2011 Annual Report
May 2012

San Pedro Bay Ports Clean Air Action Plan Technology Advancement Program

Moving towards zero emissions

THE PORT OF LOS ANGELES

Port of LONG BEACH
The Green Port

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Acronyms & Abbreviations

AC	Advisory Committee
ACTI	Advanced Cleanup Technologies Incorporated
AMECS	Advanced Maritime Emissions Control System
APL	Shipping line formerly known as American President Line
AQIP	Air Quality Investment Program
CAAP	Clean Air Action Plan
CARB	California Air Resources Board
CCRT	catalyzed continuously regenerating technology
CRT	continuously regenerating technology
CEC	California Energy Commission
CEMS	continuous emissions monitoring system
CHE	Cargo Handling Equipment
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CSF	catalyzed soot filter
DOC	diesel oxidation catalyst
DPF	diesel particulate filter
DPM	diesel particulate matter
DPM_{10}	diesel particulate matter – 10 micron diameter
$DPM_{2.5}$	diesel particulate matter – 2.5 micron diameter
EGR	exhaust gas recirculation
EPA	United States Environmental Protection Agency
GCVWR	gross combined vehicle weight rating
GHG	greenhouse gases
H_2	hydrogen
HC	harbor craft
HHDDT	heavy heavy-duty diesel truck
HP	horsepower
HPDI	high pressure direct injection
IMO	International Maritime Organization
LNG	liquefied natural gas
MDO	marine diesel oil

Acronyms & Abbreviations (cont'd.)

MGO	marine gas oil
MOA	Memorandum of Agreement
MW	megawatt
NO	nitric oxide
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
nm	nautical miles
OGV	ocean going vessel
O_2	oxygen
PAH	polycyclic aromatic hydrocarbon
PHL	Pacific Harbor Line
POLA	Port of Los Angeles
POLB	Port of Long Beach
PON	Program Opportunity Notice
PM	particulate matter
PM_{10}	particulate matter less than 10 micrometers in diameter
$PM_{2.5}$	particulate matter less than 2.5 micrometers in diameter
RFI	Request for Information
RFP	Request for Proposals
RFQ	Request for Qualifications
RL	railroad locomotives
RTG	rubber tired gantry crane
SCAQMD	South Coast Air Quality Management District
SCR	selective catalytic reduction
SCRT	selective catalytic reduction technology
SiC	silicon carbide
SoCalGas	Southern California Gas Company
SO_x	sulfur oxides
SO_2	sulfur dioxide
SwRI	Southwest Research Institute
TAC	toxic air contaminant
TAP	Technology Advancement Program

Acronyms & Abbreviations (cont'd.)

U.S.	United States
VOC	volatile organic compound
VSR	vessel speed reduction
ZEV	zero-emission vehicle

Executive Summary

The ports of Long Beach and Los Angeles 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 over $300 billion in trade each year and supporting more than 500,000 jobs in Southern California. Although economic conditions have caused a near-term reduction in imports and exports, the latest economic forecasts still indicate that demand for containerized cargo moving through the Southern California region will increase significantly by the year 2035. The ports recognize that their ability to accommodate the projected growth in trade will depend upon their ability to address adverse environmental impacts that result from such trade.

In 2006, the ports of Long Beach and Los Angeles adopted their landmark joint Clean Air Action Plan (CAAP)[1]. The CAAP, which was updated in 2010 (2010 CAAP Update), guides the ports in their commitment to reduce the health risks and air emissions associated with port-related operations, while allowing port development and growth to continue. The original CAAP focused on the near-term, five-year planning window between 2006 and 2011, and targeted significant reductions in diesel particulate matter (DPM), nitrogen oxides (NOx), and sulfur oxides (SOx). DPM is of particular concern as it is linked to cancer and other serious health effects. NOx and SOx are contributors to the region's ozone smog and fine particulate matter levels, which are also important health concerns. The 2010 CAAP Update identifies near-term planning goals through 2014, a health risk reduction goal for 2020, and emissions reduction goals for the years 2014 and 2023.[2]

Over the past six years, the ports have made dramatic strides in reducing air emissions. CAAP programs like the Clean Trucks Program have slashed pollution from heavy-duty trucks. Green leases and state regulations have curbed emissions from cargo-handling equipment and harbor craft. Vessel speed reduction programs, accelerated shore-power deployment through lease requirements, and low-sulfur fuel regulations have led to significant drops in ship-related air pollution. Overall, between 2005 and 2010, San Pedro Bay Ports related DPM emissions were reduced by 70%, NOx emissions were reduced by 50% and SOx emissions were reduced by 73%. Despite this progress, the ports still have work to do in order to meet the aggressive pollution-reduction goals defined in the 2010 CAAP Update.

The TAP was developed to ensure that effective air pollution reduction strategies are commercially available to enable implementation of all CAAP measures. The purpose of the TAP is to identify and demonstrate new technologies or new applications of existing technologies that have a strong potential to reduce air pollution emissions from the CAAP source categories and meet CAAP goals. The Mission Statement for the TAP is to "accelerate the verification or commercial availability of new, clean technologies through evaluation and demonstration to move towards an emissions free port."

The TAP is funded on an annual basis by both ports. Each port allocates $1.5 million annually to new projects identified through the program. The ports maximize the effectiveness of this investment by leveraging the ports' funding with contributions from stakeholder agencies, including the United States Environmental Protection Agency Region 9 (U.S. EPA Region 9),

[1] *http://www.polb.com/civica/filebank/blobdload.asp?BlobID=3452*
[2] 2010 San Pedro Bay Ports Clean Air Action Plan Update (*www.cleanairactionplan.org/reports/documents.asp*)

California Air Resources Board (CARB), and South Coast Air Quality Management District (SCAQMD). Further, a minimum 50 percent co-funding contribution is required by the project implementer for all TAP projects. The TAP implementation process adopted by the ports is thoroughly outlined in the TAP Guidelines[3]. The TAP offers grant funding to support the demonstration of advanced technologies that:

a) have a high probability of achieving significant reductions in criteria pollutants as well as CARB-classified air toxic pollutants, specifically, DPM, NO_x, and SO_x,

b) are seeking CARB verification for the technology, and

c) present a strong business case for future successful technology commercialization.

In the simplest terms, the purpose of the TAP is to facilitate the development of additional, effective air pollution reduction strategies for the CAAP "toolbox."

Technology pursuits at the ports in support of CAAP measure implementation extend beyond the TAP. However, the TAP is complementary to other air pollution reduction efforts at each port. Given the TAP's primary focus of identifying, verifying, and commercializing technologies and products proven technically feasible and commercially viable under the TAP increase the ports' options and allow the ports to be more aggressive in pursuing CAAP measure implementation.

While the TAP primarily focuses on the demonstration of technologies that have a high potential to yield substantial criteria air pollutant reductions, the technologies demonstrated under the TAP often reduce greenhouse gases (GHG) and fine particulate matter (i.e., particle size of 2.5 micron in diameter, or smaller). As a matter of practice, GHG emission reduction potential is considered in the evaluation for each technology proposed for a TAP demonstration.

The TAP serves as the catalyst for identifying, evaluating, and demonstrating new and emerging emission reduction technologies applicable to the port industry. As envisioned by the ports at the onset of program implementation, successful TAP technologies are intended to be incorporated into CAAP updates as either new control measures, alternatives to existing emission reduction strategies, or as additional mitigation options to support port growth.

The TAP Advisory Committee (AC) consists of agency partners that include the Port of Long Beach (POLB), Port of Los Angeles (POLA), SCAQMD, CARB, and U.S. EPA Region 9. A list of current AC members is included in Appendix A. The AC serves in an advisory capacity to the ports 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 agency that could potentially be used to move projects toward implementation. The AC process 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. In 2012, the ports will focus on the need to accelerate the verification of TAP projects moving through CARB's process in order to minimize the time between concept and commercial application.

[3] *http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2489*

This is the fifth TAP Annual Report under the CAAP. The 2011 TAP Annual Report documents progress with the ports' efforts to support near-term emerging technology development and demonstration. This Annual Report includes a summary of the nine (9) projects that were either selected or continued to be implemented under the TAP during 2011. These include:

Source Category	TAP Project
▪ Ocean Going Vessels	Bluefield Holdings Inc./Krystallon OGV Scrubber
▪ Locomotives	Johnson Matthey Locomotive DPF Demonstration
▪ Harbor Craft	Hug Filtersystems Tier 4 Harbor Craft Retrofit
▪ Cargo Handling Equipment	RYPOS Advanced Diesel Particulate Filter for Cargo Handling Equipment
	Supplemental Demonstration of Hybrid Yard Hostlers – Beta Test
▪ Container Drayage Trucks	Vision Motor Corp. Hydrogen Fuel Cell Hybrid Electric Trucks (ZETT and Tyrano)
	Artisan GP8 All-Electric Truck Demonstration
	Development of a Drayage Truck Chassis Dynamometer Test Cycle
	AQMD Heavy-Duty Vehicle In-Use Emissions Testing Program

Each of the aforementioned projects listed is discussed in Section 2 of this 2011 TAP Annual Report. In addition to the initiation or continued implementation of the above projects, the following six (6) projects were completed in 2011:

- Balqon Lithium-Ion Battery Demonstration
- Alternative Petroleum Technologies' Emulsified Biodiesel
- Characterization of Drayage Truck Duty-Cycles
- Long Beach Container Terminal Eco-Crane™
- Supplemental Demonstration of Hybrid Yard Hostlers – Beta Test
- Development of a Drayage Truck Chassis Dynamometer Test Cycle

Please see Appendix B for complete summaries of these six recently completed projects, as well as the other ten projects completed by the TAP to date. It is noteworthy that in addition to a detailed discussion in Section 2, a brief summary is also provided for the last two projects in the above list, which were both initiated and completed within 2011.

1.0 TECHNOLOGY ADVANCEMENT PROGRAM

1.1 Introduction

The ports of Long Beach and Los Angeles 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 500,000 jobs in Southern California. Although economic conditions have resulted in a reduction in imports and exports, the latest economic forecasts still indicate that the demand for containerized cargo moving through the Southern California region will increase significantly 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.

While the economic benefits of the ports are felt throughout the nation, the environmental impacts of trade are more locally concentrated. The ports are cognizant of the view expressed by environmental groups, local residents, and regulatory agencies that more should be done to address port-related air quality issues. The ports understand that inconsistent or conflicting environmental measures could have unintended and even counterproductive results.

On November 22, 2010, the ports adopted an update to their landmark, joint Clean Air Action Plan (CAAP), reaffirming their commitment to reduce air pollution from the nation's two busiest seaports. The 2010 CAAP Update is part of the ports' original pledge to ensure that the CAAP continues to evolve to include new pollution-control measures and technology implementation approaches as they become available. The 2010 CAAP Update sets more aggressive and longer-term goals for reducing air pollution and the associated health risks from port operations. Specifically, the 2010 CAAP Update identifies near-term planning goals through 2014, a health risk reduction goal for 2020, and emissions reduction goals for the years 2014 and 2023.

Over the past six years, the ports have made dramatic strides in reducing air emissions. CAAP programs like the Clean Trucks Program 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 lease requirements and low-sulfur fuel regulations have led to significant drops in ship-related air pollution. Overall, between 2005 and 2010, San Pedro Bay Ports related DPM emissions were reduced by 70%, NOx emissions were reduced by 50% and SOx emissions were reduced by 73%. Despite this progress, the ports still have work to do in order to meet the aggressive pollution-reduction goals defined in the 2010 CAAP Update.

This document is the fifth Technology Advancement Program Annual Report under the CAAP.

1.2 Technology Advancement Program Objectives

The TAP Mission Statement is to "accelerate the verification or commercial availability of new, clean technologies through evaluation and demonstration to move towards an emissions free port."

The TAP thus serves as the catalyst for identifying, evaluating, and demonstrating new and emerging emissions reduction technologies applicable to the port industry. These technologies will be incorporated in future updates to the CAAP as either new control measures, alternatives to existing emission reduction strategies, or as additional mitigation options to support port growth.

The emphasis of the TAP is to facilitate testing or distribution of information on emerging technologies that can be used to reduce emissions associated with the five port-related source categories. These source categories include the following:

- Ocean Going Vessels
- Harbor Craft
- Cargo Handling Equipment
- Heavy-Duty Diesel Trucks
- Railroad Locomotives

1.3 Implementation Process

There are three primary means by which projects are identified for demonstration in the Technology Advancement Program:

1. *Port Generated Projects*

Should the ports have specific interest in an emissions reduction technology or project, the ports may elect to develop a project, seek partnerships to demonstrate the technology in port applications, and manage the implementation of the project. The ports may also seek grant funding from other stakeholders to assist with project implementation. During the 2011 calendar year, two new port-sponsored projects were generated under the TAP: the "Hybrid Yard Hostler Supplemental In-Use Demonstration" and the "Development of a Drayage Truck Chassis Dynamometer Test Cycle." Both are summarized in Section 2 as well as Appendix B.

2. Solicited Proposals

The ports enjoy broad authority under the TAP to solicit proposals for a specific technology or for technologies that are applicable to specified source categories. Common methods of soliciting projects include Requests for Information (RFI), Requests for Proposals (RFP), Requests for Qualifications (RFQ), and Program Opportunity Notices (PON). In 2011, the Port of Long Beach issued a Request for Proposal (RFP) to solicit new, innovative technologies that can be used to reduce ocean-going vessel (OGV) auxiliary engine and (potentially) auxiliary boiler exhaust emissions while vessels are berthed at the ports. The RFP was released in November, 2011; with responses due January 31, 2012. Port of Long Beach's efforts related to that RFP will be summarized in the 2012 Annual Report.

3. Unsolicited Proposals

The ports frequently receive requests to fund various technology advancement projects, either from port tenants working with technology providers, regulatory agencies conducting research or demonstration projects, or from technology developers/providers directly. When an unsolicited proposal is received by port staff, it is evaluated using the following criteria:

- Technology Application – *Is the technology applicable to the port industry? Is the application feasible?*
- CARB Verification – *Is the technology developer currently seeking, or are they willing to seek, CARB verification?*
- Matching Funds – *Is the project supported by in-kind or direct capital matching funds?*
- Emission Reductions – *Are the emission reductions consistent with the 2010 CAAP Update goals? Does the technology reduce some emissions without increasing others?*
- Ability to meet the needs of the port industry – *Will the technology perform effectively in the port environment?*
- Uniqueness of the Proposal – *Is the technology new or emerging, at the pre-commercialization stage? Has the technology or demonstration been proposed by multiple vendors?*
- Cost – *Is the cost for the technology reasonable?*
- Industry Support – *Does the project have a committed port-industry partner willing to demonstrate the technology?*

Unsolicited proposals that are deemed meritorious by port staff are forwarded to the TAP Advisory Committee for further review. During the 2011 calendar year, six (6) new projects were considered and approved under the TAP. These projects are listed below and summarized in Section 2:

- Johnson Matthey Locomotive DPF Demonstration
- Hug Filtersystems Tier 4 Harbor Craft Retrofit
- Supplemental Demonstration of Hybrid Yard Hostlers – Beta Test
- Artisan GP8 All-Electric Truck Demonstration
- Development of a Drayage Truck Chassis Dynamometer Test Cycle
- AQMD Heavy-Duty Vehicle In-Use Emissions Testing Program

1.4 Advisory Committee

The TAP Advisory Committee (AC) consists of agency partners that include the Port of Long Beach, Port of Los Angeles, SCAQMD, CARB, and U.S. EPA Region 9. The AC was established by invitation during the first quarter of 2007 and meets every six weeks to deliberate the merits of proposed TAP projects.

The AC serves in an advisory capacity to the ports for screening, evaluating, and recommending projects to be considered for further development or demonstration. The AC process 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.

The stated goal of the TAP program is to accelerate the development, verification, and commercialization of technologies that reduce source category air pollution emissions. The ports seek participation and funding contributions from other agencies for TAP projects. In this context, the AC members identify potential agency co-funding that could support TAP projects.

In 2011, the ports received a significant number of unsolicited proposals submitted for funding consideration under the TAP. Due to the wide range of technologies proposed, the AC membership was augmented on an ad-hoc basis to include additional members from the partnering agencies with expertise in diverse areas such as fuel additives, diesel emission control systems, and marine vessels. A list of current AC members is included in Appendix A of this Annual Report.

2.0 KEY PROJECTS IN 2011

This fifth Technology Advancement Program Annual Report includes a summary of the nine (9) projects that were implemented or remained active in 2011. These include:

Source Category	TAP Project
▪ Ocean Going Vessels	Bluefield Holdings Inc./Krystallon OGV Scrubber
▪ Locomotives	Johnson Matthey Locomotive DPF Demonstration
▪ Harbor Craft	Hug Filtersystems Tier 4 Harbor Craft Retrofit
▪ Cargo Handling Equipment Handling Equipment	RYPOS Advanced Diesel Particulate Filter for Cargo
	Supplemental Demonstration of Hybrid Yard Hostlers – Beta Test
▪ Container Drayage Trucks Trucks (ZETT and Tyrano)	Vision Motor Corp. Hydrogen Fuel Cell Hybrid Electric
	Artisan GP8 All-Electric Truck Demonstration
	Development of a Drayage Truck Chassis Dynamometer Test Cycle
	AQMD Heavy-Duty Vehicle In-Use Emissions Testing Program

A summary and status update for each of the projects listed above is discussed in this Annual Report (Section 2).

Six (6) TAP projects were completed during 2011 (the first six projects listed below). A summary of each newly completed TAP project, as well as all TAP projects completed to date, is included in Appendix B. Completed TAP projects since the inception of the program are:

1. Balqon Lithium-Ion Battery Demonstration
2. Alternative Petroleum Technologies' Emulsified Biodiesel
3. Characterization of Drayage Truck Duty-Cycles
4. Long Beach Container Terminal Eco-Crane™
5. Supplemental Demonstration of Hybrid Yard Hostlers – Beta Test
6. Development of a Drayage Truck Chassis Dynamometer Test Cycle
7. SoCalGas CNG Drayage Truck Demonstration
8. Westport GX LNG Engine Development
9. Foss Maritime Green Assist™ Hybrid Tugboat

10. Hybrid Yard Tractor Development & Demonstration
11. Capacity Plug-In Hybrid Electric Terminal Tractor
12. APL Singapore Slide Valve & Water-In-Fuel Emulsion Demonstration Program
13. Balqon E-30 Electric Terminal Tractor Development & Demonstration Project
14. Advanced Maritime Emission Control System (AMECS) Project
15. VYCON REGEN® System for Rubber-Tired Gantry Cranes Testing & Verification
16. Liquefied Natural Gas Yard Tractor Demonstration

2.1 Ocean-Going Vessels (OGVs)

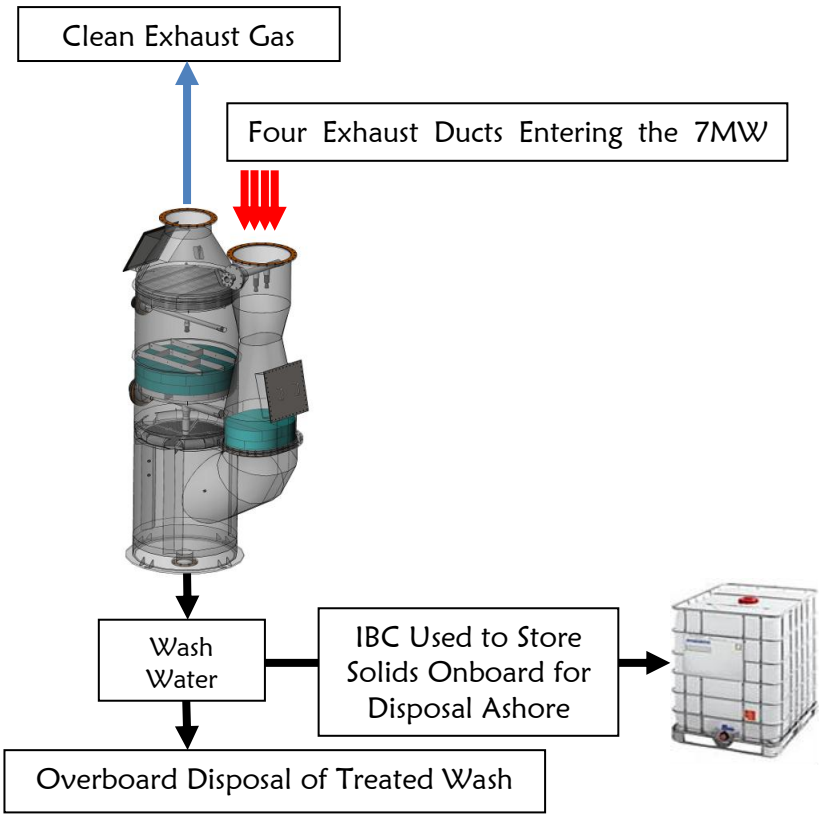
2.1.1 Bluefield Holdings Krystallon OGV Scrubber

The Bluefield Holdings/Krystallon seawater scrubber is an advanced emission control technology for OGVs. For this technology, seawater is used to "scrub," or filter, particulate contaminants from the vessel exhaust stream before the exhaust is emitted to the atmosphere. The wash water is treated to remove contaminants and chemical constituents and the pH is then adjusted to be compatible with seawater, before it is returned to the ocean. All recovered wash water contaminants are stored onboard the vessel until they can be properly disposed of ashore.

Emission Control Technology

For this TAP project, Bluefield Holdings will install, demonstrate, and quantify the emission reduction capabilities of a seven (7) megawatt (MW) Krystallon SC 500 scrubber on an APL C-11 class container ship. This will be the first SC 500 built by Krystallon to be commissioned and installed on an OGV. The Krystallon scrubber will be configured to treat the combined emissions from all auxiliary engines. The design schematic is provided below in Figure 2.1-1, and includes gas separation prior to the inlet of the scrubber, allowing the emissions from the boiler and all of the auxiliary engines to be treated simultaneously, or individually. This allows the most flexibility for the vessel and reduces the maximum emissions for the lowest capital investment and operating cost.

Figure 2.1-1: Schematic of the Krystallon Seawater Scrubber



The demonstration plan includes operating the scrubber within 200 nautical miles (nm) from shore all the way to the berth. Residual fuel oil, compliant with International Maritime Organization (IMO) regulations at the time of the evaluation, will be used in all engines from 200 nm to 24 nm; distillate fuel compliant with CARB regulations, will be used within 24 nautical miles (nm) of the California coast.

A real-time continuous emissions monitoring system (CEMS) is included as a component of the scrubber system. The challenging nature of the ship board environment, with elevated temperature and vibration, is well within the operational capabilities of the CEMS analyzers. The CEMS will allow the project team to track both emissions and discharge water from the scrubber. The continuous monitoring equipment functions whenever the scrubber is operating. Average and instantaneous measurements will be made for:

- Oxygen (O_2)
- Carbon monoxide (CO)
- Carbon dioxide (CO_2)
- Hydrocarbons (HC)
- Nitric oxide (NO)
- Nitrogen dioxide (NO_2)
- Nitric oxides (NO_x)
- Sulfur dioxide (SO_2)

In addition to the continuous monitoring, a third party contractor will collect and analyze discreet emission samples, including DPM, while at-berth. This testing will include engine operation results while the engines are operating on both residual fuel oil and marine distillate fuels. Sampling and testing of emissions and treated wash water will take place in the San Pedro Bay.

Project Partners & Funding

Significant prior investments have been made by the technology developer during the development of the multi-engine Krystallon SC 500 scrubber to be demonstrated under this TAP project. The Bluefield Holdings/Krystallon team invested over $15 million developing and commercializing seawater scrubber technology for heavy marine engines, and over the past year significant additional corporate investments have been made in the SC 500 designed specifically for the APL project. In addition to these prior investments, Krystallon will pay all costs to inspect the vessel, prepare submittals to the classification society, deliver final installation drawings to the owner and shipyard, as well as provide all supervision during the installation and commissioning process.

The ports' TAP funding contributions will be used to partially offset the costs associated with the scrubber equipment, as well as scrubber installation, testing, and reporting. Total TAP funding applied to the seawater scrubber demonstration is $1.65 million, as noted below in Table 2.1-1.

Table 2.1-1: Seawater Scrubber Demonstration Funding Partners

Project Partners	Contributions
▪ Port of Long Beach	$825,000
▪ Port of Los Angeles	$825,000
▪ Bluefield/Krystallon	$1,740,000

Environmental Benefits

This advanced version of the Krystallon scrubber is expected to remove over 80% of the total DPM normally emitted from a marine engine; including greater than 90% removal efficiency for PM_{10} and greater than 80% removal efficiency for $PM_{2.5}$. Testing of the material removed from the scrubber indicates that it can successfully remove solids down to 0.8 microns. These fine and ultrafine particles are typically composed of elemental carbon with adsorbed compounds such as polycyclic aromatic hydrocarbons (PAH), sulfate, nitrate, metals and other trace elements. These very small particles are lighter and they stay airborne longer and travel farther from the source. PM_{10} particles generally stay in the air for minutes or hours and travel as little as hundreds of yards while $PM_{2.5}$ and smaller particles can stay in the air for days or weeks and can potentially travel many hundreds of miles. The anticipated large reductions of DPM brought about by this project will be immediate; it is expected that significantly more DPM will be removed by the scrubber than simply running distillate fuel in the auxiliaries and boiler. Table 2.1-2 summarizes the expected emissions reduction results for this project.

Table 2.1-2: Expected Emission Reduction Effectiveness of the Krystallon Scrubber

Emission Reductions	PM10	PM2.5	SOx	VOC
Krystallon SC 500 Scrubber	>90%	>80%	~100%	>90%

The APL vessel to be retrofitted with the seawater scrubber technology will call at the San Pedro Bay ports at least four (4) times per year; that schedule is expected continue for the foreseeable future. Sulfur oxides (SOx), diesel particulate matter (DPM), and volatile organic compound (VOC) emissions will be significantly reduced and there will be essentially no sulfur dioxide in the emission from the scrubber.

Project Status

The scrubber was fabricated in Norway and installed on the vessel during a regularly scheduled dry-docking in China in February 2011. Krystallon engineers were onsite at the shipyard during the fabrication and installation of the scrubber. The installation was complete as of October 31, 2011. The project test plan, characterizing the emissions testing protocol to evaluate the scrubber's effectiveness, was submitted by Bluefield Holdings and is currently under staff review for approval. It is anticipated that emissions testing will be conducted in early 2012, once the final emissions testing plan is approved by port staff. It should be noted that emissions testing was delayed in order to incorporate important revision requests from CARB. These revisions expand the scope of testing with the hope that the ultimate assessment of the system's emission reduction capability may be more broadly applicable beyond a single engine size and load efficiencies. It is noteworthy that Bluefield will apply to CARB for an experimental permit that would allow engine operation on non-compliant fuels during emissions testing. This will facilitate emissions characterizations on heavy fuel oil and marine distillate fuels.

2.2 Locomotives

2.2.1 Johnson Matthey Locomotive DPF Demonstration

The ports of Los Angeles and Long Beach, in conjunction with CARB, SCAQMD, Union Pacific Railroad and Johnson Matthey have partnered to demonstrate and evaluate the effectiveness of a Johnson Matthey (JM) diesel particulate filter (DPF) as an aftertreatment device on a Union Pacific Railroad Switcher Locomotive equipped with three (3) Tier 3 700 horsepower (hp) gensets (total 2,100 hp). Once installed, it is anticipated that the JM system will help the Tier 3 engines meet Tier 4 PM emission standards, with additional reductions in CO and hyrdrocarbon emissions. This project will demonstrate the transferability of JM's DPF technology, which is typically used in on-road heavy-duty vehicle applications, to an off-road locomotive application.

CARB's Air Quality Investment Program (AQIP) grant to the SCAQMD is funding the technology development and demonstration phases of this project. The demonstration requires 2,000-3,000 engine hours of operation, and will determine the durability of the JM system against the shock and vibrational forces experienced during standard switcher locomotive operation. TAP project funding is programmed to cover emissions testing throughout the project and support the technology verification effort.

Emission Control Technologies

The JM Switcher Locomotive DPF System consists of multiple DPF, DOC, and catalyzed soot filter (CSF) components and is expected to achieve greater than 85% PM reduction, which allows Tier 3 engines to meet federal Tier 4 locomotive engine emission standards for PM. The Catalyzed Continuously Regenerating Technology (CCRT) system is a modified version of JM's Continuously Regenerating Technology (CRT) used in on-road applications, with the addition of a specialized coating to the filter. The coating enhances the passive regeneration potential of the system at lower temperatures. According to JM, lower DPF regeneration temperatures are important in a switcher locomotive application because locomotive engines have a temperature profile that is too low for other types of DPFs with the significant amount of time spent at idle. Additionally, the system is designed with a feature to minimize back pressure that helps to increase the service life between filter cleanings.

The design modifications made to the CCRT for this project consist of multiple DOC and CSF pairs. The sizing of the system and the choice of specific DOC and CSF depends on the exhaust characteristics of the engine. Johnson Matthey conducted baseline testing on a 2007 model year, QSK19 engine at Southwest Research Institute (SwRI) and gathered useful data on the engine out temperature, exhaust flow, and emissions. From this testing, an alpha system was designed and installed on one of the three genset engines of Union Pacific switcher UPY2737 (Figure 2.2-1). This earlier test served as a precursor to the current CARB AQIP demonstration, in which Union Pacific switcher UP2755 (Figure 2.2-2) was completely fitted with three DOC and CSF pairs (one for each genset).

Figure 2.2-1: JM System Installed on One Genset Engine of UP2737

Figure 2.2-2: JM System Fully Installed on all three Gensets of UP2755

Project Partners & Funding

The total budget for this project is $692,356, of which Johnson Matthey committed $146,246 in cash match funding (21% total). Half of the project costs are being covered by a fiscal year (FY) 2011-2012 CARB AQIP grant in the amount of $346,178, to support the durability demonstration effort. As a CARB policy, state funding cannot be expended to support verification-related expenses since CARB is the agency responsible for verifying emission reduction benefits of clean air technologies. In order to facilitate verification of this project, TAP funding in the amount of $150,000 ($75,000 per port) will support verification of the JM DPF system (i.e., emissions testing and verification costs).

Project costs are shown below in Table 2.2-1.

Table 2.2-1: Johnson Matthey Locomotive DPF Demonstration Funding Partners

Project Partners	Contributions
Port of Long Beach	$75,000
Port of Los Angeles	$75,000
California Air Resources Board (AQIP)	$346,178
Johnson Matthey	$146,246
Union Pacific	$49,932

Project Status

Design and installation of the Johnson Matthey system began in early 2011. After successful installation, the zero hour emissions testing showed the JM system achieved Tier 4 PM emission levels. The retrofitted switcher was placed into Union Pacific's revenue service on July 11th in fulfillment of the engine-hour durability testing requirement per the CARB AQIP agreement. As of December 31st, there were approximately 800 engine hours accrued on the switcher unit. Upon completion of the first 1,500 hours, the switcher will be sent to the SwRI, in San Antonio, TX to undergo the second round of emissions testing. A final set of emissions testing is planned at the end of the full demonstration period.

2.3 Harbor Craft

2.3.1 Hug Filtersystems Tier 4 Harbor Craft Retrofit

Under the TAP, Hug Filtersystems (Hug) will be demonstrating the effectiveness of retrofitting an existing harbor craft vessel, the Sause Brothers' tug boat Arapaho, operating at the Port of Long Beach, with an advanced diesel emission control system. The Hug mobiclean® advanced DPF/SCR system (mobiclean® system) is a passive-regeneration diesel particulate filter (DPF)/diesel oxidation catalyst (DOC) and selective catalytic reduction (SCR) system expected to reduce total particulate matter (PM) emissions by greater than 70 percent and nitrogen oxide (NOx) emissions by greater than 80 percent.

The Sause Brothers' construction tug boat Arapaho was repowered in late 2010 and is now equipped with two main propulsion 2010 Tier 2 MTU Detroit Diesel 12V 2000 M60 engines (805 hp, EPA engine family #AMDDN31.8MRR). As part of this TAP demonstration project, Hug will install and monitor two mobiclean® systems on each of the two Tier 2 main propulsion engines.

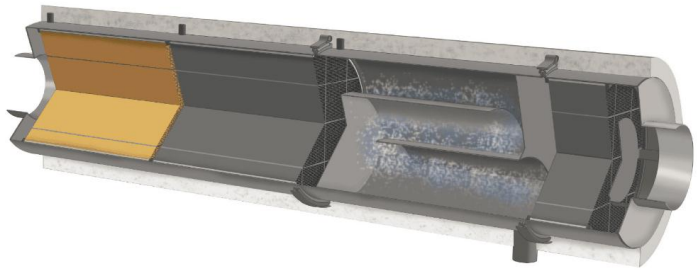
The objective of this demonstration project is to collect emission test data to submit to CARB in order to obtain Level 3 verification for the mobiclean® advanced DPF/SCR system for a broad range of harbor craft applications. Upon receiving CARB verification, Hug plans to market the mobiclean® system as a Tier 4 emission level upgrade kit for Tier 2 or newer vessel engines.

Emission Control Technologies

The Hug mobiclean® system is designed to be fitted on four-stroke marine engines with a range of 150 to 900 horsepower (hp) and a qualifying high exhaust temperature profile. The Hug mobiclean® advanced DPF/SCR system consists of a soot particle filter, soot regeneration, deNOx oxidation, and a control system.

The Hug mobiclean® filter system is based on a ceramic silicon carbide (SiC) honeycomb structure. The exhaust gases stream through the porous honeycomb walls, which help to retain more than 99 percent of fine particles (20-300 nanometers in size). Figure 2.3-1 provides an illustration of the Hug system.

Figure 2.3-1: Hug mobiclean® Diesel Particulate Filter System



The soot regeneration process is achieved by burning off particulate matter trapped in the filter. There are two types of regeneration: passive and active. The Hug mobiclean® system utilizes passive regeneration, where particulate matter is continually burned off during vessel operation using a combination of the exhaust heat and a catalyst to facilitate combustion of the soot.

In conjunction with the SCR system, the downstream DeNOx-Oxidation system reduces other pollutants in the exhaust gas, such as NOx, CO and hydrocarbon. Standard urea solutions are used as reactants and are injected before the soot filter, which helps to reduce NOx in the filter as well as in the downstream SCR-catalytic converter. The control system monitors the pollutants in the exhaust gas and adjusts the volume of urea solution injected, thus automatically adapting to different fuel qualities and pollutants.

Environmental Benefits

It is anticipated that the Hug mobiclean® system retrofit will reduce total PM emissions by greater than 70 percent and NOx emissions by greater than 80 percent on Tier 2 four-stroke marine engines. Successful demonstration of these emission reduction levels will allow Tier 2 harbor craft vessels to be retrofitted to meet Tier 4 emission standards. Table 2.3-1 compares Tier 2 standards to the emissions of engines equipped with the Hug mobiclean® system.

Table 2.3-1: Comparison of Tier 2 Emissions with and without Hug Mobiclean®

Tier 2 Engine Emission Standards		Tier 2 Engine with Hug mobiclean® Tier 4 Retrofit
PM	0.1 g/bhp-hr	PM <0.03 g/bhp-hr (>70% reduction from Tier 2)
NOx/HC	6.5 g/bhp-hr	NOx <1.3 g/bhp-hr (> 80% reduction from Tier 2)
		HC <0.14 g/bhp-hr

Project Partners & Funding

The total cost of the Hug Tier 4 retrofit demonstration project is $531,308. Using TAP funds, POLB and POLA each contributed $132,827, for a total of $265,654. The TAP funding is budgeted towards installation, emissions testing, reporting, and pursuit of CARB verification. Additionally, the SCAQMD will be contributing $100,000 in funding toward the project equipment purchase and installation. Hug and their participating vendor support team are covering the balance of project costs in the amount of $165,654. Sause Brothers is providing one of its construction tug boats, Arapaho, for use in the demonstration, though the value of this contribution is not quantified.

Project costs are summarized below in Table 2.3-2.

Table 2.3-2: Hug Filtersystems Tier 4 Retrofit Project Funding Partners

Project Partners	Contributions
Port of Long Beach	$132,827
Port of Los Angeles	$132,827
SCAQMD	$100,000
Hug Filtersystems	$165,654

Project Status

The project kick-off meeting was held on November 7, 2011. Installation of the Hug mobiclean® system is anticipated to occur in spring 2012. The demonstration project is approximately one year in duration, during which emissions testing and data collection will be conducted to support Hug's application to CARB seeking Level 3 verification.

It is noteworthy that Hug is working on a similar demonstration and verification project for 2-stroke marine engines with the SCAQMD under a CARB Air Quality Investment Program grant. TAP staff is tracking the progress of this "sister" project, although no TAP funding is allocated to that project.

2.4 Cargo Handling Equipment

2.4.1 RYPOS Advanced Diesel Particulate Filter for Cargo Handling Equipment

RYPOS Inc. (RYPOS) initiated a number of different project demonstrations in an effort to evaluate the effectiveness of their Hybrid Diesel Particulate Filter/Catalyst (HDPF/C™) system in various port equipment applications. These projects include:

- Installation of the HDPF/C™ system on an RTG crane at International Transportation Service, Inc. (ITS) at the Port of Long Beach in 2009;
- The HDPF/C™ system was installed on a top handler and a side handler at Seaside Transportation Services, LLC (STS) at the Port of Los Angeles in 2010; and
- Installation of the HDPF/C™ system on an RTG crane at STS terminal in early 2011.

The RYPOS HDPF/C™ was designed as a passive/active-regeneration diesel particulate filter estimated to reduce particulate matter emissions by more than 85 percent. The system incorporates a microprocessor-controlled, electric heating element to regenerate and burn off accumulated DPM captured by the filter without additional action by the equipment operator. A diesel oxidation catalyst (DOC) attached to the outlet of the particulate filter is used to remove the soluble organic fraction of particulate matter while also reducing hydrocarbon, carbon monoxide, and nitrogen dioxide emissions. Figure 2.3-2 provides a visual of the DPF location.

Figure 2.3-2: The RYPOS HDPF/C™ System Installed on an RTG Crane

During testing of the HDPF/C™ on the RTG crane at ITS, it was discovered that particulate matter had accumulated on the filter, indicating that the filter's regeneration process did not operate properly. This was likely a result of the RTG crane's low exhaust temperatures, low loads, and long idle periods. To address this issue, RYPOS has since redesigned and upgraded the HDPF/C™ for RTG cranes and top and side handlers with a new all-electric charged, active regeneration filter—the ActiveDPF/C™. While the previous HDPF/C™ system used on the RTG crane regenerated the filter at a specified exhaust temperature to activate the regeneration process, the ActiveDPF/C™ is designed to regenerate at any exhaust temperature and is not affected by idling.

Emission Control Technologies

The RYPOS ActiveDPF/C™ system consists of the filter housing, flow control, electrical control circuit, and filter cartridges. The electrical control circuitry automatically monitors and controls the regeneration of the filter cartridges.

The diesel particulate filter cartridge is composed of sintered metal fibers that are shaped into filter elements and then incorporated into filter cartridges. These sintered metal fiber cartridges are capable of capturing the very fine carbon particles present in the exhaust stream, with high efficiency and high holding capacity.

The diesel oxidation catalyst filter cartridge reduces CO, NO_2, and hydrocarbon emissions, and can act as a sound absorption device, replacing the muffler while occupying the same space.

The operation of the RYPOS ActiveDPF/C™ is controlled by a microprocessor. The controller monitors the filters and, as required, an electric current is passed through a filter element, which then acts as a heating element. A dedicated power source provides the required electrical current to heat each filter element individually to the temperature required to burn soot, reducing the maximum amount of electrical energy required. This regeneration strategy is designed to keep the back pressure below a pre-set level. The average power consumption required for regeneration is less than one percent of the rated power of the engine.

Project Partners & Funding

The total cost of the RYPOS ActiveDPF/C™ demonstration is $322,140. Using TAP funds, each port contributed $64,668. The TAP funding is budgeted primarily for emissions testing and receipt of CARB verification. RYPOS and their participating vendor support team are covering the balance of project costs, at $192,804. Project costs are shown below in Table 2.4-1.

Table 2.4-1: RYPOS ActiveDPF/C Demonstration Funding Partners

Project Partners	Contributions
Port of Long Beach	$64,668
Port of Los Angeles	$64,668
RYPOS	$192,804

Environmental Benefits

The RYPOS ActiveDPF/C™ has been verified by CARB to reduce particulate matter in the RTG crane application at CARB Level 2-plus verification (50%, but actual test results showed 83% effectiveness). RYPOS is working to achieve Level 3 verification for CHE in 2012.

Project Status

To demonstrate the RYPOS ActiveDPF/C™ operational effectiveness, the system was installed on a 2004 Mitsui/Paceco RTG crane at ITS in the Port of Long Beach in late 2010, and on a 2003 Mitsui/Paceco RTG crane at STS in the Port of Los Angeles in early 2011. In August 2011, RYPOS accepted a CARB Level 2 Plus verification (greater than 50 percent particulate matter reduction) for the ActiveDPF/C™ system on RTG cranes.

As a result of the filter regeneration issues encountered during testing of the HDPF/C™ system on the RTG, RYPOS developed the same ActiveDPF/C™ system for use in top handlers and side handlers. RYPOS anticipates installing the Active DPF/C on a top handler and side handler at STS in early 2012 to undergo in-use operational testing. The in-use operational test plan is currently being reviewed by CARB. Once approved, RYPOS will seek CARB Level 3 verification (greater than 85% particulate matter reduction) for the Active DPF/C™ system on top handlers and side handlers. RYPOS expects to receive verification of the system in mid- to late-2012.

In addition, RYPOS plans to further demonstrate the ActiveDPF/C™ on an older RTG crane in an attempt to achieve greater than 85% reduction in particulate matter and obtain CARB Level 3 verification by adjusting the software that dictates how often regeneration occurs. Such demonstration will be completed outside the scope of the TAP, though port staff will follow any progress made in order to provide status updates of the technology to interested terminal operators.

2.4.2 Supplemental Hybrid Yard Hostler Demonstration – Beta Test

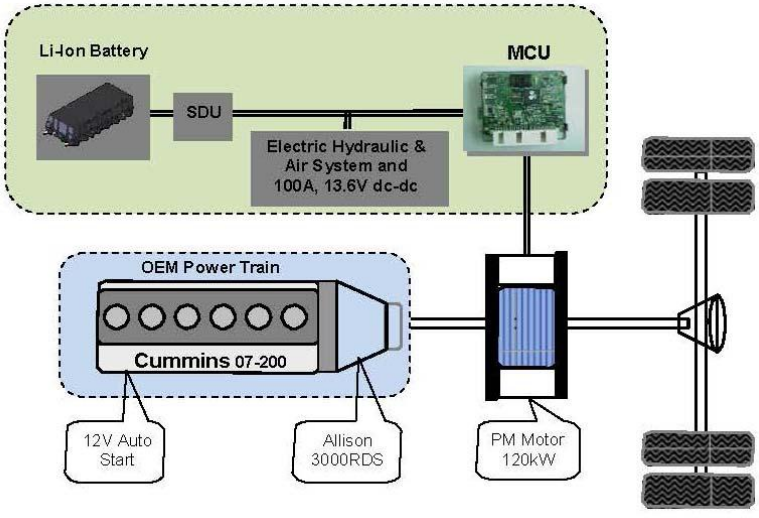
As a follow-on to the Hybrid Yard Tractor Development & Demonstration Project[4] conducted in 2010, the Port of Long Beach, Port of Los Angeles, US Hybrid and Long Beach Container Terminal (LBCT) assessed the potential in-use fuel economy performance of newly modified hybrid yard hostlers from February to June 2011 under a new project titled "Supplemental Hybrid Yard Hostler Demonstration–Beta Test".

More information regarding the previous Hybrid Yard Tractor Development & Demonstration Project may be found in Appendix B: Summary Reports for Completed Projects.

Emission Control Technologies

The hybrid yard hostlers demonstrated consist of standard Kalmar Ottawa yard hostlers fitted with a parallel hybrid-electric power train as shown in Figure 2.4-1. Following the initial demonstration of the hybrid yard hostlers in 2010, US Hybrid modified the hybrid system in an effort to improve fuel economy. In particular, US Hybrid altered the battery management algorithm, hybrid control algorithm, idle management strategy, and increased the capacity of the traction battery. These modifications resulted in what was called the "Generation 1.1" configuration. Near the end of this second demonstration, US Hybrid provided a second unit to LBCT that incorporated several additional modifications, including changes to the transmission control algorithm, electric motor, and motor control unit. This configuration is referred to as "Generation 2.0". Specifications for the baseline diesel tractors and all three generations of the hybrid tractors are provided in Table 2.4-2.

Figure 2.4-1: US Hybrid Yard Hostler Powertrain



[4] Final Report entitled "Hybrid Yard Hostler Demonstration and Commercialization Project" available for download at: *http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2516*

Table 2.4-2: Summary of Yard Hostler Configurations

Parameter	Diesel Baseline	Hybrid Generation 1	Hybrid Generation 1.1	Hybrid Generation 2.0
UTR Numbers	180,159,172	02, 03, 04	03	04
Engine	Cummins ISB 6.7L, 240 HP	Cummins ISB 6.7L, 200 HP	Cummins ISB 6.7L, 200 HP	Cummins ISB 6.7L, 200 HP
Emissions Standard	2007 On-road	2007 On-road	2007 On-road	2007 On-road
Electric Motor	N/A	120 kW	120 kW	120 kW
Battery Pack	N/A	2.3 kW-hr Li-Ion	2.3 kW-hr Li-Ion	2.8 kW-hr Li-Ion
Rear axle ratio	10.62:1	12.28:1	12.28:1	12.28:1
Modifications from previous "Generation"	N/A	N/A	1. Modified battery Energy algorithm. 2. Modified the Hybrid control algorithm to better fit the drive cycle. 3. Modified the idle control strategy.	1. Designed a new motor that fits the 12.28:1 ratio and provide high speed operation. 2. Modified transmission control algorithm 3. Modified electric motor control unit to increase the torque

Project Partners & Funding

The total cost of the supplemental demonstration was $26,000 which was split evenly between the two ports (or $13,000/port).

Project costs are shown below in Table 2.4-3.

Table 2.4-3: Hybrid Yard Hostler Supplemental In-Use Demonstration Funding Partners

Project Partners	Contributions
Port of Long Beach	$13,000
Port of Los Angeles	$13,000

Project Status and Results

To evaluate the vehicles' in-use fuel economy, US Hybrid equipped the hybrid yard hostlers used in the demonstrations with a data acquisition system known as iDrive. The iDrive system records several parameters including engine data, battery data, fuel use, and vehicle operating time. A similar system is not available for the baseline diesel tractors; therefore, iDrive data can only be compared between US Hybrid units.

Table 2.4-4 below summarizes iDrive data for the hybrid yard hostlers utilized in the Beta Test. Data for the hybrid yard hostlers (UTR 01 and UTR 02), collected during the previous demonstration period, are also shown. UTR 01 was modified to incorporate Generation 1.1 modifications, and was renamed as UTR 03 for the Beta Test, and UTR 02 was modified to incorporate Generation 2.0 changes and renamed as UTR 04 for the Beta Test.

As shown by the last two columns of Table 2.4-4, the iDrive data consistently indicated a lower fuel consumption rate than what was reported by the paper fuel logs. Comparing the iDrive data between UTR 01 and 03 in ship service[5], the average fuel economy in gallons per hour (GPH) for UTR 03 is nearly identical to UTR 01 (1.63 GPH and 1.58 GPH, respectively). Generally, the GPH fuel rates gathered from iDrive and the paper fuel logs completed by LBCT support the conclusion that no significant improvement in fuel economy was achieved by either the Generation 1.0 or Generation 1.1 hybrids in ship service. Conclusions regarding rail service or the benefits of the Generation 2.0 hybrid are not drawn as the data are too sparse to average out short term fluctuations in fuel consumption rates.

Table 2.4-4: Summary of iDrive data for US Hybrid Yard Hostlers

UTR	Date Range	Service	Power Cycles w/ Fuel Use	Fuel Consumed (gallons)	Operating Time (hours)	Avg Fuel Rate (GPH)	Paper Log Fuel Rate (GPH)
03	May 9, 2011-June 12, 2011	Ship	143	130	88	1.48	1.78
03	April 10, 2011-May 1,2011	Ship	108	190	115	1.66	1.72
03	Jan 31, 2011-April 9, 2011	Ship	280	434	261	1.66	1.84
03	Total	Ship	531	754	464	1.63	1.80**
01*	June-Nov 2010*	Ship*	1,102*	1,217*	770*	1.58*	1.8*
04	May 9, 2011-June 12, 2011	Rail	91	66	37	1.78	2.08
03	May 1, 2011-May 8, 2011	Rail	40	59	35	1.70	1.84
02*	June-Nov 2010*	Rail*	190*	314*	148*	2.12*	2.38*

Notes:
*Denotes data from previous demonstration
**Indicates a weighted average of data in each date range, based on fuel consumption
UTR 03 is UTR 01 with generation 1.1 upgrades UTR 04 is UTR 02 with Generation 2.0 upgrades.

[5] Ship service consists of container transport between a ship and the container stacks inside the terminal. Rail service is similar to ship service except that containers are transferred to and from rail cars. Yard service (also called dock work) involves moving containers between stacks or to/from loading areas for drayage trucks. Of the three services, ship service is the most consistent at LBCT. Drivers work fixed shift durations and travel a relatively consistent path within the yard.

The results of the analysis support the following conclusions:

1. Based on the iDrive data acquisition system and paper fuel logs completed by LBCT, the Generation 1.1 yard hostler placed into service at LBCT did not demonstrate significantly different fuel economy compared to either the baseline yard hostler or the Generation 1.0 hybrid yard hostler tested during the previous demonstration.

2. Because the Generation 2.0 yard hostler was placed into ship service close to the end of the demonstration period, there was insufficient fuel consumption data collected to make any conclusions regarding its fuel economy.

3. Generation 2.0 yard hostlers have been redesigned to address the fuel economy performance issues encountered in the previous demonstration. The consistency of fuel consumption data and the high level of use of tractors in ship service make this the preferred service to demonstrate the Generation 2.0 or future generation hybrid yard hostlers.

Following the completion of the project, the hybrid systems were removed and the vehicles were returned to their original equipment configuration by Kalmar. Further demonstration of the hybrid drive technology in yard hostlers continues in a separate, but parallel, project conducted by the New York Power Authority and the Port Authority of New York/New Jersey. Three of the newer generation hybrid yard hostlers have been operating in day-to-day terminal operations at New York Container Terminal since 2010. Similar to the project conducted at LBCT, the hybrid vehicles' in-use performance and fuel economy are being assessed. In addition, chassis dynamometer emissions testing will be conducted. The TAP will continue to monitor the progress of that demonstration project.

2.5 Container Drayage Trucks

2.5.1 Vision Motor Corp. Hydrogen Fuel Cell Plug-In Hybrid Electric Trucks

In 2011, Vision Motor Corporation's (Vision) continued their work to demonstrate a zero emission hydrogen fuel cell/hybrid-electric drive system in short haul drayage and terminal container movement operations. The project includes the design, development and demonstration of two vehicle types: 1) the Tyrano™ class 8 on-road truck equipped with Vision's proprietary hydrogen (H2) fuel cell/hybrid electric drive system; and 2) an off-road terminal tractor equipped with a similar zero-emission hybrid drive system. During the demonstration, each vehicle will undergo performance testing to validate maximum speed and maximum daily operating range under various payloads and conditions.

The design and development of the Tyrano™ class 8 on-road truck has been completed. The design and development of the off-road terminal tractor, or the Zero Emission Terminal Tractor (ZETT), is underway. The in-service demonstration for the Tyrano and ZETT are scheduled to begin in 2012 following a preliminary testing period prior to placing the vehicles in demonstration service.

Emission Control Technologies

The Class 8 truck is powered by a battery electric drive system that incorporates a hydrogen fuel cell range extender. The design specifications include an estimated 8-hour shift with a range of 200 miles, a governed maximum highway speed of 65 miles per hour, and ability to haul an 80,000 pound payload.

Vehicle System Specifications for the Vision TYRANO™ include the following:

- Vehicle Chassis: Freightliner Cascadia class 8 chassis or equivalent, equipped with air conditioning and heater/defroster;
- Fuel Cell: Hydrogenics Corporation hydrogen fuel cell with two (2) year/5,000 hour extended warranty or equivalent;
- Drive System: Vision Motor Corp. proprietary TYRANO™ hydrogen fuel cell/plug-in electric hybrid drive system;

Performance specifications for the TYRANO™ class 8 on-road truck include:

- Range: 200 miles over an eight (8) hour duration;
- Top Speed: Electronically governed at 65 mph at 80,000 pounds gross combined vehicle weight rating (GCVWR);
- Acceleration: Zero to 15 mph in less than or equal to twelve (12) seconds at 80,000 pounds GCVWR;
- Capacity: 80,000 pound maximum GCVWR;
- Gradeability: Forty (40) mph sustained at 6% grade with vehicle at maximum GCVWR;
- H2 Refueling Time: Average demonstrated refueling time of four (4) to seven (7) minutes;
- Operating Limits: Ambient temperature limits of -15 degrees Fahrenheit to +110 degrees Fahrenheit;
- Horsepower: 402 peak hp;
- Torque: 3,200 pound-feet electronically limited.

As mentioned earlier, Vision will be completing their design, development, and integration of a Hydrogen Fuel Cell/Plug-in Electric Hybrid Drive Zero Emission Terminal Tractor (ZETT) in 2012. The ZETT will be designed for container movement operations at a terminal yard.

Vehicle System Specifications for the ZETT include the following:

- Vehicle Chassis: Capacity terminal tractor;
- Fuel Cell: Hydrogenics Corporation hydrogen fuel cell with two (2) year/5,000 hour extended warranty or equivalent;
- Drive System: Vision Motor Corp. proprietary hydrogen fuel cell/plug-in electric hybrid drive system.

The ZETT terminal tractor will have the following minimum performance specifications:

- Range: 100 miles over an eight (8) hour duration;
- Capacity: 130,000 pound maximum GCVWR;
- H2 Refueling Time: Average demonstrated refueling time of four (4) to seven (7) minutes;
- Operating Limits: Ambient temperature limits of -15 degrees Fahrenheit to +110 degrees Fahrenheit;
- Horsepower: 402 peak hp;
- Torque: 3,200 pound-feet electronically limited.

Project Partners & Funding

Funding for the Hydrogen Fuel Cell Heavy-Duty Class 8 Short Haul Truck and Zero-Emission Terminal Tractor Demonstration is being provided by POLB and POLA, each contributing $212,500, for a total of $425,000 in TAP funding for this project. In addition, Vision committed matching funds in the amount of $574,211 toward this demonstration project. Table 2.5-1 summarizes the funding contributions from each project partner.

Table 2.5-1: Vision Demonstration Funding Partners

Project Partners	Contributions
▪ Port of Long Beach	$212,500
▪ Port of Los Angeles	$212,500
▪ Vision Motors	$574,211

Environmental Benefits

Zero-emission vehicles (ZEVs) provide significant environmental benefits. Tailpipe emissions are completely eliminated, and even on a lifecycle basis (i.e., including the fuel cycle emissions of hydrogen versus petroleum diesel fuel production and distribution), the ZEVs are cleaner than conventional alternatives. Successful completion of this project will directly support the joint port effort to increase the use of zero-emission technology in port equipment. This effort is detailed[6] in the ports' "Roadmap for Moving Forward with Zero Emission Technologies at the Ports of Long Beach and Los Angeles."

[6] This report can be downloaded from *http://www.cleanairactionplan.org/reports/default.asp*

Project Status

On July 22, 2011, the Tyrano™ class 8 was delivered to Total Terminal Services, Inc. (TTSI). Per their demonstration test plan, Vision and TTSI are currently testing the Tryano™ prior to putting the on-road truck into service. There have been some delays in initiating the demonstration due to difficulty with securing a hydrogen fuel source. Upon the successful integration of the Vision system, the ZETT will also be put through a testing period prior to being placed into service. Both the Tryano and the ZETT are scheduled to begin the 18-month in-use demonstration in early 2012, and completion is targeted by the end of 2013.

2.5.2 Artisan Vehicle Systems GP8e Electric Truck Project

Under the TAP, Artisan Vehicle Systems (Artisan) will be demonstrating a Class 8 drayage all-electric, zero emission truck (model name GP8e), which will be specifically designed for short-haul drive cycles commonly seen in drayage operations.

West Coast Container Services (WCCS) has agreed to operate the GP8e truck for transport in and out of the San Pedro Bay Ports. WCCS will facilitate registration of the truck in the ports' Clean Truck Program and obtain applicable permits to operate the GP8e truck at the ports. The demonstration will be conducted over a period of 18 months.

The objective of this project is to demonstrate a Class 8 drayage truck with zero tailpipe emissions. As part of the demonstration project, Artisan will work with CARB to receive agency validation of this vehicle's zero-emission status. While CARB's official verification program is focused on identifying emission reductions from add-on or retrofit technologies rather than engine systems, the proposed vehicles will be operated under a CARB experimental permit and will seek an acknowledgement from CARB regarding their zero emission attributes. The opportunity for CARB certification of the vehicle/engine system will also be investigated.

Emission Control Technologies

Artisan Vehicle Systems designs, engineers, and develops prototypes of zero-emission advanced technology powertrains. Artisan is the parent company of CalMotors, and is experienced in implementing several clean technology vehicle systems including parallel hybrid powertrains, series hybrid powertrains, permanent magnet motors, high power inverters, and master vehicle control systems. Artisan customers include the U.S. military, large original engine manufacturers, commercial vehicles, passenger cars, earth moving equipment, and utility vehicles.

Kenworth, a Class 8 truck manufacturer, has agreed to provide a glider for this demonstration project. The GP8e is anticipated to haul a gross vehicle weight of 80,000 pounds. Power to the all-electric powertrain (i.e., engine and transmission) is supplied by a 256 kWh lithium iron phosphate battery pack that is capable of being recharged with a 100 kW fast charging system (two to three hour recharging time), which interfaces to the truck's on-board battery management system. Regenerative braking is also integrated, capturing kinetic energy to recharge batteries and extend the range. The powertrain consists of a 313kW three-phase permanent magnet traction motor and gear reduction with 1,632 lbs/ft torque mated to a standard Eaton 10-speed transmission.

Environmental Benefits

Zero-emission vehicles provide significant environmental benefits since tailpipe emissions are completely eliminated. Successful completion of this project also supports the joint port effort to increase the use of zero-emission technology at the port. This effort is detailed[7] in the ports' "Roadmap for Moving Forward with Zero Emission Technologies at the Ports of Long Beach and Los Angeles".

Project Partners & Funding

The total cost of the GP8e truck demonstration project is $1,220,744. Using TAP funds, the POLB and POLA each committed to contribute $150,000 ($300,000 total). The TAP funding is programmed to support the design, development, integration, test plan, GP8e truck demonstration, and reporting. Artisan will cover the balance of project costs in the amount of $920,744. West Coast Container Services (WCCS) has agreed to operate the GP8e truck for transport in and out of the San Pedro Bay ports.

Project costs are summarized below in Table 2.5-3.

Table 2.5-3: Artisan Vehicle Systems GP8 Truck Project Funding Partners

Project Partners	Contributions
Port of Long Beach	$150,000
Port of Los Angeles	$150,000
Artisan	$920,744

Project Status

The project kick-off meeting was held on October 11, 2011. The detailed scope of work is currently being finalized after which the project funding contract will be processed for final approval. Notice to proceed will be issued upon contract execution and vehicle development is anticipated to begin in 2012. The delivery of the GP8e truck is anticipated for summer 2012. The demonstration project is approximately 18 months in duration, during which assessment of the GP8e truck ZEV capability will be assessed.

2.5.3 Development of a Drayage Truck Chassis Dynamometer Test Cycle

In early 2011, the Port of Long Beach and Port of Los Angeles released a report[8] that characterized the duty cycle of on-road, Class 8 drayage trucks at the ports. The report included statistics based on over 1,000 truck trips collected over a four-week period in late 2010. Based on these statistics, five modes of operation and an "average" trip associated with each mode were identified. The statistics and trip data from this earlier work provided important information on the real-world operation of drayage trucks in the South Coast Air Basin.

[7] This report can be downloaded from *http://www.cleanairactionplan.org/reports/default.asp*
[8] This report may be downloaded at: *http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2526*

As a follow-up to the TAP's earlier "Heavy-Duty Drayage Truck Duty-Cycle Characterization" project, this project provided a chassis dynamometer test cycle suitable for use when testing heavy-duty vehicles on a chassis dynamometer that is based on the modes of operation and trip data previously identified.

Project Partners & Funding

POLB and POLA initiated this project to fulfill the need for drayage truck operational profiles that the ports are uniquely positioned to support. The ports contracted with Tetra Tech and their subcontractor TIAX, LLC, an internationally recognized expert in the field of duty-cycle characterization and development. The ports funded the study to support future TAP and outside agency efforts to evaluate technologies that reduce emissions from heavy-duty trucks. Table 2.5-4 summarizes the project funding contributions.

Table 2.5-4: HDV Duty Cycle Funding Partners

Project Partners	Contributions
Port of Long Beach	$12,000
Port of Los Angeles	$11,466

Project Status

The chassis dynamometer test cycle was intended to provide the ports with a tool to compare the emissions performance from various drayage truck technologies. While this cycle has been developed using actual in-use drayage truck data and methods similar to those used to develop the widely used heavy heavy-duty diesel duty truck (HHDDT) test cycle used by test labs nationwide, this new drayage truck cycle has not yet benefitted from validation on a chassis dynamometer.

Currently, the SCAQMD is preparing to conduct emissions testing on several heavy-duty vehicles, including diesel and liquefied natural gas drayage trucks, as part of their HDV In-Use Emissions Testing Program. The ports will participate by providing the test cycle developed in this project for use in SCAQMD's multi-vehicle testing program. The drayage truck cycle will be used to assess drayage truck emissions and will also be used to compare the results of the drayage truck test cycle to other existing cycles. More information regarding SCAQMD's program may be found in the next section (Section 2.5.5).

2.5.4 AQMD HDV In-Use Emissions Testing Program

The Port of Los Angeles and the Port of Long Beach have joined an existing SCAQMD research program[9] to conduct in-use emissions testing, and if needed, to evaluate emission-reduction potential of retrofit technology on existing and new on-road heavy-duty engines. This original project scope was budgeted at a total $1,701,156. The University of California, Riverside (UCR) and West Virginia University (WVU) were selected by competitive bid to conduct this program jointly with SCAQMD. The port funding for this project will cover program enhancements to include emissions testing of additional drayage vehicles utilizing a newly developed port drive test cycle[10] specifically derived from in-use drayage operation. The ports will provide $306,552 in co-funding to test six additional heavy-duty drayage vehicles, bringing the total project budget to $2,007,708.

Technical Approach

The objectives of the project include: in-use emissions testing of heavy-duty natural gas and diesel vehicles to verify emissions standards and the emission-reduction potential of engine or aftertreatment technology to reduce regulated emissions over time; measurement of ammonia and formaldehyde emissions from heavy-duty vehicles; the effectiveness of oxidation catalysts or alternative technologies to reduce these emissions; the assessment of the emission-reduction potential of exhaust gas recirculation (EGR) to reduce PM and NOx emissions from diesel engines; and the impact of using water in-lieu of urea or no reductant for SCR technology. To achieve these objectives, the project includes on-road heavy-duty vehicles used in transit, school bus, refuse, and goods movement applications and powered by engines fueled with natural gas, propane, diesel, and combination of diesel and natural gas fuels.

The vehicles will be tested across 66 different test configurations. The engines are categorized into eight groups including natural gas engines with three-way catalysts, high pressure direct injection (HPDI) engines with EGR and DPF with or without SCR technology, propane and diesel school bus engines, propane engines certified at or below 0.2 g NOx, diesel engines certified at 1.2 g NOx, diesel engines certified above 0.2 g NOx without SCR technology, and diesel engines certified at or below 0.2g NOx with SCR technology. In addition, WVU will use its Transportable Emissions Measurement System (TEMS) and Horiba Portable Emissions Measurement System (PEMS) to measure in-use emissions from a U.S. EPA 2010 compliant heavy-duty diesel truck loaded to approximately 70,000 pounds, while driven from Morgantown WV to Riverside CA. WVU will continuously track all not-to-exceed events, and measure total and non-methane hydrocarbon, NOx, CO, CO2, NO2, nitric oxide, nitrous oxide, PM, and ammonia emissions.

Environmental Benefits

The project supports the effort to better characterize in-use emissions from port drayage truck operation. While this project does not result in actual emission reductions per se, the knowledge base gained from this comprehensive effort will provide the ports, SCAQMD and other industry stakeholders with a much better understanding of the in-use emissions that result from implementation of advanced alternative fuel and aftertreatment technologies that could potentially be used to further reduce PM emissions from on-road heavy-duty vehicles.

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[9] On December 3, 2010, the SCAQMD Board awarded contracts to the University of California, Riverside (UCR) and West Virginia University (WVU) to conduct in-use emissions testing, and if needed, to evaluate emission-reduction potential of retrofit technology on existing and new on-road heavy-duty engines.

[10] See Section 2.5.4 for more information on this new cycle.

Project Partners & Funding

The POLB and POLA are contributing $306,552 in co-funding to this project, bringing the total project budget to $2,007,708. CARB will also provide in-kind services contribution to support the project, which will include quantification of criteria pollutant emissions using a portable emission measurement system, collection and analysis of exhaust gases for N_2O emissions, data analysis, and interpretation of emissions test results and measurements. In addition, in-kind contributions from POLA, POLB, and U.S. EPA include analysis of emissions test results and measurements.

The POLB and POLA provided the additional funding for this AQMD study to support future TAP and outside agency efforts to evaluate technologies that reduce emissions from heavy-duty trucks. Table 2.5-5 summarizes the project funding contributions.

Table 2.5-5: AQMD HDV In-Use Emissions Testing Program

Project Partners	Contributions
Port of Long Beach	$153,276
Port of Los Angeles	$153,276
South Coast Air Quality Management District Team	$1,701,156

Project Status

The SCAQMD is the project manager for this program. An MOA between the ports and SCAQMD will be implemented in early 2012 to facilitate port co-funding of this project and increase the scope to include port-related testing.

Project vehicle testing began in late 2011. Emissions testing for the following five vehicles were completed as of December 31, 2011:

- Two diesel fueled drayage trucks
- One CNG fueled drayage truck
- One CNG fueled refuse truck
- One diesel fueled school bus

3.0 Additional Port-Related Advanced Technology Efforts

The TAP tracks other related efforts that support the overall TAP goals and mission. Currently, there are two major port initiatives underway that synergistically support the TAP mission. These include the Zero-Emission Technology Development Program and the implementation of 2010 CAAP Update measures OGV-5 and OGV-6.

Zero-Emission Technology Development Program

The mission statement for the ports' TAP is *"…to accelerate the verification or commercial availability of new, clean technologies, through evaluation and demonstration, to move towards an emissions-free port."* As summarized above in Section 2, the TAP is currently evaluating and demonstrating technologies that could eventually lead to deployment of zero-emission technologies for sources in port-related operations. Some of those technologies represent interim or transitional technologies that help to significantly reduce air emissions, but are not yet emissions-free. Nonetheless, the deployment of these technologies in the near term will help the ports reduce air emissions and associated health risks while continuing to strive for full deployment of zero-emission technologies in the appropriate areas of port goods movement for the future.

In July 2011, the POLB and POLA Harbor Commissions met jointly to consider the staff report[11] entitled "Roadmap for Moving Forward with Zero Emission Technologies at the Ports of Long Beach and Los Angeles." An outcome of this meeting was to direct staff to expand the TAP guidelines to allow for consideration and potential funding of early stage zero-emission technology projects. This expansion is necessary since the TAP is currently focused on near-term technologies that are ready for commercial deployment following an in-use demonstration in the port environment. An expansion of the guidelines will facilitate the opportunity for promising, early stage technologies to potentially participate in the TAP.

2010 CAAP Update Measures OGV-5 & OGV-6

Ships remain the San Pedro Bay's biggest contributor to poor air quality. As indicated by the ports' respective 2010 Emissions Inventories, ocean-going vessels (OGVs) account for approximately 61% of the port-related diesel particulate matter, 54% of NO_x emissions, and almost all of SO_x emissions. As such, the 2010 CAAP Update called for a two-pronged approach to clean up the San Pedro Bay shipping fleet: (1) attract newly built ships that meet the most up-to-date, strictest environmental standards, and (2) reduce emissions in the legacy fleet through retrofit technologies or operational changes. The CAAP identifies these efforts as control measures OGV-5 and OGV-6 respectively.

Over the past year, working closely with industry stakeholders, the ports have been working to identify mechanisms to attract the newest ships, including investigation into new incentive programs. The ports have also been identifying promising emission-reduction technologies for OGVs, which will be demonstrated through the TAP to determine their effectiveness in the real-world operating conditions in San Pedro Bay.

[11] This report can be downloaded from *http://www.cleanairactionplan.org/reports/default.asp*

In 2011, the ports convened an Industry Working Group to raise awareness of OGV-6 and to solicit partners for future TAP demonstrations of marine technologies. Additionally, the ports met with a Regulatory Working Group comprised of U.S. EPA, CARB and SCAQMD to discuss the challenges and opportunities in advancing OGV emission reduction technologies. The ports released an initial version of the "San Pedro Bay Ports Emission Reduction Strategy Guide," which provides details on promising OGV technologies as a resource for regulatory agencies and shipping lines. Additionally, the ports are developing a framework so ports and regulatory agencies can agree on the emission reductions from OGV technologies that reduce NOx, DPM and SOx.

Additional Technology Advancement Efforts Tracked by TAP

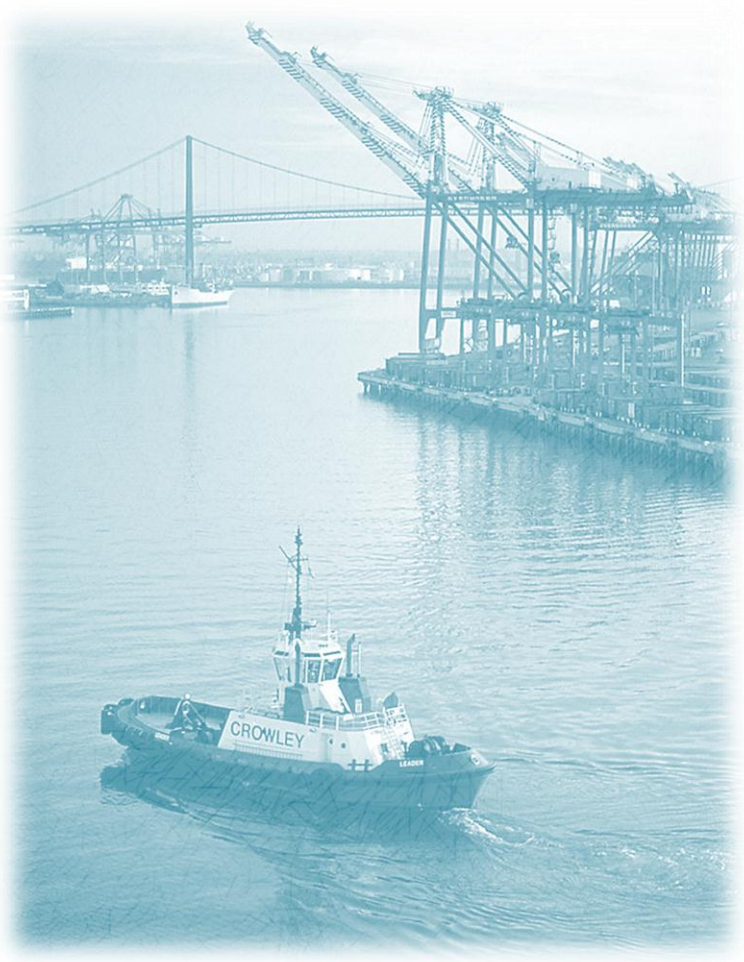
In addition to the above major initiatives, there are a number of other TAP-related efforts being tracked by the TAP. These include:

- In June 2010, ARB awarded $1 million via competitive solicitation to the POLB to demonstrate the use of hybrid technology to reduce emissions from marine vessels by converting an existing diesel tugboat to operate with a hybrid engine. The hybrid engine has the potential to reduce NOx emissions by 50 percent and fuel use by 20 percent compared to a conventional diesel engine. This project supports CARB's goals of demonstrating hybrid technology in off-road applications and providing an alternative compliance mechanism for ARB's harbor craft regulation. The tugboat project began operational testing at the ports of Long Beach and Los Angeles in the fall of 2011, with project completion by mid-2012. If successful, the converted tugboat is expected to remain in service at the ports beyond the scheduled demonstration period, and the technology provider intends to formally validate the emission reductions which would to allow these types of project to be funded through the Carl Moyer Program.

- Hug Filtersystems is working on a demonstration and verification project to demonstrate a combined diesel particulate filter and selective catalytic reduction technology on 2-stroke marine vessel engines at a cost not to exceed $396,580. This project is being conducted by the SCAQMD under a CARB Air Quality Investment Program grant and is similar in scope to the TAP project described above in Section 2.3.1. The primary difference between the two projects is that the TAP project's demonstration engine is a 4-strioke engine while the SCAQMD project engine is a 2-stroke engine.

- Port staff is tracking the status of the efforts resulting from the continued demonstration of the hybrid drive technology in yard hostlers in a separate, but parallel, project conducted by the New York Power Authority and the Port Authority of New York/New Jersey. Three of the newer generation hybrid yard hostlers have been operating in day-to-day terminal operations at New York Container Terminal since 2010. Similar to the TAP project conducted at LBCT (See Section 2.4.1), the hybrid vehicles' in-use performance and fuel economy are being assessed. In addition, chassis dynamometer emissions testing will be conducted. The TAP will continue to monitor the progress of this demonstration project.

- The SCAQMD and Volvo Technology of America, Inc. have partnered to develop and demonstrate a Class 8 plug-in, hybrid-electric, Class 8 drayage truck. The power and torque capabilities of the hybrid system will allow the combustion engine to be significantly downsized. The preliminary design includes the capability to operate in 100% all-electric mode (via stored energy from the battery pack), which would be targeted for in-port operation. The plug-in propulsion system might also be connected to a wayside power supply in the future though this is not a feature of the current project. The total project cost is estimated to be $2.4 million. Volvo estimates that NOx and PM will be reduced 40 and 50 percent per mile, respectively. All tailpipe emissions would be eliminated when the truck is operating in all-electric mode.



4.0 2011 TAP Funding Awards

The TAP is supported by both ports as an element of the CAAP at an annual level of $1,500,000 from each port ($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 California Energy Commission (CEC). Project co-funding is also contributed by the project proponent as either cash or in-kind contribution, or a combination of both.

The port and agency stakeholder investment for all past and current TAP projects approved to date is shown in Table 4.1, below. Six projects were funded by the TAP in 2011; these are indicated in bold type within the table. Contributions from participating agencies other than the ports are typically made on a project-by-project basis. In addition to the funding amounts reflected below, 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 4.1-1, but are noted within each project summary in Section 2.

Table 4.1-1: TAP Projects Funded from Program Inception through December 31, 2011

Project Category	POLB	POLA	AQMD	CARB	U.S. EPA	CEC	Total Port & Agency Stakeholder
Ocean Going Vessels							
APL Singapore Slide Valve/WiFE	$22,500	$22,500		$783,628			$828,628
ACTI AMECS Emissions Testing	$149,527	$149,527	$55,000				$354,054
Bluefield Holdings Krystallon OGV Scrubber	$825,000	$825,000					$1,650,000
Harbor Craft							
Foss Maritime Hybrid Tugboat	$500,000	$889,920*					$1,389,920
Hug Filtersystems Tier 4 Tugboat Retrofit	**$132,827**	**$132,827**					**$265,654**
Cargo Handling Equipment							
LNG Yard Tractor	$350,000				$75,000**		$425,000
Vycon RTG REGEN Flywheel	$11,500	$11,500	$8,000				$31,000
Hybrid Yard Tractor	$300,000*	$300,000*			$300,000**		$900,000
LBCT Eco-Crane	$42,467.50	$42,467.50		$130,130			$215,065
Capacity Plug-In Hybrid Tractor	$29,500*	$32,000*					$61,500
APT Emulsified Biodiesel	$44,000	$44,000					$88,000
RYPOS Diesel Emission Control	$64,668	$64,668					$129,336
Supplemental Demonstration of Hybrid Yard Hostlers – Beta Test	**$13,000***	**$13,000***					**$26,000**
Container Drayage Trucks							
Vision Motor Corp. Hydrogen Fuel Cell Plug-In Hybrid Electric Truck	$212,500	$212,500					$425,000
Artisan Vehicle Systems GP8 Electric truck	**$150,000**	**$150,000**					**$300,000**
Balqon Electric Class 8 Tractor		$263,500	$263,500				$527,000
Balqon Lithium Battery Upgrade		$400,000					**$400,000**
Westport ISX LNG Engine	$250,000	$250,000	$1,250,000			$500,000	$2,250,000
SoCalGas CNG Drayage Truck	$111,577.50	$111,577.50	$421,250				$644,405
Locomotives							
Johnson Matthey DPF Locomotive Demonstration	**$75,000**	**$75,000**		**$346,178**			**$496,178**
Research Projects							
Heavy-Duty Drayage Truck Duty Cycle Characterization	$12,681*	$13,000*					$25,681
Development of Drayage Truck Chassis Dynamometer Test Cycle	**$12,000***	**$11,466***					**$23,466**
AQMD HDV In-Use Emissions Testing Program	**$153,276**	**$153,276**	**$1,101,156**				**$2,007,708**
Total Investment	$3,462,024	$4,167,729	$3,698,906	$1,259,936	$375,000	$500,000	$13,463,595
Total TAP Investment	$3,094,843	$2,908,343					
Total Ports' TAP Investment	**$6,203,186**						

*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).

5.0 TAP Priorities for 2012

To support the recently adopted 2010 CAAP Update, port staff set important goals for the TAP in 2011. Two key areas of focus of the TAP in 2011 were to provide support to port staff efforts to develop and implement both the Zero-Emission Technology Development Program as well as 2010 CAAP Update measure OGV-6.

In July 2011, the POLB and POLA Harbor Commissions met jointly to consider the staff report[12] entitled "Roadmap for Moving Forward with Zero Emission Technologies at the Ports of Long Beach and Los Angeles." An outcome of this meeting was to direct staff to expand the TAP guidelines to allow for consideration and potential funding of early stage zero-emission technology projects. This expansion is necessary since currently the TAP is focused on near-term technologies that are ready for commercial deployment following an in-use demonstration of the port environment. An expansion of the guidelines will facilitate the opportunity for promising, early stage technologies to potentially participate in the TAP.

Measure OGV-6 focuses on reducing emissions from existing vessels (i.e., through implementation of retrofit technologies). Port staff and its consultant teams are working to implement these measures. Now that the OGV6 efforts are fully formed, the TAP can provide increased support in 2012 to incorporate technologies requiring evaluation before being incorporated into the OGV measures.

Beyond the emphasis on OGVs, the TAP will continue to support the identification, development and demonstration, and, ultimately, CARB verification of lower emitting technologies applicable to all source categories and focus areas identified in the CAAP. Therefore, the TAP funding priorities for 2012 will be based on the technology needs identified in the 2010 CAAP Update to improve air quality at the ports and protect the health of residents of the South Coast Air Basin. The technical and programmatic TAP priorities for 2012 are summarized below.

2012 Technical Priorities:

For 2012, the ports will continue the effort to identify and develop TAP technologies for the key source categories that contribute to port emissions. This includes targeting emission reductions from ocean-going vessels, locomotives, on-road and off-road trucks, and a continued focus on zero or near-zero emission technologies.

Specifically, 2012 will emphasize the identification and demonstration of technologies that target emission reductions from ocean going vessels. Emission reduction technologies will be evaluated for integration into vessel new builds and use of these technologies as a retrofit for existing vessels will be explored. The ports will continue to work cooperatively with vessel owners and engine and technology manufacturers to advance these efforts. For example, the feasibility and cost-effectiveness of using onboard systems such as exhaust scrubbers, selective catalytic reduction and other technologies that have the potential to significantly reduce ocean-going vessel and locomotive emissions beyond regulatory requirements will be evaluated.

[12] This report can be downloaded from *http://www.cleanairactionplan.org/reports/default.asp*

Specific technical priorities are listed below:

- A major addition to the 2010 CAAP Update is the development of the San Pedro Bay Standards, which establish long-term goals for emissions and health risk reductions for the port complex. Continued aggressive implementation of the TAP to demonstrate, verify and commercialize new, cleaner engine technologies in general will support port staff efforts to achieve these emissions and health risk reductions.
- The 2010 CAAP Update includes control measure OGV-6, entitled "OGV Engine Emissions Reduction Technology Improvements." The goal of this measure is to encourage demonstration and deployment of cleaner OGV technologies to be installed on the in-use fleet. The TAP will support this measure by facilitating the validation of emerging clean OGV retrofit technologies.
- In 2011, a Request for Proposals (RFP) was released by the POLB to solicit new, innovative technologies that can be used to reduce ocean-going vessel auxiliary engine and (potentially) auxiliary boiler exhaust emissions while vessels are at-berth at the ports. Responses to the RFP for Ocean-Going Vessel At-Berth Emissions Reduction Technologies resulted are due January 31, 2012. POLB anticipates the review and selection of a proposal for technology demonstration in early 2012.

2012 Programmatic/Policy Priorities:

For 2012, a number of program enhancements are planned, including:

- Port staff shall work to identify opportunities to further integrate port operators and other stakeholders into the technology review process, with the goal of facilitating acceptance into port operations following demonstration. This will support both the zero-emission technology and OGV-6 efforts;
- Facilitate "matching" potential fleets with technology companies. This goal stems from the difficulty some companies encounter when trying to find a project partner;
- The ports will focus on providing additional support to TAP contractors to better navigate CARB's verification process; the goal is to minimize the time between concept and commercial application;
- Increase coordination and the level of communication with other domestic and world ports as it relates to air quality improvement technologies and the potential for inclusion in the CAAP;
- Partner with the TAP Advisory Committee member agencies, other agency stakeholders, and project proponents in an effort to leverage TAP funding and maximize the effectiveness of the TAP;
- Ensure that port equipment operators are aware of grant program eligibility, and when appropriate, facilitate application to such programs, which include, but are not limited to, the U.S. EPA Emerging Technologies Program, CARB's AB 118 Air Quality Investment Program and SCAQMD's Carl Moyer Program.

APPENDIX A

TECHNOLOGY ADVANCEMENT PROGRAM ADVISORY COMMITTEE MEMBERSHIP

Dr. Matt Miyasato, South Coast AQMD	mmiyasato@aqmd.gov
Dipankar Sarkar, South Coast AQMD	dsarkar@aqmd.gov
Peggy Taricco, California Air Resources Board	ptaricco@arb.ca.gov
John Lee, California Air Resources Board	jlee@arb.ca.gov
Roxanne Johnson, U.S. EPA Region 9	johnson.roxanne@epa.gov

TECHNOLOGY ADVANCEMENT PROGRAM STAFF

Port of Long Beach
925 Harbor Plaza
Long Beach, CA 90802

POLB Technology Advancement Program Staff

- Rose Siengsubcharti, POLB TAP Coordinator — sieng@polb.com
- Heather Tomley, Asst. Director of Environmental Planning — tomley@polb.com
- Allyson Teramoto, Environmental Specialist — teramoto@polb.com
- Janna Watanabe, Environmental Specialist Associate — watanabe@polb.com
- Renee Moilanen, Environmental Specialist Associate — moilanen@polb.com

Port of Los Angeles
425 S. Palos Verdes Street
San Pedro, CA 90731

POLA Technology Advancement Program Staff

- Kevin Maggay, POLA TAP Coordinator — kmaggay@pola.org
- Teresa Pisano, Environmental Specialist — tpisano@pola.org
- Carter Atkins, Environmental Specialist — catkins@portla.org

Additional Administrative & Technical Support Staff

- Tunisia Hardy, Tetra Tech — thardy@portla.org
- Ray Gorski, Starcrest Consulting Group, LLC — rgorski@starcrestllc.com
- Lauren Dunlap, Starcrest Consulting Group, LLC — ldunlap@starcressllc.com

Appendix B

Summary Reports for Completed Projects

The following Technology Advancement Program projects are complete:

1. Balqon Lithium-Ion Battery Demonstration (2011)
2. Alternative Petroleum Technologies' Emulsified Biodiesel (2011)
3. Characterization of Drayage Truck Duty-Cycles (2011)
4. Long Beach Container Terminal Eco-Crane™ (2011)
5. Supplemental Demonstration of Hybrid Yard Hostlers – Beta Test (2011)
6. Development of a Drayage Truck Chassis Dynamometer Test Cycle (2011)
7. SoCalGas CNG Drayage Truck Demonstration
8. Westport GX LNG Engine Development
9. Foss Maritime Green Assist™ Hybrid Tugboat
10. Hybrid Yard Tractor Development & Demonstration
11. Capacity Plug-In Hybrid Electric Terminal Tractor
12. APL Singapore Slide Valve & Water-In-Fuel Emulsion Demonstration Program
13. Balqon E-30 Electric Terminal Tractor Development & Demonstration Project
14. Advanced Maritime Emission Control System (AMECS) Project
15. VYCON REGEN® System for Rubber-Tired Gantry Cranes Testing & Verification
16. Liquefied Natural Gas Yard Tractor Demonstration

Summaries of the Final Reports submitted for these projects are included herein. Final reports are available for download at *http://www.cleanairactionplan.org/programs/tap/techdemos.asp*

Balqon Lithium-Ion Battery Demonstration

Technology Manufacturer
Balqon Corporation

Co-Participants
Port of Los Angeles

Background
The Balqon Lithium-Ion Battery Demonstration project was a follow-on project to the Balqon Class 8 Electric Truck Demonstration TAP project completed in 2008. During this earlier project, the Port of Los Angeles TAP and the SCAQMD partnered to demonstrate a Class 8 electric truck for port drayage operations. For the project, a Balqon Nautilus Model E30 terminal tractor successfully completed cargo terminal tests during 2008.

Project Objective
This objective of this follow-on project is to evaluate and demonstrate a lithium-ion battery as a technological upgrade to the lead-acid battery pack used in the previous TAP demonstration. The advanced technology lithium-ion batteries were anticipated to more than double the vehicle range, without adding additional weight.

Lithium-ion batteries have several important advantages over competing battery technologies. Primarily, lithium is a highly reactive element which translates into a very high energy density in a much lighter package. The electrodes are composed of lightweight lithium and carbon, offering a much lighter weight as compared to other rechargeable batteries of a similar size. Lithium-ion batteries retain their charge longer than other battery chemistries, and exhibit no "memory effect" – some high energy density battery chemistries, such as nickel cadmium, can become degraded if recharged before the battery has been fully discharged. Lithium-ion batteries can be recharged without completely discharging with no battery degradation, and can withstand literally hundreds of charge/discharge cycles, increasing battery lifespan.

Technology Demonstration
Under this follow-on TAP demonstration, one electric drayage vehicle and electric yard tractor were converted from lead acid battery to lithium battery technology. The vehicles demonstrated include:

- Balqon Nautilus Model XE-30, a zero emission all-electric tractor designed to transport containers in terminal or on-road use applications. The 100,000 lb. capacity fifth wheel hydraulic lift can reduce operation time by 70% when compared to a conventional fixed fifth wheel design. The XE-30 operates at maximum speed of almost 28 mi/hr and can carry 30 tons of cargo with a range of 60 miles (unloaded) and 30 miles (fully loaded). The XE-30 is equipped with proprietary flux vector control technology equipped with five speed automatic transmission.

- Balqon Corporation Model Nautilus E20, a smaller, all-electric terminal tractor that can carry loads up to 60,000 lb. with a range of 40 miles on a single charge. The vehicle is equipped with a fast charge system to allow the vehicle to be fully charged in 30-45 minutes. The

E20 model is designed to transport containers at shipping ports and large warehouses and is also equipped with the hydraulic fifth wheel.

The lithium battery cells were assembled into the battery packs at Balqon's Harbor City facility and fitted with a proprietary Battery Management System (BMS) specifically designed for lithium-ion battery chemistry and characteristics. This TAP project also supported development of new charging algorithms to allow fast charge the lithium-ion batteries using the existing Balqon fast charger.

Vehicle range tests were conducted using both dynamometer and field test protocols. Installation of lithium batteries was expected to increase range by a factor greater than two as compared to the lead acid battery-equipped vehicle. It was anticipated that unloaded range would increase to 180 miles on single charge. Range at a loaded weight of 60,000 lbs at 45 mph during short haul drayage was expected to exceed 100 miles on a single charge.

Results

In June 2009, Balqon completed assembly of a Nautilus E30 all-electric tractor retrofitted with lithium ion battery packs. A one-day demonstration of the Nautilus E30 confirmed a range of over 150 miles on a single charge with unloaded conditions at 80% depth of discharge. The new lithium-ion battery packs included Balqon's battery management system, which allows batteries to be fast charged and self-equalize during idle operation. It is noteworthy that the lead-acid battery system provided 30 to 50 mile range under comparable test conditions.

Status

As of late 2010, Balqon had not yet initiated the full–scale vehicle range testing (either on the dynamometer or in the field) and the Balqon TAP agreement expired. Due to project constraints, results were not quantified, however initial testing did indicate a range of >150 miles. The project was not deemed incomplete with the hope that testing would be complete during 2011. Unfortunately, the testing was never completed in 2011, the last project payment was forfeited and POLA closed out the project in 2011.

Benefits

Zero-emission drayage trucks provide significant environmental benefits. However, operational concerns regarding range and charging times limit the applicability of zero-emission technology for the dray industry. Completion of this advanced battery demonstration project supports the long-term goal of increasing the use of zero-emission electric truck technologies in the drayage truck sector.

Project Costs

The total project cost was $940,000. The Port of Los Angeles, under TAP, contributed $400,000. Balqon Corporation provided the two vehicles as well as additional in-kind engineering and test resources; the Balqon contribution was valued in excess of $540,000.

Commercialization and Applications

In July 2009, Balqon announced the release of lithium-ion batteries as an alternative to lead acid traction batteries for its entire product line of Class 8 yard tractors and drayage vehicles.

APT Emulsified Biodiesel Fuel Demonstration

Technology Manufacturer
Alternative Petroleum Technologies, Inc.

Co-Participants
Port of Long Beach, Port of Los Angeles, West Basin Container Terminal (Ports America)

Background
The use of biodiesel fuel blends as a method to reduce diesel particulate matter (DPM) and greenhouse gas (GHG) emissions from diesel engines has been studied extensively. The results consistently show that while biodiesel fuels produced from renewable sources have the potential to effectively reduce hydrocarbon, carbon monoxide (CO), and DPM emissions, there is often a corresponding increase in oxides of nitrogen (NO_x) emissions on the order of 2% or greater. Given the serious nonattainment status for ozone in the South Coast Air Basin, any air pollution reduction strategy that increases NO_x emissions, a principal ozone precursor, is not recommended by state and local air quality regulatory agencies.

Project Objective
Under the TAP, Alternative Petroleum Technologies, Inc. (APT) set out to demonstrate that their soy-derived, emulsified fuel technology could mitigate the NOx emissions increase that is historically associated with the use of traditional biodiesel fuels. The TAP project consisted of both laboratory-based emissions testing and an in-use, field demonstration of the fuel in standard cargo handling activities at the West Basin Container Terminal.

Technology Demonstration
To demonstrate the viability and effectiveness of the emulsified biodiesel fuel in cargo handling equipment, APT performed a two-phased demonstration that consisted of an evaluation of the emulsified fuel with and without a diesel oxidation catalyst (DOC) in a laboratory setting and a real-time demonstration of the fuel in yard equipment at a port terminal.

The first phase of the project was conducted at Olson EcoLogic Engine Testing Laboratories. Emissions testing was conducted on a 2004 Cummins QSM 11C engine certified to tier 2 standards, since it is representative of the engines installed in the top handler units featured in the field evaluations. The QSM 11 C is rated at 330hp at 2100 rpm. The engine was tested according to the non-road transient cycle, a standardized engine dynamometer transient driving schedule.

In the second project phase, a field trial was conducted at Ports America, which operated three 2008 model year top handlers in regular container movement operation for a period of five (5) months. Three primary activities constituted the in-use demonstration phase:

1. Operation of three top-handler units on regular B20 biodiesel fuel;
2. Operation of three top-handler units on emulsified B20 biodiesel fuel;
3. Operation of one top-handler unit on emulsified B20 biodiesel fuel with a DOC.

Status

The APT demonstration project was completed in August 2011 and is available for download on the TAP website[13].

Results

The APT demonstration successfully proved that APT's emulsified B-20 blend mitigated an increase in NOx emissions, while also providing additional reductions in PM when coupled with a verified diesel emissions control system. This provides port drayage operators an alternative fuel selection for their existing fleet of container yard equipment.

Benefits

The testing demonstrated that a 6% water emulsion effectively mitigated the NOx increase associated with the regular B20 biodiesel fuel. The inclusion of a DOC after-treatment unit showed a beneficial effect on the total PM emission reduction by 40% in comparison to a 29% reduction with the fuel as a stand-alone emissions control strategy. Additionally, there were no perceptible operational differences in the dedicated top handlers during the demonstration.

Project Costs

Funding for the emulsified biodiesel demonstration was provided by POLB and POLA, each contributing $44,000, for a total of $88,000 in TAP funding for this project. APT committed matching funds in the amount of $88,000 towards the demonstration project as well as committed to pursue CARB Level 2 verification for both their emulsified diesel fuel and their fuel in combination with currently verified diesel exhaust after-treatment systems.

Commercialization and Applications

APT is seeking further extension of emulsified biodiesel fuel utilization at port entities by seeking CARB verification of the emulsified biodiesel technology. APT plans to leverage the findings of this TAP demonstration by pursuing their plans for CARB verification. This would enable future sales and marketing of the APT biodiesel blend fuel to existing cargo handling equipment fleet operators in the state of California.

[13] *http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2533*

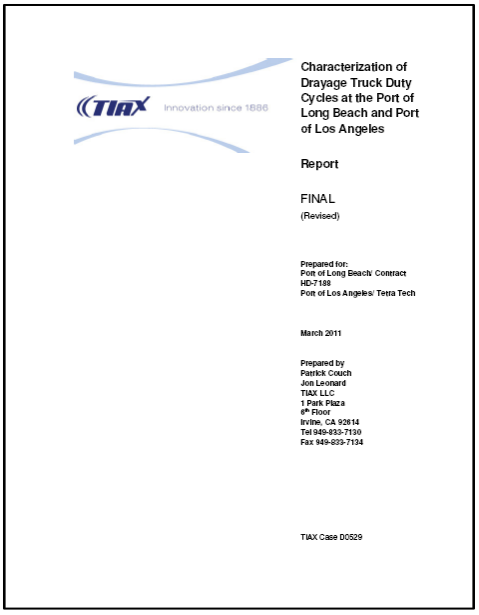
Characterization of Drayage Truck Duty-Cycles

Technology Manufacturer
Not applicable

Co-Participants
Port of Long Beach, Port of Los Angeles, TIAX, LLC

Background
Currently, there are approximately 11,000 heavy-duty diesel drayage trucks in service at the Port of Long Beach and Port of Los Angeles. According to the ports' 2010 emissions inventories, the drayage truck fleet is the second largest source of NOx emissions and the fourth largest source of DPM emissions at the ports. Even with increasingly stringent emissions standards promulgated by regulatory agencies, the drayage truck source category must continue to be as clean as possible. The introduction of zero-emission, hybrid-electric or other advanced heavy-duty truck technologies into the drayage fleet has the potential to provide significant emission reductions for this source category.

Project Objective
The ports initiated the Drayage Truck Duty-Cycle Characterization project in order to provide drayage truck equipment manufacturers with a thorough understanding of typical duty cycles associated with drayage service. The goal of this project was to collect detailed duty cycle information for drayage truck operations in near-dock, local, and regional operation. This duty cycle information, and raw data collected for the study, is now available online[14] for equipment manufacturers to help accelerate and improve the development of advanced drayage truck technologies.


TIAX Innovation since 1686

Characterization of Drayage Truck Duty Cycles at the Port of Long Beach and Port of Los Angeles

Report

FINAL
(Revised)

Prepared for:
Port of Long Beach/ Contract HD-7188
Port of Los Angeles/ Terra Tech

March 2011

Prepared by
Patrick Couch
Jon Leonard
TIAX LLC
1 Park Plaza
6th Floor
Irvine, CA 92614
Tel 949-833-7130
Fax 949-833-7134

TIAX Case D0529

Benefits
While this project did not result in direct emission reduction benefits, it is anticipated that a wide variety of clean heavy-duty drayage truck technology developers would benefit from this duty-cycle characterization project.

Results
For this project, vehicle operational data for multiple trucks were collected over a period of several weeks in the later part of 2010. Project trucks were equipped with data loggers and produced data in each of three operating regions: near-dock, local, and regional operation. The characterization of port drayage truck operation resulting from this project was used to develop a composite duty-cycle that will be used in upcoming drayage truck emissions evaluations. In addition, the duty-cycle will be distributed to engine and vehicle original equipment manufacturers (OEMs) with technology targeted to the drayage market.

[14] *http://www.cleanairactionplan.org/programs/tap/techdemos.asp*

Data from this study was used to develop a chassis dynamometer test schedule for drayage trucks serving the Port of Long Beach and Port of Los Angeles in 2011. More information on the "Development of a Drayage Truck Chassis Dynamometer Test Cycle" project may be found in the body of this report.

Project Costs

The Port of Long Beach and Port of Los Angeles initiated this project to fulfill the need for drayage truck operational profiles that the ports are uniquely positioned to support. The ports contracted with Tetra Tech and their subcontractor TIAX, LLC, an internationally recognized expert in the field of duty-cycle characterization and development. The ports funded the study to support future TAP efforts to support technologies that reduce emissions from heavy-duty trucks.

The combined TAP funding from both ports was $25,681.

Long Beach Container Terminal EcoCrane™

Technology Manufacturer
R.J. Corman EcoPower Hybrid Systems, Inc., formerly Railpower Technologies, Inc.

Co-Participants
Port of Long Beach, Port of Los Angeles, Long Beach Container Terminal

Background
This project involved the demonstration of a rubber tired gantry crane (RTG) equipped with an advanced energy capture and battery storage system. The system, called EcoCrane™, was developed by R.J. Corman EcoPower Hybrid Systems, Inc., formerly Railpower Technologies, Inc. The project was sponsored by the Port of Long Beach (POLB) and Port of Los Angeles (POLA) under the joint Technology Advancement Program (TAP).

Project Objective
A conventional diesel-electric RTG uses a diesel-fueled engine to generate electricity that powers electric motors used in container lifting as well as the motive power to move the RTG along the container stack. An RTG diesel genset used in port operations has a diesel engine rated, on average, at greater than 600 horsepower.

In the EcoCrane™ configuration, the diesel genset is equipped with a much smaller diesel engine – less than half of the rated horsepower of a conventional RTG. The reduced engine size and ability to turn the engine off during idling results in significantly lower fuel consumption and exhaust emissions. In addition, the smaller engine used in the EcoCrane™ genset is rated by the EPA at Tier 3, representing the current state-of-the-art diesel engines for off-road applications. This enables the EcoCrane™ to achieve substantial emission reductions as compared to a conventional RTG crane.

Technology Demonstration
During operation of a conventional diesel genset RTG, electric motors are used to lift the container and reposition the RTG along the container stack. Once in the proper position, the RTG lowers the container at a controlled rate. In a conventional RTG, the energy available when a container is lowered is wasted. In contrast, a hybrid RTG configuration captures the energy associated with lowering a container and stores in an energy storage system.

The EcoCrane™ uses a regenerative braking energy capture and storage system, similar to a hybrid-electric automobile. When a container is lowered using the EcoCrane, the motor used to lift the container is "reversed"; the motor becomes a generator, and the electricity produced as the container is lowered is directed to a bank of batteries - the electric energy storage system. The energy stored in the batteries can then be used to augment the EcoCrane's™ electric motor during the crane's subsequent lift.

Because batteries provide a portion of the energy used by the EcoCrane™ during container lifting, the amount of energy required from the diesel genset is

substantially reduced. In the EcoCrane™ hybrid electric configuration, the reduction in power required from the diesel genset is greater than 50%. This means that the existing diesel genset can operate at a much lower load factor. The EcoCrane™ hybrid RTG is equipped with a 134 kW (180 brake horsepower (bhp)) Tier 3 John Deere diesel engine. This engine replaced a Cummins KTA-19 diesel engine rated at approximately 507 bhp at an engine speed of 1,800 RPM. Therefore, the EcoCrane™ diesel engine is approximately 65% smaller than the conventional RTG diesel engine in terms of rated power. A comparison of the EcoCrane™ diesel engine as compared to the original RTG diesel engine is shown below in Table 1.

Table 1: EcoCrane™ Diesel Genset Engine as Compared to RTG Diesel Genset Engine

	Conventional RTG Cummins KTA-19	EcoCrane™ RTG Tier 3 John Deere
Rated Horsepower (bhp)	507	180
Fuel Consumption (1,800 RPM)	27.3 gallons per hour	9.1 gallons per hour
NOx + Hydrocarbon Emissions Standard	4.8 g/bhp-hr	3.0 g/bhp-hr

Status

The experience gained from the LBCT project resulted in EcoPower Hybrid Systems modifying the original EcoCrane design and developing a second-generation EcoCrane™ hybrid RTG system. The new design is equipped with alternating current (AC) motors and eliminates the high power inverter. Control, power electronics, and hardware have also been improved. In addition, the new EcoCrane™ configuration is equipped with a dual battery pack with a total capacity of 440 amp-hours (Ah), compared to the LBCT EcoCrane™ battery capacity of 180Ah. This new battery configuration was designed to adapt to the voltage and energy requirements of existing RTG crane drive systems.

Results and Benefits

The LBCT EcoCrane™ project demonstrated the application of hybrid-electric technology to cargo handling equipment in a marine terminal environment. Significant reductions in criteria air pollutant emissions, as well as reductions in fuel consumption and greenhouse gases, are being achieved by the EcoCrane™ as compared to a conventional diesel-electric RTG crane. Specifically, NOx plus hydrocarbon emissions of the Tier 3 John Deere engine are approximately 38% lower than RTG original equipment engine. Fuel consumption of the smaller John Deere engine is also significantly lower than a conventionally-equipped RTG.

Project Costs

The cost of the demonstration project was $169,870, with LBCT providing a fifty-percent cost share. The balance of funds, $84,935, was provided by the TAP.

Commercialization and Applications

Ports America will demonstrate the next generation of EcoCrane™ at the Port of Los Angeles' West Basin Container Terminal. The new design has targeted reductions in diesel particulate matter of 85% and reductions in greenhouse gases on the order of 70%.

The next generation EcoCrane™ will be tested over a twelve month period. Following successful completion of the demonstration phase, it is expected that EcoPower Hybrid Systems, Inc. will seek EPA and CARB verification for the EcoCrane™ system.

Supplemental Demonstration of Hybrid Yard Hostlers – Beta Test

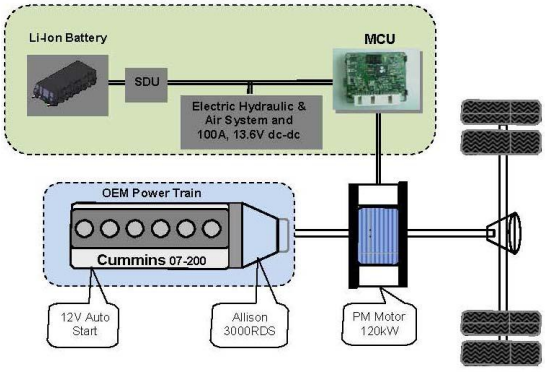
Technology Manufacturer
US Hybrid

Co-Participants
Port of Long Beach, Port of Los Angeles, Long Beach Container Terminal

Background
Terminal operators at the Port of Los Angeles and Port of Long Beach currently operate more than 1,500 yard hostlers in three service types: ship, rail, and yard service. Ship service consists of the transport of containers between a ship and the container stacks inside the terminal. Rail service is similar to ship service except that containers are transferred to and from rail cars. Yard service (also called dock work) involves moving containers between stacks or to/from loading areas for drayage trucks.

For the majority of the demonstration period, LBCT had use of only one US Hybrid yard hostler. Based on the consistency of ship service relative to the other two service types, LBCT elected to use the US Hybrid yard hostler in ship service. Ship service provided the greatest amount of vehicle operation and fuel consumption data possible, relative to the other two service types. Late in the demonstration, a second US Hybrid unit was made available to LBCT and this unit was placed into rail service.

Project Objective
As a follow-on Hybrid Yard Tractor Development & Demonstration Project[15] conducted in 2010, the Port of Long Beach, Port of Los Angeles, US Hybrid and Long Beach Container Terminal (LBCT) assessed the potential in-use fuel economy performance of newly modified hybrid yard hostlers from February to June 2011 under a new project, Supplemental Hybrid Yard Hostler Demonstration–Beta Test.



Technology Demonstration
The hybrid yard hostlers demonstrated consist of standard Kalmar Ottawa yard hostlers fitted with a parallel hybrid-electric power trains. Following the initial demonstration of the hybrid yard hostlers in 2010, US Hybrid made modifications to the hybrid system to improve fuel economy from the previous demonstration. In particular, US Hybrid altered the battery management algorithm, hybrid control algorithm, idle management strategy, and increased the capacity of the traction battery. These modifications resulted in a Generation 1.1 configuration. Near the end of the current demonstration, US Hybrid provided a second unit to LBCT that incorporated several additional modifications, including changes to the transmission control algorithm, electric motor, and motor control unit. This configuration is referred to as Generation 2.0.

[15] Final Report entitled "Hybrid Yard Hostler Demonstration and Commercialization Project" available for download at: *http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2516*

Status and Results

The results of the analysis support the following conclusions:

1. Based on the iDrive data acquisition system and paper fuel logs completed by LBCT, the Generation 1.1 yard hostler placed into service at LBCT did not demonstrate significantly different fuel economy compared to either the baseline yard hostler or the Generation 1.0 hybrid yard hostler tested during the previous demonstration.
2. Because the Generation 2.0 yard hostler was placed into service close to the end of the demonstration period, there was insufficient fuel consumption data collected to make any conclusions regarding its fuel economy.
3. Generation 2.0 yard hostlers have been redesigned to address the fuel economy performance issues encountered in the previous demonstration. The consistency of fuel consumption data and the high level of use of tractors in service make this the preferred service to demonstrate the Generation 2.0 or future generation hybrid yard hostlers.

Following the completion of the project, the hybrid systems were removed and the vehicles returned to their original state by Kalmar. Further demonstration of the hybrid drive technology in yard hostlers continues in a separate parallel project conducted by the New York Power Authority and the Port Authority of New York/New Jersey. Three of the newer generation hybrid yard hostlers have been operating in day-to-day terminal operations at New York Container Terminal since 2010. Similar to the project conducted at LBCT, the hybrid vehicles' in-use performance and fuel economy is being assessed. In addition, chassis dynamometer emissions testing will be conducted. The TAP will continue to monitor the progress of the project.

Project Costs

The total cost of the supplemental demonstration was $26,000 which was split evenly between the two ports (or $13,000/port).

Development of a Drayage Truck Chassis Dynamometer Test Cycle

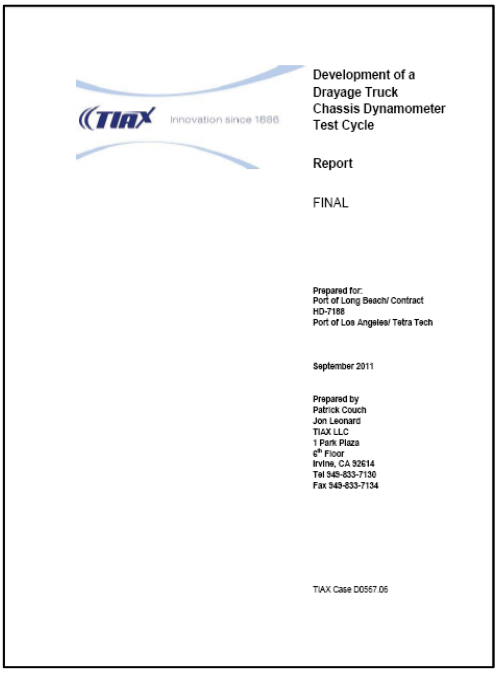
Technology Manufacturer
Not applicable

Co-Participants
Port of Long Beach, Port of Los Angeles, TIAX, LLC

Background
In early 2011, the Port of Long Beach and Port of Los Angeles released a report authored by TIAX, LLC that characterized the duty cycle of on-road, Class 8 drayage trucks at the ports. The report included statistics based on over 1,000 truck trips collected over a four-week period in late 2010. Based on these statistics, TIAX, LLC identified five modes of operation and an "average" trip associated with each mode. The statistics and trip data from this earlier work provided important information on the real-world operation of drayage trucks in the South Coast Air Basin.

Project Objective
As a follow-up to the earlier "Heavy-Duty Drayage Truck Duty-Cycle Characterization" project, this study encompassed the development of a detailed driving schedule suitable for use when testing heavy-duty vehicles on a chassis dynamometer that is based on the modes of operation and trip data previously identified in the earlier study.

Status/Results
The Port of Long Beach and Port of Los Angeles initiated this project to fulfill the need for drayage truck operational profiles that the ports are uniquely positioned to support. The ports contracted with Tetra Tech and their subcontractor TIAX, LLC, an internationally recognized expert in the field


TIAX Innovation since 1886

Development of a Drayage Truck Chassis Dynamometer Test Cycle

Report

FINAL

Prepared for:
Port of Long Beach/ Contract HD-7188
Port of Los Angeles/ Tetra Tech

September 2011

Prepared by
Patrick Couch
Jon Leonard
TIAX LLC
1 Park Plaza
6th Floor
Irvine, CA 92614
Tel 949-833-7130
Fax 949-833-7134

TIAX Case D0567.06

of duty-cycle characterization and development. The ports funded the study to support future TAP and outside agency efforts to evaluate technologies that reduce emissions from heavy-duty trucks.

The chassis dynamometer test cycle was developed to provide the Port of Long Beach and Port of Los Angeles with a tool to compare the emissions performance from various drayage truck technologies. While this cycle was developed using actual in-use vehicle data and methods similar to those used to develop the widely used heavy heavy-duty diesel duty truck (HHDDT) test cycle used by test labs nationwide, this new drayage truck cycle has not yet benefitted from validation on a chassis dynamometer.

The final report is available in the public domain for all interested parties to utilize. The final report can be accessed at the ports' Clean Air Action Plan website at *http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2526.*

Currently, the SCAQMD is preparing to conduct emissions testing on several heavy-duty vehicles, including diesel and liquefied natural gas drayage trucks, as part of their HDV In-Use Emissions Testing Program. The ports will participate by providing the test cycle developed in this project for use in SCAQMD's multi-vehicle testing program. The drayage truck cycle will be used to assess drayage truck emissions and will also be used to compare the results of the drayage truck test cycle to other existing cycles.

Benefits

The successful completion of this study resulted in a test cycle that reflects typical port drayage truck operation. Use of this cycle in emission testing programs and engine/vehicle system design projects will help ensure that emission reduction efforts of agencies and technology developers will result in information or products that are relevant to port operation or can meet rigorous port duty cycles.

Project Costs

The ports shared the cost of this study. The Port of Long Beach contributed $12,000 and the Port of Los Angeles contributed $11,466.

SoCalGas CNG Drayage Truck Demonstration

Technology Manufacturer
Cummins Westport
Autocar LLC

Co-Participants
Port of Long Beach, Port of Los Angeles, SoCalGas Company, California Cartage Company, South Coast Air Quality Management District

Background
The ports are committed to reducing air pollution from drayage operations as exemplified by their respective Clean Truck Programs and research into zero-emission container movement. The TAP is also supporting the ports' transition to low emission drayage operations by demonstrating technologies that have high potential to be both commercially viable and significantly reduce pollution from container drayage.

Project Objective
Under the TAP, the ports embarked upon a collaborative effort with Southern California Gas Company (SoCalGas) and their partners, California Cartage Company and Autocar LLC, to develop and demonstrate the nation's first drayage trucks powered by compressed natural gas (CNG). Four trucks were delivered June 2008 and used to move containers between the ports and nearby freight consolidation yards.

Technology Demonstration
The trucks were manufactured by Autocar LLC and are powered by the Cummins Westport ISL G engine. The Cummins Westport ISL G is currently the cleanest heavy-duty internal combustion engine commercially available, with certified NO_x levels one-half that of U.S. EPA's stringent 2010 on-road heavy-duty emissions standard.

To demonstrate the viability of the ISL G CNG engine in port drayage operations, California Cartage Company (CCC), the largest trucking company operating at the ports, operated the four CNG-powered trucks in regular revenue drayage operations for a one-year demonstration period. This period covered calendar year 2009. During this period, the trucks underwent continuous monitoring to assess performance capabilities, operability, driver impressions, and vehicle reliability.

Status
The CNG trucks operated throughout 2009. Initially, the trucks were used exclusively in local drayage service around the ports in an effort to familiarize the drivers with the new vehicles and to build confidence in the local, public CNG infrastructure. In early May 2009, CCC's management decided they had the comfort level with the TAP-funded CNG truck to begin running it on longer inland routes. Beginning on May 4, 2009, the TAP-funded CNG truck began running one inland route from CCC to Ontario each morning. The truck ran local routes each afternoon. The CNG truck continued running this single daily inland route for most of May 2009 through September 2009. After September, the CNG truck returned to running two local shifts per day.

Results

The SoCalGas demonstration proved the feasibility and capability of using CNG fuel in commercially available heavy-duty engines for port drayage operations. This provides port drayage operators an additional low emission technology choice when replacing or upgrading their fleet vehicles. This project's final report is available for download on the TAP website[16].

Benefits

The certified NO_x emission levels of the Cummins Westport ISL G engine are about 90 percent below a model year 2007 diesel drayage truck. The use of "low carbon content" natural gas will also help California achieve its goals under its Low-Carbon Fuel Standard and reduce greenhouse gas emissions by approximately 20 percent as compared to diesel fuel.

Project Costs

The combined TAP funding from both ports was $223,155, which was applied to the capital purchase cost of one demonstration vehicle. The remaining three demonstration trucks were purchased by SoCalGas. The SCAQMD co-funded the construction of a temporary CNG refueling station to support the demonstration trucks' daily refueling needs. The SCAQMD also contributed $421,250 towards the purchase of capital equipment for the temporary refueling station.

Commercialization and Applications

The Cummins Westport ISL G engine is commercially available today, and an increasing number of heavy-duty truck chassis manufacturers are offering vehicles equipped with the ISL G in a compressed natural gas configuration. The relatively low cost of CNG, as compared to diesel fuel, makes this engine an attractive option for port drayage operators.

[16] *http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2471*

Westport GX LNG Engine Development

Technology Manufacturer
Westport Innovations
Kenworth Truck Company

Co-Participants
Port of Los Angeles, Port of Long Beach, South Coast Air Quality Management District, California Energy Commission

Background
Westport Innovations (Westport), developer of the High Pressure/Direct Injection (HPDI) liquefied natural gas (LNG) fuel system technology, developed an LNG 15-liter heavy-duty truck engine that was certified to the 2010 on-road NO_x emission standard of 0.2 grams per brake horsepower-hour (g/bhp-hr).

The 400- and 450-horsepower rated heavy-duty engines are based on the 15-liter Cummins ISX diesel engine platform and are designed to satisfy the performance requirements of class 8 tractors that provide drayage service at the ports.

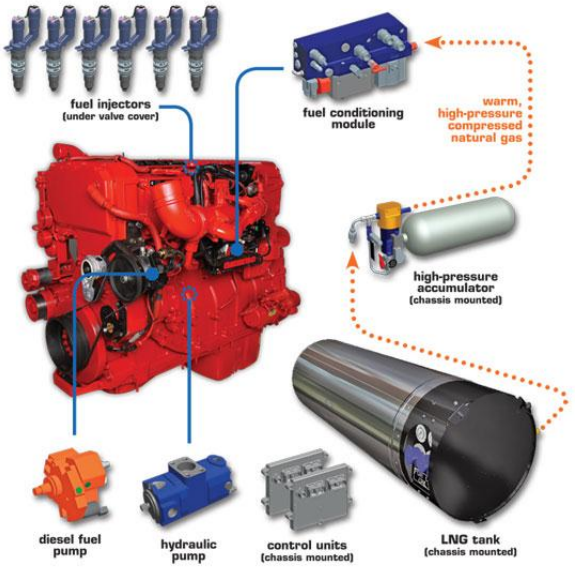
Project Objective
The GX LNG heavy-duty engine development project had three primary objectives:

1. Development and certification of a 2007 LNG high-pressure direct-injection engine to 0.6 g/bhp-hr NO_x by early 2008;
2. Establish the manufacturing capacity to produce LNG trucks in a high volume truck production facility;
3. Certification of a 0.2 g/bhp-hr NO_x (2010 standard) compliant truck by early 2010 for deployment in mid-2010.

Technology Demonstration
Westport's HPDI technology facilitates the use of natural gas as an engine fuel while retaining typical diesel engine combustion, power, and torque. The technology differs from other natural gas engines through the absence of spark plugs. A patented injector delivers a small amount of diesel fuel (approximately 6% by energy content) and high pressure natural gas directly to the engine combustion chamber, where the diesel fuel acts as the ignition source.

LNG fuel for the Westport GX engine is stored in the LNG tank mounted to the chassis of the vehicle. The liquid natural gas is drawn from the tank using a proprietary LNG pump that is powered by an engine-driven hydraulic pump. The LNG is then vaporized using excess heat from the engine's coolant system.

Simultaneously, a diesel fuel pump draws and pressurizes diesel fuel from its storage tank. Both the natural gas and diesel are then routed to a fuel conditioning module, where both fuels are pressure regulated, filtered, and sent to the fuel injector nozzles.



HPDI relies on late-cycle high pressure injection of natural gas into the combustion chamber. The natural gas is injected at the end of the compression stroke, similar to the diesel fuel in a diesel engine. Natural gas has a higher ignition temperature compared to diesel, so a diesel pilot injection is used to initiate combustion.

The benefits of the high pressure direct injection cycle include horsepower and torque output similar to a conventional diesel engine and fuel cost savings due to the high substitution of lower cost LNG as compared to diesel.

With the low emissions profile of natural gas and the high efficiency of the diesel combustion cycle, HPDI technology combines high energy efficiency with low emissions. The HPDI system extends beyond the fuel injection equipment, and is developed as a fully integrated system including fuel system management electronics, LNG tanks, and vehicle installation.

Results

The Westport GX demonstrated emission levels during certification testing at or below 0.2 g/bhp-hr NO_x in mid-2009. Westport worked closely with the U.S. EPA to finalize the deterioration rate for the engine. While this resulted in a slight delay in achieving final certification, the Westport GX heavy-duty LNG engine was granted a CARB Executive Order at the 0.2 g/bhp-hr NOx certification level on July 6, 2010.

Benefits

The Westport GX LNG engine will accelerate NOx emission reductions by achieving the final 2010 standard in early 2010. Diesel engines of a comparable displacement are not expected to meet the 2010 standard initially – engine manufacturers will instead use credits generated from family emission level (FEL) engines to offset the higher emissions of their large displacement on-road engines. Westport estimates emission reductions of at least 0.45 tons of NOx per year per truck above the equivalent model year diesel truck, until the 0.2 standard is phased in for diesel engines. The LNG heavy-duty truck also emits 15 to 20 percent less greenhouse gases compared to diesel engines.

Project Costs

The total project cost for development and certification of Westport GX natural gas engine is estimated at $9,894,027. Westport contributed $7,144,027 of the project development cost (in-kind) and secured additional funding in the amount of $500,000 from Clean Energy, a provider of LNG fuel, to assist with integration of the engine and related fuel system. The California Energy Commission (CEC) provided $500,000 under the PIER program. Kenworth Truck Company was a key partner in the project and will provide in-kind contributions to assist with the future deployment of GX-equipped LNG trucks. The SCAQMD contributed $1.25 million, and the ports of Long Beach and Los Angeles contributed $250,000 in TAP funding.

Commercialization and Applications

This large displacement, low emission natural gas engine is commercially available and can be used in port drayage, as well as other heavy-duty vehicle applications. For 2012, the engine is certified by CARB to have lower NOx emissions than the comparably sized diesel engine.

Foss Maritime Green Assist™ Hybrid Tugboat

Foss Maritime
Aspin Kemp & Associates
XeroPoint

Co-Participants
Port of Long Beach, Port of Los Angeles, South Coast Air Quality Management District, California Air Resources Board

Background
Foss Maritime achieved several significant milestones in the development of the World's first diesel electric hybrid tugboat. Christened the *Carolyn Dorothy*, the FOSS Green Assist™ hybrid tug was unveiled on January 23, 2009 and began working in the harbor immediately, even though some systems were still being commissioned. All system commissioning was complete on March 1, 2009, at which point the *Carolyn Dorothy* became a full working member of the Foss Maritime tug fleet. Since this time, the hybrid tug demonstrated performance comparable to a conventional Dolphin Class tugboat.

Technology Demonstration
The Green Assist™ hybrid tug was built by Seattle-based Foss Maritime in partnership with Aspin Kemp & Associates and their affiliate XeroPoint, which developed the unique hybrid power management system. At the heart of the Foss Green Assist™ project is the Dolphin class tug currently operated by Foss at the ports of Long Beach and Los Angeles. The conventional diesel-fueled tugs are powered by Caterpillar main engines producing a total of 5,080 bhp and a bollard pull of 60 tons. Externally, the *Carolyn Dorothy* is quite similar in appearance to its conventionally powered forebears. The only noticeable evidence of its unique power plant is a pair of smaller exhaust stacks.

The tug's diesel-battery-electric propulsion system comprises two fully azimuthing propulsion units powered by batteries, diesel generators and/or two diesel main engines. A modified engine room accommodates two battery packs, producing the equivalent of 670 horsepower, and two 335 horsepower diesel powered generators. The main engines are substantially smaller and less powerful than those in the existing Dolphin class tugs.

An essential feature is the power management system required to produce seamless transition from one power source to another, depending on the tug's duties and the power demand. In its various modes of operation, the new tug employs battery power idling and no-wake low speed maneuvering and a combination of battery and generators for transiting. When full power is required, the diesel main engines start automatically and are coupled by clutches to the drive system in addition to the electric motors. Surplus power generated at any stage is used to recharge the battery packs.

Although the main engines in the new tug are smaller than those of existing vessels, the same total horsepower and the same 60 tons bollard pull is available. The Green Assist™ Tug has four distinct modes of operation:

STOP - When the tug is docked at the pier. Main engines are off-line; power is provided by batteries for hotel loads (lighting, HVAC, etc.) and can be recharged by shore power;

IDLE - When the vessel is not secured to a pier but is stopped at sea. Main engines are off-line. Batteries provide power for hotel loads and station keeping. A generator automatically starts up and comes on line to recharge batteries;

TRANSIT - Continuous slow and fast transit 6-8 knots. One generator for the slower "harbor –speed" transit of approximately 6 knots. The second generator automatically starts when the throttle setting calls for a faster speed transit of about 8 knots. Batteries provide "ride-through" power until the second generator is online. The generators also are providing hotel loads and are recharging the batteries while simultaneously providing the propulsive power.

ASSIST - Full power ship-assist requirements. Both main engines, generator sets and batteries provide full power.

Based on the operating profile of the conventional Dolphin tugs currently operating in the ports, it is estimated that the hybrid will spend at least 75 percent of its operating hours in the operating modes without main engines. Only batteries and generators are used during idle or low speed/low load operation, but the vessel is able to access full power on demand.

Results

Foss completed development of the project test plan in September 2009, and formed a Technical Working Group (TWG) with Foss, POLB, POLA, CARB, EPA, SCAQMD, and the Pacific Merchant Shipping Association (PMSA) in the fall of 2009. In late 2009, the UC Riverside College of Engineering – Center for Environmental Research and Technology (CE-CERT) began test equipment acquisition and software code upgrades to prepare for test plan implementation. Full system and emissions testing was conducted in early 2010. This project's final report is available for download from the TAP website[17].

Benefits

The hybrid tugboat achieved emission reductions that exceed original targets (to reduce both NO_x and PM by approximately 44%) when compared with the Dolphin tugs currently operating in the San Pedro Bay. The *Carolyn Dorothy* reduced PM, NOx and CO2 emissions by 73%, 51% and 27%, respectively[18]. Based on this evaluation, fuel consumption is expected to be reduced by approximately 20 to 30 percent.

The measured emission levels of the *Carolyn Dorothy* are cleaner than the U.S. EPA's Tier 2 emissions standard for marine engines. Along with less pollution, the Green Assist™ tug offers improved fuel economy and requires significantly less maintenance. It is also quieter than its Dolphin sister tugs when operating on batteries that can be recharged using environmentally friendly shore power.

Project Costs

The overall cost for the design, development and commissioning of the *Carolyn Dorothy* was over $8 million. The Port of Long Beach provided $500,000 in TAP funding, and the Port of Los Angeles provided $889,920 in non-TAP funding to support this project. Additional in-kind support was provided by CARB and SCAQMD. Remaining costs were covered by Foss Maritime.

Commercialization and Applications

The Port of Long Beach and the Port of Los Angeles teamed with Foss to implement the "Tugboat Hybridization Project". This $2.3 million project is funded in part by a $1 million grant from ARB's AB 118 Air Quality Investment Program. The tugboat *Campbell Foss* will be retrofitted with hybrid technology, followed by an in-service evaluation for emissions reductions and fuel savings.

[17] *http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2501*

[18] *http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2502*

Hybrid Yard Tractor Development & Demonstration

Technology Manufacturer
US Hybrid

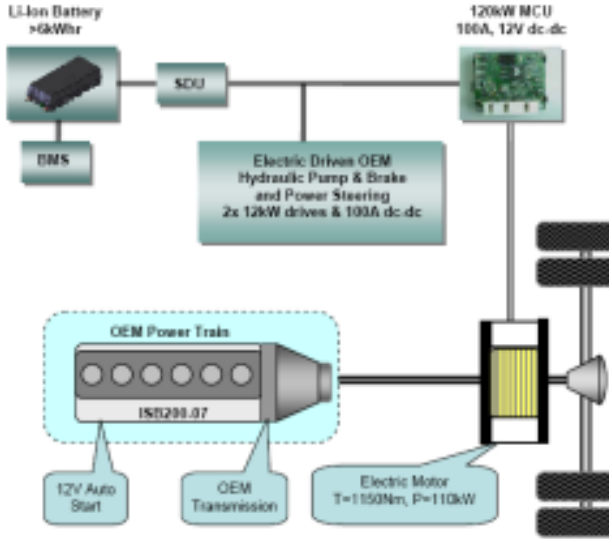
Co-Participants
Port of Los Angeles, Port of Long Beach, CALSTART,U.S. Environmental Protection Agency, Kalmar Industries, Long Beach Container Terminal (LBCT)

Background
As a follow on to the demonstration of LNG yard tractors operating at the ports, the TAP investigated the feasibility and commercial viability of using advanced technology drive systems in cargo handling equipment. The ports' TAP, in partnership with the U.S. EPA's West Coast Collaborative, worked together to develop and test hybrid technology yard tractors for use at container terminals.

Yard hostlers (also known as yard tractors, terminal tractors, or utility tractor rigs) are common at port terminals, rail yards, and distribution centers. Their function is to move containers around the facility. At a port, containers are loaded off a ship onto a bobtail rig that is pulled by the yard hostler to an intermodal point or to a storage facility. Yard hostlers often sit idling as they wait in queues to pick up or drop off their loads.

Project Objective
The ports of Long Beach and Los Angeles partnered with CALSTART, a non-profit company that focuses on advancing cleaner technologies, to manage the demonstration of three (3) diesel-hybrid yard hostlers at the Long Beach Container Terminal (LBCT). The U.S. EPA also provided grant funds for the design and development of the hybrid drive system. Vehicle emissions and performance were evaluated relative to diesel yard hostlers, and a business case/lifecycle cost benefit assessment was performed to determine the financial viability for large-scale use of hybrid yard hostlers in marine terminals.

Technology Description
US Hybrid was selected as the hybrid drive system supplier through a competitive bid process. US Hybrid designed and developed a diesel-electric parallel hybrid, post-transmission configuration system that was integrated into a Kalmar Industries Ottawa 4x2 terminal tractor.

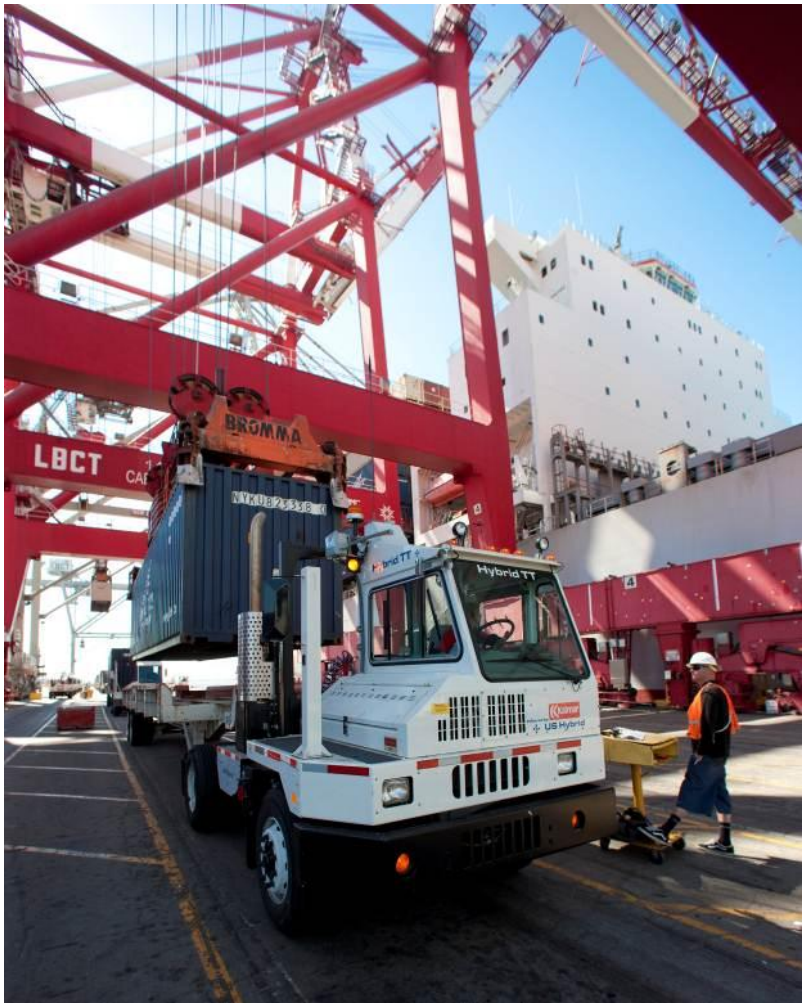


Benefits
The three hybrid yard hostlers underwent six months of operation and in-use testing at LBCT and were able to perform all the tasks required of yard hostlers in real-world port operations, and were well accepted by drivers and maintenance staff. Fuel economy and emissions benefits were evaluated, but a difference discovered in the mechanical specifications of the vehicles limited comparability. Based on all the evaluations and analyses conducted, the hybrid system is estimated to provide a 12% to 18% improvement in fuel economy. Further development of the hybrid system is underway in an effort to improve fuel economy and emissions reductions. The lifecycle cost assessment for large-scale use of hybrid yard hostlers showed that incentives of approximately $18,000 per vehicle would be needed to ensure payback of the hybrid

system. The final report for this project is available for download from the TAP website[19].

Project Costs

The project was valued at $1.2 million. The ports contributed $300,000 each and the U.S. EPA contributed $300,000 through a West Coast Collaborative grant. LBCT and other project suppliers provided in-kind labor contributions estimated at $300,000. CALSTART provided technical project management assistance.



[19] *http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2516*

Capacity Plug-In Hybrid Electric Terminal Tractor

Technology Manufacturer
Capacity of Texas, Inc.

Co-Participants
Port of Long Beach, Port of Los Angeles
Ports America, Total Terminals, Inc., and
Yusen Terminals, Inc.

Background
Terminal tractors are essential to the daily operations of a port terminal. However, they also consume large volumes of diesel fuel and generate significant levels of harmful diesel emissions within the ports they serve. The development and deployment of low-emission, high-efficiency terminal tractors are high priorities for the ports under the Clean Air Action Plan.

In response to the need for environmentally friendly yard hostlers, Capacity of Texas, Inc. developed a Pluggable Hybrid Electric Terminal Tractor (PHETT™). The Port of Long Beach, in conjunction with Capacity, Ports America, and Total Terminals, Inc. (TTI) conducted a three-week trial of the PHETT™ from June 8 to June 25, 2009. Results from this trial are available for download from the TAP website[20].

A follow-on trial test to evaluate improvements made to the PHETT™ following the initial trial was conducted from December 8 to December 29, 2009 at the Port of Los Angeles' Yusen Terminals, Inc. (YTI). The final report for this trial is available for download from the TAP website[21].

Project Objective
The purpose of the demonstrations was to evaluate the performance and emissions of the PHETT™. In order to characterize the PHETT™ duty cycle and measure its load factor, the vehicle was equipped with a multi-channeled data logging system. The PHETT™ fuel economy was evaluated using the data collected by the data logger and supplemented with information provided by Capacity and site demonstration partners. In addition, surveys were developed and distributed to operators and maintenance personnel to assess the overall capability of the PHETT™.

Technology Description
The PHETT™is a diesel-electric plug-in hybrid terminal tractor that uses a small diesel generator and a large lead-acid battery pack to provide power for vehicle operation. As a plug-in hybrid, the PHETT™ offers a modest all-electric range and higher overall efficiency, which can significantly reduce fuel consumption and emissions compared to a conventional diesel-fueled terminal tractor.

The PHETT™ operates as a series diesel-electric hybrid. In this configuration, all of the energy demands of the vehicle are supplied through the battery; regardless of whether the energy is stored in the battery by a grid-connected charger or the on-board

[20] *http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2416*
[21] *http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2517*

diesel generator. Given a fully charged battery, the PHETT™ will operate entirely from battery power, providing a limited "all-electric range" with zero tailpipe emissions. Once the battery has been depleted to a predetermined state of charge, the diesel generator will start and attempt to sustain the current level of charge in the battery.

According to Capacity, this diesel-electric hybrid terminal tractor is a "charge sustaining series hybrid that utilizes a constant and efficient rate generator to supply power, reducing fuel consumption by as much as 60 percent and audible db by 30 percent.

Three electrical inverters are used to supply the vehicle subsystems with power. The inverters convert the DC voltage of the battery pack into AC voltage that is better suited to operate the numerous AC electrical motors in the PHETT™.

Additionally, several systems on the vehicle use a 12VDC auxiliary power supply including the safety light, radios, and cabin HVAC fan. Capacity estimates a fixed power draw of 500 watts, assumed to be constant while the vehicle is in use.

TAP funding in the amount of $29,500 was allocated to the Port of Long Beach PHETT™ demonstration and testing project. The Port of Los Angeles also conducted a follow-on study at Yusen Terminal, Inc (YTI) with non-TAP funding in the amount of $32,000. Additional in-kind contributions were provided by Capacity, Ports America, TTI and YTI; however, the equivalent dollar values of these additional contributions were not quantified.

Results

The load factor for the PHETT™ was determined by measuring the diesel generator output over the entire operating time of the PHETT™. During the demonstration at TTI, the PHETT's™ load factor was evaluated as 0.58, equivalent to an average engine load of 23.3 hp. The PHETT™ was estimated to achieve a 77% reduction in NO_x emissions, and an 82% reduction in PM emissions compared, to the baseline diesel fleet (2002 levels). The emission rates of the PHETT™ were also found to be lower compared to a 2009 diesel yard tractor. Due to a lack of fueling logs, fuel economy improvements were difficult to verify; however, fuel improvements were estimated to be in the range of 28% to 60% over the baseline fleet.

During the demonstration of the "beta" unit at YTI, the PHETT's™ load factor was determined to be 0.54, equivalent to an average engine load of 21.7 hp. The beta PHETT™ was estimated to achieve a 44% reduction in NO_x emissions, and a 56% reduction in PM emissions compared to a 2009 diesel yard tractor at 43% load (CARB's approved load factor for yard tractors). However, the emission rates of the PHETT™ were similar to those of a 2009 MY diesel yard tractor at actual load (18%). Fuel consumption measurements showed a 34% improvement over the baseline fleet. Information gathered from the operators and maintenance personnel at both ports indicated no significant problems with the PHETT™ and comparable performance to diesel yard tractors.

APL Singapore Slide Valve & Water-In-Fuel Emulsion Demonstration Project

Technology Manufacturer
MAN B&W Diesel
Sea to Sky Pollution Solutions

Co-Participants
Port of Long Beach, Port of Los Angeles, University of California-Riverside CE-CERT, Bay Area AQMD, Ventura County APCD, San Luis Obispo County APCD, Santa Barbara County APCD, California Air Resources Board, U.S. EPA Region 9

Background
The Technology Advancement Program completed participation in a demonstration of emission reduction technologies aboard the container ship *APL Singapore.* Two emission control technologies were demonstrated - the use of slide valves in the vessel's main engines, and water-emulsified bunker fuel using an innovative onboard water in fuel emulsifier.

Project Objective
To investigate the technical feasibility, engineering requirements, and potential for replication in other ocean going-vessels (OGVs), the San Pedro Bay Ports partnered with the U.S. EPA, CARB, and Air Districts to demonstrate two retrofit technologies that have the potential to significantly reduce both particulate matter and oxides of nitrogen (NO_x) emissions. The primary objectives of the demonstration project were to:

- Evaluate the particulate matter (PM) emission reduction effectiveness of retrofitting OGV main engines with an improved injector design known as a slide valve;
- Demonstrate demand-based onboard water in fuel emulsification system and measure the NO_x reduction effectiveness of varying the water content.

Technology Demonstration
Slide Valve Injectors – Slide valves installed on the APL Singapore's main engine differ from conventional valves in their spray patterns and are designed to reduce dripping of fuel from the injector during the combustion process. Particulate matter is a product of incomplete combustion and unburned fuel. Optimization of the fuel injection system was expected to result in a reduction in fuel consumption and a reduction of PM emissions on the order of 10% to 25%. The slide valve technology was provided by MAN B&W Diesel (MAN).

Water-in-Fuel Emulsification (WiFE) – WiFE is the process of introducing water into fuel prior to injection into the combustion cylinder. The fuel-water emulsion technology was provided by Sea to Sky Pollution

Solutions. A fuel homogenizer was installed in the APL Singapore's engine room to produce the emulsification. Fuel and water are carried by separate lines into a mixing chamber called a "homogenizer/emulsifier" which is essentially a large funnel. Inside the funnel is a rotor that spins with a very small clearance next to the funnel's walls. The spinning rotor draws in the fuel and water, mixes them together and squeezes the mixture out of the funnel with water present in the fuel as tiny droplets. The water droplets, as small as one micron (0.000001 meter in diameter) are fully contained within the fuel.

The fuel/water mixture is immediately injected and atomized within the engine's combustion chamber. The heat inside the combustion chamber causes the water droplets to vaporize into steam – this requires energy from the combustion process and results in lower peak combustion temperatures. The lower combustion temperatures reduce NO_x formation.

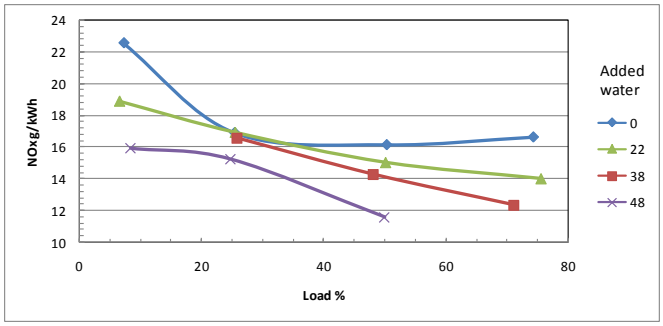
Status

The first emissions tests were conducted during a 15-day transpacific voyage from Kaohsiung Taiwan to the San Pedro harbor. Testing was conducted in parallel by University of California-Riverside and MAN B&W. A second test protocol was performed in spring 2008, also conducted by the University of California-Riverside in cooperation with engine manufacturer MAN B&W Diesel.

Results

Project test conditions resulted in an evaluation that indicated the benefits of slide valves appear to be limited. Emissions testing data were inconclusive and a clear determination of the technology benefits could not be made. Due to the importance of reducing emissions from OGVs, further study is being considered to gain more data and experience with slide valves as a potential emission reduction strategy.

Testing of the WiFE system aboard the APL Singapore yielded the results shown below in the figure below. As shown, water concentrations as high as 48% were successfully demonstrated, yielding NO_x reductions on the order of 30%[22].



Project Costs

Seven funding partners contributed approximately $1.3 million toward this demonstration and evaluation project. The San Pedro Bay Ports, the Bay Area, Ventura County, San Luis Obispo County, and Santa Barbara County Air Pollution Control Districts contributed funds towards the emissions testing element of the project. The San Pedro Bay Ports contributed $45,000 in TAP funding toward emissions testing.

Looking Forward

This project demonstrated the potential for NO_x reductions that can be achieved through OGV retrofit using commercially available emulsification technology. The ports are considering additional research to further evaluate the potential for OGV engine emission reductions from the use of slide valves. Engine designers (i.e., MAN and Warstilla) are working to meet/exceed customer need for reduced emissions and enhanced fuel economy. Slide valves are one of the many strategies being considered in this regard.

[22] *Measurement uncertainty ranges from 3% to 15% for these results.*

Balqon E-30 Electric Terminal Tractor Development & Demonstration Project

Technology Manufacturer
Balqon Corporation

Co-Participants
Port of Los Angeles
South Coast Air Quality Management District
(SCAQMD)

Background
The Balqon E-30 Electric Terminal Tractor was built as a demonstration vehicle, co-funded by the Port of Los Angeles and SCAQMD, and designed specifically for drayage operations. Developed by the Balqon Corporation as a Port of Los Angeles initiative, the prototype E-30 all- electric terminal tractor successfully completed cargo terminal tests during 2008.

Project Objective
Today, fleets of hundreds of hostlers - which are mostly diesel vehicles and a small number of LNG test units - move thousands of containers each day between the port's docks and terminal backland. The objective of the E-30 Electric Terminal Tractor demonstration project was to prove the performance capabilities and commercial feasibility and practicality of using zero-emission electric terminal tractors to perform this function.

Technology Description
Designed specifically for short-haul or "drayage" operations, this heavy-duty terminal tractor can pull a 60,000 pound cargo container at a top speed of 40 mph, and has a range between 30 to 60 miles per battery charge. The battery charger can charge up to four electric trucks simultaneously in four hours and can also provide up to 60 percent of the charge in one hour to meet peak demands during daily

operations. Key design and performance attributes of the Balqon E-30 electric terminal tractor are highlighted below:

Vehicle Performance	Maximum speed 45 mph; unloaded grade 10%, loaded 5%; Max GCWR 125,000 lbs; Range: unloaded 150 miles; fully loaded range 90 miles
Vehicle Dimensions (inches)	Overall – 210" X 96" X 120"; wheelbase 135"; fifth wheel height 46"; front wheel overhang 44", rear wheel overhang 31"
Electric Motor	300 hp rated 230 volt AC electric motor connected to flux vector variable frequency controller; 300% peak load rating
Traction Controller	Proprietary flux vector motor controller 240 KW liquid cooled; integrated CAN BUS and self-diagnostic system
Traction Battery	280 kW-hr lead acid battery pack, 336 Volt; battery management system monitors battery cell performance
Battery Charger	100 KW multi-vehicle fast charger; 4 charging ports standard; priority smart charge algorithm based on vehicle state of charge

Benefits

The Balqon E-30 is a zero emission electric vehicle using electric motors for motive power and batteries for energy storage; thus, "tailpipe emissions" for this low-speed electric terminal tractor are zero. Based on the average emissions generated by the existing fleet of drayage trucks that serve the San Pedro Bay ports, POLA estimated the average pollution discharge generated by the estimated 1.2 million truck trips that occurred in 2006 between the ports and the Intermodal Container Transfer Facility or ICTF. If those 1.2 million truck trips were to be made with zero emission electric trucks, an estimated **35,605.6 tons** of tailpipe emissions would be eliminated, including:

- 21.8 tons per year of Diesel PM
- 427.7 tons of localized NOx
- 168.5 tons of carbon monoxide (CO)
- 34,987.6 tons of CO_2

On a "kilowatt-hour of energy" cost basis, the Balqon electric truck costs approximately 20 cents per mile to operate. A typical class 8 diesel truck could cost anywhere from four to nine times as much, depending on the cost of diesel fuel and truck duty cycle.

Status

Following the completion of cargo terminal tests during 2008, the Los Angeles Harbor Commission approved the purchase of 20 electric trucks from the manufacturer as part of the "Green Terminal" program. These trucks will be deployed as a zero emissions alternative to fossil fuel-powered yard tractors. The Green Terminal program will also include the production of five on-road electric trucks. In total, the Port of Los Angeles is investing more than $5.6 million to demonstrate the viability of electric drayage trucks.

Project Costs

The development and demonstration of the Balqon electric terminal tractor was co-funded by the Port of Los Angeles and SCAQMD at a total cost of $527,000.

Project Partners	Contributions
Port of Los Angeles	$263,500
South Coast AQMD	$263,500

Commercialization and Applications

As a provision of future electric truck orders, POLA required Balqon to locate its manufacturing facility in the City of Los Angeles and pay the Port a royalty for every electric truck it sells or leases worldwide. Those funds will be used to advance other Port TAP initiatives. The new Balqon manufacturing plant will support the creation of approximately 50 new "green collar" jobs.

Advanced Maritime Emission Control System (AMECS)

Technology Manufacturer
Advanced Cleanup Technologies, Inc. (ACTI)

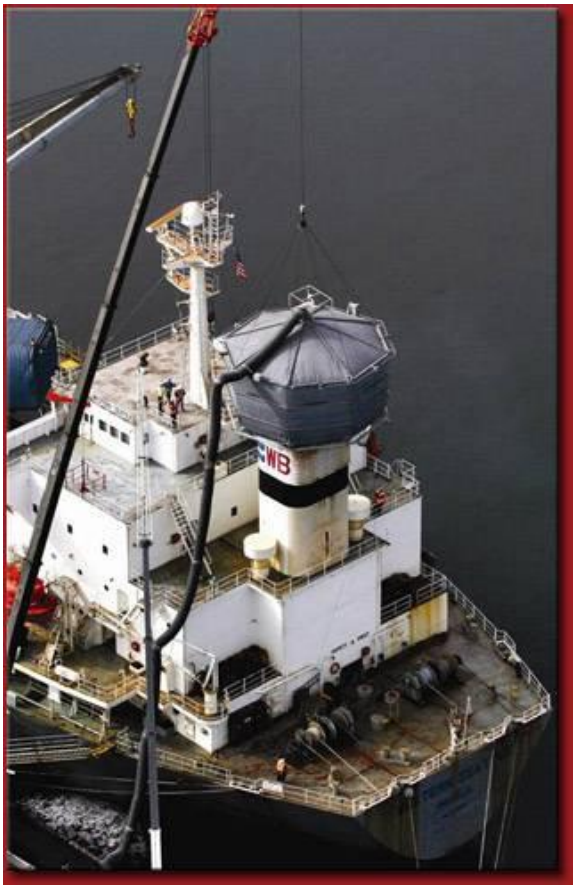
Co-Participants
Port of Long Beach, Port of Los Angeles, South Coast Air Quality Management District, Metropolitan Stevedore Company, Engine Fuel & Emissions Engineering, Inc., Professional Environmental Services

Background
Advanced Cleanup Technologies, Inc. (ACTI) is a professional full service firm specializing in environmental emergency response, hazardous waste cleanup, and air pollution control technology. ACTI developed the Advanced Maritime Emissions Control System, or AMECS, as an alternative pollution control method for ocean-going vessels that are not configured to use shore power, also known as "cold ironing", while at berth.

Project Objective
To investigate the technical and commercial feasibility of reducing emissions from ocean-going vessels not configured to use shore power while at berth. The goal was to demonstrate pollution reduction efficiencies equal to cold ironing for nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM).

Technology Demonstration
The AMECS uses a shroud lifted over the vessel exhaust stack by means of a specially designed crane and deployment arm. The shroud is then lowered over the stack and then cinched to provide a soft attachment between the shroud and the ship's stack.

A seal closes the open area between the perimeters of the bonnet and ship's stack to limit the amount of air entering the bonnet as well as to prevent exhaust gases from escaping. The exhaust gases from the ship's auxiliary engines and the boilers are routed through a flexible duct to an Emission Treatment System (ETS) located on the dock adjacent to the vessel's berth. The ETS uses multiple exhaust gas treatment technologies to remove both gaseous and particulate pollution:



The **Pre-Conditioning Chamber** (PCC), which uses a counter-flow spray system to remove PM and water soluble organic gases. The spray water is treated with sodium hydroxide to simultaneously remove sulfur oxide pollution. The water spray also cools the exhaust gas, allowing smaller particles to coalesce such that they are more efficiently captured in subsequent phases of exhaust gas treatment;

Cloud Chamber Scrubbers (CCS) remove the remaining exhaust PM. Three separate units generate a fog of very fine water droplets with a high electrical charge. The charged water droplets attract and capture multiple PM particles. The PM laden water is circulated through filters where the PM is removed. The three cloud chambers are identical except for the polarity of the charge imparted to the water droplets. Sodium hydroxide is also injected into the water streams of the cloud chambers to remove any remaining sulfur oxides;

Selective Catalytic Reduction (SCR) **Reactor** removes NO_x emissions. Liquid urea is injected into the hot gas stream ahead of the SCR where it is converted to ammonia. The ammonia reacts with the NO_x while passing through the catalyst to form nitrogen and water vapor, which are then vented to atmosphere. The SCR Reactor is designed to remove at least 99% of the NO_x emitted by the vessel while at berth;

The **Continuous Emissions Monitoring System** (CEMS) is used to measure exhaust gas pollution levels both into and out of the ETS. This system is used to gauge pollutant removal efficiency, as well as control the injection rates of sodium hydroxide and urea used during exhaust treatment.

Status

The TAP-sponsored AMECS demonstration and testing project was completed as of July, 2008. The Final Report documenting the test protocols and measured emission reduction efficiency levels was prepared by TIAX LLC on behalf of ACTI and submitted to the ports and South Coast AQMD for review and comment. The demonstration results were also provided to and underwent an independent evaluation by the California Air Resources Board (CARB). As a result of their evaluation, CARB submitted a letter on December 15, 2008, stating their concurrence with the AMECS emissions efficiency testing results.

Results

The AMECS was demonstrated at Metropolitan Stevedore/Port of Long Beach on multiple vessels with varying exhaust stack configurations. During the demonstration period, two full-scale emission reduction efficiency tests were conducted, the results of which were independently verified by two testing laboratories.

Benefits

During emissions testing, NO_x and PM emissions were reduced by 99% and 95.5%, respectively. In addition, sulfur oxides (SOx) were reduced by 99%, and volatile organic compound (VOC) emissions were reduced by greater than 97 percent.

Project Costs

The total project cost was $603,211. Funding included $149,527 from each port's TAP budget and a $55,000 contribution from the South Coast AQMD.

Commercialization and Applications

Further demonstration of this technology is necessary to determine how it functions in day-to-day operations, including evaluation of costs, durability, integration into operations, etc. ACTI is conducting additional testing with SCAQMD, using a grant from EPA. At the conclusion of the demonstration, the system should secure validation of the emission performance from EPA and CARB, which can clear the way for future commercialization of the technology.

Vycon REGEN® System for Rubber-Tired Gantry Cranes

Technology Manufacturer
VYCON Energy

Co-Participants
Port of Los Angeles, Port of Long Beach, South Coast Air Quality Management District, California Air Resources Board, ITS, Evergreen and VYCON

Background
The VYCON REGEN® system supports the goal of clean air and a healthier environment through the reduction of air pollution from port equipment. Specifically for this project, a rubber tire gantry (RTG) crane operating at each port was retrofit with the VYCON system.

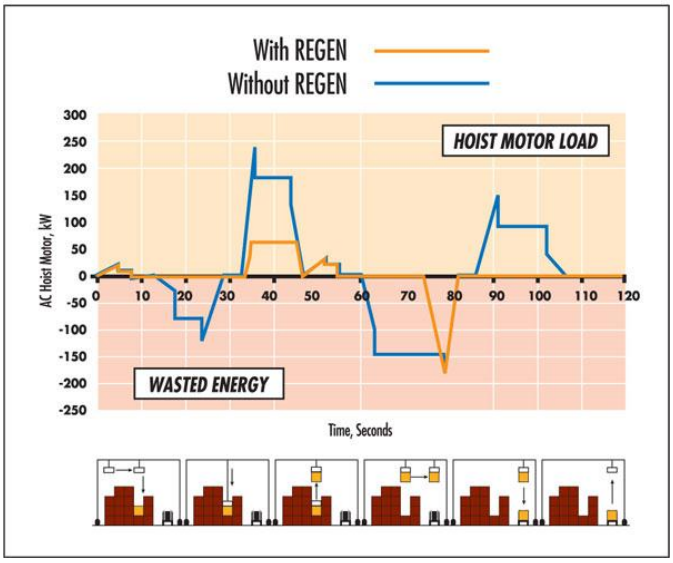
Project Objective
Two marine terminals, ITS in the Port of Long Beach and Evergreen in the Port of Los Angeles, installed VYCON's REGEN system onto one of the terminals' rubber tire gantry (RTG) cranes.

Technology Description
VYCON's REGEN system is an energy storage system that is also capable of supplying the stored energy on demand.

The REGEN system is re-charged each time the AC motor in the hoist regenerates power (i.e., on the down cycle). This stored energy is then quickly released back to the AC motors during the "up" cycle, resulting in increased efficiency during each lift cycle. The transitions are seamless and instantaneous. This conserves energy, increases fuel efficiency, and reduces emissions as well as operating costs. The REGEN System can be retrofitted onto in-use cranes or installed at the factory as part of a new crane.

Results
The primary TAP role in this project was to co-fund emissions testing in support of CARB verification. This work was completed and VYCON received its Level 1 CARB verification in October, 2007.

Typical Load Profile vs. Load Profile with REGEN



Benefits

VYCON's REGEN system is verified to reduce particulate matter (PM) emissions by a minimum of 25 percent and is estimated to reduce oxides of nitrogen (NOx) emissions by 30 percent. Emissions of carbon dioxide (CO2) are estimated to be reduced by about 30 percent, resulting from the associated reduction in diesel fuel consumption up to 35 percent.

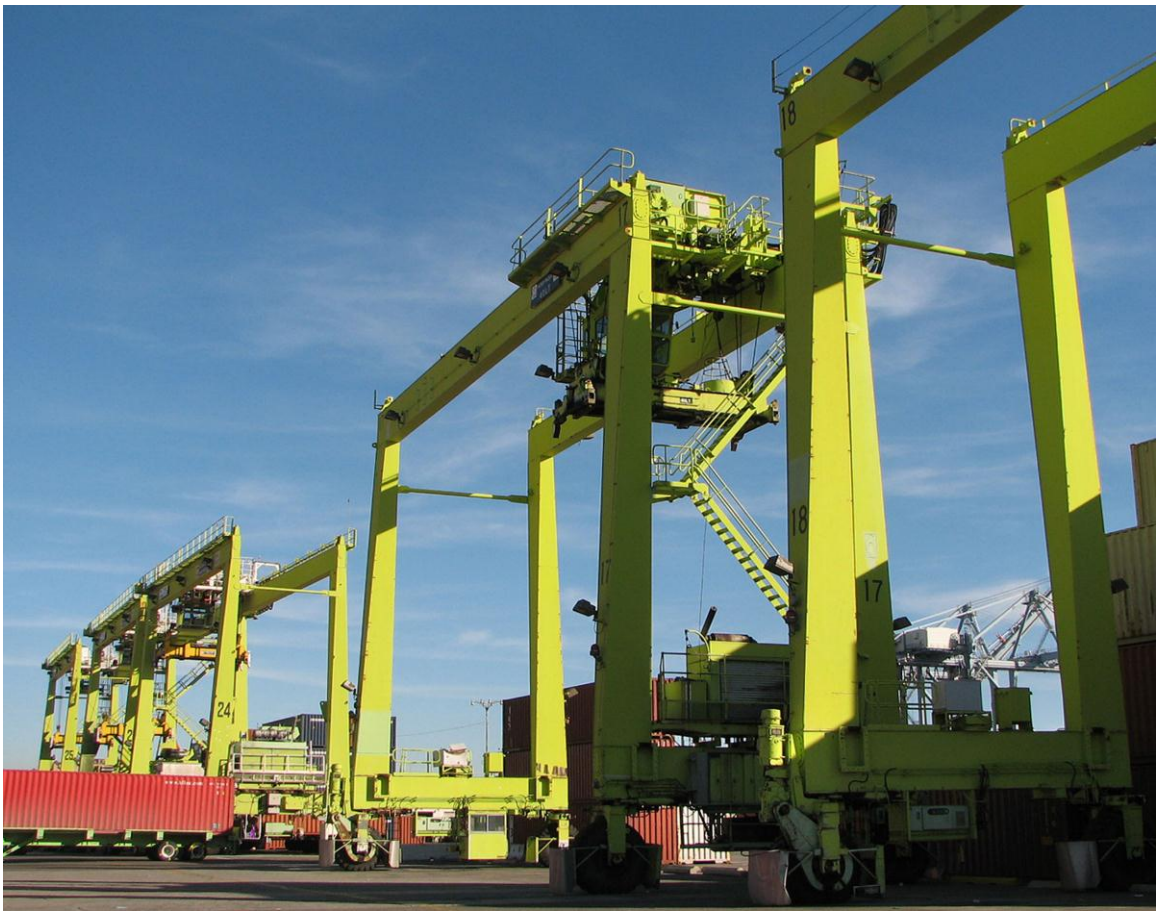
Project Costs

The TAP supported the VYCON verification effort by co-funding emissions testing of the project equipment. Each port committed $11,500 for a total cost of $23,000.

Commercialization and Applications

The VYCON flywheel regeneration system already has a number of applications. In addition to the Level 1 RTG crane application, VYCON's REGEN system is also used in rail, uninterruptable power supply (UPS) and wind power applications.

Air Resources Board.



Liquefied Natural Gas (LNG) Yard Tractor Project

Technology Manufacturer
Kalmar Industries
Cummins Engine Company

Co-Participants
Port of Long Beach, U.S. EPA Region 9, Long Beach Container Terminal, CALSTART

Background
Yard tractors, also referred to as yard hostlers, terminal tractors, and yard goats, are heavy-duty off-road truck tractors designed for moving cargo containers within port container terminals and other off-road areas. These vehicles are the most common type of cargo handling equipment (CHE) used at container terminals at the ports. According to emission inventories compiled by the Ports of Long Beach and Los Angeles, yard tractors emit approximately 64% of the particulate matter (PM) and 59% of the nitrogen oxides (NO_x) emissions for all cargo handling equipment, as shown in Figures 2.3-1 and 2.3-2, below. Further, yard tractors are the single largest landside source of PM and NO_x emissions at the ports.

Project Objective
To investigate the technical and commercial feasibility of reducing emissions from yard tractors, the Port of Long Beach, in partnership with the U.S. EPA, funded the demonstration of yard tractors equipped with low-emission liquefied natural gas (LNG) engines.

Technology Demonstration
The project was divided into three phases. The first phase focused on development of LNG yard tractor specifications, procurement, and installation of temporary LNG refueling.

Phase 2 included operation of the LNG yard tractors at a marine terminal for a period of eight months. Demonstration commenced in June 2006 and was completed in January 2007. During this time, data were collected on the performance of the LNG yard tractors compared to a group of baseline diesel vehicles. Emissions testing was also conducted at the conclusion of the second phase;

The third phase of the project was the development of a business case assessment to determine the cost-effectiveness and return on investment of using LNG equipment as opposed to diesel.

The project team consisted of the Port of Long Beach, U.S. EPA Region 9, Sound Energy Solutions, CALSTART, and Long Beach Container Terminal (LBCT). LBCT volunteered to test the LNG yard tractors in their container terminal operations during the eight month evaluation period.

A total of three LNG yard tractors were deployed for performance testing and evaluation. Specifications for the LNG yard tractors were based on the Ottawa Commando 50 4x2 off-road terminal tractor performance specifications.

The LNG engine specified for the demonstration was the model year 2005 Cummins C Gas Plus 8.3 liter natural gas engine, rated at 250 hp and certified to the CARB on-road Optional NO_x standard.

Eight diesel yard tractors were selected from LBCT's fleet to serve as the baseline yard tractor group for comparative purposes. The baseline vehicles were equipped with various off-road diesel engines, ranging from model year 2001 to 2003 Cummins 8.3 liter 6CT engines rated at 205-215 hp and certified at Tier 1 or Tier2, to model year 2005 Cummins 5.9 liter ISB engines certified to the on-road emissions standard. All baseline diesel engines were equipped with diesel oxidation catalysts and closed crankcase ventilation (CCV) to reduce particulate matter emissions. Data was collected on the baseline yard tractor group in parallel with the LNG tractors under similar operating conditions.

Results

Data collection was performed for quantitative parameters, such as fuel consumption and exhaust emissions, as well as qualitative attributes, such as operator perceptions of vehicle drivability. With respect to fuel economy, the LNG yard tractors used approximately 30% more fuel, on a diesel equivalent gallon basis, as compared to the average for baseline diesel vehicles. This result is consistent with expectations for the relative efficiency of a spark-ignited natural gas engine compared to a compression-ignited diesel engine.

Operator acceptance was assessed via surveys given to all LNG yard tractor drivers. Drivers were asked to rate the LNG yard tractor as 'better", "same", or "worse" in key performance areas compared to a typical diesel tractor. The areas covered by the survey included maneuverability, pulling power, acceleration, shifting, steering, in-cab visibility, ride comfort, etc.

Based on the driver surveys, 97% of the drivers found the LNG yard tractors to have the same or better performance compared to the diesel tractors; 67% of the drivers rated the LNG tractors as having superior performance in general.

Benefits

During emissions testing, the lowest NO_x and PM emissions were produced by the 2005 on-road diesel engine-equipped tractor and the 2005 LNG tractor, respectively. NOx emissions from the LNG yard tractor were approximately 21% higher than NO_x emissions from the on-road diesel engine equipped with a diesel oxidation catalyst and closed crankcase ventilation system.

Project Costs

The total project cost was $425,000. Funding included $350,000 from the Port of Long Beach TAP Program and a $75,000 contribution from U.S. EPA Region 9.

Commercialization and Applications

Original Equipment Manufacturer (OEM) yard tractor chassis manufacturers now offer LNG yard tractors equipped with the Cummins Westport ISL G natural gas engine. This 8.9 liter heavy-duty on-road engine is certified at the 2010 emission standard of 0.2 g/bhp-hr.