# IAPH TOOL BOX FOR PORT CLEAN AIR PROGRAMS

Improving Air Quality While Promoting Business Development

A Reference Guide provided by the International Association of Ports and Harbors (IAPH)

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## Introduction

Welcome to the International Association of Ports and Harbors (IAPH) Air quality and Greenhouse Gas Tool Box. The purpose of this Tool Box is to provide ports, both members and non members of the IAPH, quick access to the tools needed to start the planning process for addressing port-related air quality and climate change related issues.

Balancing port operations and development with environmental considerations can be challenging, especially with issues like air quality and climate change that are complex and evolving. This Tool Box provides information on air and climate issues and their relationship to port and maritime activities. Based on actual port experiences, it describes strategies to reduce emissions and guidance on how to develop a Clean Air Program and a Climate Protection Plan. Strategies such as repowering older engines, applying effective technologies for efficiency and emission control, and using alternative and cleaner fuels in maritime operations will dramatically reduce air pollution and greenhouse gas emissions. Undertaking such bold strategies will improve local air quality, safeguard public health, and protect ports and the planet from the effects of climate change.

Every port in every country has different needs and capabilities. The resources in this toolbox are intended to help initiate, inspire, and inform your internal discussions about what course of action is right for you. You are invited to explore this Tool Box and join other ports around the world in seeking solutions to these challenging problems.

## About The Toolbox

In prior years, this Tool Box has dealt primarily with the reduction of air emissions associated with local health impacts; however, with the increased concern for the effects of global climate change, the Tool Box has been expanded to include additional tools focusing on greenhouse gas (GHG) mitigation.

In April 2008, the IAPH requested its Port Environment Committee, in consultation with regional Port Organizations, to provide a mechanism for assisting the ports in mitigating climate change. Through this request, in July 2008 a group of 55 ports from all over the world adopted the C40 World Ports Climate Declaration to work together to reduce the threat of global climate change. This group is now known as the World Ports Climate Initiative (WPCI).

The mission of the WPCI is to:

***raise*** *awareness in the port and maritime community of need for action*
***initiate*** *studies, strategies and actions to reduce GHG emissions and improve air quality*
***provide*** *a platform for the maritime port sector for the exchange of information thereon*
***make*** *available information on the effects of climate change on the maritime port environment and measures for its mitigation*

In support of this mission, the WPCI has developed a website and formed subgroups focusing on "Themes" that will provide guidance to ports looking to monitor and reduce their GHG emissions. These themes currently include:

- Carbon Footprinting and Modeling Tools
- On-shore Power Supply
- Environmental Shipping Index
- Cargo-handling Equipment
- Intermodal Transport
- Lease Agreement Template

The Tool Box compliments and supports the WPCI website by providing a resource for GHG case studies and emission reduction strategies. As with an air toxics emissions inventory, establishing a carbon footprint will guide ports to strategies that have the greatest reduction potential at their facility. The WPCI Carbon Footprinting Working Group is currently preparing a Guidance Document that will assist ports interested in developing their carbon footprint.

## Navigating the Tool Box

This Tool Box is constructed with two main sections: air quality and greenhouse gases. These topics are accessible from tabs on the main page. The additional tab, "Integration," describes how and when strategies from each of the toolboxes create "co-benefits;" strategies that accomplish the goals of both subjects. Links embedded among many of the strategies in each toolbox also provide a path for understanding co-benefits. Key sections of each Tool Box are described below:

### Priority Gasses Tool Box

Learn what ports are doing to improve air quality through successful clean air programs. Click "Case Studies" to learn more about port clean air programs.

Looking to reduce diesel emissions from cargo handling equipment or trucks? There are a number of strategies that can help you improve air quality. Click "Improving Air Quality Through Effective Strategies" to learn more.

Ready to create your own port clean air program? This Tool Box provides steps you can take to begin putting your program into action. Click "Creating Your Clean Air Program" to get started!

Need information on engine standards, air quality monitoring or a glossary of terms? This Tool Box provides valuable resources to help address questions you might have. Visit our "Air Quality Tools and Resource Library."

### Greenhouse Gas Tool Box

Learn about the International Context for efforts to curb the threat of climate change and what international maritime and other partnerships are supporting the cause.

Learn about ways to reduce your carbon emissions in "Strategies for Reducing Greenhouse Gas Emissions".

Start creating your own GHG plan using information and approaches described in "Developing a Climate Protection Plan."

Share your port's experiences and projects by filling in a simple form -- or find out what others are doing in the "Climate Change Project Forum."

# Priority Pollutants

## Introduction

This Tool Box is constructed with two main sections: air quality and greenhouse gases. These topics are accessible from tabs on the main page. The additional tab, “Integration,” describes how and when strategies from each of the toolboxes create “co-benefits;” strategies that accomplish the goals of both subjects. Links embedded among many of the strategies in each toolbox also provide a path for understanding co-benefits

## A Call to Action

The Challenge
As international trade continues to increase each year, port cities are booming from the increase in jobs, taxes, and secondary industries supporting the transportation and distribution of these goods. However, the increase in goods movement has also led to the increase in air emissions from port-related maritime activities as well as local and regional goods-transport. The potential health risk impacts associated with the goods movement sector have extended fully along the network between manufacturer and consumer.

Some of this impact can be seen in and adjacent to port marine terminals because all modes of transport (trucks, ships, cargo handling equipment, harbor craft, and rail locomotives) often meet at these intermodal hubs. When residential communities are located adjacent to port marine terminals, the residents are exposed to emissions from international, regional, and local freight movement sources. National and regional regulations control a subset of the source categories, with little overarching regulation. International regulations, as they stand now, likewise provide limited controls.

There is a special ‘call to action' between ports around the world to address international port-related air quality issues. In the last years, within the International Association of Ports and Harbors important discussions have been held between international ports and industries on how to address these issues on both the local and international fronts. This has resulted in the adoption of a resolution on Clean Air Programs for Ports at the 25th World Port Conference in Houston , Texas on 4 May 2007 in which the Members of IAPH have resolved that:

• IAPH reaffirms its recognition of ports' need to adopt clean air programs to better sustain development of the global society and its commitment to promote integrated approaches in such programs.

• IAPH urges ports, members and non-members alike, to take active and effective steps towards clean air programs while stressing the critical need to develop integrated action plans for respective ports and recognizing that no one-size-fits-all solution exists for ports with their large variations in pollution level, emission sources, geographical and meteorological conditions;

• IAPH will continue to provide a unique and effective forum to share best practices and experiences among the world's ports and various parties concerned, and will develop and disseminate guidelines, reference materials and information.

APH will collaborate further with UN agencies and other international organizations such as the International Chamber of Shipping (ICS), the Oil Companies International Marine Forum (OCIMF) and regional Port and Trade Associations to achieve the goal of creating clean air programs thereby assisting in the abatement of global warming.

## CASE STUDY: **SAN PEDRO BAY PORTS CLEAN AIR ACTION PLAN**

Located in the South Coast Air Basin (SoCAB) in the state of California, the second largest urban area in the United States of America, the Ports of Los Angeles and Long Beach (collectively, the San Pedro Bay Ports) are situated in an area with the worst air quality in the nation. US regulatory agencies have identified ozone and particulate matter less than 2.5 microns (PM2.5) to be of particular concern with diesel particulate matter (DPM) as a surrogate for total emissions. This poses a serious risk to Southern California residents who live near the Ports, transportation corridors and other areas with high levels of diesel-related activity. The California Air Resources Board predicts that 70 percent of the potential cancer risk from toxic air contaminants in California can be attributed to DPM.

With the need to accommodate the rapid growth in trade and the increased demands of goods movement, the San Pedro Bay Ports recognize the necessity to reduce their “fair share” with respect to other sources in the South Coast Air Basin . In doing so, the Ports would have to address all maritime operations by implementing strategies that would substantially reduce diesel emissions from ocean going vessels, harbor craft, cargo handling equipment, trucks and locomotives.

In March 2006, an important partnership was formed between the Port of Los Angeles and the Port of Long Beach along with the South Coast Air Quality Management District, California Air Resources Board and the United States Environmental Protection Agency Region 9 to work jointly toward solutions to enhance air quality and the quality of life for the residents of Southern California. Collaborating as team, the partnership developed the San Pedro Bay Clean Air Action Plan (CAAP).

The Clean Air Action Plan sets forth an array of control measures and implementation strategies that the Ports will use to reduce public health risk from port/maritime operations. The five-year Action Plan includes performance driven goals, emission reductions, and budgetary needs. In addition, the Ports have created a Technology Advancement Program that will evaluate promising projects and technologies that will demonstrate effectiveness in port-related emission reductions. The Plan also includes a program to evaluate infrastructure and operational efficiencies.

Tenants, railroads, and the trucking industry will be expected to ‘sign on' and participate in the CAAP starting in 2007. The Ports will work with tenants and the railroads to assist them in developing their own programs to meet CAAP standards. To substantially address diesel emissions from trucks, the Ports are adopting a goal to eliminate “dirty” trucks from the San Pedro Bay terminals within 5 years of CAAP adoption. The Ports are working with all concerned parties to establish new relationships and business paradigms to secure adequate funding to make this program successful.

One of the most valuable aspects of the CAAP is that both Ports will combine resources and expertise to supplement the actions of the federal, state, and local regulators as necessary to implement cleaner technologies for various source categories.

## CASE STUDY: **NORTHWEST PORTS CLEAN AIR STRATEGY**

The Ports of Seattle and Tacoma in the Pacific Northwest of the United States and the Vancouver Port Authority in British Columbia, Canada are located in areas that meet federal, state, and local ambient air quality standards. Some areas in the region are expected to have difficulties in the future meeting stricter United States standards for fine particulate matter. To this end, the ports are committed to helping the region maintain compliance to protect the environment and public health.

As maritime operations grow, the Northwest Ports are successfully reducing air emissions by means of a voluntary and collaborative approach. Through the Puget Sound Maritime Forum, the Northwest Ports aim to proactively reduce diesel emissions voluntarily, in order to protect the environment and public health from the potential negative impacts of maritime-related emissions. The three Ports are currently working on the Northwest Ports Clean Air Strategy , a joint plan aimed to substantially reduce diesel particulate matter and greenhouse gas emissions. The plan will utilize the recently completed and comprehensive Puget Sound Maritime Air Emissions Inventory as a baseline. Using proven emission reduction strategies successfully implemented by ports in the region, the plan proposes performance goals to reduce particulate matter by 70 percent from ships at berth and 30 percent from cargo handling equipment by 2010. The Northwest Ports Clean Air Strategy will also address emissions from port-related trucks, locomotives and harbor craft and includes long-term goals for additional emissions reductions.

For cargo and cruise ships that make regularly scheduled calls at the three Ports, the proposed 2010 performance goal calls for a reduction in particulate matter equivalent to what can be achieved by using cleaner distillate fuels while at dock. There is a 2015 performance goal for ocean-going vessels that calls for compliance with standards that the International Maritime Organization (IMO) adopts. The Northwest Ports intend to support the United States IMO proposal, which currently proposes emission reductions equivalent to a sulfur level of 0.1% or less for fuels burned by ocean-going vessels while operating in the coastal waters of the United States and Canada . If new performance standards are not adopted, the Ports agree to continue to work towards meeting these goals, recognizing that technology and fuel availability will impact shipping lines ability to achieve these goals.

For cargo-handling equipment, the proposed performance goal aims to reduce emissions through the use of ultra low sulfur diesel fuel with no more than 15 parts per million sulfur, a bio-diesel blend in addition to repowering with newer engines and/or through the use of advanced emission control technologies.

The three Ports are encouraging stakeholder groups to help implement emissions reduction measures and formally sign on as partners.

**CASE STUDY: PORT OF NEW YORK AND NEW JERSEY CLEAN AIR INITIAITVES AND HARBOR AIR MANAGEMENT PLAN**

The Port of New York and New Jersey, the largest port complex on the East Coast of North America, is located in the Atlantic Northeast of the United States within the USEPA-designated New York/New Jersey/Long Island Non-Attainment Area (NYNJLINA) for Nitrogen Oxides (NOx). Portions of the NYNJLINA are unlikely to meet federal ambient air quality standards for fine particulate matter as new stricter US standards come into place.

The Port Commerce Department of the Port Authority of New York and New Jersey (PANYNJ) is a landlord for six marine cargo terminals. Dedicated to Environmental Stewardship as one of its key business objectives, the Port Commerce Department is committed to promoting air quality enhancement efforts as it accommodates growing cargo volumes to satisfy the needs of the largest consumer demand region in the United States . In order to be successful, the Port aims to be a sustainable port, by promoting regional prosperity, financial return and the dual imperatives of security and the environment.

PANYNJ has adopted a proactive strategy to improve air quality that involves compliance with existing regulations, exceeding all mitigation requirements and undertaking voluntary initiatives to reduce air emissions. The Port Commerce Department has implemented an Environmental Management System to ensure compliance with air quality laws and regulations. In addition, there are initiatives underway to offset NOx emissions generated during channel-deepening construction that will exceed regulatory requirements. The Port Commerce Department also has several on-going voluntary, collaborative efforts that are evaluated for their ability to reduce air emissions and cost effectiveness.

For example, a cargo handling equipment (CHE) emissions inventory undertaken to assess the impact of our container terminal tenants' voluntary modernization of CHE and use of cleaner burning fuels showed a greater emission reductions across the full spectrum of pollutants despite a 25% increase in cargo handled. A subsequent emission inventory of vessels dwelling at these same facilities showed that they contributed a small percentage of overall pollutants in the non-attainment area.

In order to meet growing cargo demands, the Port Commerce Department is investing nearly two billion dollars over the next decade to reconfigure existing terminals, deepen the harbor's channels and berths and improve inland access by rail and barge. This investment will create an efficient and cost-effective port, while also reducing local congestion, enhancing air quality and conserving energy. Improvements include installing infrastructure to support electric-regenerative cranes, and significantly enhancing on-dock and regional rail capabilities. In addition, our marine tenants are investing heavily in gate improvements, electric cranes, yard equipment modernization and use of cleaner fuels, all of which enhance air quality. The Port Commerce Department, along with its tenants, public agencies and private partners collaborate on voluntary efforts to field test new off road technologies and develop clean equipment prototypes, such as active diesel particulate filters and hybrid yard tractors. Collaborative efforts that go beyond the immediate port area include working with the EPA, state regulators and port members of the Northeast Diesel Collaborative to develop voluntary regional strategies and USEPA's Clean Ports Program to help develop voluntary industry wide initiatives.

## CASE STUDY: RIJNMOND REGIONAL AIR QUALITY ACTION PROGRAM PORT OF ROTTERDAM

Air quality in Rijnmond among other regions in the Netherlands , has improved over the last 30 years. However, according to recent figures, emissions have increased beyond their limit values. The increase in emissions poses a serious risk to spatial and economic development and can adversely affect public health. Projections show that emissions for particulate matter (PM) and oxides of nitrogen (NOx) in the Rijnmond region will exceed European air quality standards set for 2010 if actions are not taken to reduce air pollution.

To address Rijnmond's growing air quality problems, the ROM Rijnmond Executive Council (BOR) has united in a partnership with administrative authorities to develop a package of measures to mitigate air pollution in the Rijnmond region. Better known as the Rijnmond Regional Air Quality Action Program, the program builds upon existing clean air programs. The combination of air quality programs include; Rotterdam's Approach to Air Quality, the Air Quality Master Plan developed by BOR, the Air Quality Plan of Approach by the Rotterdam Metropolitan Region, and the Plan of Approach to Air by the Rotterdam Port Authority.

Through the Top Management Steering Committee on Air, a committee comprised of leaders from all participating parties under BOR, commissioned the DCMR Rijnmond Environmental Agency to develop the Rijnmond Regional Air Quality Action Program. The program is carried out in close coordination with the participating administrative authorities and other parties such as members from the business community. In order to establish greater uniformity for measuring and calculating control measures, the Top Management Steering Committee on Air organized five task groups to focus on different source categories. The five task groups were divided into the following groups; road traffic, shipping, railway, industry and households. Each of the sources identified by the Committee, account for 90% of the emissions in the region.

Clean air strategies were evaluated by the impact on air quality, costs, feasibility, side effects, and time frame. Efforts from the five task groups resulted in 100 different strategies of which 34 were selected as most promising. The proposed strategies aim to impact air quality both in a local and regional manner. Local measures included strategies such as shore side power for ocean-going vessels and low emission zones in urban centers. Regional measures included pushing for stronger EU regulations. The 34 promising strategies are prioritized for implementation through a phased approach, which include: immediate, near-term and long term implementation.

There are a number of recommended strategies that aim to reduce emissions related to goods movement. The following strategies relate to port/maritime activities.

Shipping:
- Support for existing and future policies and legislation;
- Shore side electricity; and
- Development and implementation of emission control technologies.

Trucks and Road Haulage:
- Intelligent loading;
- Clean vehicles; and
- Clean vehicle technology.

Rail:
- Conversion of diesel to electric long haul locomotives and
- Cleaner EU emission standards for locomotives

The consultation in the task groups has contributed to creating support among the parties involved. Consultation between the parties has also contributed to a better mutual understanding and provided tools for reaching joint agreements more quickly. The Rijnmond Regional Air Quality Action Plan also includes a communications and outreach approach to encourage the public to participate in environmentally friendly practices that promote cleaner air.

## Improving Air Quality Through Effective Strategies

Similar to the approaches identified in the case studies, you can develop your own Clean Air Program that will help address diesel emissions at your own port. The following is an overview of effective strategies that can be taken to address diesel emissions for each maritime operation.

**Ocean Going Vessels**
- Vessel Speed Reduction
- Operational Improvements
- Clean Fuels
- Emission Control Technologies
- Shore Power

**Harbor Craft**
- Engine Replacement with Engines Meeting Cleaner Standards
- Clean Fuels
- Emission Control Technologies
- Electrification (including Shore Power and Hybridization

**Cargo Handling Equipment**
- Equipment Replacement with Engines Meeting Cleaner Standards
- Operational Improvements
- Clean Fuels
- Emission Control Technologies

**Heavy Duty Vehicles – Trucks**
- Equipment Replacement Engines Meeting Cleaner Standards
- Operational Improvements
- Clean Fuels
- Emission Control Technologies
- Idle-Reduction Technologies

**Light Duty Vehicles**
- Equipment Replacement Engines Meeting Cleaner Standards
- Operational Improvements
- Clean Fuels
- Emission Control Technologies
- Idle-Reduction Technologies

**Locomotives and Rail**
- Equipment Replacement Engines Meeting Cleaner Standards
- Operational Improvements
- Clean Fuels
- Emission Control Technologies
- Idle-Reduction Technologies

**Construction Equipment**
- Equipment Replacement Engines Meeting Cleaner Standards
- Operational Improvements
- Clean Fuels
- Emission Control Technologies
- Idle-Reduction Technologies

Now, take a look at a more detailed approach to reduce diesel emissions from each maritime operation. It should be recognized that the order of operations and/or strategies does not in any way imply weight or preference.

## EFFECTIVE STRATEGIES TO REDUCE EMISSIONS FROM **OCEAN-GOING VESSELS (OGV)**

**Strategies**

Here are some effective strategies that can be applied to address emissions from Ocean-Going Vessels (OGV):

**Vessel Speed Reduction (VSR)**

Strategy – A VSR program is aimed to reduce NOx from OGVs by slowing vessel speeds as OGVs approach a port. This would include a speed reduction possibly down to 12 knots or lower when OGVs are within the coastal waters of a port or within the port area.

Technical Consideration – No operational changes are required of the engine. Technical considerations may include updating existing radars and communication devices to communicate with local navigation and communication centers. Vessel speed at which emissions are lowest is based on limited data and likely to vary with engine.

Options for Implementation – Assure compliance through tariff reduction incentives, lease requirements for renewed lease agreements, or voluntary programs. Create a memorandum of understanding with shipping companies, ports and regulatory agencies.

Pros and Cons – VSR has many benefits. In addition to NOx, PM and GHGs are also reduced. There may also be a fuel economy benefit but there can be additional operational costs. Some VSR programs have been put in place on the East Coast of the United States to protect endangered species.

**Operational Improvements**

Strategy - Reconfigure existing terminals, deepen channels and berths and improve inland access by rail and barge; install infrastructure to support electric-regenerative cranes; significantly enhance on-dock and regional rail capabilities; invest in gate improvements; and speed up vessel loading and unloading time. The latter further enhances air quality by reducing vessel dwelling time.

Technical Considerations – Design must be incorporated that will provide a reasonable return on investment through operational efficiencies.

Options for Implementation – Appropriate design will support a business case, and thus, voluntary action.

Pros and Cons – If designed properly to support the business case, the result is higher efficiency and lower emissions, a win-win scenario.

**Clean Fuels**

Strategy – Require the use of lower sulfur distillate fuels in auxiliary and/or propulsion engines of OGVs within the coastal waters of a port. A substantial reduction in DPM can be achieved if OGVs use distillate fuels that have a sulfur content of < 0.2 S.

Technical Considerations – Consider an on-board fuel tank for lower sulfur fuels. Work with ports, fuel suppliers, shipping lines, and others to ensure low sulfur fuel availability.

Options for Implementation – Implementation strategies may include the use of lease requirements and tariff changes.

Pros and Cons – Positive emission reduction benefits for NOx, PM and GHGs. Challenges may arise with low sulfur fuel availability and putting in place an on-board tank/fueling station. Fuel contamination may be another drawback. Fuel tank cleaning may be required for ultra-low sulfur diesel fuels.

**Emission Control Technologies**

Strategy – Improvements to main and auxiliary engines help reduce DPM, NOx and SOx emissions. Measures for main engine improvements may include; slide valves, seawater scrubbing as well and engine upgrades. Measures for auxiliary engines include; Selective Catalytic Reduction (SCR) and engine upgrades or repowers.

Technical Considerations – Operational and feasibility testing is required to ensure the function and appropriateness of an emissions control technology on marine applications. In particular, many ECTs require exhaust gas temperature analysis by conducting exhaust gas temperature datalogging to measure exhaust gas temperatures. Many ECTs have exhaust temperature thresholds that are required for the operation and effectiveness of the technology. Emission control technologies which have been certified or verified by regulatory agencies (such as those programs at the US Environmental Protection Agency and the California Air Resources Board) are most likely to deliver the claimed benefits

Options for Implementation – Implement strategy through lease requirements, tariff charges, and incentives. Design a Technology Advancement Program that would demonstrate feasibility of ECTs on marine applications. The Technology Advancement Program would consider use of newer technologies.

Pros and Cons – Positive emission reduction benefits. Challenges may occur with technology feasibility.

**Shore Power**

Strategy – Shore Power focuses on reducing dwelling (hotelling) emissions from OGVs while at berth. This strategy has two approaches 1) shore-power (transferring the electrical generation needs for OGVs while at berth – power generated by regulated/controlled stationary sources) and 2) hotelling emissions reduction requirements through alternative technologies for ships that do not fit the shore power model. Shore power is best for OGVs that make multiple calls at a particular terminal for multiple years. The best candidates for shore power are container ships, reefer ships, and cruise ships.

Technical Considerations – Provide shore power infrastructure on-dock and on-board vessels. Determine necessary power needed and ensure adaptability. It is important to consider the local power company that is providing the electrical power to the terminal. Some power companies operate coal-burning power plants without the use of scrubbers and other types of emission control technologies. Ensure that the local power company is using a cleaner source of energy with use of emission control technologies. In some cases, it may be better not to use shore power if the local power company has dirty polluting power plants.

Options for Implementation – Implementation strategies include lease requirements, incentives, tariff changes and capital funding.

Pros and Cons – Positive emission reduction benefits while at port with shore power. Challenges occur with infrastructure cost and shore power hook up. Shore power requires extensive infrastructure improvements. Additionally, shore power only addresses local port emission reduction benefits only during the period when the vessel is at berth and does not address OGV voyage emissions.

## EFFECTIVE STRATEGIES TO REDUCE EMISSIONS FROM HARBOR CRAFT

### Strategies

Here are some effective strategies that can be applied to address emissions from Harbor Craft (HC). Some of the strategies can also apply to dredging equipment.

### Engine Replacement

Strategy – Repower HC main and auxiliary engine with cleaner engines that meet newest national air quality standards. For example, the United States has diesel engines that meet U.S. EPA Tier II and Tier III engine standards. Replacing a Tier 0 engine with a Tier II engine will reduce NOx up to 47%. Tier III engines will reduce NOx and PM up to 90%. The European Commission has an equivalent engine that meets Stage IIIA engine standards.

Technical Considerations – Ensure technical feasibility. Strategy will involve the careful removal of the original engine and replacing it with a newer, cleaner engine.

Options for Implementation – Implementation through voluntary programs, incentives, and/or lease renewals/renegotiations.

Pros and Cons – Replacing main-propulsion engines with cleaner engines will provide great emission benefits. Cleaner engines are costly and may cause an economic burden. Technology availability may also be a concern. Destroying old engines may increase costs. Ideally, engines should be rendered inoperable so they are not able to continue to pollute.

### Clean Fuels

Strategy – Implement the use of cleaner fuels with low sulfur content. Cleaner fuels include; low and ultra low sulfur diesel fuel, emulsified diesel fuels, oxygenated fuel (O2 diesel fuel), and biodiesel.

Technical Considerations – Work with ports and fuel suppliers on the availability and supply of clean fuels. Depending on the type of clean fuel used, cleaning of the fuel tank may be required in order to avoid fuel contamination.

Options for Implementation – Implementation strategies may include the use of lease requirements and tariff changes.

Pros and Cons – Positive emission reduction benefits for NOx, PM and GHGs. The use of biodiesel may present a slight increase in NOx. Challenges may arise with fuel availability.

## Emission Control Technologies

Strategy – Retrofit HC with the best available engine controls, fuel additives and aftertreatment emission control technologies (ECTs). Depending on the appropriate application of ECT, ECTs can include exhaust aftertreatment devices such as; diesel oxidation catalyst (DOC), diesel particulate filter (DPF), or selective catalytic reduction (SCR) or engine and fuel efficiency technologies such as modern injectors, computer controls and software upgrades, which result in more efficient engine air fuel mixtures and fuel savings. The engine manufacturers and distributors of emission control technologies can provide technical guidance to HC owners and operators in the selection of appropriate ETCs for their vessel. While evaluating different emission control technologies, consider ECTs that have had proven success with HC similar to the HC under evaluation. To further improve emission reductions from auxiliary engines, retrofit cleaner engines with ECTs.

Technical Considerations – Operational and feasibility testing is required to ensure the function and applicability of an emissions control technology on marine applications. In particular, many ECTs require exhaust gas temperature analysis by conducting exhaust gas temperature datalogging to measure exhaust gas temperatures. Many ECTs have exhaust temperature thresholds that are required for the operation and effectiveness of the technology. Emission control technologies which have been certified or verified by regulatory agencies (such as those programs at the US Environmental Protection Agency and the California Air Resources Board) are most likely to deliver the claimed benefits

Options for Implementation – Implement strategy through lease requirements, tariff charges, and incentives. Design a Technology Advancement Program that would demonstrate feasibility and effectiveness (this comment should be included in all of the sections which discuss emission control technologies) of ECTs on marine applications. The Technology Advancement Program would consider use of newer technologies.

Pros and Cons – Applying ECTs prove to have positive emission benefits in reducing particulate matter (PM), Oxides of Nitrogen (NOx), carbon monoxide (CO) and hydrocarbon (HC). Not all ECTs reduce all pollutants. Retrofitting HC with ECTs can be challenging, careful evaluation and analysis is a must.

## Electrification (including Shore Power and Hybridization)

Strategy – Reduce harbor craft hotelling emissions by hybridization and providing shore power hook up . Similar to OGV, HC can utilize shore-power by transferring the electrical generation needs for HC while at berth to power generated by regulated/controlled stationary sources.can be utilized by HC at berth. Hybridization is best for HC that are in constant transit mode.

Technical Considerations – Provide shore power infrastructure on-dock and on-board HC. Determine necessary power needed and ensure adaptability. Again, it is important to consider the local power company that is providing the electrical power to the terminal. Some power companies operate coal-burning power plants without the use of scrubbers and other types of emission control technologies. Ensure that the local power company is using a cleaner source of energy along with emission control technologies. In some cases, it is better not to use shore power if the local power company has dirty polluting power plants. Evaluate the HC engine and duty cycles to determine whether the vessel is a good candidate for hybridization which is currently being developed and used on tugboats and ferries. Substantial fuel savings can be realized in addition to lowering emissions by use of hybrid technology

Options for Implementation – Implementation strategies include lease requirements, incentives, tariff changes and capital funding.

Pros and Cons – Positive emission reduction benefits while at port with shore power. Challenges occur with infrastructure cost and shore power hook up. Shore power requires extensive infrastructure improvements.

EFFECTIVE STRATEGIES TO REDUCE EMISSIONS FROM **CARGO HANDLING EQUIPMENT**

**Strategies**
Here are some effective strategies that can be applied to address diesel emissions from Cargo Handling Equipment (CHE):

## Equipment Replacement with Engines Meeting Cleaner Standards

In some cases, cargo handling equipment (CHE) fleet managers prefer to buy new equipment with new engines rather than repower old cargo handling equipment with new engines. The cost of the CHE is a small fraction of the overall life cycle costs relative to operations and maintenance costs. The labor costs for terminal maintenance shops to repower CHE also need to be factored into the decision-making process. New CHE would come with warranties which could lower maintenance costs. Each fleet manager will need to consider the relative costs and benefits for their operation. The emissions benefits would be similar in either case.

Strategy – Replace older off-road yard tractors, top picks, forklifts, reach stackers, RTGs, and straddle carriers <750 hp with new equipment that meet cleaner on-road and off-road engine standards. Replace CHE with >750 hp with new equipment that meet cleaner off-road engine standards.

For example; the San Pedro Bay Ports Clean Air Action Plan will require the replacement of older CHE with new clean engines over a specific time period. The Ports aim to implement the cleanest available NOx alternative-fueled engine or the cleanest available NOx diesel-fueled engine that will meet 0.01 g/bhp-hr for particulate matter (PM). If there are no engines that meet the 0.01 g/bhp-hr for PM, then the CAAP recommends the purchase of the cleanest available engine along with the best available emissions control technology that would meet the 0.01 g/bhp-hr for PM. The European Commission has similar clean engine standards, Euro III, IV, and V.

In the Port of New York and New Jersey , the major container terminal operators are systematically replacing yard tractors, at the end of their five to ten-year duty cycle, with brand-new equipment that come equipped with the cleanest available, on-road engines, and are doing this voluntarily because there is a business case to do so. These terminal operators are also investing heavily to replace older diesel- powered gantry cranes with pieces that feature regenerative electric capabilities, which likewise are supported by a strong business case.

Technical Considerations – Ensure technical feasibility. Strategy will involve the careful removal of original engine and replacing it with newer-cleaner engine. Equipment which includes regenerative electric capabilities (e.g. some of the new Rubber Tire Gantry (RTG) and Rail Mounted Gantry Cranes) will increase fuel efficiency and further reduce emissions.

Options for Implementation – Implementation through voluntary programs, incentives, and/or lease renewals/renegotiations.

Pros and Cons – The purchase of newer cargo handling equipment that meet cleaner on-road or off-road engine standards will demonstrate great emission reduction benefits and, under the right conditions, make a good business case. The challenge may be the availability of cleaner engines internationally.

### Clean Fuels

Strategy – Implement the use of cleaner fuels with low sulfur content. Cleaner fuels include; low to ultra low sulfur diesel fuel, emulsified diesel fuels, oxygenated fuel (O2 diesel fuel), and biodiesel. Additional clean fuel options for CHE include LNG and CNG.

Technical Considerations – Work with ports and fuel suppliers on the availability and supply of clean fuels. Depending on the type of clean fuel used, cleaning of the fuel tank may be required in order to avoid fuel contamination.

Options for Implementation – Implementation strategies may include the use of lease requirements and tariff changes.

Pros and Cons – Positive emission reduction benefits for NOx, PM and GHGs. The use of biodiesel may present a slight increase in NOx. Challenges may arise with fuel availability. Cleaner fuels often cost more than standard ones.

### Emission Control Technologies

Strategy – Retrofit CHE with the best available emission control technologies (ECTs). Depending on the appropriate application of ECT, ECTs can include; diesel oxidation catalyst (DOC), diesel particulate filter (DPF), or selective catalytic reduction (SCR). While evaluating different emission control technologies, consider ECTs that have had proven success with CHE similar to the CHE under evaluation. To further improve emission reductions, retrofit cleaner CHE engines with ECTs.

Technical Considerations – Operational and feasibility testing is required to ensure the function and applicability of an emissions control technology on CHE. In particular, many ECTs require exhaust gas temperature analysis by conducting exhaust gas temperature datalogging to measure exhaust gas temperatures. Many ECTs have exhaust temperature thresholds that are required for the operation and effectiveness of the technology. Emission control technologies which have been certified or verified by regulatory agencies (such as those programs at the US Environmental Protection Agency and the California Air Resources Board) are most likely to deliver the claimed benefits.

Options for Implementation – Implement strategy through lease requirements, tariff charges, and incentives. Design a Technology Advancement Program that would demonstrate feasibility of ECTs on CHE. The Technology Advancement Program would consider use of newer technologies.

Pros and Cons – Applying ECTs has proved to have positive emission benefits in reducing particulate matter (PM), Oxides of Nitrogen (NOx), carbon monoxide (CO) and hydrocarbon (HC). Retrofitting CHE with ECTs can be challenging, careful evaluation and analysis is a must.

EFFECTIVE STRATEGIES TO REDUCE EMISSIONS FROM **HEAVY DUTY VEHICLES - TRUCKS**

## Strategies

Here are some effective strategies that can be applied to address emissions from Heavy-Duty Vehicles – Trucks:

## Equipment Replacement

Strategy – Maximize emission reductions by replacing frequent and semi-frequent caller older trucks that service the port with newer trucks that meet cleaner engine standards. For example, the San Pedro Bay Ports Clean Air Action Plan is encouraging trucks with model years 1992 and older to meet cleaner on-road emission standards (0.01 g/bhp-hr for PM) and the cleanest available NOx technology at time of replacement.

Technical Considerations – Retire older equipment that has visible dark soot coming from the exhaust. Sometimes the color of the exhaust can depict several operational conditions that are of concern such as the need for filter replacement, oil changes, and engine upgrades. Frequent maintenance of newer trucks is very important to maintain clean operation in addition to extending sustainable use of vehicle.

Options for Implementation – Implementation strategies may include; lease requirements, tariffs, and incentives.

Pros and Cons – Positive emission reduction benefits for PM. Consider NOx reduction technologies such as SCRs or Lean NOx Catalyst (LNC). The costs of replacing engines and/or vehicles may be prohibitive.

## Operational Improvements

Strategy – Repower frequent to semi-frequent caller trucks with cleaner on-road engines. Redevelop infrastructure and use technology, such as radio frequency identification (RFID) and optical character readers (OCR), to enhance the efficiency of gates and terminals, relieve congestion and reduce emissions. Extended/off-peak terminal hours and moving more cargo to rail and water (via short sea shipping) where feasible can also reduce congestion and air pollution.

Technical Considerations – Ensure technical feasibility. Cost of technology versus benefit achieved should be a consideration in assessing potential improvements

Options for Implementation – Implementation through voluntary programs, incentives, and/or lease renewals/renegotiations.

Pros and Cons – Some of these options involve capital investment; others could increase terminal operating costs. However, if designed and planned properly, can result in a significant return on investment due to enhanced operational efficiencies.

## Clean Fuels

Strategy – Implement the use of cleaner fuels. Cleaner fuels include; ultra low sulfur diesel fuel, emulsified diesel fuels, oxygenated fuel (O2 diesel fuel), and biodiesel. Additional clean fuel options for trucks include LNG and CNG.

Technical Considerations – Work with ports and fuel suppliers on the availability and supply of clean fuels. Depending on the type of clean fuel used, cleaning of the fuel tank may be required in order to avoid fuel contamination.

Options for Implementation – Implementation strategies may include the use of lease requirements and tariff changes.

Pros and Cons – Positive emission reduction benefits for NOx, PM and GHGs. The use of biodiesel may present a slight increase in NOx. Challenges may arise with fuel availability depending on international location. Cleaner fuels tend to be more costly.

## Emission Control Technologies

Strategy – Retrofit model years 1993 to 2003 and newer with emission control technologies that are less polluting. Consider technologies that have demonstrated a history of effectiveness and durability. Emission control technologies may include but are not limited to; diesel particulate filters (active and passive), diesel oxidation catalyst (50% PM reduction or more), selective catalytic reduction (SCR), Lean NOx Catalyst (LNC), Gas Recirculation (EGR), closed crankcase ventilation systems (CCV) and or a combination of the above.

Technical Considerations – Operational and feasibility testing is required to ensure the function and applicability of an emissions control technology on the truck. In particular, many ECTs require exhaust gas temperature analysis by conducting exhaust gas temperature datalogging to measure exhaust gas temperatures. Many ECTs have exhaust temperature thresholds that are required for the operation and effectiveness of the technology. Considerations must include duty cycle, exhaust temperatures, and preventative maintenance schedules. Emission control technologies which have been certified or verified by regulatory agencies (such as those programs at the US Environmental Protection Agency and the California Air Resources Board) are most likely to deliver the claimed benefits.

Options for Implementation – Implement strategy through lease requirements, tariff charges, and incentives. Design a Technology Advancement Program that would demonstrate feasibility of ECTs on trucks. The Technology Advancement Program would consider use of newer technologies.

Pros and Cons – Positive PM, NOx, HC and CO emission reduction benefits. Challenges may occur while assessing appropriate technologies. Some technologies such as DPFs have strict exhaust temperature requirements. Retrofitting may include exhaust reconfiguration and cutting of the exhaust pipe. DPFs require annual cleaning depending on the technology and can be costly. SCRs require urea dosing units and may acquire an increase in fuel cost with urea + diesel. Emission control technologies and/or vehicles vary in cost and can be expensive.

## Idle-Reduction Technologies

Strategy – Reduce idling emissions by using idle-reduction technologies. Stationary idle-reduction technologies include shore power for trucks also known as "Truck-Stop-Electrification" (TSE). TSE provides cab power for the truck while a truck is stationed in an area for a period of time. Mobile idle-reduction technologies include; automatic shut down and star up systems, battery power, auxiliary power units, and diesel driven heating systems. These mobile idle-reduction technologies are on-board technologies that help provide power to the cab of the truck. These technologies could also be used for reefer trucks.

Technical Considerations – Test feasibility of idle-reduction technology.

Options for Implementation – Implement strategy through lease requirements, tariff charges, and incentives.

Pros and Cons – Eliminating idling time by using an idle-reduction technology greatly reduces emissions that would be generated from idling. International availability may create a challenge for some ports.

EFFECTIVE STRATEGIES TO REDUCE EMISSIONS FROM **LIGHT DUTY VEHICLES**

## Strategies

Here are some effective strategies that can be applied to address emissions from Light-Duty Vehicles

## Equipment Replacement

Strategy – Maximize emission reductions by replacing light duty trucks serving the port with new equipment that meets cleaner engine standards. Prioritize vehicle modernization by first replacing vehicles with the highest vehicle miles traveled or usage levels to get the biggest emission reduction benefit for the investment.

Technical Considerations – Retire older equipment that has higher emissions and more miles per year of operation, especially any that emits visible smoke which indicates the need for repairs such as the need for filter replacement, oil changes, and engine upgrades. Frequent maintenance of light duty vehicles and buses is very important to maintain clean operation in addition to extending sustainable use of vehicle. Inexpensive emissions testing equipment is available to periodically verify that fleet maintenance practices to minimize emissions are effective and identify equipment that have excess repairable emissions.

Options for Implementation – Implementation strategies may include; technical support, lease requirements, tariffs, and incentives.

Pros and Cons – Positive emission reduction benefits for air toxics, VOCs, NOx and PM. The costs of replacing engines and/or vehicles may be substantial.

## Operational Improvements

Strategy – Encourage more efficient use of light duty vehicles.

Technical Considerations – Evaluate current usage patterns and identify opportunities for vehicle miles traveled reductions through schedule revisions, ridesharing, and other alternatives.

Options for Implementation – Implementation through voluntary programs, incentives, and/or lease renewals/renegotiations.

Pros and Cons – Light duty vehicles are relatively cleaner than heavy duty diesel equipment so the total emissions from these engines at ports are relatively small. Emissions of toxic air pollution and volatile organic compounds from gasoline-fueled engines can be significant. Some of this equipment is diesel-fueled and could be addressed by strategies similar to those outlined for heavy duty diesel equipment. As mentioned earlier, replacing older engines and vehicles with newer cleaner equipment can improve emission reductions. However, international availability may be a concern. The costs of replacing engines and/or vehicles may be prohibitive.

## Clean Fuels

Strategy – Implement the use of cleaner fuels. Hybrid and all electric vehicles are good choices for on terminal light duty vehicles. Cleaner fuels to consider include; biodiesel, natural gas, propane, ethanol blends, ultra low sulfur diesel fuel, emulsified diesel fuels, and oxygenated gasoline and diesel fuels (O2 diesel fuel).

Technical Considerations – Work with ports and fuel suppliers on the availability and supply of clean fuels, vehicles, and refueling stations. Depending on the type of clean fuel used, cleaning of the fuel tank may be required in order to avoid fuel contamination. This is particularly true for fuels containing ethanol or biodiesel.

Options for Implementation – Implementation strategies may include the use of lease requirements and tariff changes.

Pros and Cons – Positive emission reduction benefits for air toxics, VOC, SOx, NOx, PM and GHGs. The use of biodiesel may present a slight increase in NOx. Challenges may arise with fuel availability depending on international location. Some options such as natural gas, propane or electricity may require a substantial capital investment in refueling or powering infrastructure.

## Emission Control Technologies

Strategy – Retrofit vehicle model years 1993 to 2003 and newer with emission control technologies that are less polluting. Consider technologies that have demonstrated a history of effectiveness and durability. Emission control technologies may include but are not limited to; diesel particulate filters (DPF) (active and passive), diesel oxidation catalyst (DOC) (50% PM reduction or more), selective catalytic reduction (SCR), Lean NOx Catalyst (LNC), Gas Recirculation (EGR), closed crankcase ventilation systems (CCV) and or a combination of the above.

Technical Considerations – Operational and feasibility testing is required to ensure the function and applicability of an emissions control technology on the bus. In particular, many ECTs require exhaust gas temperature analysis by conducting exhaust gas temperature datalogging to measure exhaust gas temperatures. Many ECTs have exhaust temperature thresholds that are required for the operation and effectiveness of the technology. Considerations must include duty cycle, exhaust temperatures, and preventative maintenance schedules. Emission control technologies which have been certified or verified by regulatory agencies (such as those programs at the US Environmental Protection Agency and the California Air Resources Board) are most likely to deliver the claimed benefits.

Options for Implementation – Implement strategy through lease requirements, tariff charges, and incentives. Design a Technology Advancement Program that would demonstrate feasibility of ECTs on buses. The Technology Advancement Program would consider use of newer technologies.

Pros and Cons – Positive PM, NOx, HC and CO emission reduction benefits. Challenges may occur while assessing appropriate technologies. Some technologies such as DPFs have strict exhaust temperature requirements. Retrofitting may include exhaust reconfiguration and cutting of the exhaust pipe. DPFs require annual cleaning depending on the technology and can be costly. SCRs require urea dosing units and may acquire an increase in fuel cost with urea + diesel. The costs of emission control technologies and/or vehicles may be prohibitive.

## Idle-Reduction Technologies

Strategy – Reduce idling emissions by using idle-reduction technologies. Mobile idle-reduction technologies include; automatic shut down and start up systems. These mobile idle-reduction technologies are on-board technologies that help provide power to the bus or light duty vehicle. Driver education is a necessary and effective component of idle-reduction programs.

Technical Considerations – Test feasibility of idle-reduction technology.

Options for Implementation – Implement strategy through education and outreach, lease requirements, tariff charges, and incentives.

Pros and Cons – Eliminating idling time by using an idle-reduction technology greatly reduces emissions that would be generated from idling. International availability may create a challenge for some ports. A major advantage of anti-idling programs for light duty vehicles is that they can save fuel costs with very little capital investment.

EFFECTIVE STRATEGIES TO REDUCE EMISSIONS FROM **LOCOMOTIVES AND RAIL**

### Strategies

Here are some effective strategies that can be applied to address emissions from Locomotives and Rail:

## Equipment Replacement

Strategy – Replace older locomotives with locomotives that meet cleaner engine standards. New and cleaner locomotives could include electric or hybrid locomotives. For example; the San Pedro Bay Ports Clean Air Action Plan requires switch and Class I locomotives to meet EPA Tier II engine standards and when Tier III locomotives when they become more available. The European Union currently has standards for cleaner locomotives, Euro III and IV.

Technical Considerations – Retire older locomotives.

Options for Implementation – Implementation may include setting an operational agreement with the locomotive companies or creating a memorandum of understanding with the port, regulatory agencies and other stakeholders.

Pros and Cons – Replacing old locomotives with newer locomotives has a significant emissions benefit. Locomotive replacement is costly and international availability may be a concern for some ports.

**Operational Improvements**

Ports should evaluate the feasibility of increased use of on-dock and near dock rail, address rail bottlenecks in and around ports, and use of RFID and OCR at rail yards. Increasing the efficiency how trains are stacked and queued, building trains to reduce drag and/or building longer trains for overall fuel efficiency will also reduce air emissions.

Strategy – Repower older locomotives with cleaner engines.

Technical Considerations – Assess technical feasibility.

Options for Implementation – Implementation may include setting an operational agreement with locomotive companies or creating a memorandum of understanding with the port, regulatory agencies, and other stakeholders.

Pros and Cons – Engine repowers demonstrate great emission reduction benefits. However, locomotive engine replacement is a costly procedure notwithstanding the cost for the cleaner engine itself. Purchasing a new cleaner locomotive may prove to be a better option. International availability may be a concern for some ports.

## Clean Fuels

Strategy – Implement the use of cleaner fuels with low sulfur content. Cleaner fuels include; low to ultra low sulfur diesel fuel, emulsified diesel fuels, oxygenated fuel (O2 diesel fuel), LNG and CNG.

Technical Considerations – Work with ports and fuel suppliers on the availability and supply of clean fuels. Depending on the type of clean fuel used, cleaning of the fuel tank may be required in order to avoid fuel contamination. For LNG or CNG locomotives, a fueling infrastructure is required for some ports that may not be near LNG or CNG fueling stations. Railroads interested in using LNG or CNG need to be converted to handle that fuel type.

Options for Implementation – Implementation strategies may include the use of incentives, lease requirements, tariff changes, or a memorandum of understanding.

Pros and Cons – Positive emission reduction benefits for NOx, PM and GHGs. Challenges may arise with fuel availability.

## Emission Control Technologies

Strategy – Consider retrofitting locomotives with proven emission control technologies. Some of these technologies include diesel oxidation catalysts (DOCs), diesel particulate filters (DPFs) with PM emission reduction benefits, and selective catalytic reduction (SCR) that reduce NOx. The use of ultra low sulfur diesel fuel (ULSD) is mandatory for locomotives retrofitted with DPFs.

Technical Considerations – Technical and operational feasibility testing is required. Emission control technologies which have been certified or verified by regulatory agencies are most likely to deliver the claimed benefits,

Options for Implementation – Implementation strategies may include the use of incentives, lease requirements, tariff changes, or a memorandum of understanding.

Pros and Cons – There can be positive emission benefits from using emission control technologies. However, retrofitting locomotives with the appropriate ECT can be difficult. Due to various operational constraints, some ECTs may not be appropriate depending on the locomotive. A thorough technical assessment and feasibility study is required to carry out a successful retrofit. It is recommended to retrofit locomotives that have cleaner operating engines.

### Idle-Reduction Technologies

Strategy – Reduce idling emissions by putting in place idle-reduction technologies. Technologies include: automatic engine stop-start controls (AESS); auxiliary power unit (APU); diesel-driven heating systems (DDHS); shore power plug-in unit and a hybrid switching locomotive.

Technical Considerations – Test operational feasibility.

Options for Implementation – Implementation strategies may include the use of incentives, lease requirements, tariff changes, or a memorandum of understanding.

Pros and Cons - Eliminating idling time by using an idle-reduction technology greatly reduces emissions that would be generated from regular idling. International availability of idle-reduction technology may present a challenge for some ports. Applying idle-reduction technologies to locomotives can yield significant fuel savings, which results in a significant cost savings.

## EFFECTIVE STRATEGIES TO REDUCE EMISSIONS FROM **CONSTRUCTION EQUIPMENT**

### Strategies

Here are some effective strategies that can be applied to address diesel emissions from construction equipment.

### Equipment Replacement

Strategy – Replace older on-road and off-road excavators, tractors, compactors, earth movers and cranes <750 hp with new equipment that meet cleaner on-road and off-road engine standards. Implement the cleanest available NOx and PM alternative-fueled engine or the cleanest available NOx diesel-fueled engine that will meet 0.01 g/bhp-hr for particulate matter (PM). If there are no engines that meet the 0.01 g/bhp-hr for PM, then purchase of the cleanest available engine long with the best available emission control technology that would meet the 0.01 g/bhp-hr for PM.

Technical Considerations – Ensure technical feasibility. Strategy will involve carefully removing the original engine and replacing it with a newer-cleaner engine.

Options for Implementation – Implementation through voluntary programs, incentives, lease renewals/renegotiations and/or contractual agreements.

Pros and Cons – The purchase of newer construction equipment that meet cleaner on-road or off-road engine standards will demonstrate great emission reduction benefits. The challenge may be the availability of cleaner engines internationally.

## Operational Improvements

Strategy – Repower construction equipment <750 hp with cleaner on-road and off-road engines. With construction equipment >750 hp, repower engines with cleaner off-road engines

Technical Considerations – Ensure technical feasibility. Strategy will involve carefully removing the original engine and replacing it with a newer-cleaner engine.

Options for Implementation – Implementation through voluntary programs, incentives, lease renewals/renegotiations and/or contractual agreements.

Pros and Cons – As mentioned above, repowering older diesel engines with cleaner on-road or off-road engines can greatly improve emission reductions. However, international availability may be a concern.

## Idle-Reduction Strategies

Strategy – Reduce idling emissions by using idle-reduction technologies. Mobile idle-reduction technologies include; automatic shut down and start up systems. These mobile idle-reduction technologies are on-board technologies that help provide power to the equipment. Operator education is a necessary and effective component of idle-reduction programs.

Technical Considerations – Test feasibility of idle-reduction technology on construction equipment.

Options for Implementation – Implement strategy through education and outreach, lease requirements, tariff charges, and incentives.

Pros and Cons – Eliminating idling time by using an idle-reduction policies, education and technology greatly reduces emissions that would be generated from idling. International availability of technology tools such as on board computer systems with anti-idling settings may create a challenge for some ports. A major advantage of anti-idling programs for construction equipment is that they can save fuel costs with very little capital investment.

## Cleaner Fuels

Strategy – Implement the use of cleaner fuels with low sulfur content. Cleaner fuels include; low to ultra low sulfur diesel fuel, emulsified diesel fuels, oxygenated fuel (O2 diesel fuel), and biodiesel.

Technical Considerations – Work with ports and fuel suppliers on the availability and supply of clean fuels. Depending on the type of clean fuel used, cleaning of the fuel tank may be required in order to avoid fuel contamination.

Options for Implementation – Implementation strategies may include the use of lease requirements, tariff changes, or through contractual agreements.

Pros and Cons – Positive emission reduction benefits for NOx, PM and GHGs. The use of biodiesel may present a slight increase in NOx. Challenges may arise with fuel availability and cost.

### Emission Control Technologies

Strategy – Retrofit construction equipment with the best available emission control technologies (ECTs). Depending on the appropriate application of ECT, ECTs can include; diesel oxidation catalyst (DOC), diesel particulate filter (DPF), or selective catalytic reduction (SCR). While evaluating different emission control technologies, consider ECTs that have had proven success with construction equipment similar to the construction equipment under evaluation. To further improve emission reductions, retrofit cleaner construction equipment engines with ECTs.

Technical Considerations – Operational and feasibility testing is required to ensure the function and applicability of an emissions control technology on construction equipment. In particular, many ECTs require exhaust gas temperature analysis by conducting exhaust gas temperature datalogging to measure exhaust gas temperatures. Many ECTs have exhaust temperature thresholds that are required for the operation and effectiveness of the technology. Emission control technologies which have been certified or verified by regulatory agencies (such as those programs at the US Environmental Protection Agency and the California Air Resources Board) are most likely to deliver the claimed benefits.

Options for Implementation – Implement strategy through lease requirements, tariff charges, incentives and/or contractual agreements.

Pros and Cons – Applying ECTs has proved to have positive emission benefits in reducing particulate matter (PM), Oxides of Nitrogen (NOx), carbon monoxide (CO) and hydrocarbon (HC). Retrofitting construction equipment with ECTs can be challenging, careful evaluation and analysis is a must.

# CREATING YOUR CLEAN AIR PROGRAM

## Commiting to Clean Air

PLAN – Planning Your Clean Air Program

DO – Implementing Strategies

CHECK – Measuring Results

ACT – Review Your Clean Air Plan

Steps You Can Take

So far, you have learned about the challenges facing ports today with balancing business and environmental needs. You have also learned about the different port activities and the resulting emissions; the potential effects on the environment and public health; and how ports are moving forward to promote clean air through effective strategies. By following the systematic process called 'Plan, Do, Check and Act' cycle, you will be able to create your Clean Air Program that promotes continual improvement.

## COMMITTING TO CLEAN AIR

Before you create your very own Clean Air Program, you have to make a commitment . By making a commitment, you are making a promise to fully carry out the actions necessary to ensure that your Clean Air Program is a success. In addition, you are starting the process of developing the support and dedication from people within your organization to participate in reducing emissions. The size or type of organization does not make a difference; the most important element of a successful Clean Air Program is commitment.

### Institute a Clean Air Policy

A Clean Air Policy provides the groundwork for setting performance goals and integrating clean air management into the organization's culture and operations

A Clean Air Policy should include the following
Stated objective
Establishment of accountability
Ensure continuous improvement
Promotion of goals

A Clean Air Policy will ensure senior management support and support among the staff. It also communicates the organization's commitment to the Port, customers, tenants and business partners, stakeholders and the community.

### Appoint a Clean Air Director

The Clean Air Director would be responsible for setting goals, tracking progress and promoting the Clean Air Program. An existing staff member can serve in this role. This individual would be someone that is capable of effectively overseeing the creation, management and implementation of a port clean air program.

### Establish a Clean Air Team

The Clean Air Team executes clean air management strategies depending on the maritime operation, while ensuring integration of best practices.

The Clean Air Team monitors and tracks progress. Regular reporting is made to the Clean Air Director on program progress.

Clean Air Team members may include staff involved in engineering, operations and maintenance, building/facilities management, environmental health and safety, construction management, and contractors and suppliers.

## Coordinate with Stakeholders and Regulatory Agencies

Developing your Clean Air Program with the support of your customers, tenants, business partners, stakeholders and regulatory agencies will ensure the Program's sustainability. In addition, involving your customers, tenants, business partners, stakeholders and regulators in the decision and goal-setting process brings in different perspectives that will give the Clean Air Program more diversity.

## Case Studies

*San Pedro Bay Ports Clean Air Action Plan*
The Port of Los Angeles partnered with its sister port, the Port of Long Beach , and engaged the United States Environmental Protection Agency, California Air Resources Board and the South Coast Air Quality Management District in a partnership to develop the world's first multi-port, comprehensive port-related air management plan – the San Pedro Bay Ports Clean Air Action Plan .

*Northwest Ports Clean Air Strategy*
The ports of Seattle and Tacoma in the Pacific Northwest of the United States and the Vancouver Port Authority have been working closely with federal, state and local air agencies for years on successful voluntary collaborative approaches to reduce air emissions from maritime-related sources in the region. They are currently working on the Northwest Ports Clean Air Strategy to establish common performance goals and further reduce emissions to protect public health and the environment.

*Port Authority of New York and New Jersey Clean Air Initiatives and Harbor Air Management Plan*
The Port Commerce Department of the Port Authority of New York and New Jersey in the Atlantic Northeast of the United States, along with its tenants, public agencies and private partners, collaborate on voluntary efforts to field test new off road technologies and develop clean equipment prototypes. Collaborative efforts are conducted under the Department's participation with the Regional Air Team on the Harbor Air Management Plan, the Northeast Diesel Collaborative and through U.S. EPA's Clean Ports Program.

*Rijnmond Regional Air Quality Action Program*
ROM Rijnmond Executive Council commissioned the DCMR Rijnmond Environmental Agency to draw up a regional plan through the Top Management Steering Committee on Air, which comprise of leaders from Ministries of Housing, Spatial Planning and the Environment; Transport, Public Works and Water Management; Economic Affairs; Agriculture; Nature and Food Quality; the Province of Zuid-Holland, the city of Rotterdam, Rotterdam Metropolitan Region; and Rotterdam Port Authority. The Rijnmond Regional Air Quality Action Program draws up existing air quality programs and creates a great uniformity of air quality control measures.

## Creating and Implementing Your Clean Air Program

Use the 'Plan, Do, Check, and Act' (PDCA) cycle as a tool to create and implement your Clean Air Plan. The PDCA cycle will guide you through the process to develop a program that strives to achieve continual improvement. For Ports which have or are implementing an Environmental Management System (EMS), this approach can be used to make the Clean Air Plan compatible with the Port's overall environmental management program.

## PLAN – Planning Your Clean Air Program

**Set Up A Process To Identify Objectives and Targets**
• Evaluate clean air programs currently in place.
• Design your Clean Air Program to follow approaches that have demonstrated success in other clean air programs. For example: San Pedro Bay Ports Clean Air Action Plan.
• Create a Clean Air Program that is most suitable to meet your business needs.

**Estimate Emission Reduction Potential**
• Determine emissions to be reduced.
• Evaluate the strategies needed to bring about your estimated emission reduction potential.
• Design a benchmarking goal to measure emission reduction progress.

**Define Goals**
• Define set emission reductions.
• Define maritime activity of focus.
• Determine what equipment by identifying the number and types of equipment to be improved.
• Determine the timeline that the Clean Air Program will be carried out.

**Determine Technical Approach**
• Identify the technical steps to reduce emissions from the selected maritime activity.
For example, here are the types of questions that will help identify what technical steps are needed. The maritime activity in this example is cargo handling equipment.
• How will operational staff schedule selected CHE to be retrofitted with emission control technologies without creating operational and schedule conflicts?
• What equipment will be retrofitted first?
• What training is required to educate maintenance/operational staff on technical implementation?
• What are the steps needed to retrofit a top loader with a diesel oxidation catalyst (DOC)?
• Once CHE is retrofitted, what maintenance is involved?

**Determine Performance Targets**
• Determine the emissions to be reduced from maritime activity. One performance target may look like this -
By retrofitting 50 pieces of CHE, X tons in particulate matter will be reduced every year.
• Set specific timelines for defined actions in the Clean Air Program.
Timelines may include: the number of CHE retrofitted over a period of time; meetings to discuss goals and evaluate progress; and dates which certain actions would be completed.

**Establish a Tracking System to Help Monitor Progress**
• In order to measure the success of the Clean Air Program, design a tracking system that will help you monitor progress.
A tracking system will ensure that actions laid out in the Program are achieved over the assigned time frame.

## DO – Implementing Strategies

### Technical Approach

**Conduct an Activity-Based Emissions Inventory**

• Depending on the maritime operation (ex: cargo handling equipment), collect data on the type of equipment, the individual equipment number, the engine type, model, year, hours of activity, fuel use, and whether the equipment has been upgraded or given a special after-treatment.

• Once you have a detailed list of all of your equipment, assess your older equipment, determine what equipment is going to be replaced or repowered with a newer engine. Examine what equipment is most actively used on a daily basis.

• After examining your equipment, calculate the emissions. Determine what the emissions factor is for each engine type. This is a very important component in the equation.

• A number of port-wide activity-based emission inventories have been conducted at ports in the United States .

The ports that have conducted port-wide emissions inventories include:

• Port of Los Angeles
• Port of Long Beach
• Port of Seattle
• Port of Tacoma
• Port Authority of Houston
• Port Authority of New York and New Jersey

**Establish a Baseline and Set a Benchmark**

• Using the results of the emissions inventory, set a starting point from which to measure progress.
• Compare performance to other maritime activities and prioritize which activities to focus on.
• Make a qualitative assessment to current in-use practices, such as; preventive maintenance, equipment replacement schedules, and efficiency practices.

**Analysis and Evaluation**

• Analyze the results of your emissions inventory by determining what maritime operation is generating the most emissions. Take into consideration the age of the equipment, the hours in operation, the type of fuel, the load in which the equipment is operating under and the maintenance schedule.
• Evaluate over-all performance of your equipment. Meet with the operators of the equipment and inquire on how each piece of equipment operates.
• Evaluate where there is a lack of efficiency in daily operations; for example, trucks waiting more than 15 minutes to enter the gate and/or facility.
• Generate a report on your assessment.

**Research Different Emission Control Strategies**

• Using the Tool Box for Port Clean Air Programs as a guide, evaluate the strategies recommended for the source category of focus. For example, refer to the strategies recommended for cargo handling equipment (CHE).

• Depending on the strategy, research the various options available that will work best with the identified equipment. For example, research the different emission control technology companies that provide diesel particulate filters (DPFs) for non-road applications such as CHE. There are differences in operational measures, effectiveness, maintenance and cost. The Tool Box provides helpful websites you can use to learn more about DPFs.

• Identify where to improve operational efficiency either through idle-reduction strategies, gate efficiencies and/or better maintenance programs.

**Determine Control Strategy(s)**

• After researching the various control options for your selected maritime operation, determine the control option(s) that is technically feasible and provides the most environmental benefits.

• Carry out a pilot test to ensure feasibility.

**Implement Your Program**

• Apply control strategy to maritime operation.

• Follow implementation schedule.

## Communication Approach

**Communicating Your Program**

• Determine how to communicate your Program to your audience. Depending on how your port is organized, your message may need to be adapted to the different groups of people within your company. The same applies to communicating to people outside of your port – customers, tenants, business partners, stakeholders and the port community.

• Create a communication plan that will direct how you will communicate your Program to your audiences.

**Raise Awareness (Internal and External)**

Identify the different mediums on how to communicate your Clean Air Program. Mediums may include; meetings,workshops, written materials, campaigns, and the internet (include a program link on your port's webpage).

**Capacity Building**

Open up opportunities for your employees to learn and share ideas. Training allows for the exchange of helpful information on best practices. Capacity building will help sustain the success of the program. The more people are aware of and understand the purpose and benefits of the Clean Air Program, the higher the likelihood that people will support it.

**Motivating Your Team**

Motivate your team through incentives. It is very important that people feel like they are a part of something that is special and important. Recognize staff who have worked hard on the program and staff who have made achievements while supporting the goals of the Clean Air Program.

## CHECK – Measuring Results

**Monitor and Evaluate Progress**

- By using your tracking system, monitor the progress of your Clean Air Program.
- Evaluate how well your Program is operating under the measures you've established.
- Measure the results of the control strategy.
  Determine how much emissions have been reduced and where operational performances have improved.

## ACT – Review Your Clean Air Program

**Make Improvements to Your Program**

- As you evaluate the progress of your Program, identify where improvements can be made.
- Work with your Clean Air Team to update your action plan.

**Celebrate Program Achievement**

- Recognize and commend the achievements of your staff that have helped make the Clean Air Program a success. It is very important to recognize the efforts of your team and the hard work they have put forward to bring the Clean Air Program into reality. Determine what criteria you will use to recognize achievements and how to reward those recognized.

- Communicate the success of the Clean Air Program to the port community and stakeholders. Share the benefits of your program with the public. A great way to share success and receive recognition is to apply for achievement or environmental awards. This will help build positive public awareness and support.

## TOOLS AND RESOURCE LIBRARY

The Tool Box for Port Clean Air Programs includes additional tools and resources to help you create a successful Clean Air Program. The Tools and Resource Library includes the following fact sheets for your information:

International Maritime Regulations

Engine Standards

Clean Technologies and More

Air Quality Monitoring

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## INTERNATIONAL MARITIME REGULATIONS

The demand on ocean/sea going vessels (OGVs) to transport goods is dramatically increasing to accommodate to the rapid growth in international goods movement. Although OGVs are the most efficient mode of global transport, the increase in OGV movements and the resulting increase in emissions from OGV propulsion and auxiliary engines are causing concern. It is projected that ocean-going emissions will surpass land-based emissions if stricter standards are not put in place to address air emissions from OGVs.

Currently, there are international maritime regulations in place to reduce emissions from OGVs. However, there is a growing concern amongst ports and the maritime industry that the current regulations are not keeping pace with the increased demand on ship cargo transport and the emerging and proven technologies available to address OGV emissions. The following fact sheet provides a summary of the international maritime regulations established for ocean/sea going vessels.

### MARPOL Annex VI

Under the authority of the United Nations (UN), the International Maritime Organization's (IMO) Marine Environment Protection Committee (MEPC) provides oversight on ocean/sea going vessels. On May 19, 2005 , the Protocol of 1997 (MARPOL Annex VI) entered into force. MARPOL Annex VI sets limits on emissions of sulfur oxides (SOx) and nitrogen oxides (NOx) from ship exhausts and prohibits deliberate emissions of ozone depleting substances. The limits apply to the Parties or the Flag States under the conference delegation.

Annex VI will reduce SOx by setting a global cap of 4.5% (on a mass basis, m/m) on the sulfur content of fuel used on board ocean/sea going vessels and by requiring the IMO to monitor worldwide average sulfur content on fuel. In addition, Annex VI contains provisions allowing for SOx Emission Control Areas (SECAs) that will result in stricter controls on sulfur emissions in designated areas. Areas that have established a SECA require use of fuel with a sulfur content of 1.5% m/m. Under the Protocol of 1997, the Baltic Sea was established as a SECA.

Annex VI also sets limits on emissions of NOx from diesel marine engines rated above 130 kW. The IMO developed a Technical Code which defines how this will be done. The current limits are based on the engine's rated speed as presented in the following table:

| Rated Engine Speed | Emission Limit, g/kW-hr |
|---|---|
| Less than 130 rpm | 17 |
| 130 rpm to less than 2,000 rpm | 45.0 x rpm -0.2 |
| 2,000 rpm or greater | 9.8 |

**IMO Review and Amendments**

**2005**

In July 2005, MEPC adopted amendments to MARPOL Annex VI at its 53 rd session. The new amendments included the North Sea SECA and an update to the NOx Technical Code. In addition, the Committee released information gained from the monitoring of worldwide sulfur content in fuel oils for 2004 which gave a three-year (2002 – 2004) rolling average of sulfur content in fuel oil worldwide of 2.67% m/m.

At the 53 rd session, MEPC agreed to review and revise Annex VI and the NOx Technical Code in order to take in account current technologies as well as advancing further emission reductions from ships. Specific orders from MEPC were given to the Sub-Committee on Bulk Liquids and Gases (BLG) to carry out the review by 2007. The BLG Committee's instructions included:

• Examine available and developing techniques for the reduction of emissions of air pollutants; review the relevant technologies and the potential for reduction of NOx emissions and recommend future limits for NOx emissions;

• Review technology and the need for a reduction of SOx emissions and justify and recommend future limits for SOx emissions;

• Consider the need, justification and possibility of controlling volatile organic compounds emissions from cargoes;

• With a view to controlling emissions of particulate matter (PM), study current emission levels of PM from marine engines, including their size distribution and quantity, and recommend actions to be taken for the reduction of PM from ships. Since reduction of NOx and SOx emissions is expected to reduce PM emissions, estimate the level of PM emission reduction through this route;

• Consider reducing NOx and PM emission limits for existing engines;

• Consider whether Annex VI emission reductions or limitations should be extended to include diesel engines that use alternative fuels and engine systems/power plants other than diesel engines; and

• Review the texts of Annex VI, NOx Technical Code and related guidelines and recommend necessary amendments.

**2006**

In October 2006, MEPC moved forward on amendments to review and revise MARPOL Annex VI. The issues discussed by the MEPC include:

• Agreement on eight unified interpretations relating to the implementation and enforcement of MARPOL Annex VI, the NOx Technical Code and related guidelines;

• Approval of standard form of the Sulfur Emissions Control Area (SECA) Compliance Certificate to facilitate uniform enforcement and port State control;

• Approval of the establishment of a correspondence group to develop wash water discharge criteria for exhaust gas SOx cleaning systems;

• Agreement on a global standard on shore-power supply connections with ships, but agreed to await the finalization of such a standard before taking any decision on its possible inclusion in the revised MARPOL Annex VI, noting that the International Organization for Standardization (ISO) and the International Electro technical Commission (EIC) have established a working group on the standardization of on-shore power supply for ships at berth; and

• Agreement on the cooperation between the secretariats of the International Civil Organization (ICAO) and IMO should be strengthened and that developments related to GHG emissions in both Organizations should be communicated to each other.

**Addressing Greenhouse Gases**

MEPC agreed on a work plan and timetable, to identify and develop the mechanisms needed to achieve the limitation or reduction of carbon dioxide (CO2) emissions from ships in order to address the growing concern of climate change caused by greenhouse gases (GHGs). The work plan includes the development of a CO2 Emission Indexing Scheme. Member States and the industry were asked to carry out trials in accordance with the Interim Guidelines for Voluntary Ship CO2 Emission indexing for In-Use Trials (MEPC/Cir. 471, issued in 2005); the consideration and evaluation of methodology for CO2 emission baseline(s); and the consideration of technical, operational and market-based methods for dealing with GHG emissions. The timeline to accomplish the work under this work plan calls for completion by 2008/2009.

**2007**

In April 2007, the IMO's Bulk Liquid and Gas Subcommittee held a meeting in London to discuss ocean/sea going vessel emission standards under Annex VI. The subcommittee noted that the contribution of ship emissions is greatly impacting air quality in many parts of the world and that emissions will continue to grow with the growth in global trade. In addition, the IMO noted that action is required to avoid proliferation of unilateral regional or national regulations.

Proposals from the meeting included:

• "Narrowing" of options on emission reduction strategies;

• Consolidate USA and BIMCO proposals into one "global/regional" option;

• INTERTANKO proposal – agreement on the use of distillate fuels as proposed or equivalent emission limits, allowing for LSFO or use of emission control technology(s);

• New engines – propose for Tier II engines 2 to 3.5 g/kWh reductions vs. 2011 standard and water or selective catalytic reduction technology based Tier III engines as of 2015 – 2016;

• Existing engines – bring to current standard;

• Efficient and effective instruments to address air pollution and climate change;

• Holistic approaches involving oil producers and engine manufacturers; and

• Inclusive approach engaging governments, industry and the scientific community.

# ENGINE STANDARDS

## Background

Ports around the world depend on the efficiency of the diesel engine to power port operations in each source category – ocean/sea-going vessels, harbor craft, cargo handling equipment, trucks and locomotives. Though diesel engines are the most efficient power sources compared to other internal combustion engines, they are significant contributors to air pollution. Environmental regulations are calling for cleaner engine standards and advanced emission controls to address the negative impact from diesel emissions.

The following fact sheet provides an overview on international engine emission standards. Emission standards are set requirements that limit the amount of pollutants that can be released into the atmosphere. There are emission standards set for both onroad and offroad vehicles and equipment. Generally, emission standards regulate emissions for oxides of nitrogen (NOx), particulate matter (PM) or soot, carbon monoxide (CO), or volatile hyrdrocarbons (depends on international engine standard).

## European Union Emission Standards

The European Union currently has emission standards set for all road vehicles, locomotives, and 'nonroad mobile machinery.' However, no engine standards apply to ocean/sea-going vehicles and airplanes.

### Euro Norm Emissions for Category N2, EDC, (2000 and Up)

| Standard | Date | CO (g/kWh) | NOx (g/kWh) | HC (g/kWh) | Particulates (g/kWh) |
|---|---|---|---|---|---|
| Euro 0 | 1988-1992 | 12.30 | 15.8 | 2.60 | None |
| Euro I | 1992-1995 | 4.90 | 9.00 | 1.23 | 0.40 |
| Euro II | 1995-1999 | 4.00 | 7.00 | 1.10 | 0.15 |
| Euro III | 1999-2005 | 2.10 | 5.00 | 0.66 | 0.10 |
| Euro IV | 2005-2008 | 1.50 | 3.50 | 0.46 | 0.02 |
| Euro V | 2008-2012 | 1.50 | 2.00 | 0.46 | 0.02 |
| Euro VI | Proposed regulations under review. | | | | |

### Euro Norm Emissions for (Older) ECE R49

| Standard | Date | CO (g/kWh) | NOx (g/kWh) | HC (g/kWh) | Particulates (g/kWh) |
|---|---|---|---|---|---|
| Euro 0 | 1988-1992 | 11.20 | 2.40 | 2.40 | None |
| Euro I | 1992-1995 | 4.50 | 1.10 | 1.10 | 0.36 |
| Euro II | 1995-1999 | 4.00 | 1.10 | 1.10 | 0.15 |

**Heavy-Duty Diesel Truck and Bus Engines**
The following table summarizes emission standards and implementation dates for heavy-duty trucks and bus engines.

**EU Emission Standards for HD Diesel Engines, g/kWh (smoke in m -1)**

| Standard | Date | Test | CO | HC | NOx | PM | Smoke |
|---|---|---|---|---|---|---|---|
| Euro I | 1992, > 85 kW | | 4.5 | 1.1 | 8.0 | .36 | |
| Euro II | 1996 | | 4.0 | 1.1 | 7.0 | .25 | |
| | 1998 | | 4.0 | 1.1 | 7.0 | .15 | |
| Euro III | 1999 | ESC & ELR | 1.5 | 0.25 | 2.0 | 0.02 | 0.15 |
| | 2000 | ESC & ELR | 2.1 | 0.66 | 5.0 | 0.10<br>0.13 | 0.8 |
| Euro IV | 2005 | | 1.5 | 0.46 | 3.5 | 0.02 | 0.5 |
| Euro V | 2008 | | 1.5 | 0.46 | 2.0 | 0.02 | 0.5 |

The Euro III standard includes changes in the engine test cycles (2000). Two new test cycles replace the old steady-state engine test cycle ECE R-49. The two test cycles include the European Stationary Cycle (ESC) and the European Transient Cycle (ETC). The European Load Response (ELR) measures smoke opacity.

**Nonroad Diesel Engines**
Regulations for nonroad diesels were first introduced in 1997 in two stages depending on the engine power output; Stage I – 1999 and Stage II – 2001 to 2004. Nonroad equipment included industrial drilling rigs, compressors, construction wheel loaders, bulldozers, nonroad trucks, highway excavators, forklift trucks, road maintenance equipment, snow plows, ground support equipment I air ports, aerial lifts and mobile cranes. However, ships, locomotives, aircraft, and generating sets were not covered by Stage I and II standards.

In 2004, the European Parliament adopted Stage III and IV emission standards. Stage III emission standards include a phase-in schedule from 2006 to 2013. Stage IV will come into compliance in 2014. Both Stages III and IV include emission standards for locomotives and marine engines. Standards apply only to new vehicles and equipment. Replacement engines to be used in machinery already in use (except for rail car, locomotive and harbor craft propulsion engines) should comply with the limit values that the engine to be replaced had to meet when originally placed on the market.

**Stage III/ IV Engine Standards**
The following table provides a summary for Stage III and IV engine standards. Stage III standards are divided into two sub-stages: Stage III A and Stage III B. The limits are set for all nonroad diesel engines of indicated power range for use I applications and do not apply to locomotive, rail cars and harbor craft propulsion engines.

Stage III B standards include PM limit of 0.025 g/kW-hr, which represents about 90% emission reductions compared to Stage II. In order to meet the 90% reduction, emission control technologies will have to be applied such as diesel particulate filters (DPFs). Stage IV introduces stringent NOx standards of 0.4 g/kWh also requiring the use of a NOx emission control technology.

Stage III A Standards for Nonroad Engines

| Category | Net Power | Date | CO | NOx+HC | PM |
|---|---|---|---|---|---|
| | kW | g/kWh | | | |
| H | 130 ≤ P ≤ 560 | 2006 | 3.5 | 4.0 | 0.2 |
| I | 75 ≤ P < 130 | 2007 | 5.0 | 4.0 | 0.3 |
| J | 37 ≤ P < 75 | 2008 | 5.0 | 4.7 | 0.4 |
| K | 19 ≤ P < 37 | 2007 | 5.5 | 7.5 | 0.6 |

State III B Standards for Nonroad Engines

| Category | Net Power | Date | CO | HC | NOx | PM |
|---|---|---|---|---|---|---|
| | kW | g/kWh | | | | |
| L | 130 ≤ P ≤ 560 | 2011 | 3.5 | 0.19 | 2.0 | 0.025 |
| M | 75 ≤ P < 130 | 2012 | 5.0 | 0.19 | 3.3 | 0.025 |
| N | 56 ≤ P < 75 | 2012 | 5.0 | 0.19 | 3.3 | 0.025 |
| P | 37 ≤ P < 56 | 2013 | 5.0 | 4.7 (NOx+HC) | | 0.025 |

Stage IV Standards for Nonroad Engines

| Category | Net Power | Date | CO | HC | NOx | PM |
|---|---|---|---|---|---|---|
| | kW | g/kWh | | | | |
| Q | 130 ≤ P ≤ 560 | 2014 | 3.5 | 0.19 | 0.4 | 0.025 |
| R | 56 ≤ P < 130 | 2014 | 5.0 | 0.19 | 0.4 | 0.025 |

The Nonroad Transient Cycle (NRTC) test procedure was developed to represent emissions during real conditions in cooperation with the United States Environmental Protection Agency.

**Stage III A Standards for Harbor Craft**

| Category | Displacement | Date | CO | NOx+HC | PM |
|---|---|---|---|---|---|
| | Dm3 per cylinder | g/kWh | | | |
| V1:1 | D ≤ 0.9, P > 37 kW | 2007 | 5.0 | 7.5 | 0.40 |
| V1:2 | 0.9 < D ≤ 1.2 | | 5.0 | 7.2 | 0.30 |
| V1:3 | 1.2 < D ≤ 2.5 | | 5.0 | 7.2 | 0.20 |
| V1:4 | 2.5 < D ≤ 5 | 2009 | 5.0 | 7.2 | 0.20 |
| V2:1 | 5 < D ≤ 15 | | 5.0 | 7.8 | 0.27 |
| V2:2 | 15 < D ≤ 20, P ≤ 3300 kW | | 5.0 | 8.7 | 0.50 |
| V2:3 | 15 < D ≤ 20, P > 3300 kW | | 5.0 | 9.8 | 0.50 |
| V2:4 | 20 < D ≤ 25 | | 5.0 | 9.8 | 0.50 |
| V2:5 | 25 < D ≤ 30 | | 5.0 | 11.0 | 0.50 |

**Stage III A Standards for Rail Traction Engines**

*HC = 0.4 g/kW-hr and NOx = 7.4 g/kW-hr for engines of P > 2000 kW and D > 5 liters/cylinder

| Category | Net Power | Date | CO | HC | HC+NOx | NOx | PM |
|---|---|---|---|---|---|---|---|
| | kW | g/kWh | | | | | |
| RC A | 130 < P | 2006 | 3.5 | - | 4.0 | - | 0.2 |
| RL A | 130 ≤ P ≤ 560 | 2007 | 3.5 | - | 4.0 | - | 0.2 |
| RH A | P > 560 | 2009 | 3.5 | 0.5* | - | 6.0* | 0.2 |

**Stage III B Standards for Rail Traction Engines**

| Category | Net Power | Date | CO | HC | HC+NOx | NOx | PM |
|---|---|---|---|---|---|---|---|
| | kW | g/kWh | | | | | |
| RC B | 130 < P | 2012 | 3.5 | 0.19 | - | 2.0 | 0.025 |
| R B | 130 < P | 2012 | 3.5 | - | 4.0 | - | 0.025 |

By the end of 2007, Stage III and IV emission standards will undergo technical review. This will determine the feasibility of standards, and recommended relaxing or tightening of the limits, as it may be appropriate.

## United States Emission Standards

The United States Environmental Protection Agency set national engine emission standards. In some states such as California, engine standards are set independently for that state. Some of the most strict engine standards in the world are set by the California Air Resources Board.

### Heavy-Duty Vehicles and Buses

Heavy-duty diesel vehicles are defined by their gross vehicle weight rating (GVWR). Federal regulations set emission standards for heavy-duty vehicles with a GVWR of 8,500 pounds and higher and California's heavy-duty vehicle emission standards start at 14,000 pounds.

Diesel engines in heavy-duty vehicles are broken down into service classes. These include:

- Light heavy-duty diesel engines: 8,500 < **LHDDE** < 19,500 (14,000 < **LHDDE** < 19,500 in California, 1995+)
- Medium heavy-duty diesel engines: 19,500 ≤ **MHDDE** ≤ 33,000
- Heavy heavy-duty diesel engines (including urban bus): **HHDDE** > 33,000

Basic standards are expressed in g/bhp·hr and require emission testing over the transient FTP engine dynamometer.

### Model Year 1987 – 2003

The following table summarizes federal (EPA) and California (CARB) emission standards for HDDVs.

**EPA Emission Standards for HDDV Engines, g/bhp-hr**

| Year | HC | CO | NOx | PM |
|---|---|---|---|---|
| Heavy Duty Diesel Truck Engines | | | | |
| 1988 | 1.3 | 15.5 | 10.7 | 0.60 |
| 1990 | 1.3 | 15.5 | 6.0 | 0.60 |
| 1991 | 1.3 | 15.5 | 5.0 | 0.25 |
| 1994 | 1.3 | 15.5 | 5.0 | 0.10 |
| 1998 | 1.3 | 15.5 | 4.0 | 0.10 |
| Urban Bus Engines | | | | |
| 1991 | 1.3 | 15.5 | 5.0 | 0.25 |
| 1993 | 1.3 | 15.5 | 5.0 | 0.10 |
| 1994 | 1.3 | 15.5 | 5.0 | 0.07 |
| 1996 | 1.3 | 15.5 | 5.0 | 0.05 |
| 1998 | 1.3 | 15.5 | 4.0 | 0.05 |

**California Emission Standard for HDDV Engines, g/bhp-hr**

| Year | NMHC | THC | CO | NOx | PM |
|---|---|---|---|---|---|
| Heavy-Duty Diesel Truck Engines | | | | | |
| 1987 | - | 1.3 | 15.5 | 6.0 | 0.60 |
| 1991 | 1.2 | 1.3 | 15.5 | 5.0 | 0.25 |
| 1994 | 1.2 | 1.3 | 15.5 | 5.0 | 0.10 |
| Urban Bus Engines | | | | | |
| 1991 | 1.2 | 1.3 | 15.5 | 5.0 | 0.10 |
| 1994 | 1.2 | 1.3 | 15.5 | 5.0 | 0.07 |
| 1996 | 1.2 | 1.3 | 15.5 | 4.0 | 0.05 |

The HDDV emission standards include a useful life and warranty period.

- LHDDE – 8 years/110,000 miles
- MHDDE – 8 years/185,000 miles
- HHDDE – 8 years/290,000 miles

## Model Year 2004 and Later

In October 1997, EPA adopted new emission standards for model year 2004 and later for heavy-duty diesel truck and bus engines.

EPA Emission Standards for MY 2004 and Later HDDV Diesel Engines, g/bhp-hr

| Option | NMHC + NOx | NMHC |
|---|---|---|
| 1 | 2.4 | n/a |
| 2 | 2.5 | 0.5 |

Under this ruling, all emission standards other than NMHC and NOx applying to 1998 and later model year heavy-duty engines would continue at their 1998 levels.

Useful life requirements were significantly extended compared to earlier rulings.

- LHDDE – 110,000 miles/10 years
- MHDDE – 185,000 miles/10 years
- HHDDE – 435,000 miles/10 years

The federal 2004 standards for highway trucks are coordinated with California standards.

## Model Year 2007 and Later

Emission standards were set for heavy-duty trucks model year 2007 and newer in December 2000. California Air Resources Board adopted very similar standards in October 2001. The rule included two important approaches to further emission reductions; stricter emission standards and diesel fuel regulations.

### Emission Standards

The emission standards for HDDVs model year 2007 and newer included:

- PM 0.01 g/bhp-hr
- NOx 0.20 g/bhp-hr
- NMHC 0.14 g/bhp-hr

In 2007, the PM emission standard will take full effect. Standards for NOx and NMHC will be phased in between 2007 to 2010.

### Crankcase Emissions

As a part of the 2007 regulation for HDDVs, crankcase emissions will be eliminated. Through the use of emission control technologies, crankcase emissions will be routed back to the engine intake or to the exhaust upstream as a means of recycling the emissions back through the crank shaft.

**Cleaner Fuels**
As of July 2006, all on-highway diesel fuel required a lower sulfur content of 15 parts per million (ppm) from the 500 ppm on-highway diesel fuel. Retail stations and wholesale purchasers were required to meet this standard by selling the 15 ppm ultra low sulfur diesel fuel (ULSD) by September 2006. ULSD is a "technology enabler" for sulfur-intolerant exhaust emission control technologies, such as diesel particulate filters and NOx catalyst, technologies that are necessary to meet 2007 emission standards.

**Nonroad Equipment**
Similar to the onroad regulations for cleaner engines and the use of ultra low sulfur diesel fuel, the US EPA introduced the Clean Air Nonroad Diesel Rule in May 2004. This comprehensive rule requires that emissions be reduced by integrating engine and fuel controls as an approach to achieve the greatest emission reductions. New nonroad engines are required to have emission control technologies similar to on-road HDDVs. This regulation will help reduce exhaust emissions by more than 90 percent.

EPA's Clean Air Nonroad Diesel Rule applies to diesel engines in most construction, agricultural, industrial, and airport equipment. The standards will take effect for new engines in 2008 and will be completely phased in by 2014.

**Nonroad Emission Standards, g/hp-hr**

| Rated Power | First Year that Standards Apply | PM | NOx |
|---|---|---|---|
| hp < 25 | 2008 | 0.30 | - |
| 25 ≤ hp < 75 | 2013 | 0.02 | 3.5* |
| 75 ≤ hp < 175 | 2012 – 2013 | 0.01 | 0.30 |
| 175 ≤ hp < 750 | 2011 – 2013 | 0.01 | 0.30 |
| hp ≥ 750 | 2011 – 2014, 2015 | 0.075, 0.02/0.03** | 2.6/0.50 |

* 3.5 g/hp-hr standard includes both NOx and nonmethane hydrocarbons.
** The 0.02 g/hp-hr standard applies to gensets; the 0.03 g/hp-hr standard applies to other engines.
2011 to 2014 – 0.50 applies to gensets over 1200 hp.
2015 – 0.50 applies to all gensets.

**Nonroad Diesel Fuel Rule**
In 2007, all nonroad equipment will be required to use lower sulfur diesel fuel with a maximum sulfur content of 500 ppm. By 2010, all nonroad equipment will be required to use on-highway ULSD with a sulfur content of 15 ppm. This limit also applies to locomotive and marine applications (though not very large marine engines that depend on residual fuel).

**Locomotive and Marine Engines**

In March 2007, the EPA proposed more stringent exhaust emission standards for locomotives and marine diesel engines. The new emission standards would significantly reduce harmful emissions of PM and NOx. Under this program, three approaches would be put in place.

1. Tighten emission standards for existing locomotives when they are remanufactured. These standards would take effect as soon as certified remanufacture systems are available (as early as 2008), but no later than 2010 (2013 for Tier 2 locomotives).
2. Set near-term engine-out emission standards, referred to as Tier 3 standards, for newly-built locomotives and marine diesel engines. These standards would reflect the application of emission control technologies to reduce PM and NOx exhaust emissions and would start a phase-in by 2009.
3. Set longer-term standards, referred to as Tier 4 standards, for newly-built locomotives and marine diesel engines that reflect the application of high-efficiency aftertreatment technology. These standards would apply to marine engines in 2014 and locomotives by 2015. By 2012, ULSD will be available for US locomotives and marine engines, which would be a “technology enabler” for some emission control technologies such as diesel particulate filters (DPFs).

In addition to these standards, EPA is proposing provisions to eliminate unnecessary idling.

**Locomotive Engines**

The regulations would apply to all line-haul, passenger, and switch locomotives that operate extensively within the United States, including newly manufactured locomotives and remanufactured locomotives that were originally manufactured after 1972. There is a primary exception that new remanufacturing standards would not apply to existing fleets of locomotives owned by very small railroads.

**Marine Engines**

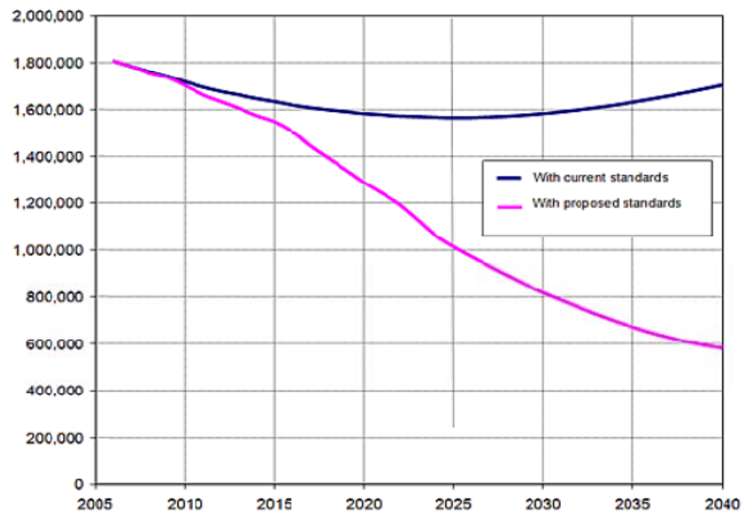
The regulations would apply to newly-built marine diesel engines with displacements less than 30 liters per cylinder installed on vessels flagged or registered in the United States. The marine diesel engines are divided into three categories.

- Category 1 – engines above 50 horsepower (hp) and up to 5 liters per cylinder displacement.
- Category 2 – engines 5 to 30 liters per cylinder.
- Category 3 – engines 30 per cylinder.

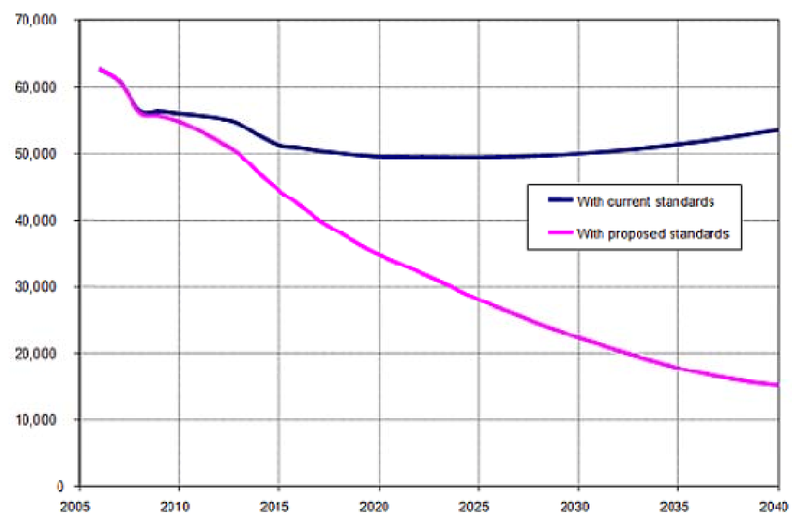
The following figures provide projected emission reductions for NOx and PM under the new emission standards for locomotive and marine diesel engines.[1]

[1] NOx and PM figures from EPA fact sheet on *Locomotive and Marine Diesel Engines Proposed Rule*, March 2007

**Projected NOx Emissions (tons per year 'with' and 'without' Proposed New Controls)**




**Projected PM Emissions (tons per year 'with' and 'without' Proposed New Controls)**



# CLEAN TECHNOLOGIES AND MORE

There are a number of emission control strategies available to reduce diesel emissions. In this section, we provide more information on the types of emission control technologies, clean and alternative fuels, idle reduction technologies, hybrid/electric technologies and efficiency strategies.

## Emission Control Technologies

### Diesel Oxidation Catalysts (DOCs)

**ECT Background**

Diesel oxidation catalysts (DOCs) were one of the first retrofit emission reduction technologies to have widespread use. Similar to the size and shape of the conventional muffler, a DOC is essentially a direct replacement with the muffler. There are no requirements to modify or adjust engine controls. Generally, DOCs are a little heavier than a conventional muffler and may require more robust mounting brackets. A DOC's performance is further enhanced with the use of ultra low sulfur diesel fuel (ULSD) with a sulfur content of < 30 ppm.

DOCs generally exhibit PM reduction efficiencies of 20 percent, which is modest compared to other, more advanced technologies. However the ease of installation, minimal modification to the vehicle structure or operational parameters (such as engine recalibration or low-sulfur fuel substitution), coupled with their low-cost, makes them an ideal PM retrofit technology when used in large-scale applications.

As the name suggests, the oxidation catalyst "oxidizes", or "adds oxygen" to hydrocarbons in the exhaust, to form carbon dioxide ($CO_2$) and water. Oxygen is present in diesel exhaust in large quantities, so oxidation occurs naturally; a DOC speeds up the reaction rate. The soluble organic fraction (SOF) is the hydrocarbon derivative organic carbon (so called "wet" carbon) portion of PM; DOCs oxidize the SOF fraction of PM and this reaction results in PM reductions.

**"At A Glance"**
**Diesel Oxidation Catalyst**

| Benefits | Drawbacks |
|---|---|
| **1. Moderate emission reductions in PM (20 – 30%), HC (50 – 90%) and CO (70 – 90%).<br>2. Comparatively a low cost.<br>3. Direct muffler replacement making it an easy installation.<br>4. More tolerant of higher sulfured fuels <500 ppm.** | **1. Low PM reduction and no NOx reduction.<br>2. Ineffective in reducing elemental carbon or soot.<br>3. May require more robust mounting brackets.<br>4. Potential for sulfate make.** |

**Technical Considerations**

**"Sulfate Make"**
A potential concern with DOCs is their ability to create "sulfate make." Under certain operational conditions along with the type of fuel use, DOCs can generate unwanted sulfate. This can outweigh any benefit in total PM reduction. Sulfate make is dependent primarily upon sulfur content in the diesel fuel, the operating conditions of the vehicle (and hence the resultant catalyst temperature) and the formulation of the metal on the catalyst itself.

The best defense against sulfate make is to use low-sulfur fuels. DOCs are attractive for retrofits since they are not poisoned by the use of higher sulfur fuels (300 ppm and above) the way many DPFs are. However, higher sulfur content can contribute to sulfate make, and their use with lower sulfur content fuel will ensure minimal sulfate production. Additionally, DOCs are becoming more sophisticated and coating formulations are selectively minimizing sulfate make. Finally, sulfur formation tends to decrease with increasing temperatures above a certain threshold point; there is a design trend for modern diesel, engines toward higher engine and exhaust temperatures.

**Field Experience**
DOCs have widespread use in on-highway applications; become more prevalent for nonroad construction, cargo handling equipment and marine applications.

**ECT Cost**

<u>On-Road</u>
Trucks= $1,000 to $2,000

<u>Non-Road</u>
CHE (>750 hp= $1,000 to $2,000
Marine and CHE (<750 hp) = $3,000 to $4,000
Locomotives= Cost may vary (Currently in demonstration.)

**Closed Crankcase Ventilation (CCV)**

**ECT Background**

Closed crankcase ventilation (CCV) systems prevent "blow by" gases from entering the atmosphere. Crankcase emissions result from a diesel combustion process in the engine. There are a certain percentage of engine exhaust gases that pass by the piston rings and valve seals and essentially make their way into the crankcase of the engine. Eventually, these "blow by" gases make it into the atmosphere. The gases contain harmful pollutants such as PM, NOx, HC and CO.

To effectively and safely perform this "recirculation" operation requires a vapor separator, filtering and re-circulating device, generically known as *closed crankcase ventilation* or *CCV*.

**"At A Glance"**
**Closed Crankcase Ventilation (CCV) Systems**

| Benefits | Drawbacks |
|---|---|
| 1. PM reduction of 15 – 20%. Added emissions benefit when combined with a DOC.<br>2. Low cost.<br>3. Minimal maintenance – filter replacement. | 1. Negligible NOx, HC and CO reduction. Difficult to test.<br>2. Challenging installation on the first few retrofits. Becomes easier with installation experience. |

**ECT Cost**

On-Road
Truck= $700 for typical "on-highway" derivative engine.

Non-Road
CHE= $700 (engines >750hp)
Marine and Locomotives= NA

Cost for filter replacement=$48 to $50.

**Diesel Particulate Filters (DPFs)**

**ECT Background**

Diesel particulate filters (DPFs) are one of the most effective emission control technologies to reduce particulate matter (PM). When use in conjunction with a catalyst, DPFs are capable of reducing up to 90 percent of PM. This makes them a very attractive retrofit option. DPFs have been very successful across on-highway heavy duty diesel vehicles. More and more, demonstration projects are testing the feasibility of DPFs on non-road applications such as marine, locomotives and CHE.

DPFs remove PM through a two-stage process. First, the DPF physically entraps the elemental carbon portion of PM. Then, through elevated exhaust temperatures, the DPF oxidizes particulates to form gaseous products, primarily $CO_2$. This process is termed “regeneration.”

Passive DPFs vs. Active DPFs

*Passive DPFs* do not use an external source of heat to promote regeneration. Exhaust temperatures are elevated by the increased backpressure in the exhaust as the DPF fills with PM. As the PM level increases, the exhaust backpressure and hence the exhaust temperature increase to specific threshold values. When this threshold exhaust backpressure and temperature is reached, the PM is oxidized and removed, and the exhaust temperature subsequently reduces. The DPF starts to trap more PM and the process is repeated.

*Active DPFs* employ the same principal, but heat is added by one of a number of external means to promote regeneration – electric heating, injection of diesel fuel into the exhaust, or engine calibration to temporarily raise the exhaust temperature. Active DPFs are used when the engine exhaust temperatures are too low for the use of passive DPFs.

By combining a DPF with an oxidation catalyst (DOC), the SOF portion can also be removed, enhancing PM reduction up to 90 percent. Most DPF manufacturers have commercialized these dual-based systems into one container or “can”, using a DPF in addition with a DOC or applying a catalytic coating to the DPF substrate itself, to facilitate retrofit installation.

**“At A Glance”**
**Diesel Particulate Filters (DPFs)**

| Benefits | Drawbacks |
|---|---|
| 1. Excellent PM reductions up to 90%. HC and CO reductions from 60 to 90%.<br>2. Comparatively easy installation – not as straightforward as the DOC, but replaces the muffler. | 1. High cost.<br>2. Requires the use of ULSD.<br>3. Requires threshold exhaust temperatures to ensure regeneration.<br>4. Requires annual soot/ash removal. |

**Technical Considerations**

**Installation**
Similar to the installation of DOCs, DPFs are generally designed as a direct replacement for the original muffler. However, DPFs tend to be larger and heavier than DOCs and require some engineering to fit properly. Special adaptations such as mounting brackets must be designed to sustain the increased weight and larger size of the DPF.

**Exhaust Temperatures**
The requirements of certain threshold exhaust temperatures to promote regeneration can complicate the use of DPFs for some applications. To determine whether a specific application has the exhaust temperatures necessary for regeneration, it is important to conduct a thorough temperature analysis. This can be done by conducting exhaust temperature data logging. Data logging instruments are installed to record the vehicle's exhaust temperature "history" prior to DPF retrofit installation. This approach ensures that the exhaust temperature, on average, is sufficiently high to promote timely and consistent regeneration of the DPF. Once a DPF is installed, an exhaust backpressure sensor and dashboard-mounted indicator light is installed to ensure consistent regeneration in-use. Monitoring exhaust gas backpressure (EGBP) ensures that the DPF in not becoming plugged with soot due to insufficient regeneration. An increase in EGBP can result in an engine failure.

**Field Experience**
DPFs have proven successful with on-highway heavy duty diesel vehicles. There are numerous demonstration projects testing the viability of DPFs on non-road applications.

**ECT Cost**

<u>On-Road</u>
Trucks= $6 to $10K, depending upon engine displacement, for passive systems; active systems range up to $18K. Installation cost run around $4K. Annual cleaning can cost up to $500 per DPF.

<u>Non-Road</u>
CHE (>750 hp)= similar cost to an on-road application.
Marine and Locomotives= prices range and can go up to $40K. Currently under demonstration.

**Selective Catalytic Reduction (SCR)**

**ECT Descriptive Narrative**

SCR is one of three commercially available technologies that are proven to show significant reduction in NOx from diesel engines (emulsified diesel fuel and lean NOx catalysts are the others). SCR systems have a history of being used in stationary applications, such as diesel engines that power generator sets, compressors and pumps. They have also been successfully used in large powerplant and other industrial applications. Due to the more prevalent use of SCRs on stationary sources, there is a lack of mobility experience for on-highway and non-road applications. Some of the challenges include transporting the requisite supply of ammonia, and ensuring that the engine operates within a rather narrow exhaust temperature band to ensure proper SCR operation. Nevertheless, SCRs have been more widely used on-highway. In addition, with the less transient duty-cycle of many marine applications, as well as central-fuelling of vessels, typical of the ferry industry, makes SCR an attractive NOx-reduction option.

SCR systems are inherently more complex than other NOx-reduction strategies, or than typical PM-reducing retrofit options such as DPFs and DOCS, in that they require an elaborate injection or "dosing" mechanism to provide the correct measure of ammonia into the exhaust stream to reduce engine-out NOx. As a result, the initial unit cost is higher, as are the installation costs. Furthermore, a constant ammonia/urea supply is needed, and care must be taken to ensure operators maintain ammonia/urea in the SCR fill tank.

SCR uses an outside agent, ammonia, to convert NOx to harmless nitrogen ($N_2$) and water. Because ammonia is quite toxic and corrosive in its pure form, a non-toxic substitute, urea, is used. The urea essentially "locks in" ammonia in a non-toxic, easy to handle and commercially available solution. When the injection or "dosing" unit releases the urea into the exhaust, the heat from the exhaust (minimum temperature of 160 °C) releases the ammonia component of the urea stimulating the chemical reaction that converts NOx into $N_2$ and $H_2O$.

**"At A Glance"**
**Selective Catalytic Reduction (SCR)**

| Benefits | Drawbacks |
|---|---|
| 1. Excellent NOx reduction from 70 to 95%.<br>2. Does not require low sulfur diesel fuels.<br>3. No additional maintenance. | 1. High cost.<br>2. Requires infrastructure for urea additive.<br>3. Requires on-board dosing unit.<br>4. Requires careful urea injection strategy to avoid "ammonia slip."<br>5. Requires strict monitoring of exhaust temperatures to avoid excessive NOx formation. |

**Technical Considerations**

**SCR - A Complex System**
SCR units are large, heavy, complex and bulky systems. The system includes a catalyst (which is typically installed in series with the engine's muffler), a urea holding tank, and a dosing injection unit. The dosing unit includes an injector and attendant electronic controls, and usually requires compressed air to aerate the injected urea. Compressed air is used for this purpose, either from on-board systems or as a stand alone device consisting of the air compressor, accumulator, associated piping and pressure regulator. Due to the heavy weight of the SCR, extra brackets may be required as well as careful attention to weight influence on the vessel's maximum load rating.

**Dosing with Urea**
SCR systems must maintain a careful balance of proper urea dosing. Not using the appropriate amount of urea results in poor (sometimes zero) NOx reduction. Additionally, excessive amounts of urea result in a phenomena known as "ammonia slip", where pure ammonia – a toxic substance – discharges from the exhaust.

**Exhaust Temperatures**
Similarly, vessel operation and resultant exhaust temperatures that are too low (generally less than 200 °C) can cause "secondary reactions" that can increase NOx formation. SCR, if improperly engineered, will contribute to NOx formation, rather than reducing it. These lower temperatures are often characteristic of light-load vessel duty cycles.

**Field Experience**
SCRs have been widely used on on-highway heavy duty diesel vehicles. There has been reasonably extensive use of SCRs on marine applications. Of all potential NOx-reduction strategies, SCR has become the most attractive.

**ECT Costs**

<u>On-Road</u>
Trucks= $30K for on-highway derivative engines. Installation cost is around $6K. There is also the additional fuel cost of urea.

<u>Non-Road</u>
CHE (>750hp)= Similar cost to on-highway trucks.
Marine= Cost range from $60K to $120K.
Locomotives= currently under demonstration.

**Lean NOx Catalyst (LNC)**

**ECT Background**

Similar to an SCR, a lean NOx catalyst (LNC) selectively reduces NOx through the introduction of an enabling "outside agent." Instead of using urea as the fuel additive, a LNC injects a "shot of hydrocarbons" into the exhaust. This can be done in two ways, either through direct injection of fuel into the exhaust stream or through late injection of fuel, via the fuel injection equipment system, directly into the cylinder of the engine.

**Oxides of Nitrogen + hydrocarbons (typically diesel fuel sprayed into the exhaust stream) = atmospheric nitrogen + carbon dioxide + water**

$$\{HC\} + NOx = N_2 + CO_2 + H_20$$

While there are challenges to using a LNC, the capability of the technology to employ an activation mechanism already on board the vehicle, diesel fuel – makes it far more attractive than the urea-infrastructure-intensive SCR system.

**"At A Glance"**
**Lean NOx Catalyst (LNC)**

| Benefits | Drawbacks |
|---|---|
| 1. Moderate NOx reductions.<br>2. Diesel fuel is used as the enabling fuel additive that is already on board the vehicle; diesel fuel infrastructure already in place.<br>3. Emission control technology combinations available to reduce PM – such as LNC in combination with a DPF. | 1. High cost.<br>2. Lower NOx reduction that SCR. No reduction in PM, CO and HC.<br>3. Specific exhaust temperature required.<br>4. Must use ULSD.<br>5. Can create nitrous oxide, a greenhouse gas.<br>6. Fuel penalty 6 to 9%. |

**Technical Considerations**

**Size**
LNC units are typically designed and constructed in conjunction with some form of PM reduction device, usually a DOC or DPF. Size and weight become factors to consider when fitting the ECT in certain applications such as harbor craft.

**Fuel Penalty**
Both diesel/HC injection strategies (in-cylinder injection or direct injection into the exhaust) enable the lean NOx catalyst to convert NOx to harmless nitrogen, carbon dioxide and water. However, both strategies bring about penalties in fuel economy.

**Field Experience**
Pilot programs in the on-highway sector are becoming more prevalent: a number of programs are underway in California using Carl Moyer Program funds. There is, at present, little marine activity, in large part because the cost, complexity and comparatively smaller NOx reductions from LNCs, which make SCR more attractive.

**ECT Cost**

On-Road
Truck= $14,000 for on-highway derivative engines. Installation costs are similar to SCR around $6K.

Non-Road
Marine= Cost could cost up to $40,000.

**ON-ENGINE MODIFICATIONS**
**Exhaust Gas Recirculation (EGR)**

**ECT Background**

Exhaust gas recirculation systems (EGRs) reduce NOx by re-circulating a portion of the engine exhaust gases back into the engine. These essentially non-reactive exhaust gases reduce combustion temperatures and pressure in the engine, lowering NOx. There are two processes at work to reduce NOx.

1. *Dilution of the intake air* with non-reactive exhaust gases decreases oxygen content in the combustion process, reducing combustion temperatures and pressures.
2. *Heat absorption* by the EGR stream through the heat absorbing capacity of $CO_2$ (thermal effect) and dissociation of $CO_2$ (chemical effect) also leads to a reduction of engine combustion temperatures and pressures.

EGR systems work very well with DPFs. DPFs not only function to reduce PM but are very important to the functionality and effectiveness of an EGR system. Since EGR systems require a clean exhaust supply before the exhaust gases are directed back to the engine, the use of a DPF fulfills this process while reducing PM at the same time.

**"At A Glance"**
**Exhaust Gas Recirculation**

| Benefits | Drawbacks |
|---|---|
| 1. Moderate NOx reduction 40 to 50%.<br>2. Packaged with a DPF reducing PM up to 70%. CO and HC are also reduced with DPF combination.<br>3. Widespread use in field. | 1. Requires careful installation.<br>2. Slightly reduces engine power.<br>3. Exhaust cooling is required and may result in engine wear due to excess water vapor.<br>4. Requires ULSD.<br>5. Requires electronic control strategy to ensure operation. |

**Technical Considerations**

**Field Experience**
EGR is already in widespread use as an OEM strategy for heavy-duty diesel engines. EGR use on marine and locomotives are under demonstration.

**ECT Cost**

<u>On-Road</u>
Trucks= $12K including DPF, for on-highway derivative engines, more for larger engines. Installation cost around $6K.

## Clean and Alternative Fuels

### ULTRA LOW SULFUR DIESEL (ULSD)

#### Fuel Background

Ultra low sulfur diesel fuel (ULSD) is a petroleum distillate product that undergoes hydro-desulfurization at the refining level to eliminate more than 99% sulfur content. Sulfur, a component of all petroleum based feedstocks and grades, serves the primary role of engine lubricant, though undesirably so because it creates corrosive combustion by products, releases sulfur oxides into the environment, and increases deposits on fuel injectors and combustion components[2].

October 2006 marked the widespread availability of ULSD in the United States. The movement was supported federally by an EPA final rulemaking that mandated that the fuel arrived at the retail and wholesale level for all on-highway applications. Sulfur levels in ULSD are set at 15 ppm allowing the facilitation of emission control technologies that require a lower sulfur fuel. This enables diesel engine manufacturers to meet more stringent diesel engine standards of 2007 which require a dramatic reduction in engine-outpollutants from heavy duty diesel vehicles. By contrast, some nonroad fuel grades contain sulfur in fuel levels of up to 3000 ppm. Even higher levels can be found in industrial boiler and marine applications. Future nonroad regulations will bring down sulfur in fuel standards to 2006 on-highway levels by 2014.

ULSD is an 'enabling technology' which allows the application of aggressive emission control technologies. Even without the use of ECTs, ULSD is used as a stand alone technology primarily for minimal PM reduction and secondary emissions of sulfate particles ($SO_4$).

**"At A Glance"**
**Ultra Low Sulfur Diesel (ULSD)**

| Benefits | Drawbacks |
|---|---|
| 1. PM reduction 5 to 15% as a stand alone technology.<br>2. Enables use of aggressive PM and NOx emission control technologies.<br>3. On road availability widespread in US.<br>4. Proven effective in maritime activities. | 1. No impact on other criteria pollutants (HC, CO, etc.).<br>2. Reduced lubricity.<br>3. May have availability issues internationally in some geographic locations. |

#### Technical Considerations

**Field Experience**
ULSD has had widespread use for both onroad and nonroad applications on the West Coast, US and Canada.

[2] http://www.techtransfer.anl.gov/techtour/desulfur.html.

**Fuel Cost**
Cost surcharge of 5.0 to 15.0 cents per gallon.

**BIODIESEL FUEL (BXX)**

**Fuel Background**
Biodiesel fuel (BXX) operates as a cleaner burning fuel and a fuel additive, if mixed in concentration with petroleum diesel that is biologically derived from domestic, renewable sources such as fats and vegetable oils[3]. Biodiesel refers to the pure fuel ("neat") before blending with diesel fuel. Blends are denoted as "BXX", with "XX" representing the percentage of biodiesel contained in the blend; B20 is 20% biodiesel, 80% petroleum diesel. Pure biodiesel (B100) is biodegradable, non-toxic, and virtually free of sulfur and aromatics.

Biodiesel fuels are produced from different types of feedstocks that include soybeans, rapeseeds, canola oil, grease, tallow and lard. Most biodiesel production in the US is soybean-based due to the abundant supply of this feedstock in the heartland states.

Used as an alternative to conventional diesel fuel, biodiesel achieves emission reductions of PM, CO, HC and poly-aromatic hydrocarbons (PAH). The emission reductions vary with BXX%, where the lowest figure applying to B20 and the highest to B100. Generally, there is a modest, application specific NOx penalty of between 2 and 10 percent associated with the use of biodiesel. Increasing the level of biodiesel in the fuel blend increases NOx with a proportionally greater reduction in PM. Reduction in CO and HC improves linearly with the addition of biodiesel, according to the literature. This is indicative of more complete combustion, thought to be promoted by the increased presence of oxygen in the fuel.

From an air quality and emissions control technology perspective, fueling with biodiesel will reduce the solid or carbonaceous fraction of the PM which cannot be removed by an oxidation catalyst. Thus from a PM standpoint, the use of biodiesel in combination with a CCRT-SCR system (catalyzed, continuously regenerating trap and selective catalytic reduction) would serve to further remove the solid PM component from the exhaust, providing an opportunity to oxidize the soluble fraction stemming from engine lubricant and address NOx reductions[4].

[3] http://www.biodiesel.org/resources/biodiesel_basics/.

[4] Schumacher, L.G. et al (1995). 6V-92TA Detroit Diesel Corporation Engine Emissions Test Using Soybean Oil/Diesel Fuel Blends - B10, B20, B30, B40.

**"At A Glance"**
**Biodiesel (BXX)**

| Benefits | Drawbacks |
|---|---|
| 1. PM, HC and CO emission reductions depending on the BXX ratio. (PM 15 to 70%, HC 10 to 40%, and CO 10 to 50%).<br>2. CO2 lifecycle emissions reductions potential of 70%.<br>3. Lower sulfur content.<br>4. Renewable fuel.<br>5. Biodegradable.<br>6. Better lubricity. | 1. Potential increase in NOx.<br>2. More corrosive.<br>3. Higher freezing temperature. Cold weather can cause operational issues.<br>4. Potential loss in engine power – about 2%.<br>5. Reduced fuel economy. |

**Biodiesel Schematic**

**Table 1: Biodiesel production process.**

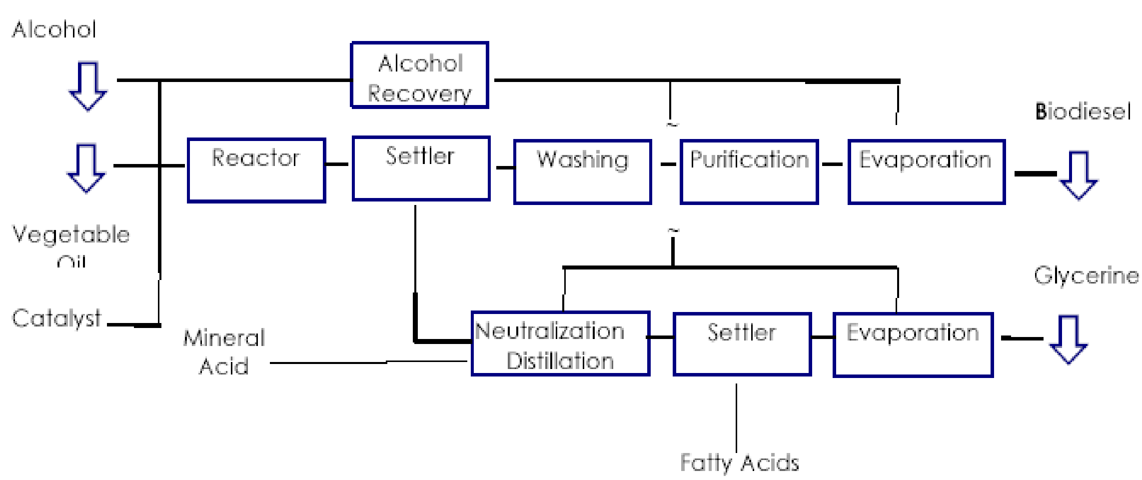


**Table 2: Biodiesel Emissions Reduction Potential (EPA Verified), National Biodiesel Board.**

AVERAGE BIODIESEL EMISSIONS COMPARED TO CONVENTIONAL DIESEL, ACCORDING TO EPA

| Emission Type | B100 | B20 |
|---|---|---|
| **Regulated** | | |
| Total Unburned Hydrocarbons | -67% | -20% |
| Carbon Monoxide | -48% | -12% |
| Particulate Matter | -47% | -12% |
| Nox | +10% | +2% |
| **Non-Regulated** | | |
| Sulfates | -100% | -20%* |
| PAH (Polycyclic Aromatic Hydrocarbons)** | -80% | -13% |
| nPAH (nitrated PAH's)** | -90% | -50%*** |
| Ozone potential of speciated HC | -50% | -10% |

* Estimated from B100 result
** Average reduction across all compounds measured
*** 2-nitroflourine results were within test method variability

**Technical Considerations**

**Field Experience**
Extensive onroad and offroad experience.

**Fuel Cost**
Projected cost surcharge of 25.0 to 40.0 cents per gallon.

**EMULSIFIED DIESEL FUEL (EDF)**

**Fuel Background**

Emulsified diesel fuel (EDF) is a petroleum distillate based fuel that undergoes emulsification, a process whereby one liquid is suspended within another, with a proprietary chemical additive agent to suspend water micro-droplets in the fuel, typically at the following ratio: 77% diesel, 20% water, and 3% emulsifying agent. Water content can range from 5 to 40%, depending on the production specification and end user application.

The practice of emulsifying fluids in diesel is not new, however the science of using additive chemistry and blending techniques to specifically address the air quality characteristics of diesel exhaust emissions is new and evolving, with a number of US based and international companies taking a lead role in its advancement. Key to this practice is the suspension of sub-micron sized water droplets in the fuel, a process accomplished by using additives that encapsulate and suspend the droplets during the blending process, thereby creating a secure, stabilized product ready for delivery, storage and combustion.

The principle effect of water in fuel is to lower the combustion temperature, i.e. reduce the peak flame temperature within the combustion chamber to modify the combustion process itself and mitigate the formation of NOx emissions. NOx formation in the diesel combustion engine is influenced by $N_2$, $O_2$, the temperature of combustion ($T_{combust}$), and the residency time ($t_{res}$). Water emulsions work by lowering the overall $T_{combust}$ to rate limit NOx formation and lower downstream engine out NOx emissions. Water also serves to alter fuel flow properties and injection characteristics, thus resulting in a PM (particulate matter) benefit. This benefit is realized due to:

1. Increased liquid column penetration during pre-mixed combustion, resulting in more entrainment and less PM formation; and
2. Larger flame light off length, resulting in a less rich combustion process and lower PM (especially at higher loads).

Actual emission reductions achievable using EDF are highly variable, depend on the engine, test cycle, emulsification process, water content, baseline diesel fuel properties, and peak torque vs. torque loss comparison (less work per composite duty cycle). There is conflicting data in the literature concerning PM mitigation/production; CO, HC, and toxic air contaminants have propensity to increase w/emulsion, some by factor of 2 or more though not in quantities above regulatory standards, due to inherently low emissions output.

From an operational perspective, significant losses in fuel economy have been experienced with EDF, on the order of 10-30%. This is due to the water in fuel %, on-road vs. off-road engine application, and age of the engine (mechanically vs. electronically controlled). In some engines, longer flame length may lead to excess PM due to EDF "splashing" on the combustion bowl during incomplete combustion. Higher PM is then expelled during the exhaust stroke.

The market for EDF in the United States is supported by counties in non-attainment that have an immediate need for an alternative to diesel that addresses both NOx and PM reductions simultaneously, by demonstration projects in those areas and others throughout the country, and by the EPA ETV program, which verified and approved EDF for use in diesel engines.

**"At A Glance"**
**Emulsified Diesel Fuel (EDF)**

| Benefits | Drawbacks |
|---|---|
| 1. Emission reduction benefits of both NOx and PM (NOx 10 to 20% and PM 15 to 60%).<br>2. No major engine modifications required.<br>3. No new fuel infrastructure needed.<br>4. No increase in other pollutants. | 1. Incremental cost differential.<br>2. Potential engine durability issues with older pre-1994 engines (corrosion).<br>3. Fuel stability – balanced mixture.<br>4. Reduction in engine power – potential 5 to 10 %.<br>5. Reduced fuel economy. |

**Technical Considerations**

**Fuel Penalty**
Emulsified diesel fuel may have a fuel penalty of 10 to 30% and peak torque loss of 6 to 7% peak torque loss. The engine will do less work per unit fuel consumption vs. No. 2 diesel over comparable duty cycle.

**Field Experience**
On-road and off-road application experience; Port of Houston, TX, Big Dig Project, Boston, MA; Texas Fuels Project – TX DOT, Houston and Dallas, TX; Marine application experience; MV Golden Gate, WTA (Water Transit Authority) San Francisco, CA.

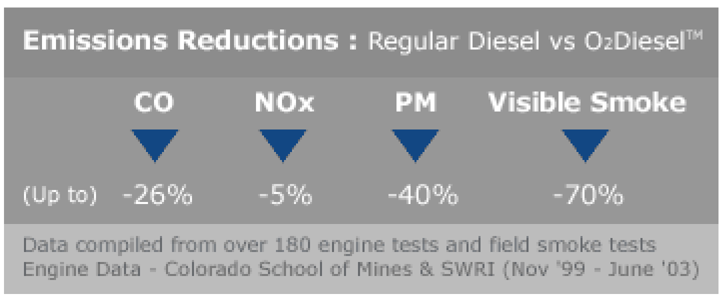
**Fuel Cost**
Projected cost surcharge of 25.0 to 40.0 cents per gallon

## OXYGENATED DIESEL FUEL (02D)

### Fuel Background

Oxygenated diesel fuel is a diesel fuel blend using the oxygenate ethanol and a stabilizing proprietary additive technology. Manufacturers of oxygenated diesel fuels claim a significant reduction in PM and visible smoke along with some NOx and CO reductions. The product can be used with all diesel fuels and can be blended effectively with any base diesel fuel. One manufacturer, O2Diesel Inc., provides a drop-in replacement fuel for "typical" No. 1 or 2 diesels, ULSD, etc. O2Diesel claims their oxygenated diesel results in cleaner combustion, decreased engine corrosion, reduced cylinder wear and extended life of the engine lubricant. O2Diesel's product has ARB (but not EPA) verification.

### Summary of Emission Reduction Performance (O2 Diesel Literature)




**"At A Glance"**
**Oxygenated Diesel Fuel (O2D)**

| Benefits | Drawbacks |
|---|---|
| 1. NOx reduction up to 6%. PM reduction potential of 46% when combined with a DOC. CO reduction of 25%.<br>2. Visible smoke reduction up to 70%.<br>3. Reduction of GHGs.<br>4. Provide cleaner combustion with decreased engine corrosion.<br>5. Improves overall performance.<br>6. Mixes with any type of diesel fuel. | 1. Low NOx reductions. |

**Technical Considerations**

**Field Experience**
O2 Diesel has completed the first testing of the oxygenated diesel fuel in a new Navistar DT -466 engine coupled with a DOC, and achieved nearly 50% PM reductions (Environment Canada). Department of Defense (DOD) is evaluating O2Diesel™ as a fuel for non-tactical military vehicles and other diesel powered equipment such as electric generators.

**Fuel Cost**
Price can range from zero net incremental cost, to 10 – 15 cents above "rack" No. 2 diesel fuel prices.

## AIR QUALITY MONITORING

With the increased concern in diesel emissions and its associated negative impacts on public health, air quality monitoring is becoming more widely used as a tool to measure air quality in areas of concern. Today, specialized monitoring instruments (samplers) are being used at designated stations located in and around ports to measure for harmful pollutants such as; diesel particulate matter (DPM), particulate matter (PM10 & PM 2.5), ozone (O3), nitrogen dioxide (NO2), sulfur dioxide (SO2), carbon monoxide (CO), and Lead (Pb). Meteorological parameters such as ambient temperature, wind speed and direction, and humidity are also monitored for.

Air quality monitoring stations are strategically designated in areas that have elevated levels of port-related diesel activity and/or are located in neighboring communities as way to study port-related emissions impacts on local communities. Designed to provide continuous real-time data, air quality monitoring can be helpful to determine what days experience elevated levels of port-related emissions compared to others days with lower levels. Meteorological parameters can also help explain why some monitoring stations reported better or poorer air quality days.

Air quality monitoring can be used to further expand upon other clean air programs. For example, the Port of Los Angeles (POLA) has an air quality monitoring program that compliments two other air quality programs; the Port of Los Angeles Port-Wide Emissions Inventory and Health Risk Assessments. The two main objectives of POLA's air quality monitoring program include

• Estimating ambient levels of DPM in proximity to the Port that are due to Port operational activities and

• Estimating ambient PM levels due to Port emissions within adjacent communities.

Due to public and regulatory interest in air quality issues in the Port, POLA worked closely with the California Air Resources Board and the South Coast Air Quality Management District on the development of their air quality monitoring program.

The data collected from air quality monitoring provides data for on-going studies. Air quality monitoring can also be used to measure and monitor diesel emission reduction programs at a port. Since monitoring is tracked over a period of time, comparisons can be made between air quality at the port today compared to air quality at the port a year ago. Noticeable differences can be made if certain control strategies prove to be effective.

Implement Your Air Quality Monitoring Program

To implement your own air quality monitoring program, you can establish criteria that will help you put in place a successful monitoring program. The following criteria were used by the Port of Los Angeles to implement their air quality monitoring program.

• Deploy the sampling network to bound Port emission sources on four sides. This network structure will provide opportunities for at least 1 sampler to be impacted primarily by Port emissions, regardless of wind direction. This design also will provide for opportunities for upwind/downwind analysis, such as during periods of on/off shore events.

• Locate samplers within neighboring communities. Locate the primary monitoring station, which will use federal reference method monitors to collect PM10 and PM2.5 samples at one of the community sites, for comparison with ambient air quality standards.

• Choose locations that provide adequate and unobstructed exposure to Port emission sources and the local environment.

• Select locations that are secure from natural and human elements to ensure survivability of samplers for the duration of the program.

• Site a sampler near the southern edge of the outer harbor to enable sampling of upwind (absence of Port emissions) conditions during onshore flow.

• Site a sampler in proximity to an emissions hot spot within the Port.

• Provide grid power to minimize the need for battery-powered equipment.

• Install air sampling inlets at heights above ground that are consistent to each sampling location.

## HOW TO CONDUCT AN EMISSIONS INVENTORY

One of the most accurate methods for estimating air emissions is through an activity-based emissions inventory where emission estimates are based on activity levels versus fuel or cargo based inventories. Several ports around the world have conducted activity-based emissions inventories (EI) to better assess the contribution of emissions from port-related activities. Since 2001, the Port of Los Angeles has conducted port-wide emissions inventories every year to evaluate their contribution of air pollutants to the South Coast Air Basin. The POLA EI reports have been instrumental in the development of the *San Pedro Bay Clean Air Action Plan*. By evaluating emission contributions from each source category, POLA has been able to determine what control strategies provide the best emission reduction benefits. Due to the human health risk factor, reducing emissions from POLA's port activities is very important. The annual EIs help show where emissions may have increased and where emissions have decreased due to the control options put in place.

In the technical field of estimating air emissions, there are significant distinctions between off-road and on-road vehicles or equipment. Off-road equipment includes vehicles or equipment that are not designed or licensed to operate on public roads. Off-road equipment includes cargo handling equipment, locomotives, and marine vessels. The on-road category consists of vehicles that are typically licensed to operate on public roads, such as trucks. The important distinction between these two source categories are; first, the methods by which emission are estimated and, second, that the on-road vehicles have been significantly regulated in the past (with respect to emissions) as compared to off-road equipment. Each of the source categories has different emission estimating methodologies that are summarized below. Most of the estimating methodologies are used in the United States, in particular California. Emission factors may be different for international ports. To conduct your own air emissions inventory, use emission factors recommended by your local regulatory agency.

**Ocean/Sea-Going Vessels (OGVs)**
OGVs consist of various types of vessels commonly distinguished by the cargo they carry. The most common classes include: auto carriers, bulk carriers, containerships, cruise ships, general cargo ships, ocean/sea-going tug boats, refrigerated vessels, roll-on roll-off (RoRo) ships, and bulk liquid tankers. The basic methodology for estimating emissions from vessels is built on previous marine emissions studies developed in California, other U.S. states, and international studies. The Port of Los Angeles developed a Vessel Boarding Program that focused on gathering specific vessel characteristics and operational data in addition to gaining a better understanding of the vessel schedules. Though the arrival and departure of an OGV into a port is a small component of the OGVs voyage, the emissions contribution is significant, especially hotelling emissions. Activity data and vessel characteristics should be used with the latest emission factors, developed from the latest emission testing data sets.

In developing an activity-based emissions inventory for marine vessels, emissions are estimated as a function of vessel power demand (expressed in kW-hrs) multiplied by an emissions factor, where the emission is expressed in terms of grams per kilowatt hour (g/kW-hr). There are two equations used to estimate OGV emissions.

**Equation 1**

E = Energy * EF

Where:

E = Emissions from the engine(s) that are included in the “Energy” term discussed below, usually calculated as grams of emissions per unit of time (e.g. per year), but converted to tons of emission by dividing by 453.6 grams per pound and 2000 pounds per ton.

Energy = Energy demand in kW-hrs, calculated using Equation 2 below as the energy output of the engine (or engines) over the period of time covered by the estimate.

EF = Emission Factor, usually expressed in terms of g/kW-hr, discussed in more detail below.

The “Energy” term of the equation is where most of the location specific information is used. Energy is calculated using Equation 2.

**Equation 2**

Energy = MCR * LF * A

Where:

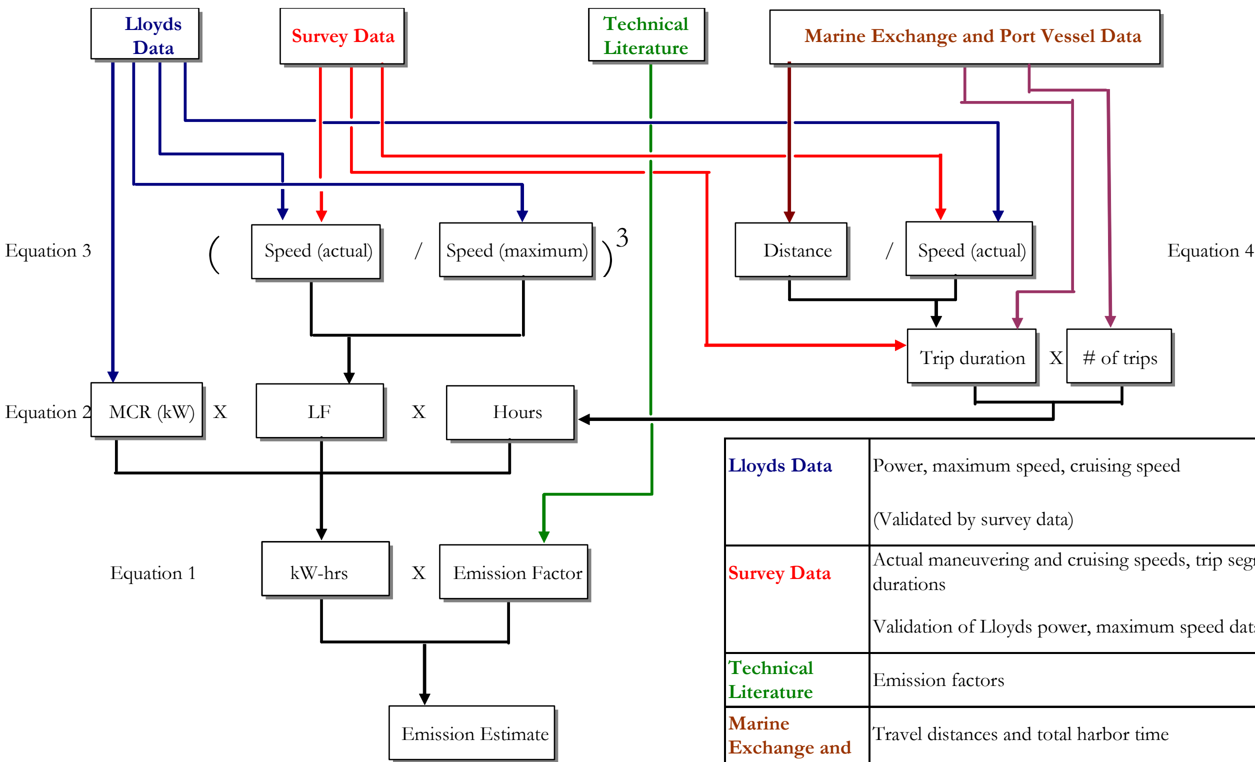
MCR = Maximum continuous rated engine power, kW

LF = Load factor (no units)

A = Activity, hours

The process for estimating emissions from propulsion engines is depicted as a process flow diagram.

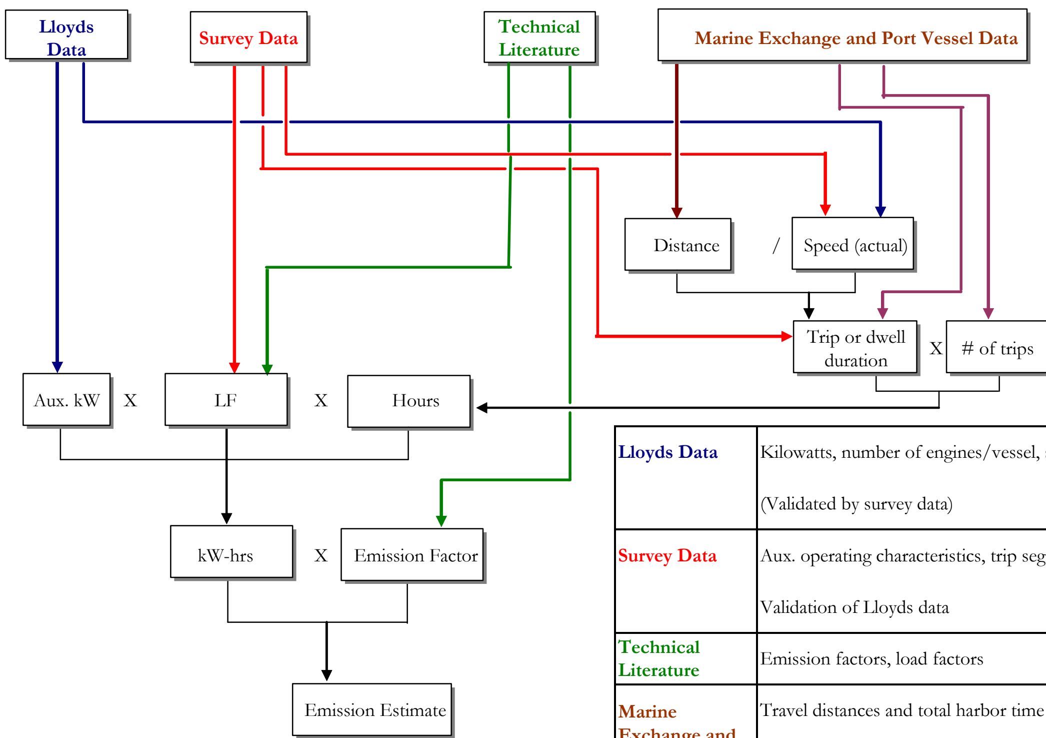
## Propulsion Engine Emission Estimation Flow Diagram




| | |
|---|---|
| **Lloyds Data** | Power, maximum speed, cruising speed<br><br>(Validated by survey data) |
| **Survey Data** | Actual maneuvering and cruising speeds, trip segment durations<br><br>Validation of Lloyds power, maximum speed data |
| **Technical Literature** | Emission factors |
| **Marine Exchange and Port Vessel Data** | Travel distances and total harbor time<br><br>Number of calls, vessel identification |

The process for estimating emissions for auxiliary engines is expressed in the following flow diagram.

**Auxiliary Engine Emission Estimation Flow Diagram**




| | |
|---|---|
| **Lloyds Data** | Kilowatts, number of engines/vessel, speeds<br>(Validated by survey data) |
| **Survey Data** | Aux. operating characteristics, trip segment durations<br>Validation of Lloyds data |
| **Technical Literature** | Emission factors, load factors |
| **Marine Exchange and Port Vessel Data** | Travel distances and total harbor time<br>Number of calls, vessel identification |

**Harbor Craft**

Harbor craft are commercial marine vessels that spend the majority of their time within or near the Port and harbor. Harbor craft are a separate source category from ocean/sea-going vessels due to the different emission estimate methodology used.

Harbor craft include:

- Assist boats
- Work boats
- Towboats/push-boats/tugboats
- Ferries and excursion vessels
- Crew boats
- Government vessels
- Dredges and dredging support vessels
- Commercial fishing vessels
- Recreational vessels

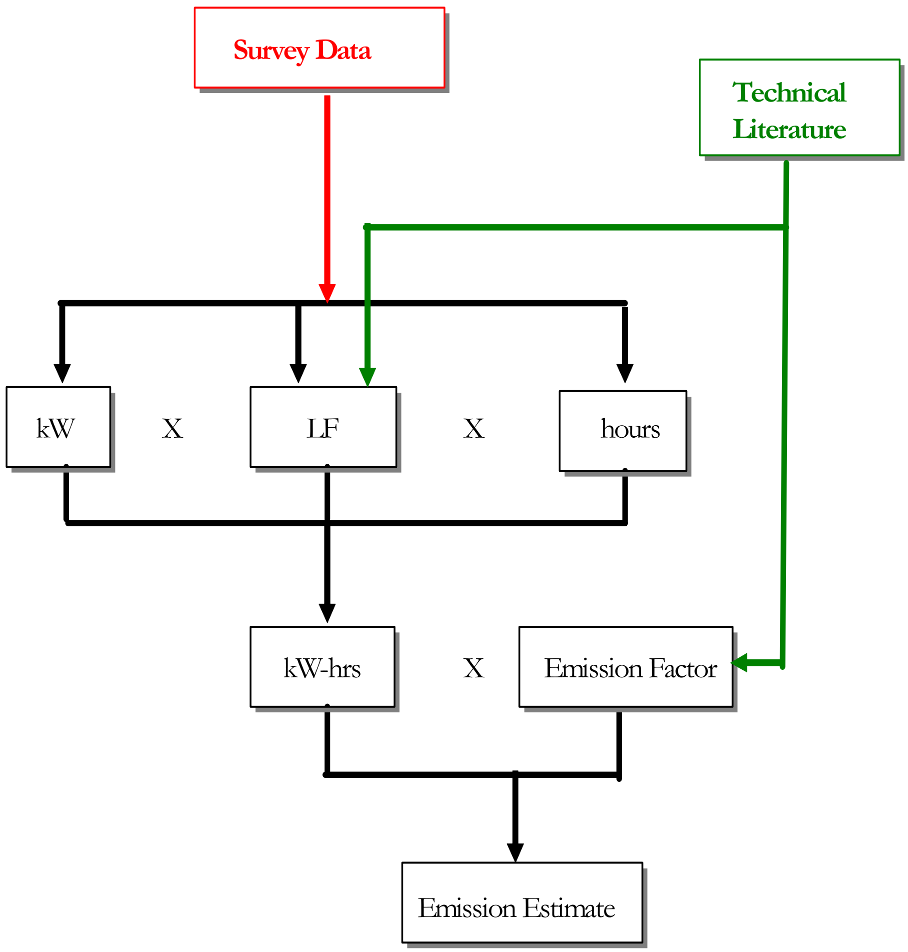
To obtain information on the types of harbor craft, interview harbor vessel operators and marina managers to help develop a harbor craft inventory list. Emission inventories in the United States used emission factors found in the 1999 EPA Final Regulatory Impact Analysis (RIA) to estimate emissions for harbor craft and Category 1 engines. For Category 2 engines emission factors were used for medium speed vessels.

To collect data for the harbor craft, identify and interview the vessel owners and operators to determine key operating parameters of interest. The following are recommended operating parameters in which to seek information on.

- Hours of operation (annual and average daily, plus schedules if relevant and available)
- Percent of time in operational modes (idling, half power, full power, etc.)
- Vessel characteristics
- Number, type and horsepower (or kilowatts) of main engine(s)
- Number, type and horsepower (or kilowatts) of auxiliary engines
- Other operational parameters such as fuel consumption rates, dredging volumes
- Qualitative information regarding how the vessels are used in service
- Information on percentage of time operating within harbor, 25 and 50 mile ranges

The process for estimating emissions for harbor craft is expressed in the following flow chart.

**Harbor Craft Emissions Estimation Flow Chart**



**Cargo Handling Equipment**

CHE consists of various types of equipment and vehicles that fall within the off-road designation and are used to move cargo within terminals and other off-road areas. For CHE, collect the following specifications for each piece of equipment:

- Equipment type, make and model
- Engine make and model
- Model year
- Horsepower
- Load data
- Annual operating hours
- Fuel used

**Rail/Locomotive Activity**

Railroad operations are typically described in terms of two different types of operation, line haul and switching. Line haul refers to the movement of cargo over long distances (e.g. cross country) and occurs within a port at the initiation or termination of a line haul trip, as cargo is either picked up for transport to destinations across the country or is dropped off for shipment overseas. Switching refers to the assembling and disassembling of groups of railcars at various locations in and around the Port, the sorting of the cars of inbound cargo trains into contiguous "fragments" for subsequent delivery to terminals, and the short distance hauling of rail cargo within a port.

To estimate emissions from railroad activities within a port, interview railroad operators on rail activities and board switch engines while in operation to get a better sense of their normal operations. Estimating emissions is different for line haul and switching due to the difference in operational loads and conditions.

**Trucks**

There are two components to the estimation of truck emissions: on-road travel and on-terminal operations. Most truck activity within a port, in terms of operating hours and miles traveled, take place on the public roads within a port as trucks travel to and from the terminals to drop off or pick up their cargo, and as they sometimes wait for entry outside terminal gates. The trucks also operate within each terminal, typically entering through a controlled access gate, traveling through the terminal to drop off and/or pick up cargo, and then exiting the terminal.

Estimating emissions for trucks may differ depending on on-terminal and off-terminal activity. Emission factors also differ depending on the model year range of the vehicle. Other elements to consider in estimating truck emissions include; gross vehicle weight rating (GVWR), distance traveled, idling time while on terminal, and fuel type.

## AIR POLLUTANTS OF CONCERN

Today, reducing emissions from diesel engines is one of the most important air quality challenges facing ports. Though there are strict engine standards put into place in Europe, the United States and in other countries, diesel engines continue to produce emissions that are harmful to public health and the environment. Diesel engines emit large amounts of oxides of nitrogen (NOx) and particulate matter (PM). Both pollutants contribute to serious health problems such as premature mortality, asthma attacks, millions of lost work days, and numerous other health impacts. Several Health Authorities have listed diesel particulate matter (DPM) as a toxic air contaminant and a known human carcinogen.

Particulates from diesel exhaust irritate eyes and nose and aggravate respiratory problems, including asthma. NOx also contribute to the formation of 'ground level' ozone, the major ingredient in the smog that overwhelms cities around the world. Ground level ozone formed from the reaction of nitrogen oxides and hydrocarbons when combined with sunlight can irritate the respiratory system, invoke coughing, choking, and reduced lung capacity. Increased hospital visits for respiratory problems such as asthma especially among children are due to urban ozone pollution.

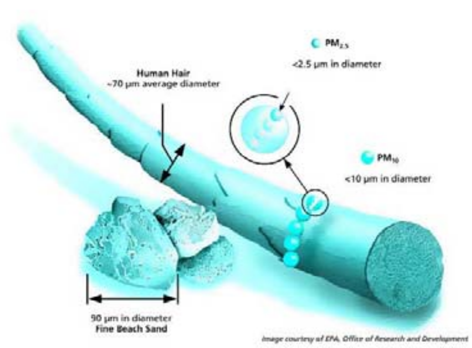
More and more, studies are finding direct linkages to health problems from exposure to diesel exhaust. The extremity of the impacts on human health from diesel emissions can no longer be ignored. This is why it is important that a balance is made between the growth in goods movement and the environment as ports make decisions for the future.

To give IAPH members a better understanding of air pollution and public health, this fact sheet provides information on the different harmful pollutants related to diesel emissions and their associated health effects.

### Particulate Matter (PM)

Particle pollution also known as particulate matter (PM) Is the term for a mixture of solid particles and liquid droplets found in the air. There are two forms of particle pollution that are regulated due to their potential impact to human health; inhalable coarse particles with diameters larger than 2.5 micrometers and smaller than 10 micrometers and fine particles that are 2.5 micrometers and smaller. How small is 2.5 micrometers? Think about a single strand of hair. The average human hair is about 70 micrometers in diameter, which is about 30 times the size of a fine particle.

**How Big is Particle Pollution?**



**Health Effects of PM**

PM contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems. The size of the particles determines how severe the impact on human health. Particulates that are smaller than 10 micrometers can penetrate deeper into the lungs and can even enter the blood stream.

**Oxides of Nitrogen (NOx)**

NOx is a colorless and odorless gas and is formed when fuel is burned at high temperatures, as in a combustion process. As mentioned before, NOx is a precursor to the development of ground level ozone. Environmental impacts from NOx also include acid rain, nutrient overload in water bodies, visibility impairment when combined with atmospheric particles. The effects of ground level ozone are more frequent during the warmer summer months.

**Health Effects of NOx**

One of the most harmful effects of NOx on human health is its contribution to the formation of ground level ozone. As mentioned before, ground level ozone aggravates respiratory illnesses such as asthma. Children, elderly, and people who work or exercise outdoors are especially vulnerable to the impacts of ground level ozone. Health effects such as damage to the lung tissue and reduction in lung function may result from ozone. Today, there are millions of people that live in cities that do not meet air quality standards for ozone.

**Sulfur Dioxide ($SO_2$)**

$SO_2$ comes from the family of sulfur oxide gases (SOx). Gases in this family can easily dissolve in water. Sulfur is found in raw materials such as crude oil, coal, and ore that contain common metals (aluminum, copper, zinc, lead, and iron). Fuel containing sulfur, such as coal and oil when burned can lead to the production of SOx gases. SOx emissions from ships are a huge concern in the maritime industry.

**Health Effects of $SO_2$**

$SO_2$ emissions negatively impacts public health and the environment. Because $SO_2$ interacts with other substances in the air, the results negatively impact sensitive groups who have asthma, are active outdoors, children and elderly. $SO_2$ also negatively impairs visibility and can add to the formation of acid rain

**Carbon Monoxide (CO)**

CO is a colorless and odorless gas that is formed when carbon in fuel is not burned completely. It is a common component of diesel exhaust. In the United States, 56 percent of all CO emissions are related to motor vehicle exhaust. Nonroad engines contribute 22 percent of CO emissions.

Highest levels of CO occur during the colder months of the year when inversion conditions are more frequent and air pollutants become trapped near the ground beneath a layer of warm air.

**Health Effects of CO**

The health effects of CO can result from the reduction of oxygen delivery to the body's organs (such as the heart and the brain) and tissues. Cardiovascular effects are the most serious effects of CO for those who suffer from heart disease. There are also effects on the central nervous system. Breathing in high levels of CO can result in blurred vision, reduced ability to work or learn, and reduced manual dexterity. CO also contributes to the formation of smog.

## GLOSSARY OF TERMs

***Air quality monitoring*** – Method used to measure ambient air quality.

***Air toxics*** – Toxic air pollutants, also known as hazardous air pollutants, are those pollutants that are known or suspected to cause cancer or other serious, chronic health effects, such as reproductive effects or birth defects, or adverse environmental effects.

***Alternative fuel*** – Also known as "non-conventional fuels," is any material or substance that can be used as a fuel, other than fossil fuels, or conventional fuels of petroleum (oil), coal, propane, and natural gas. The term "alternative fuels" usually refers to a source of which energy is renewable (See "renewable fuel").

***Area source*** – A general term for a source that is an aggregate of all emission sources within a defined spatial boundary. Though emissions from individual sources in an area are relatively small, collectively their emissions can be of concern - particularly where large numbers of sources are located in heavily populated areas.

***Auxiliary engine*** – A small engine often used when a ship is hotelling.

***Baseline Air Emissions Inventory*** – For a given air emission source category, a baseline inventory establishes a reference point with more detailed emission data than previously existed. An established baseline allows comparison with future inventories of similar precision to describe changes to the characteristics of the source category and intensity of the emissions.

***Brake-Specific Fuel Consumption*** – A way to measure the efficiency of an engine by dividing rate of fuel consumption by the rate of power production.

***Bunker Fuel*** – See *"Fuel Oil"*

***Cargo Handling Equipment (CHE)*** – Equipment used to move cargo to and from marine vessels, railcars and trucks. This includes equipment such as cranes, rubber tired gantry cranes, terminal trucks, container handlers, bulk loaders, and forklifts.

***Cold Ironing*** – Also called "Alternative Maritime Power" and more generally referred to as "Shore Power." This specifically refers to an electrical connection made between the vessel and the terminal to provide full or partial operational power during hoteling periods. The primary motivation for cold ironing has been as a method to reduce emissions from the exhausts of auxiliary engines that would normally operate during hoteling. "Cold iron" is a reference to when ships mainly used boilers to produce steam for propulsion, heat, and power. When the steam production was shut down, the iron in the boiler housing would go cold.

***Commercial vessel*** – Any vessel involved in commercial trade or business.

***Criteria pollutants*** – A regulatory term that refers specifically to six outdoor air pollutants for which EPA is required to develop National Ambient Air Quality Standards (NAAQS), as codified in the federal Clean Air Act. These six are carbon monoxide (CO), lead, nitrogen dioxide ($NO_2$), particulate matter (PMx), ozone, and sulfur oxides (SOx).

***Deadweight tonnage*** – Refers to the total amount of weight that a vessel is carrying, minus the actual weight of the vessel. Historically, tonnage was the tax on tons (casks) of wine that held approximately 252 gallons of wine and weighed approximately 2,240 pounds. This suggests that the unit of weight measurement, long tons (also 2,240 lb) and tonnage both share the same etymology. The confusion between weight based terms (deadweight and displacement) stems from this common source and the eventual decision to assess dues based on a ship's deadweight rather than counting the tons of wine.

***Deterioration factor*** – For use in emission or performance calculation, this number accounts for the effect of gradual wear in the internal engine components in the course of normal operation.

***Diesel*** – In standard use, this refers to a specific fractional distillate of fuel oil that is used as fuel in a compression-ignition (CI) engine. Practically, diesel can refer generally to any hydrocarbon-dense oil with relatively low volatility that can be used as a combustion fuel. In common maritime use, diesel can refer to several varieties of distillate fuels including “Marine Diesel Oil” (MDO, aka DMB or DMC) and “Marine Gas Oil” (MGO, aka DMA or DMX) as specified by ISO 8217. Diesel can also be referred to by its sulfur content, such as the case of LSD (low sulfur diesel with less than 500 ppm sulfur) or ULSD (ultra low sulfur diesel with less than 15 ppm sulfur).

***Diesel electric –*** Refers to equipment that uses electric motive systems that rely on electricity from diesel generators.

***Diesel Oxidation Catalyst (DOC)*** – A flow-through canister, fit to an engine exhaust pipe, containing a honeycomb-like structure or substrate. The substrate has a large surface area that is coated with an active catalyst layer. This layer contains a small, well dispersed amount of precious metals such as platinum or palladium. As exhaust gases pass over the catalyst, carbon monoxide, gaseous hydrocarbons and liquid hydrocarbon particles (unburned fuel and oil) are oxidized, thereby reducing harmful emissions.

***Diesel Particulate Matter (DPM)*** – Refers to particulate components of combustion products that are directly emitted from diesel engines. These include soot (“elemental” or “black” carbon) and other aerosols that are complex aggregates of hydrocarbons, metals, silicates, and other chemicals. In recent years, DPM has been singled out as posing a carcinogenic risk to people who regularly work in proximity to diesel equipment over the course of many years.

***Diesel Particulate Filter (DPF)*** – A filter installed on the exhaust pipe of diesel engine to physically separate particulate matter from the exhaust stream. Some filters are single use (disposable), while others are designed to burn off the accumulated particulate, either through the use of a catalyst (passive), or through an active technology, such as a fuel burner which heats the filter to soot combustion temperatures

***Economizer*** – A heat exchanger that transfers heat from the exhaust stream to a water circulation system to produce steam. Often used when a vessel is in transit, an economizer can allow the regular diesel powered boiler to be shut off.

***Emission factor*** – A number specific to an engine or system that describes the amount of a pollutant that is generated per unit of activity, e.g. mg/mile or g/hr

***Emulsified fuel*** – A homogenized blend of water into diesel fuel that changes the fuel combustion characteristics and resulting emissions. This strategy is mainly employed to reduce NOx emissions but may also reduce PM and improve fuel economy.

***Environmental Protection Agency (EPA)*** – A US federal or state agency responsible for standard setting in the environmental field

***EPA NONROAD model*** – NONROAD is a computer modeling program created and regularly updated by EPA that calculates past, present, and future emission inventories (i.e., tons of pollutant) for all offroad equipment categories except commercial marine, locomotives, and aircraft. For a specified geographic area, time period, and fuel type, the model estimates exhaust and evaporative hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), particulate matter (PM), sulfur dioxide ($SO_2$), and carbon dioxide ($CO_2$).

***Exhaust gas recirculation (EGR)*** – A technique used in most gasoline and diesel powered engines to control emissions. Engine exhaust is mixed with engine intake air and recirculated through the combustion process. The result is a reduction in NOx emissions due to lower combustion temperatures and reduction of excess oxygen.

***Fine particulate matter*** – See *Particulate Matter*

***Four-stroke engines*** – The most common type of engine for cars and trucks. This engine uses the 'Otto cycle' and consists of four strokes: 1. in-take stroke, 2. compression stroke, 3. power (ignition) stroke, and 4. exhaust stroke.

***Fuel correction factor (FCF)*** – A number used in emission inventory models to reflect the impact on emissions of commercially dispensed fuel compared to fuel used during the certification process. These factors are derived as the ratio of the impact of the dispensed fuel to the impact of the certification fuel.

***Fuel Oil –*** A general term for viscous liquid fuels used for powering engines. In the maritime industry the following classifications are used.

- ***MGO (Marine gas oil) –*** A purely distillate fuel (see "diesel")
- ***MDO (Marine diesel oil) -*** A blend of gas oil and heavy fuel oil
- ***IFO (Intermediate fuel oil)*** A blend of gas oil and heavy fuel oil, with less gas oil than marine diesel oil

- ***MFO (Medium fuel oil) -*** A blend of gas oil and heavy fuel oil, with less gas oil than intermediate fuel oil
- ***HFO (Heavy fuel oil) -*** Pure or nearly pure residual oil (bunker fuel)

***Fugitive emissions*** – Emissions not created through a defined process or controlled by a dedicated system. These can be due to equipment leaks, evaporative processes, materials processing, and windblown disturbances

***GHG equivalent*** – Similar to "carbon equivalent" this refers to a method by which air emissions are standardized for comparison based on their "global warming potential" (GWP) as greenhouse gases. Each greenhouse gas differs in its ability to absorb heat in the atmosphere so will be presented in units of carbon equivalents, which weighs each gas by its GWP relative to carbon dioxide. For example, methane traps over 21 times more heat per molecule than carbon dioxide, and nitrous oxide absorbs 310 times more heat per molecule than carbon dioxide.

***Greenhouse Gas (GHG)*** – Substances in the atmosphere that absorb radiated heat form the earth's surface and also radiate heat back to the surface, causing a net retention of heat energy. Carbon dioxide, methane, and nitrous oxide are common examples.

***Gross vehicle weight rating*** – The estimated total weight of a road vehicle that is loaded to capacity, including the weight of the vehicle, the passengers, fuel, cargo, and miscellaneous items. The rating allows the vehicle driver to know what routes are acceptable, depending on whether the roadways can accommodate a vehicle of the estimated weight.

***Harbor craft*** – A term that generally refers to vessels that do not make regular ocean passage. These include fishing boats, tug boats, ferries, and other commercial workboats. For the purpose of this report, any craft that is not an ocean-going vessel, recreational vessel, or tank barge, has been categorized as a harbor craft.

***Hoteling –*** The period during which a vessel is secured at berth

***Hydrocarbon*** – A chemical term referring to compounds that consists of carbon and hydrogen in various structures. Most common liquid fuels are primarily comprised of some form of hydrocarbon.

***Integrated tug/barge*** – Any tug and barge combination with a specially designed connection system joining the two together. The combination allows the vessel to have increased seakeeping capabilities when compared to a separated tug and barge.

***Intermediate fuel oil (IFO)*** – See *Fuel Oil*

***Intermodal Container Transfer Facility*** – A rail yard that is located close to a port facility and is where a cargo transition between two different transportation modes (e.g. trucks, trains, or ships) occurs.

***Liquefied Natural Gas (LNG)*** – Natural gas that has been processed to remove impurities and heavy hydrocarbons and is then condensed into a liquid using extremely low temperature or high pressure.

***Liquefied Petroleum Gas (LPG)*** – A mixture of hydrocarbon gases that are commonly used to fuel heating appliances and vehicles. The two most common forms of liquefied petroleum gas are propane and butane.

***Load Factor (LF)*** – A ratio of an engine's average actual power used to its maximum power rating.

***Low Sulfur Diesel (LSD) –*** See "Diesel"

***Main line locomotives*** – Also called "line-haul," these are the largest class of locomotives and are designed for the heaviest loads, longest distances, and steepest grades.

***Main propulsion engine –*** The engines on a vessel that are dedicated to movement of a ship over long distances.

***Marine Diesel Oil (MDO) –*** See "Fuel Oil"

***Maximum continuous rating*** – A value assigned to a piece of equipment by its manufacturer that sets a guideline for which the equipment can be operated for an unlimited period of time without damage.

***Non-Methane Organic Gas (NMOG)*** – Organic gases that exclude methane but account for all other organic pollutants that form a foundation for the formation of ozone.

***Ocean-going vessel (OGV)*** – Vessels that operate in open oceanic waters.

***Particulate Matter (PM)*** – A general term for any substance, except pure water, that exists as a liquid or solid in the atmosphere under normal conditions and is of microscopic or sub-microscopic size but larger than molecular dimensions. Airborne PM can result from direct emissions of particles (primary PM) or from condensation of certain gases that have themselves been directly emitted or chemically transformed in the atmosphere (secondary PM). PM is often classified by size:

- ***$PM_{2.5}$*** – Also known as "fine" particulate matter, $PM_{2.5}$ refers to the fraction of PM in a sample that is 2.5 microns in diameter or less. This size of PM is commonly associated with combustion and secondary PM.
- ***$PM_{10}$*** – Also known as "coarse" particulate matter, $PM_{10}$ refers to the fraction of PM in a sample that is 10 microns in diameter or less.

***Polycyclic Aromatic Hydrocarbon (PAH)*** – One of the first atmospheric species to be identified as carcinogenic. PAH's are formed during the incomplete combustion of organic matter, e.g. coal, oil, wood, and petroleum. PAH's consist of two or more fused benzene rings in various configurations that, by definition, contain only carbon and hydrogen.

***Polycyclic organic material*** – Compounds containing polycyclic aromatic hydrocarbons and derivatives.

***Renewable Fuels*** – Fuels derived from sources that are regenerative or for all practical purposes can not be depleted.

***Residual oil –*** "Residual Fuel Oil" or "Bunker Fuel" – See "Fuel Oil"**.**

***Roll-on/Roll-off (RoRo)*** – A vessel featuring a built-in ramp for wheeled cargo to be 'rolled-on' and 'rolled-off" of the vessel.

***Rubber Tired Gantry (RTG) Crane*** – A common piece of cargo handling equipment at marine terminals used to transfer containers from stacked storage to a vehicle.

***Selective Catalytic Reduction (SCR) –*** A process where a gaseous or liquid reductant (most commonly ammonia or urea) is added to the flue or exhaust gas stream and absorbed onto a catalyst. The reductant reacts with $NO_X$ in the exhaust gas to form $H_2O$ (water vapor) and $N_2$ (nitrogen gas).

***Sea water scrubbing*** – An exhaust treatment technique used on ships to reduce emissions by through physical and chemical interaction with sea water. When the exhaust comes in contact with the seawater, the $SO_X$ reacts with calcium carbonate to form a solid calcium sulfate and $CO_2$. Scrubbers also function by physically scavenging particles and gases from the air.

***Shaft generators*** – Provides electric power to a moving vessel by generating current from the rotation of the vessel's drive shaft.

***Shore power –*** See "Cold Ironing"

***Point source*** – A single, stationary point source of emissions that is immoveable for all practical purposes.

***Total organic gases –*** The sum of reactive and non-reactive organic gases in the air.

***Two-stroke engines*** – A type of internal combustion engine that completes the same four processes as a four-stroke engine (intake, compression, power, and exhaust) in only two strokes of the piston rather than four. This is accomplished by using the space below the piston for air intake and compression, thus allowing the chamber above the piston to be used for just the power and exhaust strokes. This results in a power stroke with every revolution of the crank, instead of every second revolution as in a four-stroke engine. For this reason, two-stroke engines provide high specific power, so they are valued for use in portable, lightweight applications. Two stoke diesel engines are common in large marine vessels.

***Ultra Low Sulfur Diesel (ULSD) –*** See "diesel."

***Volatile Organic Compound (VOC) –*** A very board term used to describe the entire set of vapor-phase atmospheric organic chemicals except CO and $CO_2$.

## HELPFUL WEBSITES

### Port Clean Air Programs

- The International Association of Port and Harbors – www.iaphworldports.org
- The Port of Los Angeles – http://www.portoflosangeles.org/environment/air_quality.asp
- The Port of Long Beach – www.polb.com/environment/air_quality/
- The Port of Seattle – www.portseattle.org/community/environment/air.shtml
- The Port of Oakland – www.portofoakland.com/environm/prog_04a.asp

### Port Member Associations

- The International Association of Port and Harbors – www.iaphworldports.org
- American Association of Port Authorities – www.aapa-ports.org
- North Atlantic Ports Association – www.northatlanticports.org
- Washington Ports Association – www.washingtonports.org
- Association of Canadian Port Authorities – www.acpa-ports.net
- Port Management Association of Eastern and Southern Africa – www.pmaesa.org/

### Clean Air Diesel Collaboratives

- Pacific Ports Clean Air Collaborative – www.ppcac.org
- West Coast Diesel Collaborative – www.westcoastdiesel.org
- Blue Skyways Collaborative – www.blueskyways.org
- Mid-Atlantic Diesel Collaborative – www.dieselmidatlantic.org
- Northeast Diesel Collaborative – www.northeastdiesel.org
- Southeast Diesel Collaborative – www.southeastdiesel.org

## Clean Air Organizations

- The International Council for Clean Transportation – www.theicct.org
- Clean Air Initiative for Asian Cities – www.cleanairnet.org/caiasia/1412/channel.html
- Coalition for Clean Air – www.coalitionforcleanair.org
- Clean Air – Cool Planet – www.cleanair-coolplanet.org
- Foundation for Clean Air Progress – www.cleanairprogress.org
- Puget Sound Clean Air Agency – www.pscleanair.org
- Clean Air Association for the Northeast States – www.nescaum.org
- Clean Air Communities – www.cleanaircommunities.org

## Clean Air Diesel Technologies

- Manufacturers for Emission Control Association – www.meca.org
- Association for Emission Controls by Catalyst - www.aecc.be/
- Argillon – www.argillon.com
- Cleaire Advanced Emission Controls – www.cleaire.com
- Cummins Emissions Solutions - www.cumminsfiltration.com
- Engine Control Systems – www.enginecontrolsystems.com
- Johnson Matthey - http://ect.jmcatalysts.co