zero emissions levels. The CARB Tier 4+ targets aim for a 70% reduction in both NOx and PM below current EPA Tier 4 locomotive standards. The VeRail VR-series dual fuel locomotive is projected to provide over 90% reduction of NOx and PM, and a 22% reduction of GHG. VeRail VR-series natural gas locomotives are projected to meet near-zero emissions targets for locomotives.

Figure 6.7: VeRail Turbocharged V8 600 HP NZE Engine

Accomplishments During 2016

In November 2016, the both Ports' Boards approved a $600,000 project with VeRail to develop and demonstrate the near-zero emissions locomotive with each Port contributing $300,000.

2017 Milestones

Integration of the core locomotive engine, generators, and gen-sets, including preliminary emissions testing is expected to occur in early-2017. Full locomotive conversion and

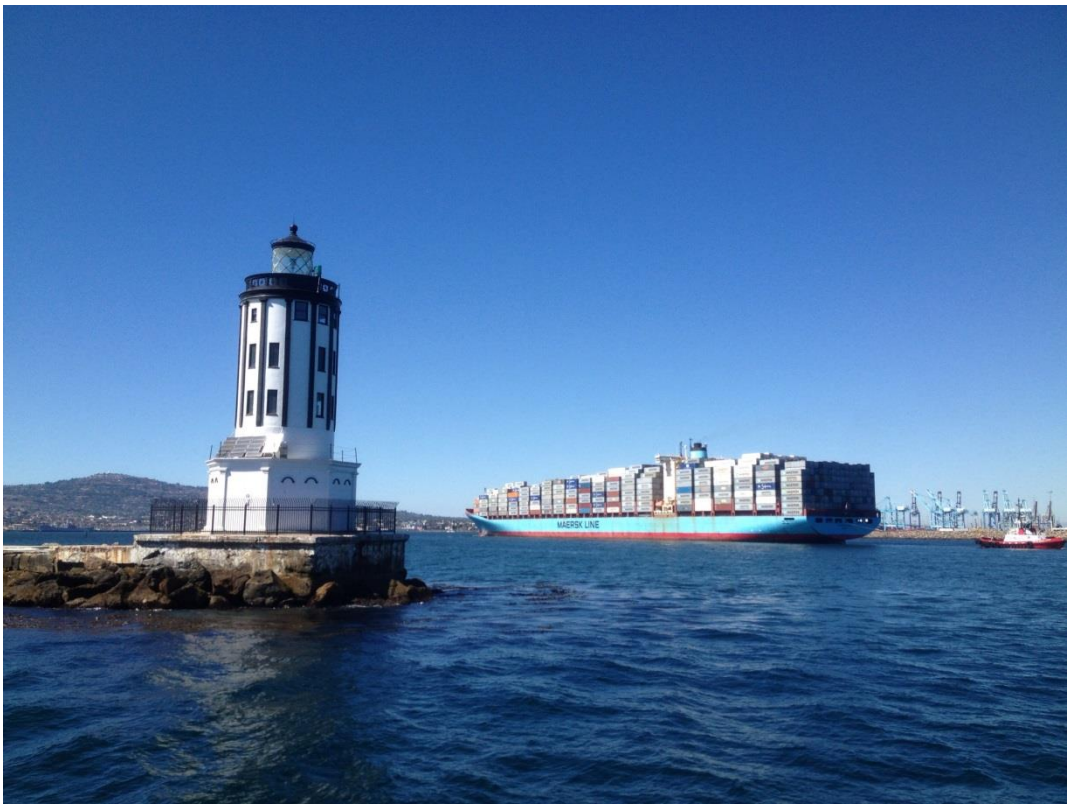
installation of the CNG fuel storage system and power modules is expected to be completed by the end of 2017 with delivery to PHL to begin the in-use performance demonstration at the end of 2017.

6.8. 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 6.8: *Gunvor Maersk* Entering Port of Los Angeles



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 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

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 CO_2 per year. DPM, NOx, and SOx are also reduced as a result of lower engine loads and the associated reduced fuel consumption.

In addition, an increase in carrying capacity will reduce the carbon footprint per container transported in line with globally accepted measurement of CO_2 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.

Accomplishments During 2016

The following tasks were completed in 2016:

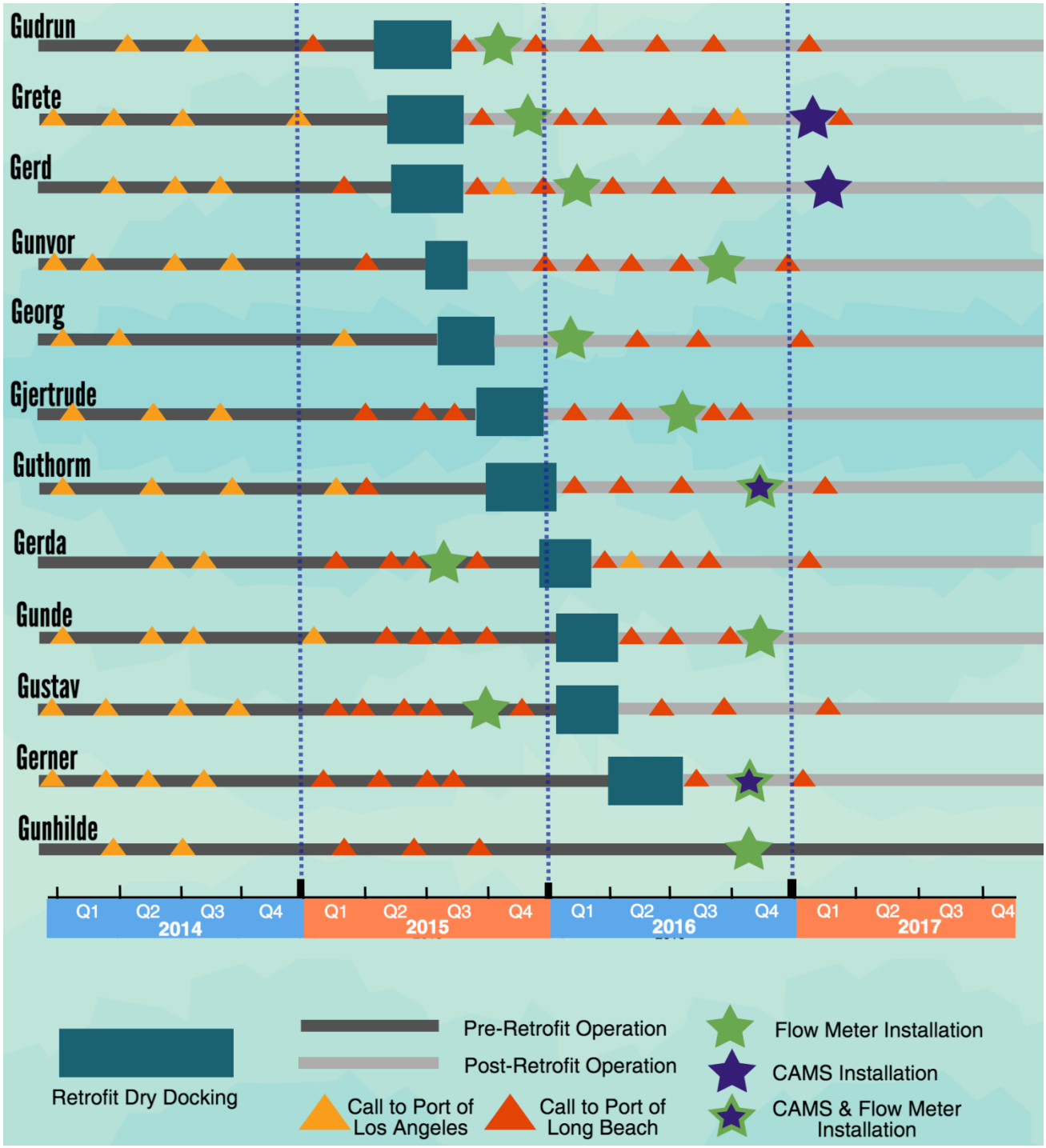
- Four primary datasets were pre-processed and initially evaluated in 2016. These datasets are the core datasets for the project and include: port call schedule, MSPS or noon reporting, 10 minute frequency Control Alarm Monitoring System (CAMS), and high frequency flow meter. The datasets were divided by pre- and post-Radical Retrofit and then temporally linked by ship. This process will continue through 2017.
- Maersk Line had completed 11 of the 12 ships through the Radical Retrofit and installation on 10 ships with enhanced fuel flow meters by the end of 2016. Figure 6.9 illustrates the progress on a ship-by-ship basis and when they called the San Pedro Bay Ports.
- Pre-Radical Retrofit data were collected from four ships in 2016, including the Gunhilde which has not undergone her Radical Retrofit and continues to provide pre-retrofit data. The pre-retrofit datasets are being pre-processed by the Global Vessel Performance Centre and made available to the Project Team.
- A team of three graduate students from the Duke University's Nicholas School of the Environment has been helping to identify and consolidate the various sources of data that will be used throughout the project. Their final report, to be completed at the end of April 2017, will include detailed summary statistics of pre- and post-retrofit data and recommendations for the methodology of further analysis. This background work will explain the scope of the project, present the sources of data, and help shape next steps.
- Work began on the Technical Work Plan, Vessel Characterization Report, and Data Collection Plan, as well as preliminary discussions on approaches to quantify energy efficiencies.

2017 Milestones

It is anticipated following work will be conducted on the Maersk TAP Project during 2017:

- Continue datasets collection from the fleet and associated pre-processing.
- Complete fleet rollout of Connected Vessel and CAMS/fuel flow meter data streams.
- Complete the alignment of the collected datasets by vessel and pre-/post- Radical Retrofit and compare all appropriate datasets temporally.
- Receive the Duke University final report and recommendations related to the larger TAP project.
- Select critical data elements to be used to quantify energy efficiency improvements and emissions. In addition, selected dataset elements will be defined and the source 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.

Figure 6.9: Radical Retrofit and Flow Meter Installation Timeline



7. 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. A brief summary for each project is provided below:

- **Overhead Catenary for Zero-Emissions Trucks:** SCAQMD's project with Siemens Industry Inc. (Siemens) to demonstrate an overhead catenary system (OCS) using Siemens' eHighway wayside power technology for heavy-duty trucks is well underway. SCAQMD and its agency partners are funding this project in the amount of $7,500,000. POLB contributed $2 million and POLA contributed $4 million from their Air Quality Mitigation Incentive Program to this project. The overall project budget is $13,500,000. The demonstration involves one mile of catenary power lines in both directions along Alameda Street in the City of Carson with four catenary accessible trucks from Volvo, TransPower and BAE/Kenworth. The trucks will demonstrate a variety of architectures such as diesel hybrid, CNG hybrid and battery electric. The hybrid drive system will extend 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.

- **METS-1 At-Berth Emission Reductions for Ships:** In 2012, the Port of Los Angeles contracted with TraPac, Inc. (TraPac) to demonstrate a mobile emissions treatment unit. TraPac demonstrated the Mobile Emissions Treatment System (METS-1), which is a barge-mounted emission control system developed by Clean Air Engineering-Maritime, Inc. This system is designed to reduce ocean going vessel at-berth auxiliary engine emissions. The system consists of two sub-systems: (1) a hood/transfer line/crane assembly designed to capture greater than 90% of the at-berth auxiliary engine exhaust, and (2) a Tri-Mer Corporation emissions treatment unit designed to achieve greater than 90% reduction in captured DPM and NOx. The Tri-Mer unit is a fourth generation design composed of a cloud chamber scrubber and a selective catalytic reduction unit to reduce the DPM and NOx emissions, respectively. Phase I measured the capture efficiency of the hood/transfer/crane assembly (emissions capture device) at the Pasha terminal. Phase II demonstrated a fully integrated system with the emissions capture device coupled with the emissions treatment unit on a mobile barge at the TraPac terminal. On June 25, 2015, CARB issued Executive Order AB-15-01, approving the METS-1 as an approved alternative technology under the At-Berth Regulation, with a capture efficiency of 90% and PM2.5 control of 95% and NOx control of 90%. Since approval of the METS-1, the system has been used on 47 ship calls to achieve shore power equivalency at the Port of Los Angeles.

- **Advanced Yard Tractor Deployment and Eco-FRATIS Drayage Truck Efficiency Project:** This project, which will begin in early 2017, includes three major components:

- Demonstrate 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.
- Demonstrate 5 yard tractors that will be equipped with BYD's zero emission 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 were executed in late 2016.

- **The Green Omni Terminal Demonstration Project:** 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.

8. 2016 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 9. Three new projects were approved and funded by the TAP in 2016. 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 9, TAP contractors are required to provide a minimum of 50 percent co-funding in the form of cash and/or in-kind contributions to each project. Required match contributions are not included in Table 9, but are noted within each project summary in Section 6.

Table 9 also contains technology projects funded by the Ports outside of the TAP budget.

Table 9: Ports' Technology Advancement Funding Investments through December 31, 2016

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 Emission Reductions for Ships	**2015**	$703,388*						$703,388
Tri-Mer Mobile Emissions Treatment System (METS-1) At-Berth Emission 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								
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
RYPOS Diesel Emission Control (L2+)	**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
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								
Vision Motor Corp. Hydrogen Fuel Cell Plug-In Hybrid Electric Truck	**2012**	*$95,625*	*$95,625*					*$191,250*
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
International Rectifier Plug-In Hybrid Electric Class 8 Truck Conversion	**2016**	*$17,500*	*$17,500*					*$35,000*

Table 9: Ports' Technology Advancement Funding Investments through December 31, 2016 (cont'd.)

Project Category	Year Completed	POLB	POLA	AQMD	CARB	US EPA/ USDOE/ METRO	CEC	Total Port & Agency Stakeholder
Container Drayage Trucks, Cont'd.								
US Hybrid On-Board Charger for Zero Emission 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 (EDII)	**2016**	$300,000	$300,000					$600,000
SCAQMD Zero Emission 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)		$7,749,496.21	$11,251,813.21	$8,673,906	$16,629,806	$13,872,200	$14,029,617	$72,206,838.42
Total Port TAP Investment		$4,678,927.21	$4,492,427.21					
Combined Ports' TAP Investment		**$9,171,354.42**						

*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.

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 Emission 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 Emission Cargo Transport Demonstration (2016)
25. VYCON REGEN® System for Rubber-Tired Gantry Cranes Testing & Verification (2007)
26. Westport GX LNG Engine Development (2010)