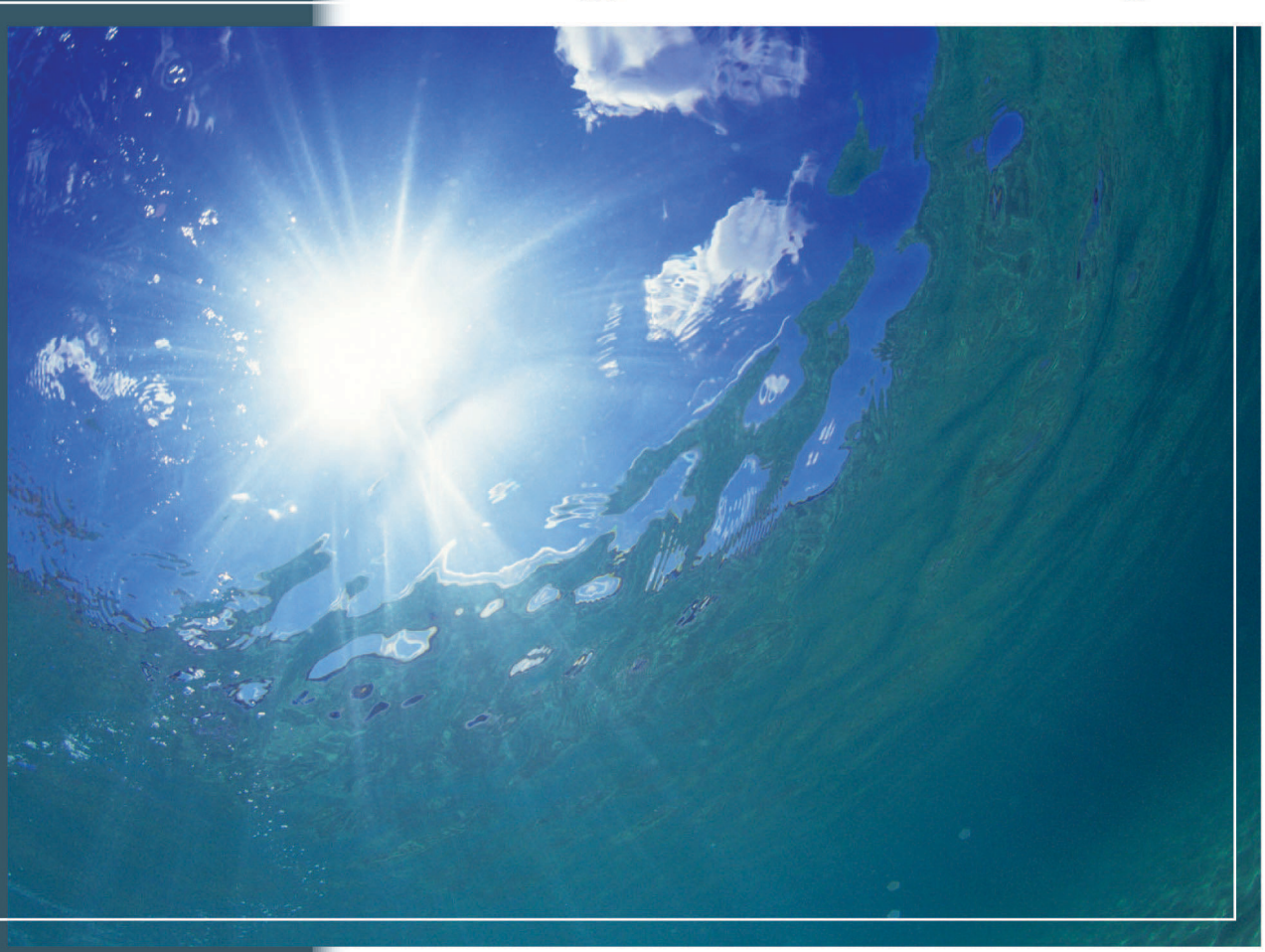
2010 Annual Report
April 2011

San Pedro Bay Ports Clean Air Action Plan Technology Advancement Program



Moving towards zero emissions

THE PORT OF LOS ANGELES

Port of LONG BEACH
Centennial Celebration

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Acronyms & Abbreviations

AC	TAP Advisory Committee
ACTI	Advanced Cleanup Technologies Incorporated
AMECS	Advanced Maritime Emissions Control System
APL	Shipping line formerly known as American President Line
CAAP	Clean Air Action Plan
CARB	California Air Resources Board
CEC	California Energy Commission
CEMS	Continuous Emissions Monitoring System
CHE	Cargo Handling Equipment
CNG	Compressed Natural Gas
CO	carbon monoxide
CO_2	carbon dioxide
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
EPA	United States Environmental Protection Agency Region 9
GHG	green house gases
HC	harbor craft
HC	hydrocarbons
IMO	International Maritime Organization
LNG	liquefied natural gas
MDO	marine diesel oil
MGO	marine gas oil
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 Lines

ACRONYMS & ABBREVIATIONS (CONT'D.)

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
SoCalGas	Southern California Gas Company
SO_x	sulfur oxides
SO_2	sulfur dioxide
SPBP	San Pedro Bay Ports
TAC	toxic air contaminant
TAP	CAAP Technology Advancement Program
U.S. EPA	United States Environmental Protection Agency
VSR	vessel speed reduction

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 recent economic conditions have caused a near-term reduction in imports and exports, latest economic forecasts still indicate that demand for containerized cargo moving through the Southern California region will increase significantly by the year 2020. 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 (NO_x), and sulfur oxides (SO_x). DPM is of particular concern as it is linked to cancer and other serious health effects. NO_x and SO_x 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]

To ensure effective air pollution reduction strategies are commercially available to enable implementation of CAAP measures, the ports developed and are currently implementing the Technology Advancement Program (TAP). 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 Technology Advancement Program is to *"accelerate the verification or commercial availability of new, clean technologies through evaluation and demonstration to move towards an emissions free port".*

[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*)

The TAP is funded on an annual basis by both ports. Each port allocates $1.5 million annually to 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), 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, 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, 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.

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

This is the fourth TAP Annual Report under the CAAP. The 2010 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 seven (7) projects that were either selected or continued to be implemented under the TAP during 2010. These include:

Source Category	TAP Project
▪ Ocean Going Vessels	Bluefield Holdings Inc. Krystallon OGV Scrubber
▪ Cargo Handling Equipment	Alternative Petroleum Technologies' Emulsified Biodiesel
	Long Beach Container Terminal Eco-Crane™
	Rypos Advanced Diesel Particulate Filter
▪ Container Drayage Trucks	Vision Motor Corp. Hydrogen Fuel Cell Hybrid Electric Truck
	Heavy-Duty Drayage Truck Duty-Cycle
	Balqon Lithium-Ion Battery Demonstration

Each of the projects listed above is discussed in Section 2 of this 2010 Annual Report. In addition to these active projects, Section 3 provides a summary of the one project that was withdrawn during 2010: the OceanAir Environmental ECO Tug™ tugboat.

2010 was an exciting year for the TAP. In addition to the initiation or continued implementation of the above projects, the following projects were completed in 2010:

- SoCalGas CNG Drayage Truck Demonstration
- Westport GX LNG Engine Development
- Foss Maritime Green Assist™ Hybrid Tugboat
- U.S. Hybrid's Hybrid Yard Tractor Development & Demonstration
- Capacity Plug-In Hybrid Electric Terminal Tractor

Please see Appendix B for complete summaries of these recently completed projects, as well as all other projects completed by the TAP to date.

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 recent economic conditions have resulted in a reduction in imports and exports, latest economic forecasts still indicate that the demand for containerized cargo moving through the Southern California region will increase significantly by the year 2020. 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.

The 2010 CAAP Update includes strategies, such as mitigation measures and incentive programs, necessary to reduce air emissions and health risks while allowing port development to continue. Since both ports have several terminal redevelopment projects that could be approved and implemented in the next five years, there are significant opportunities to implement the measures defined by the CAAP to satisfy the dual goals of clean air and economic growth.

To ensure effective air pollution reduction strategies are commercially available to satisfy CAAP mitigation measures, the ports developed and are currently implementing the TAP. 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.

This document is the fourth 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 2010 calendar year, one new port-sponsored project was generated under the TAP. This project is the Heavy-Duty Drayage Truck Duty Cycle Characterization Project, which is summarized in Section 2.

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 2010, a Request for Information (RFI) was released 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 at-berth at the ports. The RFI for Ocean-Going Vessel At-Berth Emissions Reduction Technologies resulted in 15 responses, which are currently being evaluated by port staff.

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 – *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 2010 calendar year, two unsolicited proposals were considered and approved under the TAP. The projects are Bluefield Holdings Krystallon OGV Scrubber and Vision Motor Corporation Hydrogen Fuel Cell Hybrid Electric Truck projects, which are summarized in Section 2.

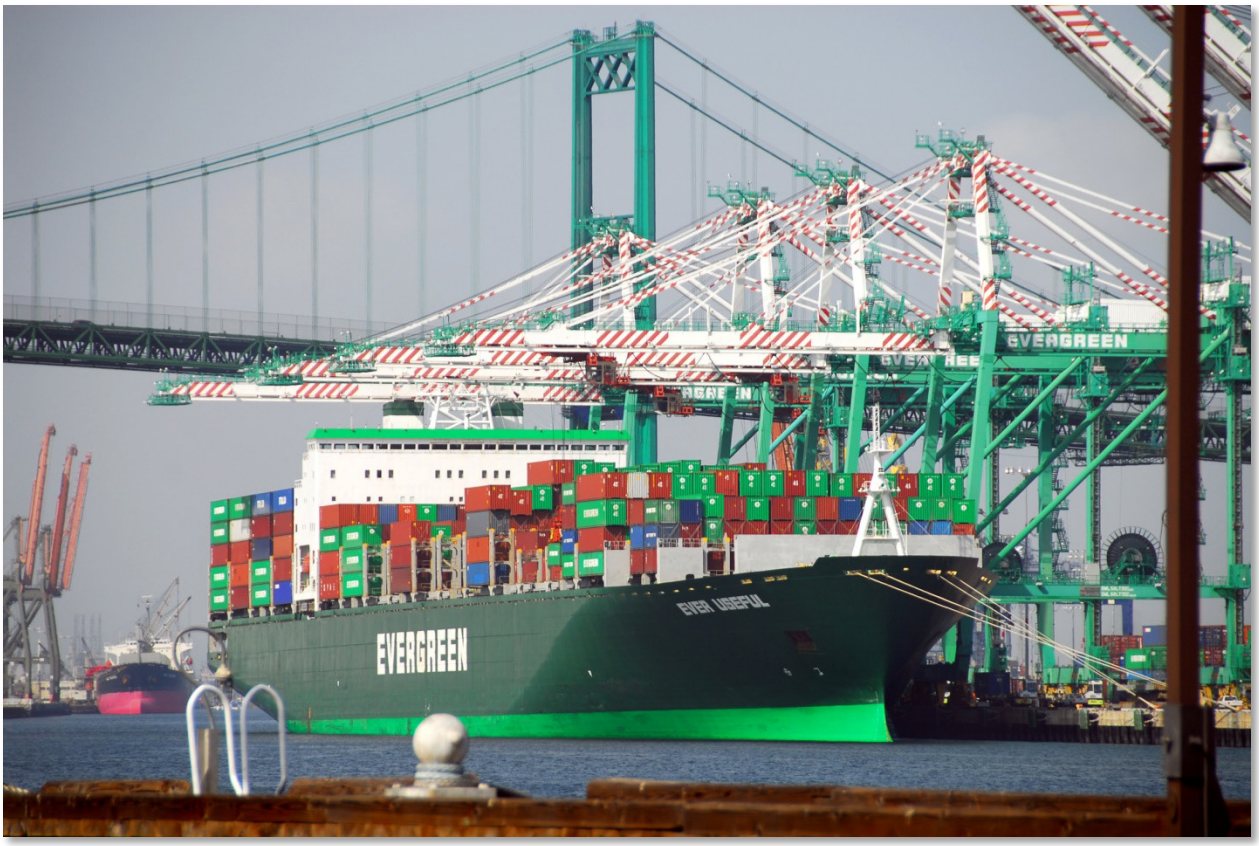
1.4 Advisory Committee

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 represent each agency's availability of co-funding from their agency that could potentially be used to move projects toward implementation.

In 2010, 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 2010

This fourth Technology Advancement Program Annual Report includes a summary of the seven (7) projects that were implemented or remained active in 2010. These include:

Source Category	TAP Project
▪ Ocean Going Vessels	Bluefield Holdings Inc. Krystallon OGV Scrubber
▪ Cargo Handling Equipment	Alternative Petroleum Technologies' Emulsified Biodiesel
	Long Beach Container Terminal Eco-Crane™
	Rypos Advanced Diesel Particulate Filter
▪ Container Drayage Trucks	Vision Motor Corp. Hydrogen Fuel Cell Plug-In Hybrid Electric Truck
	Heavy-Duty Drayage Truck Duty-Cycle
	Balqon Lithium-Ion Battery Demonstration

A summary and status update for each of the projects listed above is discussed in this Annual Report. In addition to the above projects, five (5) TAP projects were completed during 2010. 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 include:

1. SoCalGas CNG Drayage Truck Demonstration
2. Westport GX LNG Engine Development
3. Foss Maritime Green Assist™ Hybrid Tugboat
4. U.S. Hybrid's Hybrid Yard Tractor Development & Demonstration
5. Capacity Plug-In Hybrid Electric Terminal Tractor
6. APL Singapore Slide Valve & Water-In-Fuel Emulsion Demonstration Program
7. Balqon E-30 Electric Terminal Tractor Development & Demonstration Project
8. Advanced Maritime Emission Control System (AMECS) Project
9. VYCON REGEN® System for Rubber-Tired Gantry Cranes Testing & Verification
10. Liquefied Natural Gas Yard Tractor Demonstration

2.1 Ocean-Going Vessels

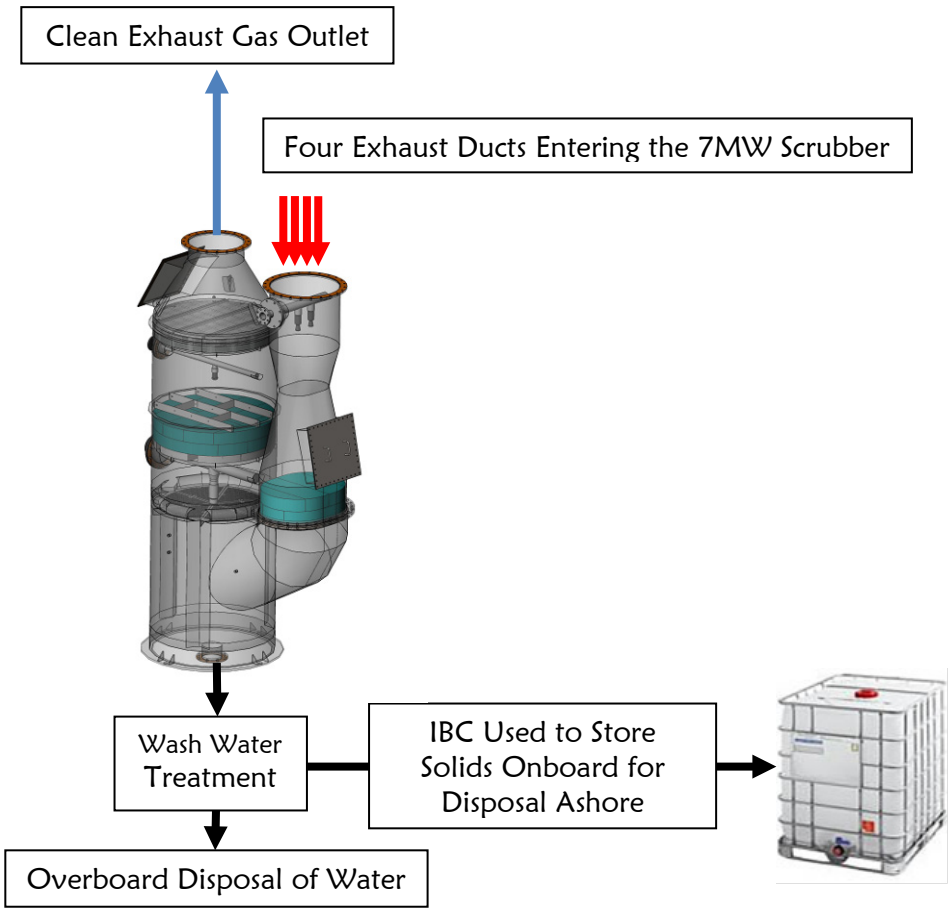
2.1.1 Bluefield Holdings Krystallon OGV Scrubber

The 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 then treated to remove contaminants and chemical constituents; 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

This TAP project 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 ocean-going vessel. The Krystallon scrubber will be configured to treat the combined emissions from all auxiliary engines. The design is shown schematically in Figure 2.1-1 below, 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 scrubber will be fabricated in Norway and fitted on the vessel during a regularly scheduled dry-docking in China in early 2011. Commissioning of the scrubber will commence before the dry-docking is complete since, the auxiliary engines are operated while the vessel is in the dry dock. Krystallon engineers will be onsite at the shipyard during the fabrication, installation and commissioning of the 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 ports 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 washwater will take place in 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. Bluefield Holdings/Krystallon has 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. TAP funding is directed to cover the actual scrubber and installation costs.

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 removes over 80% of the total DPM normally emitted from a marine engine; this includes 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 large reductions of DPM brought about by this project will be immediate; significantly more DPM will be removed by the scrubber than simply running distillate fuel in the auxiliaries and boiler. Table 2.1-2 summarized 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 calls at the San Pedro Bay Ports an average of 6 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. The residential areas immediately surrounding the port will directly benefit from this reduction in OGV exhaust emissions.

Project Status

The project kick-off meeting commenced on October 27, 2010. Sea water scrubber installation will be undertaken in early 2011. The demonstration will begin in the early part of second quarter of 2011.

2.2 Cargo Handling Equipment

2.2.1 Alternative Petroleum Technologies, Inc. Emulsified Biodiesel Fuel

The use of biodiesel fuel blends as a method to reduce DPM and GHG emissions from equipment has been studied extensively. The results consistently show that while biodiesel fuels produced from renewable sources have the potential to effectively reduce HC, CO, and DPM emissions, there is often a corresponding increase 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.

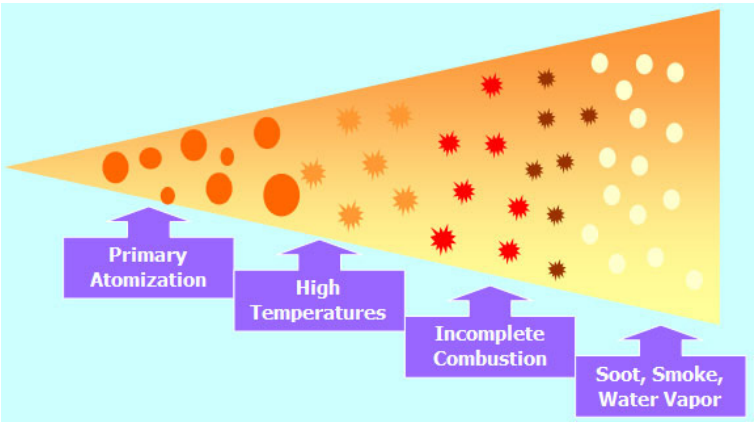
The technical community has known for many years that emulsified diesel fuel, made by blending water and additives into diesel fuel, will reduce emissions of particulate matter and NO_x as compared to conventional ultra-low sulfur diesel fuel. However, several issues, including incompatibility with certain diesel engine components and operability concerns due to power loss, have minimized widespread acceptance of diesel-water fuel blends. Many of these problems can be attributed to the high water content (on the order of 16% or more) of previously available emulsified diesel products.

Under the TAP, Alternative Petroleum Technologies, Inc. (APT) is demonstrating the viability and effectiveness of emulsified biodiesel fuel with lower water content. Preliminary test results indicate that NOx emissions are mitigated at approximately 6% water content by mass. A slight fuel consumption penalty was reported, though no operational issues have been encountered during the demonstration to date.

Emission Control Technology

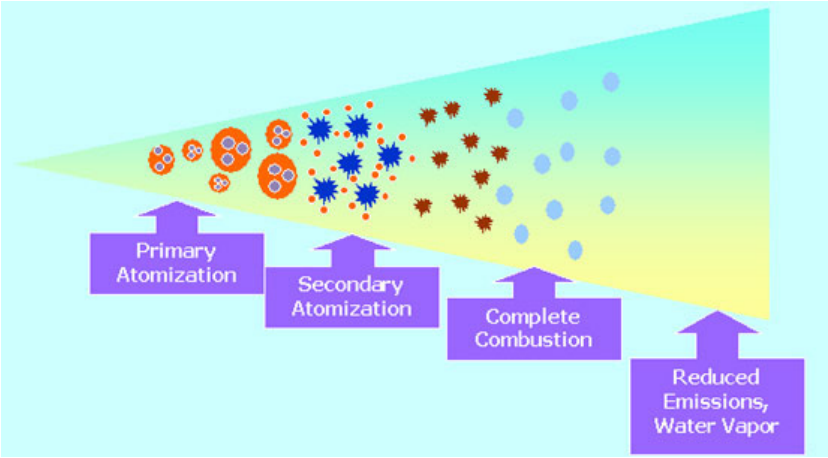
Introducing water to petroleum products for combustion is a concept that has been around for centuries; reference to water as an ancillary combustion control technique can be found as early as 1791 in a gas turbine patent. When diesel fuel is sprayed into the combustion chamber, it is atomized into droplets varying in size from 20 to 100 microns in diameter (approximately 0.001 to 0.004 inches in diameter) (See Figure 2.2-1).

Figure 2.2-1: Combustion of Conventional Diesel Fuel



Since only the surface of each fuel droplet exposed to air can burn, larger liquid fuel droplets do not burn completely, leaving unburned carbon to collect on the surfaces of a combustion chamber or escape as PM in exhaust gases. This reduces overall thermal efficiency and increases harmful emissions, as denoted in Figure 2.2-2.

Figure 2.2-2: Combustion of Emulsified Biodiesel Fuel



Unlike conventional diesel fuel, when emulsified fuel droplets are sprayed into the combustion chamber, they are atomized a second time as a result of the violent transformation of their water content into steam. This transformation of water into steam shatters the petroleum surrounding that water into much smaller droplets, shown in Figure 2.2-2 at left. Smaller droplets have a much greater surface area, significantly improving the efficiency of combustion. This unique combustion characteristic of emulsified fuels is known as "secondary atomization". A secondary effect of water transforming into steam is that peak combustion temperatures are reduced, resulting in the formation of significantly fewer ozone-forming NO_x emissions. The changes in combustion kinetics also significantly reduce PM emissions that result from incomplete combustion.

The focus of the APT emulsified biodiesel demonstration is a B-20 blend (20% biodiesel and 80% ultra-low sulfur diesel) used in off-road heavy-duty cargo handling equipment. In addition to testing the emulsified biodiesel fuel, the project will investigate the potential to achieve additional significant reductions in DPM by installing a diesel oxidation catalyst (DOC) on one unit that is using the emulsified biodiesel fuel. The manufacturers of numerous verified diesel emission control systems, such as diesel oxidation catalysts and diesel particulate filters, have indicated that their systems are compatible with biodiesel blends at B-20 or less. The combination of emulsified biodiesel fuel and verified diesel emission control system has the potential to provide cost-effective emission reductions.

Project Partners & Funding

Ports America provided three top picks for use in the demonstration. The demonstration phase is expected to last approximately six months, during which emissions testing and data collection will occur to support APT's application seeking Level 2 verification from CARB.

Funding for the emulsified biodiesel demonstration is being 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, should the demonstration prove successful. Table 2.2-1 summarizes the project partner contributions for this project.

Table 2.2-1: Emulsified Biodiesel Fuel Demonstration Funding Partners

Project Partners	Contributions
▪ Port of Long Beach	$44,000
▪ Port of Los Angeles	$44,000
▪ APT Co-funding Contribution	$88,000

Environmental Benefits

Table 2.2-2, below, shows the expected levels of emission reduction from using APT emulsified B-20 in combination with a DOC in off-road cargo handling equipment. It is significant to note that any increase in NO_x emissions resulting from the use of biodiesel is expected to be offset by the inclusion of water in the fuel blend; the net result is an expected decrease in overall NO_x emissions on the order of seven percent.

Table 2.2-2: Anticipated Emission Reduction Potential of Emulsified Biodiesel Fuel + DOC

	PM	HC	CO	NO_x	CO_2	SO_2
Reduction (%)	50%	80%	80%	7%	14%	21%

Project Status

Under the TAP, Alternative Petroleum Technologies, Inc. (APT) is demonstrating the viability and effectiveness of emulsified biodiesel fuel with lower water content. The in-use demonstration began on August 12, 2010 with operation at West Basin Container Terminal (WBCT) of three 2008 model year Taylor top handlers on B20, a blend of CARB off-road diesel fuel with 20% biodiesel (i.e., the baseline fuel). The feedstock for the biodiesel is 100% soy based. The baseline biodiesel was operated for nearly a month, with no operational complaints, though an increase in fuel consumption of up to 8% was experienced early in the demonstration (as reported in the project's Interim Report).

Fueling practices mirrored existing fueling protocols, with the addition of special staff assignment and training to ensure incorrect fueling did not occur. Fuel samples were taken weekly to ensure fuel quality and specifications remain consistent throughout the project term. To date, there have been no mis-fuelings for this project.

On September 2, 2010, WBCT received its first delivery of emulsified B20. The emulsification was prepared with 6% water by mass and a 3% (by mass) proprietary APT additive. This blend was developed based on laboratory test results indicating a 6% water emulsification would help achieve the targeted results. The emulsified B20 was operated in the test vehicles for 57 days, with no operational concerns and an 8% increase in fuel consumption.

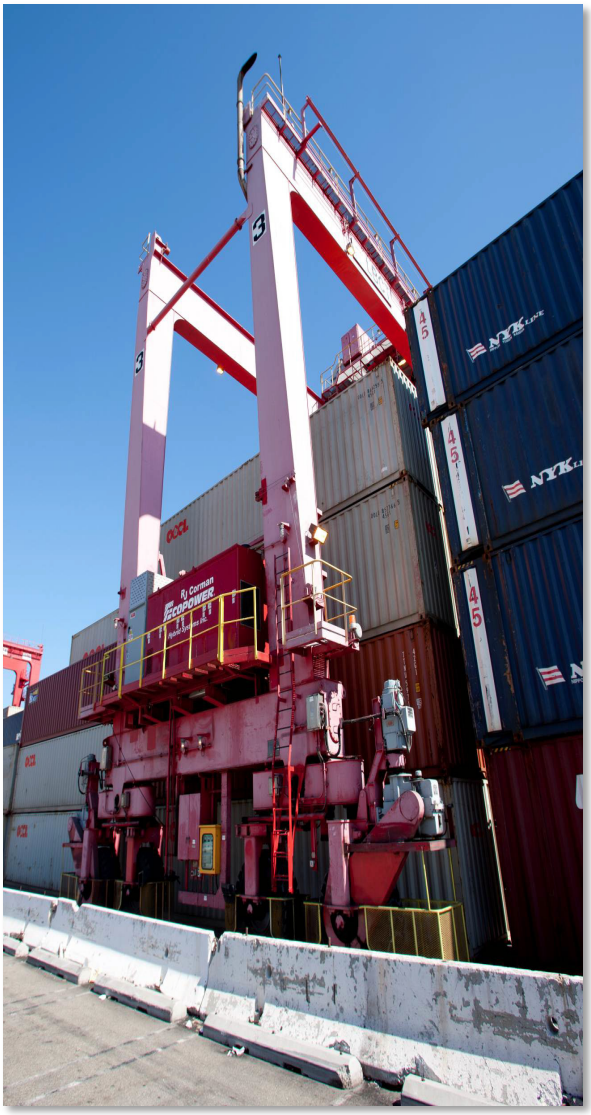
On November 5, 2010, a diesel oxidation catalyst (DOC) was installed on one of the project vehicles. Operation of the vehicle using both the emulsified B20 fuel and the DOC will continue for a few months into 2011.

Preliminary test results indicate that NOx emissions are mitigated at approximately 6% water content by mass. While fuel consumption penalties were reported, no operational issues have been encountered during the demonstration to date.

The demonstration is expected to be complete in early 2011, when final emissions testing and field testing results will be available.

2.2.2 Long Beach Container Terminal EcoCrane™

Long Beach Container Terminal, Inc. (LBCT), in partnership with Railpower Technologies, continued their demonstration of a retrofit technology that converts a conventional RTG to a "hybrid-electric" configuration. Similar to hybrid automobiles now commonplace on California roadways, the Railpower EcoCrane™ employs a smaller, lower emitting engine coupled with a regenerative braking energy capture and battery storage system. The result is significant crane efficiency improvement and corresponding reduction in air pollutant emissions.

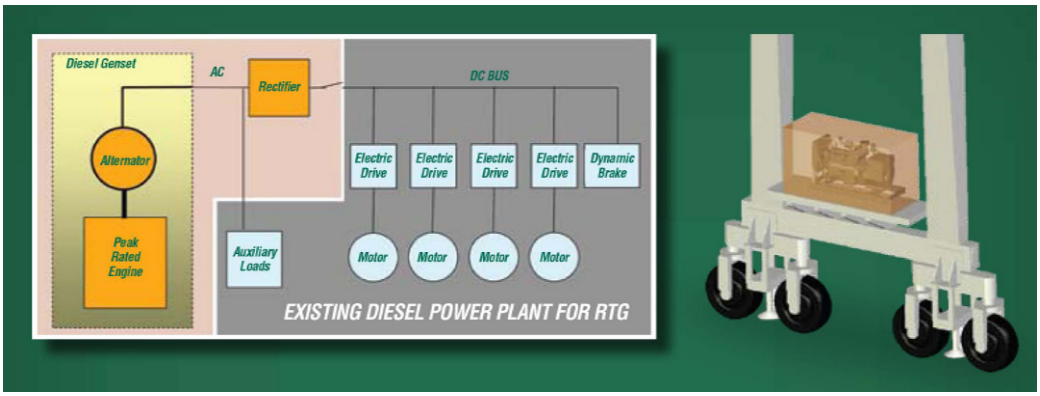


Emission Control Technologies

When applied to cranes, hybrid technology offers the opportunity to reduce fuel consumption by 60% to 85%, simultaneously reducing emissions of both criteria air pollutants as well as greenhouse gases. The use of a Level 3 verified diesel emission control system, such as a diesel particulate filter, results in a reduction in overall air pollutant emissions approaching 90 percent.

The original design for the EcoCrane™ was based on a locomotive proof of concept. Railpower Technologies has now downsized the design specifically for RTG crane use. The RTG design removes the large diesel engine from the RTG genset and replaces it with a smaller engine that consumes less fuel. The EcoCrane™ then adds a regenerative braking energy capture and battery storage system. This allows the energy that is typically wasted when lowering a container to be captured, stored, and made available for a subsequent container lift. Key differences between a conventional RTG power system and that of the EcoCrane™ system are shown in Figures 2.2-3 and 2.2-4.

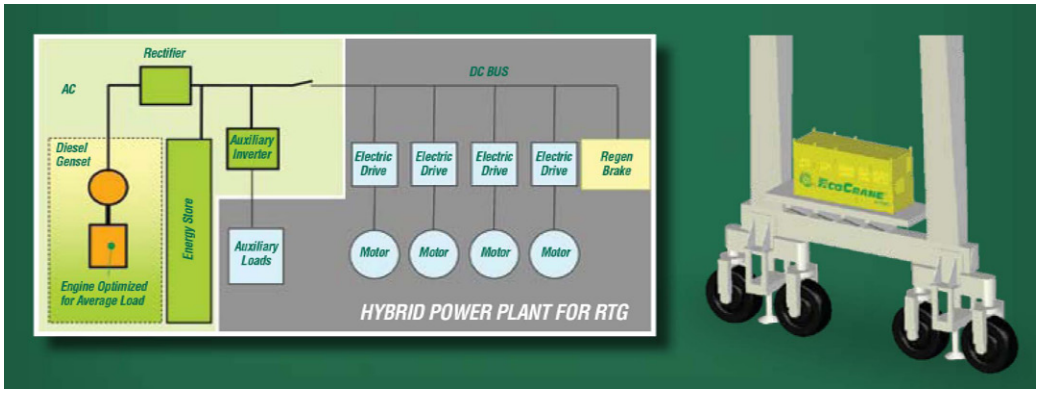
Figure 2.2-3: Conventional RTG Power System



The Railpower Technologies' EcoCrane™ power management system is shown below. Key elements include:

- A Variable Speed Generator, incorporating a Tier 3 diesel engine/alternator optimized for the average lifting load as compared to a conventional RTG whose diesel genset engine is sized for a peak load condition;
- A regenerative braking energy capture system coupled with battery energy storage which allows energy that is otherwise dissipated as heat during container lowering to be captured, stored, and used for a subsequent container lift;
- A Level 3 verified diesel emission control system that will further reduce diesel genset exhaust emissions by a minimum of 85%;
- Automatic shutdown/restart circuitry that will allow the Variable Speed Generator engine to automatically turn off when not in use, achieving additional emission reductions.

Figure 2.2-4: EcoCrane™ Hybrid Electric RTG Power System



Project Partners & Funding

Originally, LBCT was to demonstrate six EcoCranes under the TAP, with POLB and POLA funding one (1) EcoCrane™ conversion at a total cost of $350,000. U.S. EPA also contributed Supplemental Environmental Project funds to the project in the amount of $130,130 to support emissions testing. The balance of project funds was to be provided by LBCT.

Unfortunately, the recent economic downturn, coupled with technical challenges with the retrofitted equipment operation and systems integration, necessitated a significant reduction in project scope from six units to one unit. In order to address the systems integration issues that arose during this TAP project, Railpower released a newer "beta" version of the technology. Railpower is pursuing CARB verification for the beta version of the technology, negating the benefit of such verification under this TAP project. The TAP funding contribution was downscaled commensurate with this reduction in scope, as noted in Table 2.2-3, below.

Table 2.2-3: EcoCrane™ Funding Partners

Project Partners	Original Contribution	Revised Contribution
▪ Port of Long Beach	$175,000	$42,467.50
▪ Port of Los Angeles	$175,000	$42,467.50
▪ U.S. EPA/CARB Supplemental Environmental Progam	$130,130	$130,130
▪ Long Beach Container Terminal, Inc.	$1,469,870	$265,065

Environmental Benefits

Table 2.2-4 summarizes the anticipated benefits of the EcoCrane™ hybrid technology.

Table 2.2-4: Anticipated Benefits of EcoCrane™ as Compared to Conventional RTG Crane

Environmental Benefits	NO_x	CO_2	PM	Fuel Consumption
EcoCrane™ Hybrid RTG	85%	60%	90%	65%

Project Status

Installation of the EcoCrane™ was completed in the summer of 2009. The existing 680 horsepower diesel genset engine was replaced with a variable speed generator rated at 120 horsepower – this represents an 82% reduction in rated power requirements and associated fuel consumption.

As described earlier, the EcoCrane™ demonstrated under this TAP demonstration experienced significant systems integration issues. Railpower used the experienced gained from this TAP project for its second generation design, for which CARB verification is being pursued outside of the TAP. Nonetheless, the original system desgined for the TAP was operational on an intermittent basis throughout 2010. In late 2010, the EcoCrane™ was finally operational full-time. A detailed report documenting the integration issues and operational performance will be finalized in 2011.


ZPMC
S.W.L 40LT
NYK LOGISTICS
MEGACARRIER
www.nykline.com
490

2.2.3 RYPOS Advanced Diesel Particulate Filter for Cargo Handling Equipment

Under the TAP, RYPOS will demonstrate the effectiveness of an advanced diesel emission control system on cargo handling equipment operating at both the Port of Long Beach and Port of Los Angeles. The RYPOS "Hybrid Diesel Particulate Filter/Catalyst" (HDPF/C) is an active-regeneration diesel particulate/diesel oxidation catalyst expected to reduce total particulate matter emissions by greater than 85 percent.

The HDPF/C incorporates a microprocessor-controlled, electric heating element to burn off accumulated DPM captured by the filter. A DOC attached to the outlet of the particulate filter is used to remove the soluble organic fraction of particulate matter while also significantly reducing hydrocarbon, carbon monoxide, and nitrogen dioxide emissions. Regeneration of the HDPF/C occurs automatically during cargo handling equipment operations and does not require additional actions on behalf of the equipment operator.

The objectives of the RYPOS HDPF/C Demonstration are to:

- Successfully demonstrate the RYPOS HDPF/C on a broad range of container handling equipment, including rubber tired gantry cranes, top and side handler mobile lifts;
- Document 85% or greater reduction in cargo handling equipment emissions of total particulate matter (TPM), CO, NO_2, as well as reductions in other pollutants under typical cargo handling equipment operating conditions.

Upon successful demonstration of the above objectives, RYPOS will seek and obtain Level 3 verification for the HDPF/C from CARB for a broad range of cargo handling equipment applications.

Emission Control Technologies

The RYPOS HDPF/C system consists of 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 soot 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, nitrogen dioxide (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 HDPF/C is controlled by a microprocessor. The controller monitors the HDPF/C and periodically, as required, an electric current is passed through a filter element, which then acts as a heating element. The filter and heating element are one and the same. Each element, which represents a small fraction of the total filter area, is heated individually to reduce the maximum amount of electrical energy required. A dedicated power source provides the required electrical current to heat the filter element to the temperature required to burn soot.

The regeneration strategy is designed to keep the back pressure below a preset 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 HDPF/C demonstration is $322,140. Using TAP funds, each port contributed approximately $64,668. The TAP funding is budgeted primarily for emissions testing and verification costs. RYPOS and their participating vendor support team is covering the balance of project costs, $192,804. Project costs are shown below in Table 2.2-5.

Table 2.2-5: RYPOS HDPF/C Demonstration Funding Partners

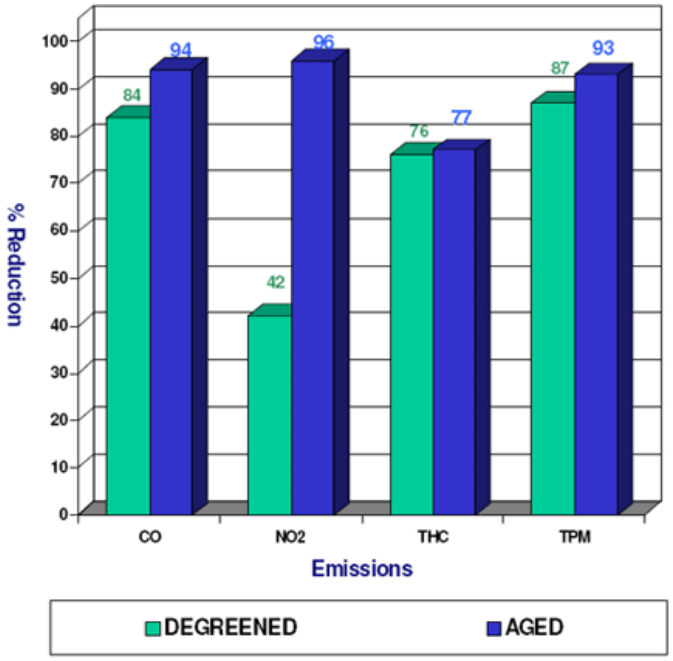
Project Partners	Contributions
Port of Long Beach	$64,668
Port of Los Angeles	$64,668
RYPOS	$192,804

Environmental Benefits

Exhaust data previously collected by independent testing laboratory Environment Canada show that the RYPOS HDPF/C™ can potentially reduce total particulate matter by more than 85% and cut nitrogen dioxide (NO_2) by up to 96% from the diesel engine exhaust.

Following a break-in or "aging" period, the RYPOS HDPF/C™ achieved the 93% PM, 77% THC, 96% NO_2 and 94% CO reductions with virtually no increase in fuel consumption. One characteristic of the RYPOS technology, as shown in Figure 2.2-5, is that the efficiency of emissions reduction actually improves with aging.

Figure 2.2-5: RYPOS Effectiveness Improves with Aging



Project Status
As of this Annual Report, RYPOS has installed:

- One HDPF/C system, on a model year 2004 Mitsui/Paceco rubber tired gantry (RTG) crane at the ITS terminal facility at the Port of Long Beach;
- One HDPF/C system on a 2003 Mitsui/Paceco RTG crane at STS Terminal located at the Port of Los Angeles;
- One HDPF/C system on a top handler at the STS Terminal; and
- One HDPF/C on a side handler at the STS Terminal.

CARB verification emissions testing begin in the fall of 2010, with receipt of Level 3 CARB verification anticipated in mid-2011.

2.3 Container Drayage Trucks

2.3.1 Vision Motor Corp. Hydrogen Fuel Cell Plug-In Hybrid Electric Truck

In 2010, Vision Motor Corporation's (Vision) project to demonstrate their zero emission hydrogen fuel cell/hybrid-electric drive system in short haul drayage and terminal container movement operations was approved. The proposed 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 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.

Total Terminal Services, Inc. (TTSI) will demonstrate the class 8 truck in short-haul drayage operations and California Cartage Company will demonstrate the zero-emission terminal tractor (ZETT), each for a period of eighteen months.

Emission Control Technologies
Vision Motor Corp. will design, develop, and integrate a Hydrogen Fuel Cell Electric Hybrid Drive class 8 on-road truck designed for short haul drayage operations at the ports. The vehicle will be marketed under the name TYRANO™. The truck is powered by a battery electric drive system that incorporates a hydrogen fuel cell as a range extender. The design specifications include an estimated 8-hour shift range of 200 miles, a governed maximum highway speed of 65 miles per hour, and ability to haul 80,000 lbs. of payload.

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) years/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;
- Grade-ability: Forty (40) mph sustained at 6% grade with vehicle at maximum GCVWR;
- 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.

Vision Motor Corp. will also design, develop, and integrate a Hydrogen Fuel Cell/Plug-in Electric Hybrid Drive Zero Emission Terminal Tractor (ZETT) designed for container movement operations at a terminal yard. The ZETT will have the following specifications:

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;
- 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 towards the demonstration project. Table 2.2-6 summarizes the funding contributions from each project partner.

Table 2.2-6: 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.

Project Status

Design and development of the two project vehicle prototypes is near completion. The in-service demonstration is scheduled to begin mid-2011.

2.3.2 Heavy-Duty Drayage Truck Duty-Cycle Characterization

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' 2009 emissions inventories, the drayage truck fleet is the second largest source of DPM and NOx emissions at the ports. Even with increasingly stringent emissions standards promulgated by regulatory agencies, the drayage truck source category must continue to become 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.

The ports initiated 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 is to collect detailed duty cycle information for drayage truck operations in near-dock, local, and regional operation. This duty cycle information will then be provided to equipment manufacturers to help accelerate and improve the development of advanced drayage truck technologies.

Project Partners & Funding

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. The ports funded the study to support future TAP efforts to support technologies that reduce emissions from heavy-duty trucks.

Table 2.2-7: HDV Duty Cycle Funding Partners

Project Partners	Contributions
▪ Port of Long Beach	$12,681
▪ Port of Los Angeles	$12,000

Environmental Benefits

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

Project Status

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

The final report and raw data collected during this study are 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.

2.3.3 Balqon Lithium-Ion Battery Demonstration

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

This follow-on project will 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 are anticipated to more than double the vehicle range, without adding additional weight.

Zero-Emission Technologies

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 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.

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

Project Partners & Funding

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

Table 2.2-8: Funding Partners in the Development of the Lithium Ion Electric Yard Tractor & Drayage Truck

Project Partners	Contributions
▪ Port of Los Angeles (TAP Funding)	$400,000
▪ Balqon Corporation Co-Funding	$540,000

Environmental 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. Successful completion of this advanced battery demonstration project will support the long-term goal of increasing the use of zero-emission electric truck technologies in the drayage truck sector.

Project Status

In June 2009, Balqon completed assembly of a Nautilus E30 all-electric tractor retrofitted with lithium ion battery packs. Initial testing of the Nautilus E30 demonstrated a range of over 150 miles on a single charge under unloaded conditions at 80% depth of discharge. The new lithium-ion battery packs include the Company's battery management system which allows batteries to be fast charged and self equalize during idle operation. 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.

3.0 Projects That Were Cancelled or Withdrawn In 2010

Unfortunately, there are situations that arise where a project previously approved, and sometimes initiated by the TAP, cannot be carried out to completion. This occurred in the case of one TAP project during 2010, as discussed below.

OceanAir Environmental LLC (OAE) and Harley Marine were working to demonstrate an emission reduction technology concept that can be retrofitted into an existing tugboat. Unfortunately, Harley Marine, a subsidiary of Millennium Maritime, Inc. was no longer able to participate in the project due to a change in economic conditions. It is OAE's intent to re-scope the project with a new project partner and re-apply to TAP at a later date. Please refer to the 2009 TAP Annual Report[4] for a complete summary of the project scope originally approved for this project.

[4] *http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2470*

4.0 2010 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. 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. Three projects were funded by the TAP in 2010; 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, but are noted within each project summary in Section 2.

Table 4.1: TAP Projects Funded from Program Inception through December 31, 2010

Project Category	POLB	POLA	AQMD	CARB	U.S. EPA	CEC	Total Port & Agency Stakeholder Investment
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
Cargo Handling Equipment							
Vycon RTG REGEN Flywheel	$11,500	$11,500	$8,000				$31,000
LNG Yard Tractor	$350,000				$75,000		$425,000
Diesel Hybrid Yard Tractor	$300,000*	$300,000*			$300,000		$900,000
LBCT Eco-Crane	$42,467.50	$42,467.50		$130,130			$215,065
APT Emulsified Biodiesel	$44,000	$44,000					$88,000
Capacity Plug-In Hybrid Tractor	$29,500	$32,000*					$61,500
Rypos Diesel Emission Control	$64,669	$64,668					$129,337
Container Drayage Trucks							
Vision Motor Corp. Hydrogen Fuel Cell Plug-In Hybrid Electric Truck	**$212,500**	**$212,500**					**$425,000**
Heavy-Duty Drayage Truck Duty Cycle Characterization	**$12,681**	**$12,000***					**$24,681**
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
Total Investment	$2,925,922	$3,631,160	$1,199,750	$913,758	$375,000	$500,000	$10,343,590
Total TAP Investment	$2,625,922	$2,397,240					
Total Ports' TAP Investment	**$5,023,162**						

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

5.0 TAP Priorities for 2011

To support the recently adopted 2010 CAAP Update, port staff set important goals for the TAP in 2011. A key area of focus of the TAP in 2011 will be significant support for 2010 CAAP Update measures OGV5 and OGV6. The goal of OGV5 is to maximize the early introduction and preferential deployment of vessels to the ports with cleaner and/or newer engines. Measure OGV6 focuses on reducing emissions from existing vessels (i.e., retrofit technologies).

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 2011 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 2011 are summarized below.

2011 Technical Priorities:

For 2011, 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, 2011 will emphasize the identification and demonstration of technologies that target emission reductions from ocean going vessels and locomotives. Numerous emission reduction technologies will be evaluated for integration into vessel/locomotive new builds and use of these technologies as a retrofit for existing vessels/locomotives will be explored. The ports intend 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. 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 included control measure, OGV5, entitled "Cleaner OGV Engines". The goal of this measure is to maximize the number of vessels meeting the IMO NOx limit of 3.4 g/kW-hr that visit the ports. The TAP will support this measure by facilitating the demonstration of emerging clean OGV engine technologies.
- The 2010 CAAP Update includes control measure OGV6, 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 2010, a Request for Information (RFI) was released 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 at-berth at the ports. The RFI for Ocean-Going Vessel At-Berth Emissions Reduction Technologies resulted in 15 responses, which are currently being evaluated by port staff. The ports antipciate the release of an RFP in 2011 to pursue technology demonstration(s) as a result of this RFI.
- Over the past several years, the ports have been evaluating various Zero Emission Container Movement Systems (ZECMS) for potential application at the ports, with the ultimate goal of pollution-free cargo movement. Beginning in 2011, the TAP will support small scale demonstration(s) of innovative technologies that can be utilized for zero-emission cargo movement.

2011 Programmatic Priorities:

For 2011, a number of program enhancements are planned, including:

- The ports will continue their effort to implement the TAP Database, which will allow the seamless sharing of data between both ports and, as appropriate, project implementers;
- 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 work to further streamline the verification of TAP projects moving through CARB's process in order 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 (AQIP) and SCAQMD's Carl Moyer Program.

APPENDIX A
TECHNOLOGY ADVANCEMENT PROGRAM ADVISORY COMMITTEE MEMBERSHIP

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Appendix B

The following Technology Advancement Program projects are complete:

1. SoCalGas CNG Drayage Truck Demonstration
2. Westport GX LNG Engine Development
3. Foss Maritime Green Assist™ Hybrid Tugboat
4. U.S. Hybrid's Hybrid Yard Tractor Development & Demonstration
5. Capacity Plug-In Hybrid Electric Terminal Tractor
6. APL Singapore Slide Valve & Water-In-Fuel Emulsion Demonstration Program
7. Balqon E-30 Electric Terminal Tractor Development & Demonstration Project
8. Advanced Maritime Emission Control System (AMECS) Project
9. VYCON REGEN® System for Rubber-Tired Gantry Cranes Testing & Verification
10. Liquefied Natural Gas Yard Tractor Demonstration

Summaries of the Final Reports submitted for these projects are included herein.

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[5].

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.

[5] *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.

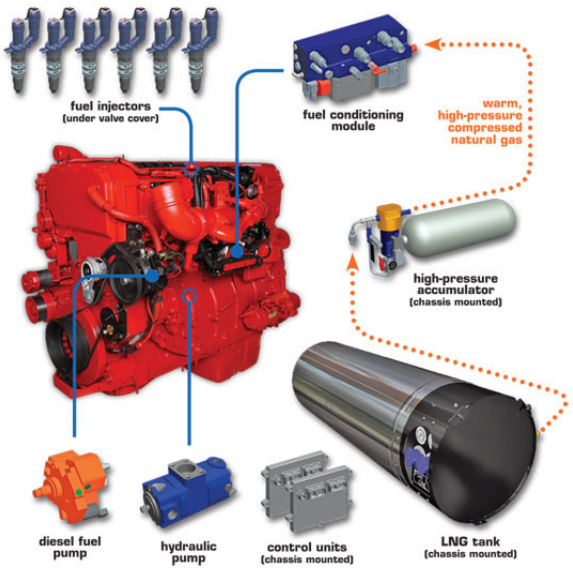
Project Objective
The GX LNG heavy-duty engine development project had three primary objectives:

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

The commercial availability of a large displacement, low emission natural gas engine directly supports the ports' Clean Air Action Plan objective of reducing NOx and particulate matter emissions from port drayage operations.

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[6].

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[7]. 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 Ports of Long Beach and 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.

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

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

Hybrid Yard Tractor Development & Demonstration

Technology Manufacturer
US Hybrid

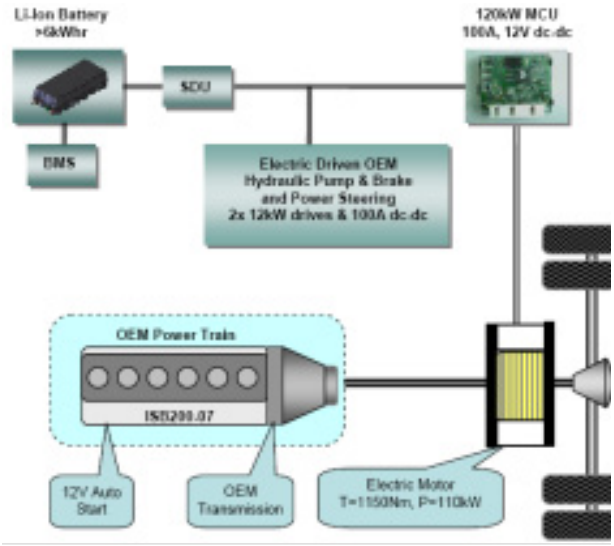
Co-Participants
Port of Los Angeles, Port of Long Beach, CALSTART,U.S. Environmental Protection Agency, Kalmar Industries, Long Beach Container Terminal (LBCT)

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 competitve 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.

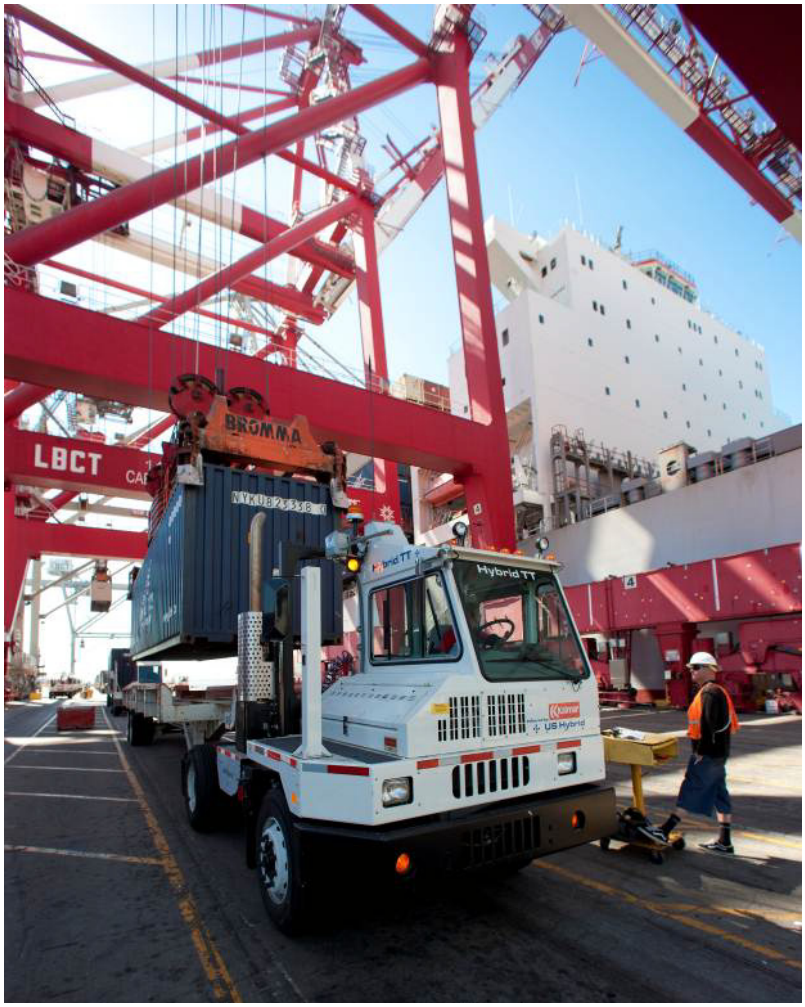


Benefits
The three hybrid yard hostlers underwent six months of operation and in-use testing at LBCT and were able to perform all the tasks required of yard hostlers in real-world port operations, and were well accepted by drivers and maintenance staff. Fuel economy and emissions benefits were evaluated, 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 assesment 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[8].

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.



[8]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[9].

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[10].

[9]http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2416
[10]http://www.cleanairactionplan.org/civica/filebank/blobdload.asp?BlobID=2517

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 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.

Project Costs

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 Termincal, 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.

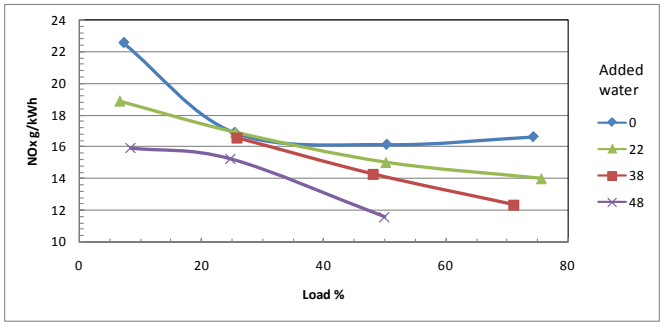
Status

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 evaulation 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%[11].



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

[11] Measurement uncertianty ranges from 3% to 15% for these results.

of the many strategies being considered in this regard.

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

The successful demonstration of the AMECS at the Port of Long Beach and the recognition by CARB of its pollution reduction efficiencies has positioned ACTI to offer this system on a commercial basis. This technology has the potential to be replicated at other ports as a viable alternative to shore power to reduce vessel hoteling emissions.

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.

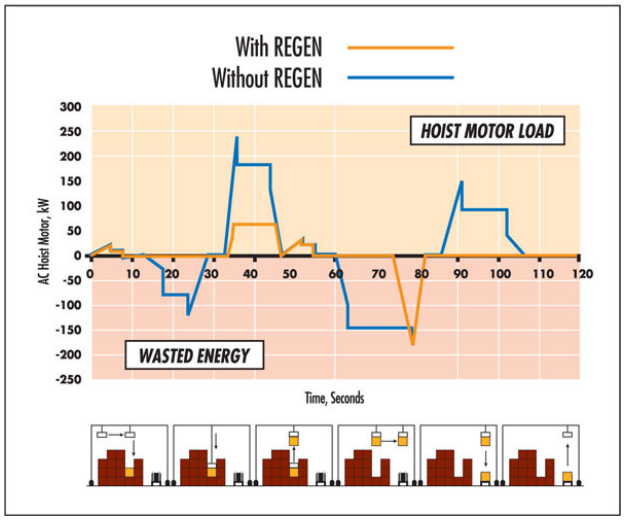
Project Objective
Two marine terminals, ITS in the Port of Long Beach and Evergreen in the Port of Los Angeles, installed VYCON's REGEN system onto one of the terminals' rubber tire gantry (RTG) cranes.

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, and is the lowest emitting heavy-duty engine certified by the California Air Resources Board.