THE EARTH'S BEST DEFENSE

HARBORING
POLLUTION

Strategies to Clean Up U.S. Ports

August 2004

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ABOUT THE COALITION FOR CLEAN AIR

The Coalition for Clean Air is a nonprofit organization dedicated to restoring clean healthful air to California by advocating responsible public health policy, providing technical and educational expertise, and promoting broad-based community involvement. The Coalition for Clean Air has offices in Los Angeles and Sacramento, CA. For more information about the coalition's work, visit www.coalitionforcleanair.org or contact us at 523 West 6th Street, 10th Floor, Los Angeles, CA 90014, 213-630-1192.

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ABBREVIATIONS

AAPA	American Association of Port Authorities
AFS	antifouling system
AMP	Alternative Maritime Power
BACT	best achievable control technology
BFO	bunker fuel oil
BMP	best management practice
CARB	California Air Resources Board
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
DOC	diesel oxidation catalyst
DNA	deoxyribonucleic acid (genetic material)
DPF	diesel particulate filter
EEZ	exclusive economic zone
EGR	exhaust gas recirculation
EMS	environmental management system
EPA	(U.S.) Environmental Protection Agency
EU	European Union
FTF	flow through filter
HFO	heavy fuel oil
HP	horsepower
IMO	International Maritime Organization
ISO	International Organization for Standardization
LNC	lean NO_x catalyst
LNG	liquefied natural gas
LPG	liquefied petroleum gas (propane)
LSD	low-sulfur diesel
MDO	marine diesel oil
MECA	Manufacturers of Emission Controls Association
MGO	marine gas oil
MOU	memorandum of understanding
MSRC	Mobile Source Air Pollution Reduction Review Committee
MTO	marine terminal operator
NDZ	no discharge zone
NG	natural gas
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PM	particulate matter
PM_{10}	particulate matter less than or equal to 10 microns in size
RTG	rubber-tired gantry crane

SCAQMD	South Coast Air Quality Management District
SCR	selective catalytic reduction
SECAT	Sacramento Emergency Clean Air Transportation (program)
SO_2	sulfur dioxide
SO_x	sulfur oxides
SWPPP	Stormwater Pollution Prevention Plan
TBT	tributyltin
TERP	Texas Emission Reduction Program
TMDL	total maximum daily load
VOCs	volatile organic compounds (similar to hydrocarbons and reactive organic gases, as some regulatory agencies commonly use)
g/bhp-hr	grams per brake horsepower-hour (a measure of the amount of a pollutant per engine energy output)
g/kWh	grams per kilowatt hour (a measure of the amount of a pollutant per unit energy output)
lb/MW-hr	pound per megawatt hour (a measure of the amount of a pollutant per unit energy output)
ppm	parts per million
tpd	tons per day

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EXECUTIVE SUMMARY

Marine ports in the United States are major hubs of economic activity and major sources of pollution. Enormous ships with engines running on the dirtiest fuel available, thousands of diesel truck visits per day, mile-long diesel locomotives hauling cargo and other polluting equipment, and activities at marine ports cause an array of environmental impacts that can seriously affect local communities and the environment. These impacts range from increased risk of illness, such as respiratory disease or cancer, to increases in regional smog, degradation of water quality, and the blight of local communities and public lands.

Most major ports in the United States are undergoing expansions to accommodate even greater cargo volumes. The growth of international trade has resulted in corresponding rapid growth in the amount of goods being shipped by sea. Despite the enormous growth within the marine shipping sector, most pollution prevention efforts at the local, state, and federal level have focused on other pollution sources, while the environmental impacts of ports have grown.

Marine ports are now among the most poorly regulated sources of pollution in the United States. The result is that most U.S. ports are heavy polluters, releasing largely unchecked quantities of health-endangering air and water pollution, causing noise and light pollution that disrupts nearby communities, and harming marine habitats.

In March 2004, NRDC and CCA issued report cards for the 10 largest U.S. ports on their efforts to control pollution—or lack of efforts to control pollution. In the short time since the grades were issued, steps to reduce port pollution have already been made. For example, the first container ship in the world plugged into shoreside power at the Port of Los Angeles. This report discusses solutions to port pollution problems and provides additional information on the health and environmental impacts of port operations; an overview of policies governing U.S. marine ports; and detailed analysis and technical recommendations to port operators, regulatory agencies, and community-based environmental and health advocates.

AIR POLLUTION AND HEALTH IMPACTS FROM PORT OPERATIONS

The diesel engines at ports, which power ships, trucks, trains, and cargo-handling equipment, create vast amounts of air pollution that affect the health of workers and people living in nearby communities and contribute significantly to regional air pollution. More than 30 human epidemiological studies have found that diesel exhaust increases cancer risks, and a 2000 California study found that diesel exhaust is responsible for 70 percent of the cancer risk from air pollution.[1] More recent studies have linked diesel exhaust with asthma.[2] Major air pollutants from diesel engines at ports that can affect human health include particulate matter (PM), volatile organic compounds (VOCs), nitrogen oxides (NO_x), and sulfur oxides (SO_x).

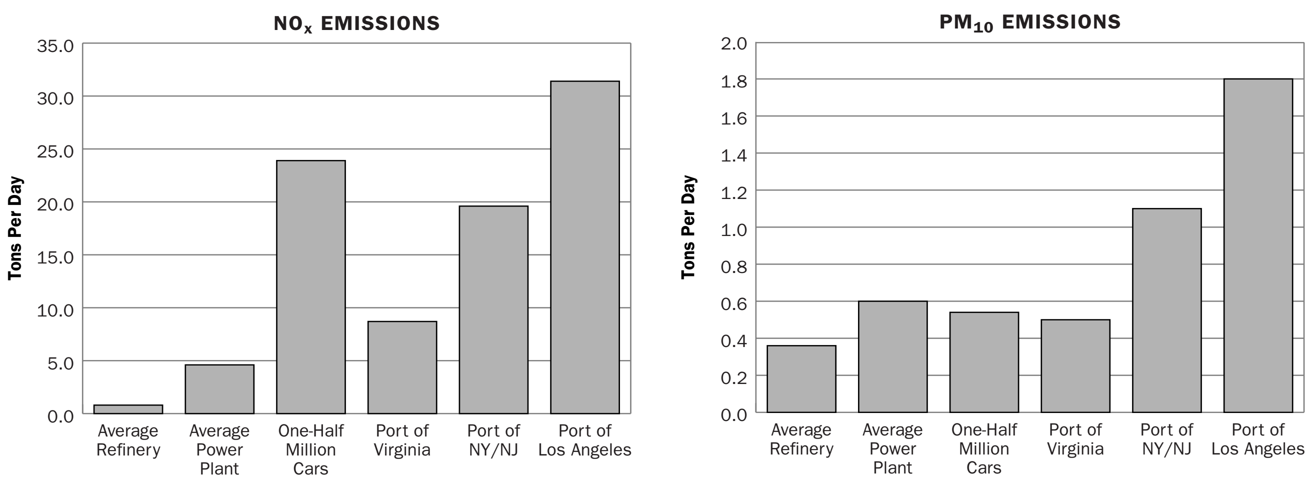
The health effects of pollution from ports may include asthma, other respiratory diseases, cardiovascular disease, lung cancer, and premature death. In children, these pollutants have been linked with asthma and bronchitis, and high levels of the pollutants have been associated with increases in school absenteeism and emergency room visits. In fact, numerous studies have shown that children living near busy diesel trucking routes are more likely to suffer from decreased lung function, wheezing, bronchitis, and allergies.[3,4,5]

Many major ports operate virtually next door to residential neighborhoods, schools, and playgrounds. Due to close proximity to ports, nearby communities face extraordinarily high health risks from associated air pollution. Many of these areas are low-income communities of color, a fact that raises environmental justice concerns.

Although cars, power plants, and refineries are all large and well-known sources of pollution, Figure E-1 demonstrates that the air pollution from ports rivals or exceeds these sources. In the Los Angeles area, oceangoing ships, harbor tugs, and commercial boats such as passenger ferries emit many times more smog-forming pollutants than all power plants in the Southern California region combined.[6] And the latest growth forecasts predicting trade to approximately triple by 2025 in the Los Angeles region mean that smog-forming emissions and diesel particulate pollution could severely increase in an area already burdened by the worst air quality in the nation. The larger contribution of port sources to air pollution can be attributed to the fact that pollution from cars, power plants, and refineries is somewhat controlled, whereas port pollution has continued to grow with almost no regulatory control.

Figure E-1 uses the Port of Los Angeles and the Port of New York and New Jersey as examples because they are the largest ports on the West Coast and East Coast, respectively. The Port of Virginia is comparable in size to other large ports such as Savannah, Houston, and Seattle. Figure E-1 also highlights emissions of NO_x and PM, because these pollutants are associated with very severe health impacts.[7] Despite very conservative assumptions used to calculate port emissions, ports out-pollute some of the largest sources of harmful emissions, raising the question, Should ports be regulated like other large sources of pollution?

FIGURE E-1
Nitrogen Oxides (NO_x) and Particulate Matter (PM_{10}) Pollution from Ports Compared to Refineries, Power Plants, and Cars



Sources: Seaports of the Americas, American Association of Port Authorities Directory (2002): 127. U.S. EPA, National Emission Trends, Average Annual Emissions, All Criteria Pollutants, 1970–2001, August 13, 2003. Energy Information Administration, Petroleum Supply Annual 1982, Volume 1, DOE/EIA-0340(82)/1 (June 1983, Washington, DC), pp. 97-103 and Petroleum Supply Annual 2000, Volume 1, DOE/EIA-0340(2000)/1 (Washington, DC, June 2001), Table 40. Energy Information Administration, Form EIA-861, “Annual Electric Utility Report.” As posted at www.eia.doe.gov/cneaf/electricity/public/t01p01.txt, U.S. Dept of Transportation, Federal Highway Administration, 2000 Highway Statistics, State Motor-Vehicle Registrations.

WATER POLLUTION FROM PORT OPERATIONS

Port operations can cause significant damage to water quality—and subsequently to marine life and ecosystems, as well as human health. These effects may include bacterial and viral contamination of commercial fish and shellfish, depletion of oxygen in water, and bioaccumulation of certain toxins in fish.[8] Major water quality concerns at ports include wastewater and leaking of toxic substances from ships, stormwater runoff, and dredging.

LAND USE PROBLEMS AT PORTS

The highly industrialized operations at ports are often in close proximity to residential areas, creating nuisances and hazards for nearby communities. Ports have several available options to avoid developing new terminals near residential areas. They can develop property previously used in an industrial capacity, or they can increase efficiency of land use at existing terminals. The land use patterns at U.S. ports suggest much room for efficiency improvements. Of the 10 largest U.S. ports, even those that are most efficient in terms of land use—Long Beach and Houston—are four times less efficient than the Port of Singapore, a model of land use efficiency.

PORT COMMUNITY RELATIONS

Ports can be bad neighbors. In addition to the air and water pollution they create, they can cause traffic jams and can be loud, ugly, and brightly lit at night. These impacts range from simple annoyances to serious negative health effects. For example, noise pollution has been linked to hearing impairment, hypertension (high blood pressure), sleep deprivation, reduced performance, and even aggressive behavior.[9] At ports bordering residential neighborhoods, bright lights at night and the flashing lights of straddle carriers and forklifts can affect nearby residents, disrupting biological rhythms and causing stress and irritation.[10,11]

Ports can also be bad neighbors by ignoring residents of the communities living next door, or making little or no effort to solicit community input into operational decisions that will directly affect the life of the community and its residents. Many U.S. ports have developed decidedly hostile relations with their neighbors, not only because of the pollution the ports produce but also because they have consistently ignored residents of nearby communities, refusing sometimes even to share critical information about possible effects of port operations.

RECOMMENDATIONS

The fact-finding for this report revealed untenable situations in many communities near ports: freeways and neighborhood streets overloaded with trucks, homes coated with soot, soaring asthma rates, containers stacked high enough to create significant neighborhood blight, piles of dredged sludge forming toxic islands, and prime marine animal habitats gouged by channeling. The following are recommendations to port operators and policymakers on how to clean up port operations. The recommendations, and the problems they seek to address, are described in greater detail throughout the report.

Recommendations for Ports

Ports must commit to protect local communities and the environment, not only during expansions but also during regular operations. Following are suggested measures used by select ports worldwide to successfully decrease impacts on local communities and ecosystems. These measures should be employed at all container ports to clean up their operations, and local activists should be aware of these options to advocate for their implementation. Ports should consider the negotiation of new or modified leases as an important opportunity to require a combination of the mitigation measures, such as the use of cleaner fuels and equipment.

Marine vessels

- ▶ Clean up harbor craft, such as tugboats, through engine repower and retrofit programs.
- ▶ Limit idling of oceangoing vessels and tugboats by providing electric power at docks and requiring ships and tugboats to “plug in” to shoreside power while at berth.
- ▶ Require ships, including oceangoing vessels, to use the cleanest grade of diesel fuel possible, with a sulfur content of 15 to 2,000 parts per million.
- ▶ Where possible, create incentives for, or otherwise promote the use of, emission controls on oceangoing vessels.

Cargo-handling equipment

- ▶ Retire equipment that is ten or more years old and replace it with the cleanest available equipment and fuel choices, preferably alternative fuels.
- ▶ Retrofit existing equipment less than ten years old to run on the best available control technology, including diesel particulate filters (DPFs) with lean NO_x catalysts (LNCs) and, if not feasible, with diesel oxidation catalysts (DOCs).
- ▶ Switch to cleaner diesel fuels, such as low-sulfur fuel with sulfur content less than 15 parts per million and diesel emulsions.

On-road trucks

- ▶ Create incentive programs that encourage fleet modernization, the retirement of older trucks, and their replacement with modern lower-emitting trucks.
- ▶ Offer incentives for the installation of pollution controls, including DPFs with LNCs or, if not feasible, with DOCs.
- ▶ Make cleaner fuels, such as diesel emulsions or low-sulfur diesel, available to off-site trucks.
- ▶ Minimize truck idling by enforcing idling limits or by installing idle shutoff controls.

Locomotives

- ▶ Repower or replace all switching locomotives that do not meet the Environmental Protection Agency (EPA) Tier 0 Standards with electric-hybrid or alternative-fuel engines.
- ▶ Install engine emissions controls where possible.

▶ Require automatic engine shutoff controls to minimize unnecessary idling.
▶ Commit to using cleaner fuels, such as on-road grade diesel.

Stormwater management

▶ Take principal responsibility, as the general permittee, for preparing a stormwater pollution prevention plan for all terminals.
▶ Provide guidance to all port tenants for development of model stormwater programs, oversight and inspections of individual terminals to confirm implementation of an acceptable program, and education and training of terminal staff.
▶ Carefully document and analyze potential water pollution problems, water quality monitoring, and best management practices for the prevention, control, and treatment of stormwater runoff.

Other measures recommended include water quality programs; traffic mitigation; land use, light, and noise abatement; improved aesthetics; and other terminal design features.

Recommendations for Policymakers

In addition to the mitigation measures ports should implement on their own, a number of policy and regulatory actions are needed to protect human health and the environment from the large, industrial, and high-polluting operations at marine ports. Ordinarily, such activities would be subject to stringent regulation, but oversight of ports falls between the regulatory cracks, defeated by confusion over jurisdictional authority and the ongoing efforts of a strong industry lobby. While a patchwork of international, federal, state, and local rules apply to various pollution sources at ports, most are weak and poorly enforced.

Marine vessels

▶ The U.S. government should officially ratify MARPOL Annexes IV and VI (an international treaty that prevents sewage pollution and sets emissions standards for ships) and the Antifouling Systems Convention, which bans toxic chemical coatings on ship hulls.
▶ The EPA should expedite efforts to establish the entire East, West, and Gulf coasts as control zones subject to stricter emission standards under MARPOL VI.
▶ The EPA should implement a graduated harbor fee system similar to a program in Sweden that requires more polluting ships to pay higher fees upon entering a port.
▶ The EPA should expedite implementation of stricter emission standards for all marine vessels within two years.
▶ States and regional authorities should create financial incentives for the cleanup and replacement of older marine vessels.
▶ States and regional authorities should require ships to plug in to shoreside power while docked.
▶ States should require that ships use low-sulfur diesel while in coastal waters and at berth (until electric power is made available). In the absence of state action, regional authorities should require this.
▶ Regional authorities should monitor and enforce ship speed limits.

On-road and nonroad vehicles

▸ The EPA must follow through with full implementation of its 2007 emissions standards for on-road, heavy-duty trucks; its 2008 emissions standards for nonroad vehicles and equipment; and the related lower sulfur diesel requirements.

▸ The EPA should adopt a series of diesel retrofit rules, similar to those proposed in the California risk reduction program, to establish a cleanup schedule for existing polluting diesel engines. In the absence of federal action, states or local authorities should adopt these programs.

▸ The EPA should set uniform federal idling limits for all diesel engines. In the absence of federal action, states or local authorities should require idling limits.

▸ States should provide incentive programs to reduce pollution from heavy-duty diesel engines, similar to programs such as California's Carl Moyer and Gateway Cities; in the absence of state action, regional authorities should sponsor such programs.

▸ Regional authorities should adopt fleet rules to clean up and require new, cleaner purchases of all heavy-duty engines, similar to those in place in the Los Angeles area.

Inland cargo transport

▸ The EPA and individual states should consider fees on each container entering a port to provide funding for mitigation of the environmental impacts of moving those containers.

▸ The U.S. government should adopt and support a sustainable transportation system program, similar to the European Union program, facilitating the shift of cargo transport from more polluting modes (such as trucking) to cleaner locomotive and barge transport.

Locomotives

▸ The EPA should implement stricter emission standards for locomotives within one year.

▸ States and regional authorities should also create financial incentives for the cleanup and replacement of older locomotives.

▸ States should negotiate memorandums of understanding that create incentives for cleaner locomotives. In the absence of state action, regional authorities should pursue this.

Land use

▸ Regional authorities should improve efforts to protect marine habitats from further infill due to port developments.

▸ Regional authorities should work together with local communities and marine terminals to improve efficiency and land use and to minimize impacts of terminals on local communities.

Community relations

▸ Neighboring states should work together in coastal alliances to protect their marine natural resources and to share information on programs and technologies, and they should work together to jointly shoulder the neglected responsibility to neighboring communities and their surrounding environment.

Stormwater

▶ The EPA should issue effluent guidelines to require a general baseline level of pollutant reduction for port facilities, or for those pollutants typically found in port runoff.

▶ States should ensure that anti-degradation provisions of federal and state law are fully implemented in stormwater permits.

▶ States should give special attention to the development of total maximum daily loads (TMDLs) for impaired waters around many ports.

▶ Local governments should prioritize port facilities when designing inspection protocols in conjunction with local regulatory programs and implementation of municipal stormwater permits.

Oil spills

▶ Congress should pass the Stop Oil Spills Act (H.R. 880) to accelerate the phase-in of double-hulled tankers in U.S. waters by 2007.

▶ Regional authorities should require ports to take steps to ensure that oil pollution does not become part of runoff and that portwide oil-recycling programs are in place.

Ballast water

▶ The U.S. Coast Guard should finalize mandatory national ballast water regulations as quickly as possible, or no later than the expected summer 2004 completion date.

▶ States should adopt ballast water regulations, similar to those in place in California and Washington, that ensure a 200-mile buffer from the U.S. coast.

Waste discharge

▶ The EPA must consider more stringent requirements on the dumping of wastes containing oxygen-depleting nitrogen and phosphorous, as well as persistent toxic compounds that continue to threaten marine life.

CONCLUSION

Based on our previous survey of 10 of the largest container ports in the United States, not nearly enough is being done to alleviate the severe impacts of the highly polluting shipping industry despite real and significant environmental and health impacts associated with marine port operations. Ports should take internal measures to reduce pollution caused by port activities. Likewise, regulatory agencies at the federal, state, and local level must provide long overdue safeguards. Further, if port expansions are to continue, all projects must be mitigated to the maximum extent possible, efficiency must be improved, and current operations should be cleaned up.

CHAPTER 1

HEALTH AND ENVIRONMENTAL EFFECTS OF PORT POLLUTION

The economic benefits of marine ports are typically accompanied by significant environmental and public health problems. Hundreds of enormous diesel-powered ships, millions of diesel trucks, and other polluting equipment and activities at modern seaports cause an array of environmental degradations that, when uncontrolled, can severely affect the health and quality of life of residential communities, as well as marine and land-based wildlife throughout a region. Among the environmental harm caused by pollution from marine ports are a significant increase in regional smog, contamination of nearby bodies of water, introduction of destructive invasive species, increased cancer and other health risks for nearby residents, and blight on local communities and public lands.

The specific sources of these various environmental hazards from marine ports are many. They include:

- Car and truck traffic, including thousands of diesel trucks servicing each of the major ports every day
- Rail and commercial ship traffic
- Cargo-handling equipment
- Chemical storage and handling
- Fueling of ships, trucks, trains, and cargo-handling equipment
- Liquid discharges from ships
- Painting and paint stripping
- Ship breaking (dismantling)
- Maintenance and repair of roads, rails, grounds, vessels, vehicles, and equipment
- Channel dredging[1]

Even though marine ports are often associated with heavy industrial activities, they are usually situated in or very near residential communities or environmentally sensitive estuaries. A variety of negative environmental consequences commonly result, including

- ▶ Air pollution from port operations and construction activities, including smog and toxic particulate pollution
- ▶ Loss or degradation of wetlands; destruction of fisheries
- ▶ Loss of habitat of local endangered species
- ▶ Contamination from wastewater and stormwater discharges
- ▶ Severe traffic congestion
- ▶ Noise and light pollution
- ▶ Loss of cultural resources
- ▶ Contamination of soil and water from leaking storage tanks and pipelines
- ▶ Air releases from chemical storage
- ▶ Solid and hazardous waste generation and soil runoff and erosion[2]

MARINE PORTS ARE MAJOR SOURCES OF AIR POLLUTION

Many of the dirtiest sources of air pollution are concentrated at marine ports, often creating a veil of brown haze that carries with it all of the severe health effects of industrial and urban air pollution. For example, marine ports attract hundreds of enormous oceangoing ships and tugboats, which burn the dirtiest grade of diesel fuel available. Cargo is moved around shipyards by fleets of highly polluting heavy-duty equipment, and it is delivered and taken away from those shipyards by millions of heavy-duty container trucks and locomotives, many of which were built well before emission standards were even considered. These and other port-related sources combine to rival the worst pollution from power plants and refineries, accounting for large percentages of the statewide air pollution in major shipping states.

Cargo is moved around shipyards by fleets of highly polluting heavy-duty equipment, and it is delivered and taken away from those shipyards by millions of heavy-duty container trucks and locomotives, many of which were built well before emission standards were even considered.

Air pollutants emitted from port-related activities adversely affect the health of port workers, as well as residents of nearby communities, and contribute significantly to regional air pollution problems. The major air pollutants related to port activities that can affect human health include nitrogen oxides (NO_x), sulfur oxides (SO_x), ozone (O_3) particulate matter (PM), diesel exhaust, and volatile organic compounds (VOCs). Other pollutants from port operations—such as carbon monoxide (CO), formaldehyde, heavy metals, dioxins, and even pesticides used to fumigate produce—can also be problematic.

Health Effects from Diesel Exhaust

The vast majority of equipment employed at ports today runs on diesel fuel, emitting a toxic brew of particles, vapors, and gases, including NO_x, VOCs, and SO_x.[3] In addition to the pollutants just listed, diesel exhaust contains an estimated total of 450 different compounds, about 40 of which are listed by the California Environmental Protection Agency as toxic air contaminants with negative effects on health and the environment.[4]

Airway Irritation and Allergies from Diesel Exhaust Many studies have shown that diesel exhaust can irritate the nose, sinuses, throat, and eyes and damage the lower airways. Studies of people exposed to diesel exhaust have documented eye and nose irritation, bronchitis, cough and phlegm, wheezing, and deterioration in the ability to take full, deep breaths.[5,6] New important scientific evidence suggests that diesel exhaust may help to cause the initiation of allergies and worsen existing allergies. [7,8] Exposure to diesel exhaust also causes elevated levels of immune cells in the airways, indicating that the body senses a hazardous substance.[9]

Increased Cancer Risk from Diesel Exhaust More than 30 human epidemiological studies have found that diesel exhaust increases cancer risk. One major study examined the effects of diesel exhaust exposure on more than 56,000 railroad workers over a 22-year period.[10] Calculations based on this study showed that chronic exposure to just one microgram per cubic meter of diesel exhaust particles—roughly the level found in many suburban areas far distant from trucking routes or ports—would result in an additional risk of 1.3 to 15 cancer cases per 10,000 exposed individuals. Using that finding as a benchmark, the South Coast Air Quality Management District in California calculated that fully 71 percent of the cancer risk due to air pollution in the South Coast Air Basin is attributable to diesel particulate pollution. Agencies in a number of other areas have reached similar conclusions.[11]

Dozens of studies have shown that long-term exposure to diesel exhaust significantly increases the risk of lung cancer.[12] In fact, workers exposed to diesel exhaust over the long term generally face an increase in lung cancer risks of between 50 and 300 percent.[13] Studies have also reported links between diesel exposure and other cancers, including cancer of the bladder, kidney, stomach, blood (including multiple myeloma, leukemia, Hodgkin's disease, and non-Hodgkin's lymphoma), the oral cavity, pharynx, and larynx.[14] A number of federal and international agencies have listed diesel exhaust as a probable or likely lung carcinogen, and in 1990, the state of California listed diesel exhaust as a known cause of lung cancer.[15]

Among chronic health conditions, the leading reason for absenteeism from school is asthma. Not surprisingly, PM pollution is associated with the increased prevalence of the condition in children.

Respiratory Illnesses Aggravated by Diesel Particulate Matter Particulate matter (PM) pollution ranges from the coarse dust kicked up from dirt roads to the very tiny sooty particles formed when wood, gasoline, or diesel are burned. At ports, construction and daily operations often create coarse PM, but it is the tiniest PM that causes the greatest health hazards. Much of this "fine" PM—so small that it is invisible to the eye—comes from diesel engine exhaust. Less than 1/20th the diameter of a human hair, fine PM can travel deep into the lungs, landing in the delicate air sacs where oxygen exchange normally occurs.[16] Numerous studies have found that these fine particles impair lung function, aggravate such respiratory illnesses as bronchitis and emphysema, and are associated with premature deaths.[17]

Dozens of studies link airborne fine particle concentrations to increased hospital admissions for asthma attacks, chronic obstructive lung disease, pneumonia, and heart disease, including an increased risk of heart attacks.[18] School absenteeism due to respiratory symptoms has also been linked to PM pollution.[19] Among chronic health conditions, the leading reason for absenteeism from school is asthma. Not surprisingly, PM pollution is associated with the increased prevalence of the condition in children. A study of asthmatic African-American children in Los Angeles found an association between reported asthma symptoms and ambient PM concentrations.[20] Not only can particulate matter from diesel exhaust trigger asthma attacks in people who already have asthma, but also recent scientific studies indicate that diesel may affect lung function and even cause asthma in previously healthy people.[21,22] For example, children living near busy diesel trucking routes have decreased lung function by comparison with children living near roads with mostly automobile traffic.[23] A survey of nearly 40,000 children in Italy found that children living on streets with heavy truck traffic were 60 to 90 percent more likely to have wheezing, phlegm, bronchitis, and pneumonia.[24] A German study of nearly 4,000 adolescent students found that those living on streets with constant truck traffic

Children raised in heavily polluted areas have reduced lung capacity, prematurely aged lungs, and an increased risk of bronchitis and asthma than do peers living in less urbanized areas.

AIR POLLUTION RISKS TO PREGNANT WOMEN AND CHILDREN

Children are at particular risk from air pollution, in part because their lungs are still developing and their airways are narrower than those of adults, and in part because they often play outdoors during the day and thus may have greater exposure. Children raised in heavily polluted areas have reduced lung capacity, prematurely aged lungs, and an increased risk of bronchitis and asthma than do peers living in less urbanized areas.

In a study comparing air pollution in six U.S. cities and the respiratory health of individuals living in those cities, the frequencies of cough, bronchitis, and lower respiratory illness in preadolescent children were significantly associated with increased levels of acidic fine particles from pollution. Illness and symptom rates in the community with the highest air pollution concentrations were twice those in the community with the lowest concentrations. In addition, some studies have suggested that children with preexisting respiratory conditions—wheezing and asthma, for example—are at an even greater risk of developing symptoms from exposure to air pollutants. Furthermore, new research shows that asthmatic children experience a significant increase in wheezing and chest tightness at ozone levels significantly below federal standards.

Recent research also indicates that cancer-causing chemicals from diesel exhaust can cross the placenta in humans, thus subjecting developing fetuses to the effects of pollution to which mothers are exposed. Although fetal exposures to these chemicals are one-tenth those of their mothers, genetic damage is detectable in newborn blood samples at levels significantly higher than in maternal blood. These indications of DNA damage demonstrate that the fetus may be significantly more susceptible than the mother to these chemicals.

Sources: DW Dockery, et al.: “Effects of inhalable particles on respiratory health of children,” *Am Rev Respir Dis* 139: 587–594, 1989. J Peters, et al. “A study of twelve southern California communities with differing levels and types of air pollution. II. Effects on pulmonary function.” *Am J. Respir, Crit Care Med* 159: 768–775, 1999. JH Ware: “Effects of ambient sulfur oxides and suspended particles on respiratory health of preadolescent children.” *Am Rev Resp Dis* 133:834–842, 1986. JA Pope, Dockery DW: “Acute health effects of PM_{10} pollution on symptomatic and asymptomatic children.” *Am Rev Respir Dis* 145: 1123–1128, 1992. KM Mortimer, et al.: “The effect of air pollution on inner-city children with asthma.” *Eur Respir J* 19:699–705, 2002. JF Gent, et al. “Association of low-level ozone and fine particles with respiratory symptoms in children with asthma,” *Journal of the American Medical Association,* 290 (14): 1859–1867, 2003. RM Whyatt, et al.: “Biomarkers of polycyclic aromatic hydrocarbon-DNA damage and cigarette smoke exposures in paired maternal and newborn blood samples as a measure of differential susceptibility.” *Cancer Epidemiol Biomarkers* Perv 10: 581–588, 2001.

were 71 percent more likely to have nasal allergies, and more than twice as likely to report wheezing.[25]

Rates of Hospitalization and Death Increase from PM Pollution A number of research studies have found that even short-term increases in PM pollution can have lethal effects. Studies in six U.S. cities and in Canada showed that daily increases in PM are associated with increased deaths in the days immediately following.[26] The deaths were among individuals with heart and lung disease—those most susceptible to the noxious effects of PM pollution. An examination of data from Detroit, Los Angeles, and Toronto led researchers to conclude that when PM pollution rises, hospitalizations for heart failure, chronic obstructive lung disease, and pneumonia in the elderly also rise.[27] Separately, a major study of 1.2 million adults followed for two decades found that exposure to PM pollution was linked with an 8 percent increase in lung cancer death for every 10 microgram per cubic meter increase of particulate matter in the air.[28]

Adverse Health Effects from Volatile Organic Compounds

Not only are volatile organic compounds inherently toxic, but also when they evaporate into the air, they can react with other pollutants to form ozone smog. Common VOCs produced by diesel engines include benzene, 1,3-butadiene, formaldehyde, and toluene, each of which poses significant health risks.[29] Benzene and butadiene are known to cause cancer in humans. Formaldehyde is very irritating to the airways and is a probable carcinogen. Toluene has been associated with birth defects and miscarriages and is listed as “known to the state of California to cause birth defects or reproductive harm.”[30] Other VOCs emitted by vehicles have also been linked to cancer, reproductive harm, asthma, or neurological disorders.[31]

A major study of 1.2 million adults followed for two decades found that exposure to PM pollution was linked with an 8 percent increase in lung cancer death.

Adverse Health Effects from Nitrogen Oxides

Nitrogen oxides include a large family of chemicals, including nitrogen dioxide, nitric acid, nitrous oxide, nitrates, and other related compounds. They can cause a wide variety of health problems, including respiratory distress, and environmental problems, including smog. In addition, NO_x also reacts with ammonia, water vapor, and air pollutants to form other chemicals, some of which can cause cell mutations and even cancer.

A number of studies have found that NO_x can have a toxic effect on the airways, leading to inflammation and asthmatic reactions.[32] In fact, people with allergies or asthma have far stronger reactions to such common allergens as pollen when they are also exposed to NO_x.[33] A European study of nearly 850 seven-year-old children living in nonurban communities found that where the nitrogen dioxide levels are consistently high, such as near major roads or ports, children were up to eight times as likely to be diagnosed with asthma.[34] In addition, children who already have asthma are more likely to cough, wheeze, and suffer from decreased pulmonary function when ambient levels of NO_x in the air are high.[35] Scientists have also found some evidence that nitrogen dioxide increases the risk of asthma attacks following respiratory infections. A yearlong study of 114 asthmatic children found that the combination of moderately elevated outdoor nitrogen dioxide levels and a respiratory infection doubled the risk of an asthma attack following either an infection or elevated NO_x levels alone.[36]

Decreased Lung Function from Ozone (Smog)

The layer of brown hazy smog found over most urban areas in the United States is not just an eyesore, it is a source of serious illnesses. Ozone, also known as smog, is a reactive gas produced when VOCs and NO_x interact with sunlight and split apart oxygen molecules in the air. Ozone is extremely irritating to the airways and the lungs, causing serious damage to the delicate cells lining the airways. It contributes to decreased lung function, increased respiratory symptoms, asthma, emergency room visits, and hospital admissions.[37] Ozone can also make people more susceptible to respiratory infections.[38] Ozone can cause irreversible changes in lung structure, eventually leading to chronic respiratory illnesses, such as emphysema and chronic bronchitis.[39] Those particularly at risk from ozone include children, people with respiratory disease, asthmatics, and people who exercise outdoors.

Children in Southern California living in areas with high ozone levels and playing outdoor sports had three times the risk of developing asthma as children who played outdoor sports in lower ozone areas.

Among the thousands of published studies on the health effects of ozone are recent research studies identifying a link between long-term ozone concentrations in air and new-onset asthma.[40] Children in Southern California living in areas with high ozone levels and playing outdoor sports had three times the risk of developing asthma as children who played outdoor sports in lower-ozone areas.[41] Asthmatic children experience a significant increase in wheezing and chest tightness at ozone levels significantly below federal standards, according to another new study.[42] A recent study in Toronto reported a relationship between short-term elevations in ozone concentrations and hospital admissions for respiratory symptoms in children younger than two years old.[43] Increased respiratory disease serious enough to cause school absences has been associated with ozone concentrations in studies from Nevada and Southern California.[44]

Short-term ozone exposure may also be a contributing factor to premature death. The inflammation caused by ozone may make elderly and other sensitive individuals more susceptible to the adverse effects of other air pollutants, such as particulate matter.[45] Even short-term exposures to high ozone levels are unhealthy for this most susceptible group of people. A study in eight European cities (London, Athens, Barcelona, Paris, Amsterdam, Basel, Geneva, and Zurich) found a correlation between specific times of death and peak ozone levels, as measured on an hourly basis.[46]

Adverse Health Effects from Sulfur Oxides

Burning sulfur-containing fuels, such as diesel and high-sulfur marine fuels, produces sulfur oxides (SO_x), including sulfur dioxide and a range of related chemical air pollutants. SO_x react with water vapor in the air to create compounds that irritate the airways, sometimes causing discomfort and coughing in healthy people and often causing severe respiratory symptoms in asthmatics.[47] One study found that when asthmatics were exposed under controlled conditions to levels of sulfur dioxide similar to those found near pollution sources—ports, for example—

lung function dropped by an average of 25 to 30 percent.[48] In addition, several studies indicate that the combination of SO_x and NO_x in the air is particularly noxious because the compounds appear to act together to increase allergic responses to such common allergens as pollen and dust mites.[49]

THE SOURCES OF AIR POLLUTION AT PORTS

Many major ports, including the ports of Los Angeles and Long Beach, operate virtually next door to residential neighborhoods, schools, and playgrounds. These nearby communities face extraordinarily high pollution-related health risks resulting from their close proximity to the ports.

The major port-related sources of diesel pollution are shown in Figure 1-1. In California, container ports account for roughly 6 percent of diesel particulate pollution.[50] This significant percentage is growing every year, in part because air emissions from port-related sources remain largely unregulated. Ships, container-handling equipment, and heavy trucks account for 95 percent of total NO_x and 98 percent of total diesel PM emissions.[51]

Marine Vessels

For fossil fuel sources worldwide, marine vessels emit 14 percent of the nitrogen oxides, 5 percent of the sulfur oxides, and 2 percent of the carbon dioxide.[52] In 2000, commercial marine vessels accounted for roughly 7 percent of NO_x and 6 percent of PM emissions from all mobile sources in the United States.[53] Because these vessels are poorly regulated, their share of polluting emissions is expected to double by 2020.[54] In fact, commercial diesel ships are expected to account for one-fifth of all diesel particulate generated in 2020, making them the second largest source of this toxic soot.

CONTAINER PORTS VERSUS CARS

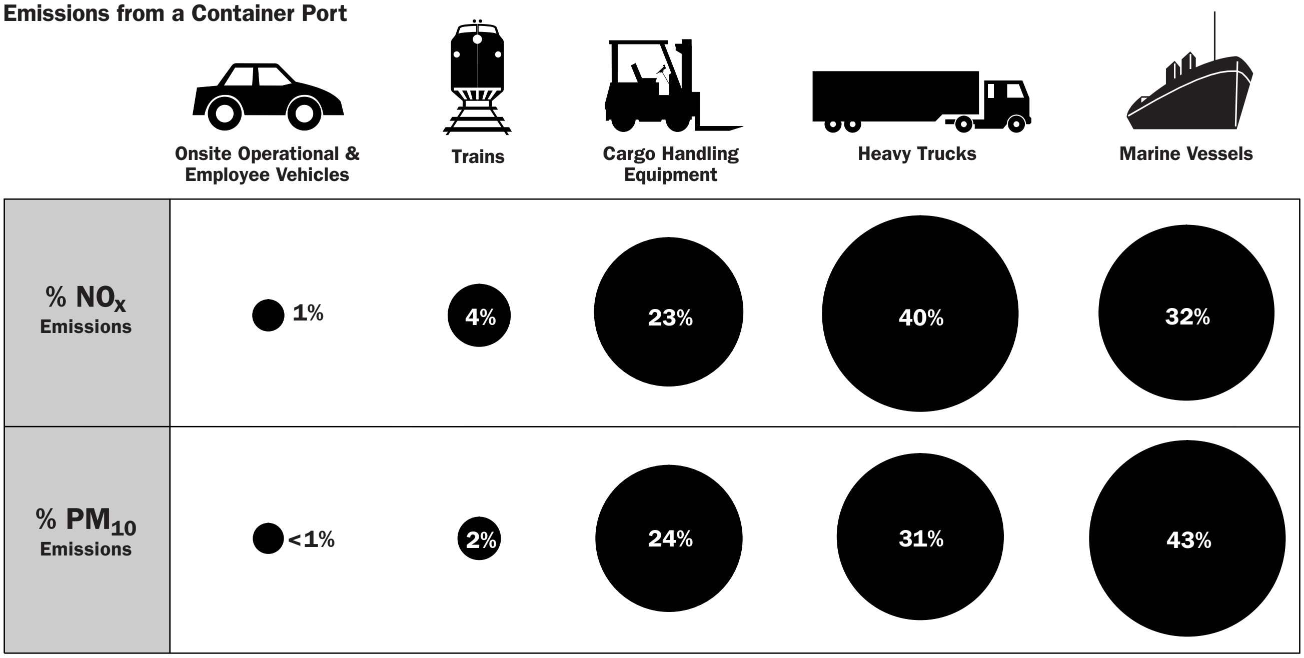
To place port pollution in context, during 2000, the 10 largest container ports combined polluted more than the following number of cars for these major pollutants:

More than **80 thousand cars** worth of CO
More than **182 thousand cars** worth of VOC
More than **3.2 million cars** worth of NO_x
More than **8.1 million cars** worth of PM_{10}
More than **18.5 million cars** worth of SO_x

In 2000, container vessels calling at the ten largest U.S. ports polluted the air with more sulfur dioxide than all of the cars in the states of New York, New Jersey, and Connecticut combined. Container-related heavy-truck traffic polluted the air with more NO_x within port terminal areas alone than the NO_x from each car in the state of Kansas. And passenger vehicle traffic in South Carolina polluted less particulate matter than all of the container-handling equipment at the ten largest ports.

Sources: Federal Highway Administration; EPA National Emission Trends 2000 Inventory; environmental impact reports and related emission inventories from Ports of Los Angeles, Long Beach, Houston, and Oakland; and Seaports of the Americas.

FIGURE 1-1
Average Contributions of Various Port-Related Sources to Total Nitrogen Oxides (NO_x) and Particulate Matter (PM_{10}) Emissions from a Container Port



Sources: *Marine Vessels Emissions Inventory* (Ports of Los Angeles and Long Beach), ARCADIS, Sept. 1999. Appendix G, pg. 6, 2000 forecast—Marine Emissions Inventory and Table 4-2, page 4-2. *The New York, Northern New Jersey, Long Island Nonattainment Area Commercial Marine Vessel Emissions Inventory, Volume 1—Report,* prepared by Starcrest Consulting Group, LLC, for the Port Authority of NY & NJ, April 2003. *The Port of New York and New Jersey Emissions Inventory for Cargo Handling Equipment, Automarine Terminal Vehicles, and Associated Locomotives,* prepared by Starcrest Consulting Group, LLC, for the Port Authority of NY & NJ, June 2003. *Port of Houston, Final Environmental Impact Statement,* Bayport Ship Channel Container/Cruise Terminal, Appendix 3, May 2003. *Port of Oakland Final Environmental Impact Report,* Berths 55-58 Project, SCH. NO. 97102076, Appendix C: Emissions Calculations, December 1998.

Container ship traffic to and from the United States doubled between 1990 and 2001, and the rate of increase is expected to continue.[55] Of the 58,000 calls made by large ships at U.S. ports in 2000, almost 30 percent were made by container ships.[56] Container ships calling in the United States weigh on average almost 38,000 tons.[57] The new generation of container ships, dubbed post-Panamax because they cannot fit through the Panama Canal, are longer than three and a half football fields, or longer than the Eiffel Tower is tall. These vessels produce great quantities of polluting emissions, both because of the power required to propel their enormous mass and because they tend to run on the dirtiest grade of diesel fuel available, called “bunker” or “residual” fuel.[58]

Other vessels contributing to pollution at U.S. ports include tanker and cruise ships and such harbor craft as tugboats and towboats. All are large consumers of diesel fuel. In the Los Angeles area, oceangoing ships, harbor tugs, and commercial boats emit twice as many smog-forming emissions as all of the area’s power plants combined.[59]

Cargo-Handling Equipment

Every day, thousands of railcar-size container units arrive by ship at U.S. ports, laden with a broad range of imported products. Once on dry land, the containers are then transferred to rail and truck and carried to market. These containers, and the ships that carry them, require special cargo-handling equipment at ports. Primarily powered by diesel fuel, the equipment is used to load and unload containers from ships, locomotives, and trucks, as well as to shuttle those containers around container yards for storage. Cargo-handling equipment includes large gantry cranes used to load and unload ships, yard trucks that shuttle containers, and various others called top-picks, side-picks, straddle carriers, and forklifts. Regulation of off-road diesel equipment lags a few decades behind the regulation of on-road diesel trucks and buses.[60] In fact, emission standards for heavy diesel equipment were not established until 1996 and are much weaker than on-road standards.[61] Indeed, by 2007, new heavy diesel equipment will create 15 times more PM and NO_x pollution than new highway trucks or buses.[62] The Environmental Protection Agency's (EPA) recently adopted off-road diesel rule will significantly strengthen standards for off-road equipment. However, the rule will be phased in from 2008 to as late as 2015 and will cover only new equipment.

Container operations have considerably larger pollution effects than other types of cargo-handling operations at ports. At the Port of Houston, for example, only 42 percent of equipment is associated with container operations, but that equipment accounts for approximately 70 percent of NO_x emissions from on-site port activities.[63] The significant emissions from container-handling equipment is problematic at ports such as Los Angeles and Long Beach, where more than 90 percent of the roughly 2,000 pieces of equipment are associated with container operations.

Heavy Trucks Transporting Cargo to and from Ports

The majority of large trucks that service ports, dropping off and picking up containers, tend to be older and more polluting than long-haul trucks.[64] Moreover, virtually all run on diesel fuel. Not only do the trucks add to existing traffic, but also they often form bottlenecks at terminal entrance gates, idling for long periods and contributing even more pollution.[65] A single port complex can receive thousands of trucks entering and leaving on a typical business day.[66]

Locomotives

More than three-quarters of all train traffic in the United States transports containers, and most of these trains are traveling to or from marine ports.[67] Overall, locomotives are a more environmentally efficient way to transport goods than trucks (see "Rail Versus Road," page 52), but train engines are less heavily regulated—and therefore more polluting—than on-road truck engines.[68] Switching locomotives, used to connect containers on flatbed railcars, are commonly so old as to predate any emission standards. Known as the dirtiest of all rail

Thousands of trucks idle in long lines outside port gates, emitting tons of harmful exhaust.

JANET GUNTER

engines, they are the workhorses of the rail yards located in or near ports, operating nearly nonstop.

Other significant sources of air pollution at ports include cars, light- and medium-duty trucks, personnel vehicles, recreational marine vessels, diesel-powered refrigeration units (reefers), various generators for power, petroleum, and chemical handling and storage equipment, maintenance and repair operations, and a variety of commercial and industrial enterprises commonly colocated at ports. Combined, all of these sources cause a major portion of regional air pollution, leading to the serious health effects described earlier. See "Container Ports Versus Cars," page 7 for a comparison of the pollution levels from the 10 largest U.S. ports compared to the amount of pollution from automobile traffic.

Control measures that can be employed to address all of the major air pollution sources outlined here are detailed in Chapter 2. Marine ports, however, affect many other aspects of the environment and public health and quality of life beyond air quality. While the focus of this report is on air pollution from ports, other important issues are briefly described next.

The new generation of container ships, dubbed post-Panamax because they cannot fit through the Panama Canal, are longer than three and a half football fields, or longer than the Eiffel Tower is tall.

MARINE PORT ACTIVITIES DEGRADE WATER QUALITY

Waste from ships, either dumped directly or leached into water, can cause significant damage to water quality, and subsequently to marine life and ecosystems and human health. These effects may include bacterial and viral contamination of commercial fish and shellfish, depletion of oxygen in water, and bioaccumulation of certain toxins in fish.[69]

Oily bilge water is one major pollutant from ships. Water collected at the bottom of the hull of a ship, known as the bilge, is often contaminated by leaking oil from machinery. This bilge water must be emptied periodically to maintain ship stability and to prevent the accumulation of hazardous vapors. This oily wastewater, combined with other ship wastes, including sewage and wastewater from other on-board uses, is a serious threat to marine life.[70]

Other pollutants from ships are the antifouling additives used in the paint on ships to prevent the growth of barnacles and other marine organisms on ship surfaces. Some of these additives contain tributyltin (TBT), a toxic chemical that can leach into water.[71] Once in the water, TBT is absorbed by marine life. In fact, TBT bioaccumulates, meaning that it is not simply released by marine life but rather builds up in the body and is taken in by predators.[72] Not surprisingly, researchers have found TBT in bottleneck dolphins and bluefin tuna. TBT can cause masculinization of female snails through disruption of endocrine systems.[73] It has also been shown to cause oyster larvae mortality and deformations in oyster shells.[74] In shipyard workers, TBT has been linked to skin irritation, stomach aches, colds, influenza, and such neurological symptoms as headaches, fatigue, and dizziness.[75] While toxic antifouling additives are slowly being phased out of use, these toxic pollutants persist in the marine environment.

Environmentally safe alternatives to TBT are widely available. They include copper-based and tin-free antifouling paints, nonstick coatings that provide a slippery surface on which organisms cannot attach, prickly coatings that also prevent attachment, regular cleaning of the hull, natural biocides that imitate corals' and sponges' antifouling secretions, and electrical current.[76]

Stormwater Runoff

Rain and other forms of precipitation are naturally occurring events that are not in and of themselves polluting. But when stormwater travels as runoff across paved surfaces, it can accumulate deposits of air pollution, automotive fluids, sediments, nutrients, pesticides, metals, and other pollutants. In fact, urban stormwater runoff from all sources, including marine ports, is the largest source of impairment in U.S. coastal waters and the second largest source of water pollution in U.S. estuaries.[77] The high quantities of pollution carried by stormwater, as well as the increased volume, velocity, and temperature of the water as it runs off paved surfaces can lead to dramatic changes in hydrology and water quality.

Virtually all of the land at a port terminal is paved and therefore impervious to water. Scientists have repeatedly demonstrated a correlation between such impervious surfaces and stormwater pollution. For example, a one-acre parking lot produces 16 times the runoff of an undeveloped meadow.[78] Numerous studies have documented the adverse environmental effects from increases in impervious surfaces in a given area, including flooding, habitat loss, water quality decline, and reduced diversity of aquatic life.[79]

A one-acre parking lot produces 16 times the runoff of an undeveloped meadow.

Eutrophication

If waterbodies are overloaded with nitrogen, then algae and plankton can rapidly increase in numbers, forming blooms—sometimes called red or brown tides. This process, called eutrophication, has been identified by the National Research Council as the most serious pollution problem facing estuaries in the United States.[80] The EPA estimates that NO_x air pollution contributes between 12 and 44 percent of total nitrogen water pollution, making it the leading cause of eutrophication.[81] The resulting algal blooms use up the oxygen in water, killing large numbers of fish and shellfish. Such blooms and resulting fish kills have been seen off the New England coast and in other areas of the United States.[82] As noted earlier, ports are major sources of NO_x and thus major contributors to eutrophication.

Oil Spills

Oil spills continue to be a large marine pollution problem. In the year 2000, 8,354 oil spills were reported in U.S. waters, accounting for more than 1.4 million gallons of spilled oil. The majority of these spills have occurred in internal and headlands waters, including the harbors and waterways upon which ports rely.[83]

A large share of oil contamination is the result of "chronic" pollution from such sources as port runoff, unloading and loading of oil tankers, and removal of bilge water, and it leads to three times as much oil pollution as do tanker accidents.[84] However, large, "catastrophic" spills also have a significant impact. One such spill in 2000, resulting from the overfilling of a tank barge, dumped 80,000 gallons of oil into the Houston Ship Channel.[85] In 2002, in Charleston, a tear in a ship spilled

12,500 gallons of oil into the Cooper River, causing much long-term ecological damage and accounting for millions of dollars in cleanup costs. Another spill of 500 gallons in Charleston's Wando Welch Terminal in February 2003 fueled concern that such spills are becoming more frequent because of the port's growth.[86]

Oil spills can harm both ecosystems and people's health, as the *Exxon Valdez* spill showed when it caused massive wildlife die-offs.[87] Oil can diminish animals' insulation by sticking to fur or feathers and can even poison animals that ingest or inhale its many toxins. These toxins also cause long-term damage to the lungs, liver, and kidneys, as well as to the digestive, reproductive, and central nervous systems. Oil may even pass from bird feathers through the pores of eggs a bird is guarding, killing or severely damaging developing chicks still in the shell.[88] Certain contaminants in oil may bioaccumulate, causing health consequences at levels higher up in the food chain.[89] In fact, oil-contaminated seafood poses a risk to humans who eat it.[90]

Each year, dredging of U.S. waterways and harbors produces more than 300 million cubic yards of sediment—enough to cover a four-lane highway with a 20-foot mound from New York City to Los Angeles.

Dredging

Ports are routinely dredged to remove sediment that builds up in ship channels from erosion and silt deposition, as well as to create new channels and deepen existing ones. Each year, more than 300 million cubic yards of sediment in waterways and harbors is dredged to allow ships to pass through.[91] The total amount of these annual "dredge spoils" is enough to cover a four-lane highway with a 20-foot mound from New York City to Los Angeles.[92] Much of this sediment is disposed of in open water or near shore, but some may also be used as fill in various land-based projects.

About 5 to 10 percent of dredged sediment is contaminated with toxics, including polychlorinated biphenyls (PCBs), mercury and other heavy metals, polycyclic aromatic VOCs (PAHs), and pesticides, all of which can cause water contamination and complicate sediment disposal.[93]

Dredging may increase water turbidity (cloudiness), harm habitat, and disturb or kill threatened and endangered species. It may also risk stirring up and releasing buried contaminants. Dredging performed by the Port of Miami in the early 1990s raised concerns over the destruction of seagrasses and the harbor's rocky seabeds, or "hardbottom." Post-dredging hardbottom restoration was fairly effective, but measures introduced to mitigate the loss of seagrass were far less so, successfully replacing only 10 percent of lost seagrass and robbing manatees and sea turtles of an important food source and habitat.[94,95]

The dangers of dredging have taken on even greater significance in recent years, with the growing popularity of post-Panamax vessels, which require channel depths of 45 to 50 feet.[96] In a scramble to remain competitive, many ports are being redredged to deepen or widen their shipping channels. The ports of Charleston, Los Angeles, Long Beach, Miami, Savannah, New York/New Jersey, and Houston are all involved in such projects, creating millions of extra cubic yards of dredge material that will need to be disposed of somewhere.[97]

Alternative methods of disposal of dredged sediment are available. They include construction and industrial uses, fill material for parking lots and roads, landfill cover, shoreline erosion control, artificial reef material, and wetland creation and restoration. The Port of Houston has built marshes and a wildlife habitat with its ship channel sediment, more than 16 million cubic yards of which has been removed since 1998. Over the course of the ongoing project, about 4,250 acres of intertidal salt marsh and a six-acre bird nesting and habitat island are being constructed, and 40 acres of an eroded island are being restored in the largest effort of its kind in the country.[98] The sediment used for the project was deemed nontoxic by a coalition of government agencies called the Beneficial Uses Group. Many organizations are advocating for the beneficial reuse of dredge material, as long as it is not contaminated.[99] A number of groups are exploring further alternative methods for disposal of contaminated dredge.[100]

Specific Threats to Marine Life

The EPA estimates that only half of the continental United States' original wetlands remain; millions of acres have been lost to development. From 1986 to 1997, some 58,500 acres of wetland were lost *each year,* and today, the remaining wetlands are home to one-third of the nation's threatened or endangered species. Because many ports are located either on former wetland sites or near remaining wetlands, they pose grave dangers to sensitive ecosystems and the surrounding areas. The combined effects of dredging, drainage, fill, runoff, and air and water pollutants include disruption of bird migration patterns, loss of biodiversity, increased flooding, chemical contamination of soil and marine life, loss of recreational opportunities, and erosion.[101]

The EPA estimates that only half of the continental United States' original wetlands remain; millions of acres have been lost to development, including development of port terminals.

Water sedimentation from erosion and dredging may also cause irreversible damage to other important centers of biodiversity such as seagrass beds. In addition, toxic contaminants in sediment or runoff may affect commercial fish populations and even make these fish unsafe for human consumption. Three-quarters of all commercial fish are caught in the estuaries in which ports are located.[102] Projects to mitigate this loss of habitat are cropping up throughout the country. As noted earlier, one such effort has been undertaken at the Port of Houston.

Collisions involving boats and marine mammals also contribute to marine mortality. Since 1995, along the East Coast, eight right whales, a species in danger of extinction, have been killed by collisions with ships. These whales must share the coastal waters they need for migration routes with the ships that travel to and from bustling East Coast ports.[103] Manatees also die from collisions with ships or from being crushed beneath barges or between docks and vessels in the shallow estuaries, bays, and canals along which ports are located.[104]

Expansive wharves built on piles can block sunlight from reaching aquatic plants upon which marine wildlife rely for survival. For example, the manatee in Florida, salmon, Dungeness crab, and Pacific herring in Puget Sound suffer from such loss of habitat.[105,106]

Exposure to debris, including plastic bags, netting, and plastic pellets, results in thousands of wildlife deaths each year, through starvation, exhaustion, or ingestion of toxics often found in plastics.[107] Plastic pellets, the raw material for plastic goods, have been found polluting oceans all over the world, as well as 13 of 14 U.S. harbors tested in an EPA study. The pellets can be spilled directly into the ocean from shipping containers or can travel via stormwater discharge. They are known to be ingested by one-quarter of all seabird species and have been found to account for 71 percent of all plastic ingested by seabirds.[108,109] In the Houston Ship Channel alone, 250,000 pellets were found in a single sample during a 1992 study.[110] The effects on seabirds include malnutrition (since they have been found to mistake pellets for food), stomach ulcers, and accumulation of PCBs in the birds' systems.[111] These pellets can also cause problems higher up in the food chain because they can store and transport toxic chemicals in addition to PCBs, including DDE (a breakdown product of DDT) and nonylphenols.[112]

Roughly 10,000 of the 100 million containers shipped annually fall overboard.[113] As containers are stacked ever taller and wider, the odds of spillage increase, which is particularly alarming given that almost one-third of all cargo is hazardous material.[114]

Ballast Water

Ballast water taken in or discharged by large ships to maintain balance is responsible for the transport of thousands of marine species into foreign habitats worldwide. These invasive species often prey upon native species, or compete for resources with them—thus posing hazards to native species and ecosystems and threatening biodiversity and human health.[115] For example, ballast water from cargo ships has been implicated in transporting a South American strain of cholera to the Gulf of Mexico, leading to fish and shellfish contamination.[116] Ballast water itself is also responsible for the introduction of "red tide" algae to the waters of several countries, contaminating shellfish and threatening human health.[117,118] The 3 billion to 5 billion tons of ballast water moved by ships annually, including the 80 million tons discharged into U.S. waters, is only loosely regulated.[119,120]

Roughly 10,000 of the 100 million containers shipped annually fall overboard.

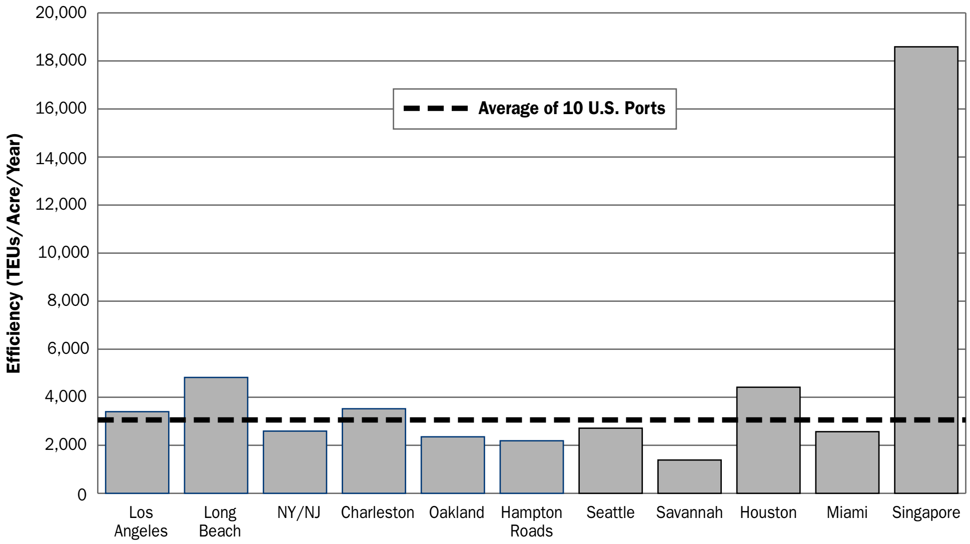
MARINE PORT LAND USE CAN ADVERSELY AFFECT NEIGHBORING COMMUNITIES

As noted, the highly industrialized operations at ports are often in close proximity to residential areas, creating a number of hazards and nuisances for nearby communities. Ports have several available options to avoid developing new terminals near residential areas. They can develop property previously used in an industrial capacity, or they can increase the land use efficiency of existing terminals. The land use patterns at U.S. ports suggest much room for effiency improvements. Of the ten largest U.S. ports, even those that are most efficient in terms of land use—Long Beach and Houston—are only one-fourth as efficient as the Port of Singapore, a model of land use efficiency. The ports of Savannah and Hampton Roads exhibit the least efficient land use, as shown in Figure 1-2. Details of this comparison can be found in Appendix A.

Brownfields

Brownfields are tracts of land developed for industrial purposes, polluted or perceived to be polluted, and then abandoned.[121] The potential costs of cleaning up brownfield sites makes them unappealing to companies looking to locate or

FIGURE 1-2
Land Use Efficiency at 10 U.S. Ports Compared to the Port of Singapore



Note: Data used to prepare this graph are explained in Appendix A.

expand. As a result, new industrial operations are often sited on pristine, undeveloped greenfield land, often leading to a loss of habitat and wildlife, increases in air and water pollution, and urbanization of open space valuable for recreation and aesthetic qualities.[122]

However, developing brownfields offers many advantages to business, communities, and the environment. Businesses benefit from locating on sites near existing transportation infrastructure and with a utility infrastructure already in place, while cleaning up contamination that poses a danger to both the community and the environment.[123] Several ports, including the ports of Seattle and Long Beach, have demonstrated the feasibility of brownfield redevelopment on their properties.[124,125]

Noise Pollution

With machines, trucks, and ships operating 24 hours a day, and pile driving and blasting from channel maintenance and expansion, ports can be loud. The noise pollution from port activities, in addition to being annoying, can have serious negative health effects. Noise pollution has been linked to hearing impairment, high blood pressure, sleep deprivation, reduced performance, and even aggressive behavior.[126] Additionally, noise from ship engines may disturb marine mammal hearing and behavior patterns, as well as bird feeding and nesting sites.[127,128]

With those dangers in mind, several ports are taking steps to reduce noise pollution. The ports of Stockholm, Helsinki, Copenhagen, and Oslo are working together to reduce noise emitted from cruise ships, for example, and a new law passed in March 2003 in Valencia, Spain, calls for a reduction in noise pollution and will most likely regulate that city port's equipment and machinery.[129,130]

Light Pollution

Artificial lights at ports, sometimes burning 24 hours a day, can have negative effects on wildlife, including disorientation, confusion of biological rhythms that are adapted to a day/night alternation, and a general degradation of habitat quality. This pollution can cause high mortality in animal populations, particularly to birds attracted to brightly lit buildings and towers; they can circle these structures until they die of exhaustion or fly head-on into them.[131,132] At ports bordering residential neighborhoods, bright nighttime lights and the flashing lights of straddle carriers and forklifts can affect nearby residents, disrupting biological rhythms and causing stress and annoyance.[133,134]

People of color and low-income families live next door to more polluters than any other group in the United States.

Environmental Justice

People of color and low-income families live next door to more polluters than any other group in the United States. As a result, these communities often suffer from higher rates of illness and diminished quality of life, by comparison with residents of middle-class suburbs and affluent communities. Environmental injustices occur next to marine terminals just as they do next to other industrial and waste disposal sites such as power plants or landfills.

Communities next to marine ports are severely affected by heavy traffic and the noise and air pollution that come with it. While many communities are becoming more active on these issues, injustices continue across the country and are one of the major motivating factors to clean up industrial marine port activities.

CHAPTER 2

Improving Port Environmental Management Practices

This chapter reviews cost-effective approaches to reduce air and water pollution from port-related activities. Recommended approaches are presented according to the source of port pollution (marine vessels, cargo-handling equipment, off-site trucks, and locomotives) and also as discussions about stormwater programs, construction design features, and other measures. Recommended measures for each air pollution source focus on reducing emissions from diesel engines through the "five R's":

- **Replace.** We recommend replacing the oldest, most polluting vehicles, equipment, and vessels with the cleanest available new models.
- **Repower.** Vehicles, equipment, and vessels with a significant amount of useful life left can often be repowered with cleaner new engines, simply swapping the old engine for a new one.
- **Retrofit.** In many cases, exhaust systems can be retrofitted with emission controls—also known as after-treatments—that significantly reduce exhaust emissions.
- **Refuel.** Some after-treatments require the use of cleaner fuel, which in itself can reduce emissions to some extent.
- **Reduce idling.** Opportunities abound to reduce idling, a practice that wastes millions of gallons of fuel in addition to polluting.

We recommend the following measures to maximize emission reductions from port-related diesel pollution sources:

- Clean up harbor craft, such as tugboats, through engine repower and retrofit programs. Limit idling of **oceangoing vessels and tugboats** by providing electrical power at docks and requiring ships and tugboats to "plug in" to shoreside power while at berth. Require ships to use the cleanest grade of diesel fuel possible, with a sulfur content of 15 to 2,000 parts per million (ppm). Finally, where possible, create incentives or otherwise promote the use of emission controls on oceangoing vessels.

ASSUMPTIONS BEHIND COST-BENEFIT DISCUSSIONS
The following four criteria were considered in the discussion of each recommendation in this section:

Available technologies. Diesel and alternative fuel and engine technologies have improved over the past few decades and continue to progress at a rapid pace. Control technologies have been further developed even during the writing of this report. We attempt in these pages to summarize only those technologies available on the market at the time of this writing.

Pollutants reduced. Emission reductions are reported based on either (a) verified or certified levels or (b) technical studies reported in trade journals or through professional organizations.

Unit costs. Because some of these measures were developed for direct application at the Port of Los Angeles, cost estimates and other criteria may differ slightly when applied to other ports. However, many of these measures are already in practice at ports around the world and are likely to be feasible elsewhere.

Cost-effectiveness. Cost-effectiveness data is presented in this report as a range to reflect variable assumptions such as the cost of certain fuels and control equipment, potential emission reductions, actual usage or mileage, and existing engine age.

▸ Make it a priority to retire the oldest **cargo-handling equipment**—that is, equipment that is ten or more years old. Then commit to replacing it with the cleanest available equipment and fuel choices—specifically, equipment that is designed to run on alternative fuels—where possible. Make it a priority to retrofit existing equipment that is less than ten years old so that it, too, can run on the best available control technology, such as diesel particulate filters (DPFs) with lean NO_x catalysts (LNCs) where feasible and diesel oxidation catalysts (DOCs) where DPFs are not practical. Also, switch to cleaner diesel fuels, such as low-sulfur fuel used with DPFs and diesel emulsions with DOCs.

▸ Create an incentive program for **off-site trucks** that encourages "fleet modernization"—the retirement of older trucks and their replacement with modern lower-emitting trucks. Also offer incentives for the installation of pollution controls, such as DPF–LNC combinations where low-sulfur diesel is available, or DOCs or flow-through filters where low-sulfur diesel is not available. Also, make cleaner fuels, such as diesel emulsions or low-sulfur diesel, available to off-site trucks. Finally, minimize truck idling by using electrical plug-in devices and automatic idle shutoff devices, and also by enforcing idling limits.

▸ Repower or replace all **switching locomotives** that do not meet the EPA Tier 0 standards with electric hybrid or alternative-fuel engines. Install engine after-treatments where possible. Require automatic engine-idling controls to minimize unnecessary idling. Finally, commit to using cleaner fuels, such as on-road grade diesel.

Each recommendation discusses the available technology, the pollutants reduced by available technology, the unit cost of the technology, and its cost-effectiveness.

Also, for each recommendation, a discussion of the potential benefits and drawbacks of implementation is included, and, where possible, examples are provided (see "Assumptions Behind Cost-Benefit Discussions, page 18"). Other recommendations discussed include model programs to reduce polluting stormwater runoff at ports and construction design features to control pollution at ports.

MARINE VESSELS

We recommend four major changes to reduce pollution of oceangoing ships and harbor craft: (1) fund the retrofit and repower of existing harbor craft; (2) reduce emissions of oceangoing ships and harbor craft while at berth by providing shoreside power to run necessary systems; (3) reduce emissions by using cleaner fuels in the vessels; and (4) control emissions from oceangoing ships.

Harbor Craft Retrofits and Repowers

Ports should fund an incentive program to encourage tugboat owner/operators to repower and retrofit vessels by replacing older engines with new, lower-emitting engines and then adding after-treatment systems. Upon receiving a cash grant,

CALCULATING COST-EFFECTIVENESS

Calculations used to determine cost-effectiveness are a common tool for evaluating the relative benefits of an emission-reduction strategy. The results are typically given in cost per unit of emissions reduced. For example, $4 per pound of particulate matter (PM) means that the strategy will cost $4 for every pound of particulate matter it reduces over a project's life.

Cost-effectiveness estimates vary significantly depending on the pollutant to be controlled, as well as on the type of source to be controlled. Many measures described here reduce multiple pollutants, a plus on the ground but a complicating factor when comparing cost-effectiveness. Higher levels of emission reductions translate into lower cost-effectiveness per ton of emission reduced; the lower, the better. However, the higher cost-effectiveness of PM reduction strategies must be qualified by the fact that PM is much more toxic than NO_x. Health effects of PM normally occur at concentrations an order of magnitude lower than for NO_x.

There is no single cost-effectiveness threshold that is appropriate for all projects. However, several California rules and programs provide examples. The California Air Resources Board (CARB) has historically adopted rules that cost $5,100 per ton ($2.55 per pound) of NO_x reduced or less and up to $32 per pound of PM reduced. The Carl Moyer heavy-duty diesel vehicle incentive program originally set the minimum cost-effectiveness at $12,000 per annual ton of NO_x reduced. Other Southern California incentive programs set the cost-effectiveness criteria as low as $6,000 per ton of NO_x reduced for on-road projects and $3,000 per ton of NO_x reduced for off-road projects, due to a high degree of competition for incentive funding.

Because new engines are manufactured according to tighter regulations, the marginal benefit of applying pollution reduction measures goes down, as the cost goes up. As a general rule, the lower the cost-effectiveness of a project, the better it is.

Source: California Air Resources Board, *Staff Report: Initial Statement of Reasons, Proposed Diesel Particulate Matter Control Measure for On-Road Heavy-Duty Residential and Commercial Solid Waste Collection Vehicles*, June 6, 2003: 56.

tugboat owner/operators would be required to take their vessels out of service on a specified schedule and install new propulsion engines or after-treatment systems or both. In prioritizing projects, criteria to consider include the emission rates of older engines, the hours the vessel operates, the age of the vessel's engines, the timetable for replacement, and the willingness of the tugboat owner/operator to remain in the same coastal waters after improving the vessel.

Most tugboats use two large diesel engines for main propulsion, along with one or two smaller engines for auxiliary power. Main propulsion engines have useful lives in excess of 20 years; in fact, one survey in the San Francisco Bay area documents many that have been maintained in service for well over 30 years. Older engines, in particular two-stroke engines, tend to be considerably more polluting than new engines available to replace them.

Pollutants Reduced Many existing marine engines can be tuned for higher fuel economy (with higher NO_x emissions) or for lower fuel economy (with lower NO_x emissions). Because no international or national emission standards apply to these older engines, operators have no economic incentive to tune them for low NO_x emissions. While NO_x reductions from tugboat repowering have been well documented, it is likely that PM, VOCs, CO, and CO_2 emissions will be lowered as well because newer engines are generally more fuel efficient. Additionally, engine after-treatments, such as oxidation catalysts, can further reduce PM, VOCs, and CO.

Specific emission reductions will vary by tug, depending on the emissions rate of existing engines, the service provided by the tug and how much it is operated, and the emission rate of replacement engines. Estimates of the annual emissions reduced due to the upgrade of "average" tugs are listed in Table 2-1. Estimates are for tugs of various sizes with two main propulsion engines, and operating 2,000 hours per year. More information on tug emissions can be found in Appendix B.

Addition of an oxidation catalyst would reduce particulates by 25 to 50 percent. Oxidation catalysts also reduce VOCs and CO; typical reductions from on-road vehicles can be as great as 90 percent for both pollutants.

Unit Cost Average prices for replacement engines range from $376,000 to $433,000 per unit.[1] Funding programs usually cover the cost of the new engine only, but labor and dry dock costs can run roughly $200,000. Tug operators usually recoup this extra

TABLE 2-1
Emission Reductions from Tugboat Engine Replacements

Engine Size (Horsepower)	NO_x Emissions Rate (g/bhp-hr)	Annual NO_x Emissions (tons)	Emission Rate for Replacement Engines (g/bhp-hr)	Annual NO_x Emissions from Replacement Engines (tons)	Annual NO_x Emissions Avoided (tons)
1,500–1,999	12.98	129	7.25	67	66
2,000–2,499	14.5	196	7.46	102	94
≥2,500	12.67	446	7.16	252	194

Source: Based on data collected in the San Francisco Bay area.

cost by selling the used engine, at roughly $150,000 for a large engine, and with fuel savings from the improved fuel economy of new engines.[2] Oxidation catalysts cost anywhere from $8 to $10 per horsepower, usually costing more per horsepower for larger units. A tugboat with two 2,000-horsepower engines would cost roughly $50,000 to retrofit with an oxidation catalyst, including the support frames and ductwork necessary for large engines.

Cost-Effectiveness The purchase of replacement engines yields a cost per ton of NO_x avoided between $200 and $600. Cost-effectiveness was not evaluated for oxidation catalysts.

EXAMPLES ▶ There are a number of precedents for successfully repowering tugs with new replacement engines. The majority of the 50 to 60 tugboats in service in the Los Angeles area have been repowered through state and local programs.[3] Tugs have also been repowered in the San Francisco Bay area and in New York Harbor. Hong Kong's Star Ferry has been fitted with an oxidation catalyst, and a retrofit project on New York ferries testing other retrofit technologies, such as selective catalytic reduction (SCR) and diesel particulate filters (DPFs), started in May 2004.[4,5]

DISCUSSION ▶ Replacement programs are relatively simple to administer and can be extremely cost-effective when applied to larger tugs with 2,000 or more hours of operation per year.

Oxidation catalysts are a relatively simple control technology that does not require special maintenance. It is wise to fit vessels with an oxidation catalyst or other after-treatment system while they are already in dry dock for engine replacement. However, it should be noted that operators who install oxidation catalysts will need to use a cleaner grade of marine diesel, with sulfur levels no higher than 500 parts per million.

Tug operators must be persuaded to sign a binding agreement to take their boats out of service temporarily to allow their engines to be replaced. Boats are usually out of service for one month while engines are replaced. Additionally, operators must agree to operate "permanently" in the same coastal waters, in order to ensure that the benefits of the repower remain in the area.

Plugging in to shoreside power should make use of near-zero or zero-emissions technology to provide cleaner power to docked vessels.

Shoreside Power

Marine vessels contribute substantial quantities of air pollution by running onboard diesel auxiliary engines for power while they are at dock. This "hoteling," as it is known, contributes significant but unnecessary pollution, aggravated by auxiliary engines run on bunker fuel—the dirtiest grade of diesel. This measure therefore employs a strategy of hooking docked marine vessels to less polluting power sources and is a critical step to reducing emissions from marine vessels. Plugging in to shoreside power, also known as "cold ironing," should make use of near-zero or zero-emissions technology to provide cleaner power to docked vessels. Several ports throughout the world, including Los Angeles, California; Juneau, Alaska; and

Tom Plenys

Long cables connect a large container ship to shoreside power.

Göteberg, Sweden, have already implemented shoreside power measures, and they serve as examples.

Specifically, this measure calls for ports to (1) require shoreside power as a condition of new terminal leases or renewals; (2) invest in infrastructure for electric power; (3) develop shoreside power for port-operated facilities; (4) subsidize the development of shoreside power for harborcraft; and (5) provide funding to offset the costs of retrofitting vessels to accommodate shoreside power. For this measure to be successful, sufficient power must be available for use at the wharves. Three specific power source options should be considered: a new installation or an upgraded substation, fuel cell units, and a "power barge."

Installation or upgrade of a port area substation would be appropriate for terminals requiring high power loads, such as cruise terminals or very large cargo areas. Requirements would include 3- to 15-megawatt transformers that meet varying voltage requirements, and flexible connections for vessels loading or off-loading at dock. The emissions associated with the electrical generation supplied by the substation must be significantly lower than the emissions generated by auxiliary engines on the receiving vessels to ensure meaningful reductions, making the use of renewable energy sources or natural gas appropriate. Any port-operated substation should employ the best available control technology (BACT) to reduce pollution impacts.

The second power-generation option is the installation of one or two fuel cell units (200 to 250 kW) at berths where smaller ships (tugboats, commercial fishing boats, and crew/supply boats, for example) are hoteling, and where natural gas is available as a fuel source.

The third option is a power barge equipped with fuel cells that can maneuver within a port to supply power at multiple locations. The fuel cell application might be particularly well suited for cargo ships in berth where diesel generators producing auxiliary loads are in the 1- to 2-megawatt range, as opposed to cruise ships, for which the load can be an order of magnitude higher. Fuel cell technology offers many significant enhancements over existing diesel generators with respect to marine applications. These enhancements include very low exhaust emissions, inherently low vibration and sound levels, and improved thermal efficiency (particularly at low-load levels). The U.S. Navy is one of many navies considering the use of integrated electric plants employing fuel cells in future ship designs. However, ships employing fuel cells for propulsion are not yet commercially available. In fact, fuel cells for auxiliary power or shoreside power generation are also still in the development stage and therefore cannot yet compete with existing technologies on a cost basis. For more information on fuel cells, see Appendix B.

Pollutants Reduced Based on currently available technology for large power applications (greater than 100 kilowatts), emissions from cold ironing would be far below the

TABLE 2-2
Comparison of Emission Rates of Power Generated from Auxiliary Diesel Engines, Conventional Power Plants, and Fuel Cells (lb/MW-hr)

Pollutant	Diesel Fuel[a]	Average U.S. Power Plant[b]	Fuel Cell[c]
NO_x	18.3	3.52	0.002–0.03
CO	25.4	0.33	0.002–0.142
THC	7.6	N/A	N/A
NMHC	N/A	0.04	0.001-0.081

Source: National Fuel Cell Research Center, University of California, Irvine. Power plant data based on the Energy Information Administrations' *Electric Power Industry 2000: The Year in Review* and EPA's *National Emission Trends*.

a Based on naturally aspirated auxiliary diesel engine
b Based on all utility production in 2000 combined, including coal (56 percent), petroleum (2 percent), natural gas (10 percent), nuclear (23 percent), and hydro (8 percent)
c Depends on fuel cell technology employed: PAFC (phosphoric acid fuel cell) or MCFC (molten carbonate fuel cell)

emissions from diesel power generation. The type of fuel used to generate shoreside electricity at a port for either technology approach, of course, will largely determine the level of emissions reductions this strategy will achieve. For cold ironing, the use of more renewables, cleaner fuels, and BACT for power plants in a utility's portfolio will also play a role in overall emissions reductions and will further alleviate concerns about the issue of transferring the pollution problem from the port area to the location of the power generation plant.

The EPA has developed estimates of the current mix of technology used in applications such as auxiliary diesel engines.[6] The range of horsepower ratings for this class of engines is from 50 to 750 hp. Table 2-2 compares current emissions from auxiliary diesel engines to emissions from average U.S. power plants and two different fuel cell technologies. The average power plant in the United States is at least five times as clean as a marine diesel engine.[7] Additionally, notoriously dirty coal-fired power plants alone release only one-third as much NO_x than marine diesel engines.

Unit Cost One major factor inhibiting cold ironing and fuel cell usage for commercial marine applications is its high cost. The price tag for construction of necessary substation(s) along with the transformers, cable, and connectors required to implement cold ironing will vary for different ports. The Princess Tours cruise line spent $2 million to retrofit four cruise ships and an additional $2.5 million on shoreside construction for electrical hookups at its Juneau, Alaska, terminal.[8] The electrical hookups, or "festooning" system, in Juneau had to accommodate 25 feet of tidal variation, winter ice, and severe storms, unlikely events to occur at ports in the lower 48 states.[9] Operating costs of electrical power versus ship fuel used in Juneau are comparable. Although the electrical power there is inexpensive at $0.045 per kilowatt-hour, as more expensive lower-sulfur marine fuel becomes mandatory, higher-priced electrical power in other regions will remain competitive.[10]

Cost-Effectiveness Because this measure has so far been implemented in only two U.S. locations (Alaska and Los Angeles) and because costs are likely to vary significantly, cost-effectiveness should be estimated on a case-by-case basis. However, the Port of Long Beach completed its year-long feasibility study in early 2004 on electric power for ships at berth and found shoreside power to be cost-effective for many applications including cruise and container ships.[11]

EXAMPLES ▶ The Swedish port of Göteborg has led the way on commercial shoreside power installations. The Göteborg project alone has reduced 80 tons of NO_x, 60 tons of SO_x, and 2 tons of PM emissions annually because of shoreside power used by ferries and several cargo vessels.[12] Efforts are currently under way to replace fossil-fuel-based shoreside energy with nearby wind energy. Other Northern European ports, such as Lubeck, Germany, have plans for similar electric ship-to-shore projects.

The Princess Tours cruise line followed suit in 2001, installing shoreside power at its terminal in Juneau, Alaska, after incurring several fines averaging $27,500 each for visible smoke from its cruise ships.[13] Although some minor technical difficulties arose during the design and construction phases of the project, they proved surmountable. In fact, Princess reports that the project is working well and that it is pleased with the program overall.[14] Each ship takes 30 to 45 minutes to hook up to the electrical power while docking, requiring an average of 6 to 10 megawatts to run full cruise ship electrical service.

Shoreside power could achieve enormous emission reductions from large oceangoing vessels, which are difficult to regulate because most are operated under foreign flags.

California ports are also slowly catching up. The Port of Oakland installed power plug-ins on a new tugboat wharf in 2001 so that tugboats could shut down their engines while at berth.[15] Oakland considers this too expensive for larger oceangoing vessels; however, the ports of Los Angeles and Long Beach are both actively exploring the possibility. The City of Los Angeles signed a memorandum of understanding with six shipping lines to participate in the development of its alternative marine power (AMP) program, and the port has recently completed electrification of a berth at the China Shipping terminal (see “China Shipping Plugs In,” page 24).

Some ports are beginning to use shoreside power for dredging equipment. Electric dredges have been used in various projects in Texas and California.[16]

DISCUSSION ▶ Cold ironing has been practiced in the past and apparently continues to be used by the U.S. Navy. It could achieve enormous emission reductions from large oceangoing vessels, which are difficult to regulate because most are operated under foreign flags. Terminal workers, especially those aboard ships on nearby docks, gain improved working conditions because they are no longer subjected to the exhaust and noise of the auxiliary engines. Of course, shoreside power is also an opportunity to develop such alternative and petroleum-independent power sources as fuel cells.

The viability of cold ironing applications and their ability to power vessels at dock depends greatly on the infrastructure outlay. A surplus of available power on the order of 2 to 10 megawatts is necessary, and land for substation development and cable-laying right-of-way must be available close to the terminals.

In addition, some ships may not have the correct electrical hookups to allow the proper connection. This problem can be overcome, however, by making agreements

CHINA SHIPPING PLUGS IN

The Port of Los Angeles unveiled the world's first electrified container terminal in June 2004, where ships can plug in to shoreside power while at berth instead of continuously running their dirty diesel engines to generate electricity. The new China Shipping Line terminal facility is expected to eliminate at least 1 ton per day of nitrogen oxides and particulate matter for each ship that plugs in, and can accommodate two ships at one time, according to the Port of Los Angeles. The Port of Los Angeles also reports that one vessel call is equivalent to about 69,000 diesel truck miles—enough to drive around the world nearly three times.

The shoreside power facility is part of a legal settlement negotiated by NRDC, Coalition for Clean Air, Communities for a Better Environment, and two San Pedro homeowner groups, who sued the Port and City of Los Angeles in 2001 alleging they had approved the China Shipping Line terminal without considering or mitigating harm to neighboring communities. The final settlement also requires the port to use terminal tractors that run on cleaner, alternative fuels instead of diesel; to evaluate the feasibility of cleaner marine fuels; and to minimize aesthetic impacts of cranes. The port must also establish a $50 million fund for mitigation of air quality and aesthetic impacts in the community, including $10 million to clean up old trucks.

Sources: Port of Los Angeles, Alternative Marine Power, 21 June 2004, http://www.portoflosangeles.org/Environmental/AMP.htm (29 June 2004).

or memoranda of understanding with shipping lines and terminal operators during lease agreements or renewals.

The Port of Los Angeles reports that pollution from one vessel call is equivalent to about 69,000 diesel truck miles—enough to drive around the world nearly three times.

Cleaner Fuels

Ports should significantly reduce emissions from marine vessels by requiring reduced sulfur content of marine diesel fuel. Large oceangoing marine vessels are notorious for running on bunker fuel, the dirtiest grade of diesel. We recommend that ships run on fuel with the lowest sulfur content possible, from 15 to 2,000 ppm.

Higher sulfur content fuels cause increased emissions of NO_x, SO_x, and PMs. Although cleaner running vessels are slowly penetrating the U.S. market (see "Quiet, Clean, Hybrid Marine Power," page 33), current marine diesel fuel can reach levels as high as 50,000 ppm sulfur (5 percent by weight). These high sulfur levels are approximately 15 times as great as current EPA non-road diesel fuel standards and 100 times as great as current EPA on-road fuel standards. Several lower-sulfur and alternative fuel options are available that are compatible with existing oceangoing and harbor-craft marine vessel engines, including fuels currently used for nonroad and on-road vehicular applications.

According to the International Organization for Standardization (ISO 8217), 19 categories of marine residual fuels are available internationally. The lowest sulfur content fuel grade must have sulfur content less than 1 percent sulfur (10,000 ppm). Table 2-3 summarizes the most common of these marine fuel specifications under ISO 8217.

The widely accepted average for marine bunker fuels in use by ships around the globe is approximately 2.7 percent sulfur (27,000 ppm). For comparison purposes,

Table 2-4 lists the various national and international sulfur content fuels that are either in use today or slated for use in the near future. Because these fuels are available nationally, and because global conventions have recognized the need for lower sulfur content fuels (see Appendix D for more information on international rules governing marine fuels), several cleaner-fuel options are available for marine propulsion and auxiliary engines, as well as for on-board, backup generators. In addition, the use of cleaner, lower-sulfur fuels enables the use of a wider range of control technologies on these engines.

Some marine vessels will be required by the EPA under its recent nonroad rule to use a cleaner blend of diesel (500 ppm sulfur) starting in 2007, and an even cleaner blend (15 ppm sulfur) starting in 2012.[17] (See Chapter 3 for details.)

TABLE 2-3
Summary of Marine Fuel Specifications

Marine Fuel Specification	Maximum Sulfur Content
Heavy fuel oil (HFO)—includes IFO380 and IFO180 (also known as bunker fuel, or BFO)	5% or 50,000 ppm
Marine Diesel Oil (MDO)—DMC	2% or 20,000 ppm
Marine Diesel Oil (MDO)—DMB (slightly lower density and viscosity than DMC)	2% or 20,000 ppm
Marine Gas Oil (MGO)—DMA	1.5% or 15,000 ppm
Marine Gas Oil (MGO)—DMX	1% or 10,000 ppm

Source: Marine fuel specifications according to the International Organization for Standardization (ISO 8217:1996) available at www.bunkerworld.com/technical/iso8217_res.htm.

Note: Marine diesel oil and marine gas oil are considered distillates and marine diesel oil is a blend of gas oil and heavy oil. Wihin each fuel grade category, the sulfur content of available fuels for purchase can be significantly lower than the maximum allowable sulfur content specified in the table.

TABLE 2-4
Summary of Sulfur Content in Various Fuels

SULFUR CONTENT		
percent	ppm	Example of Current Usage or Status
4.5	45,000	Maximum allowable level for marine fuels in the International Convention for the Prevention of Pollution From Ships (MARPOL)
2.7	27,000	Average for marine fuels (widely accepted global average)
1.5	15,000	Recently proposed by EU as its cap for marine vessels in the North Sea, English Channel, and Baltic Sea
0.5	5,000	Current U.S. EPA nonroad diesel fuel standard, which does not include marine vessels
0.1	1,000	Recently proposed by EU for marine vessels while berthed in EU ports beginning in 2010
0.05	500	Current U.S. EPA on-road diesel fuel standard
0.015	150	Current California on-road diesel fuel standard
0.0015	15	U.S. EPA on-road and California on-road and off-road diesel planned for mid-2006

Sources: *Draft Regulatory Support Document: Control of Emissions From Compression-Ignition Marine Diesel Engines at or Above 30 Liters per Cylinder,* Office of Transportation and Air Quality, U.S. EPA, April 2002, available at europa.eu.int/comm/environment/air/transport.htm#3; and EU Directive 99/32/EC, available at www.dieselnet.com/standards/fuels/.

Other cleaner-burning fuels that may be used for ferries, harbor craft, and other non-oceangoing vessels include emulsified diesel, biodiesel, compressed natural gas (CNG), or liquefied natural gas (LNG). These are potential options that can result in significant reductions in NO_x and PM emissions.

Prior to regulation, a transition to cleaner marine fuels can be facilitated through the use of incentive programs, including harbor fees or taxes that favor ships using cleaner fuels (see "Sweden Harbor Fees Deter Dirty Ships," page 32). In the absence of mandated emission control areas, incentive programs would have more success if implemented nationally or at least regionally.

Pollutants Reduced The three primary pollutants affected by the use of lower-sulfur fuel are SO_x, NO_x, and PM. Except for SO_x, the emission reduction value of lower-sulfur fuel is highly variable and depends greatly on the make, age, and quality of maintenance on the engine, the duty cycle, and many more factors.

The amount of sulfur in ship emissions is equivalent to the amount of sulfur in the fuel. Therefore, the amount of SO_x that will be reduced with use of the lower-sulfur diesel is a direct function of the level of sulfur reduced. Typically, however, a reduction from standard marine fuel with 2.7 percent sulfur content to a fuel with 0.3 percent sulfur content will yield approximately a 90 percent reduction in SO_x emissions.[18]

The cleaner fuel will affect PM emissions, both directly and indirectly. Because both SO_x and NO_x contribute to PM formation, reductions in these emissions also reduce particulate levels. PM is also reduced directly by the cleaner fuel.

According to the EPA, a switch of all vessel operations within 175 nautical miles of the U.S. coast would result in significant reductions in PM and SO_x emissions.[19] Table 2-5 shows that PM and SO_x can be reduced dramatically by changing to lower-sulfur diesel in marine engines.

PM and SO_x can be reduced dramatically by changing to lower-sulfur diesel in marine engines.

NO_x reductions are more difficult to estimate. A reduction of approximately 10 percent may be realized when a ship uses a distillate fuel instead of heavy fuel oil.[20] Further NO_x reductions may be achieved when utilizing CARB on-road diesel due to lower aromatics, but these emission reductions have not been widely demonstrated in practice.[21]

Unit Cost Whereas the price and quality of bunker fuel vary greatly, distillate fuels typically cost 50 percent more.[22] As with on-road applications, the price paid for marine fuel will fluctuate with the market and the purchase volume.

TABLE 2-5
Pollutants Reduced by Lower Sulfur Content Marine Fuels

Marine Fuel Sulfur Content	PM	SO_x
1.5% (15,000 ppm)	18%	44%
0.3% (3,000 ppm)	63%	89%

Source: Office of Transportation and Air Quality, U.S. EPA, "Draft Regulatory Support Document: Control of Emissions From Compression-Ignition Marine Diesel Engines at or Above 30 Liters per Cylinder," April 2002.

Note: Reductions are as compared to 27,000 ppm or 2.7 percent sulfur content.

SCX, Inc., a ferry manufacturer, successfully completed a demonstration project utilizing 15 ppm sulfur diesel in a ferryboat at the Port of Los Angeles. British Petroleum's ECD-1 fuel was used for the project, and the success encouraged British Petroleum to change its specifications to commit to the IMO marine fuel requirement of a minimum 60-degree Celsius flashpoint and recruit a local distributor to supply the fuel within the port.[23,24] The cost of the ECD-1 fuel will be nearly twice that of bunker fuel.

Cost-Effectiveness Because of the limited implementation of this measure in the United States and because costs are likely to vary significantly, cost-effectiveness cannot be accurately estimated.

EXAMPLES ▶ In addition to the SCX, Inc. demonstration project and many others like it, Samsung Heavy Industries, a major cargo ship manufacturer, has designed one of its newest ships, the Orient Overseas Container Line (OOCL) Long Beach, to operate on lower-sulfur fuel (although it is not doing so at the moment). OOCL plans to acquire a few more ships in this class, capable of carrying more than 8,000 containers, and then operate them at the Port of Long Beach.

Water taxis in Newport, Rhode Island, are running on 100 percent biodiesel, as does a larger boat at Channel Islands National Park.[25] The Port of Helsinki uses lower-sulfur diesel (30 ppm) in several marine vessels. Helsinki has also proposed the use of cleaner fuels in marine vessels for its large new Vousaari Container Terminal Complex.

DISCUSSION ▶ As Table 2-3 indicates, a number of lower sulfur content fuels are on the market. Their availability should alleviate the concerns about supply of lower-sulfur diesel fuel for marine vessels. For example, because of California's current on-road diesel fuel standards, today's diesel users should be able to rely on the availability of 150 parts per million (ppm) sulfur content fuel, and by mid-2006 diesel with 15 ppm sulfur content will be widely available. Furthermore, California's 2003 proposed state implementation plan for air pollution reduction includes provisions that would require the 15 ppm sulfur on-road diesel scheduled for availability in mid-2006 to also be available as marine fuel.[26]

Across the Atlantic, the European Union has made some headway in using lower sulfur content fuels. Before Annex VI of MARPOL was officially ratified, the European Union adopted a directive (E.U. Directive 99/32/EC) to strengthen sulfur limits in marine fuels so that member countries would comply in the meantime. The directive will impose a 1.5 percent (15,000 ppm) sulfur limit on all vessels that travel in the North Sea, the English Channel, and the Baltic Sea. Additionally, it is being strengthened to require all passenger vessels in regular service to or from any port in the European Union to use fuel with a sulfur limit of 1.5 percent. And finally, a 0.2 percent (2,000 ppm) and eventually a 0.1 percent (1,000 ppm) sulfur limit will be imposed on all inland water vessels and all ships while they are berthed in ports inside the European Union. (As we went to press, EU representatives came to political agreement about dropping the first 0.2 percent fuel sulfur requirement, but retaining the 0.1 percent fuel sulfur requirement starting in 2010. For more details, see Appendix D.)

Although the EU directive has not been formally ratified, refiners have already begun to supply 2,000 ppm distillates to the European market. The majority of marine gas oil meets the 2,000 ppm threshold, and half of the supplying countries are providing 2,000 ppm marine diesel oil to some degree. Market surveys performed in the European Union found that sulfur distillates of less than 2,000 ppm are available at approximately 95 to 99 percent of EU ports.[27,28]

Because ships will be required to use 2,000 ppm sulfur fuels only while berthed in an EU port, they can take on the required fuel in the port of call. Thus the in-port requirement will apply to all vessels, regardless of their flag state and regardless of their last port of call. The United States should follow suit by requiring 2,000 ppm or less sulfur content fuel for all oceangoing vessels while berthed at ports nationwide. According to Port of Los Angeles staff, one shipping line is currently testing the use of 2,000 ppm sulfur content fuel while berthed at the port.[29]

Regulatory agencies, vessel operators, fuel providers, and environmental groups are now discussing the technical and safety considerations of using lower sulfur content fuels on large oceangoing vessels. Concerns include the flashpoint, the lubricity, and the ability to switch between multiple fuels on board the vessels.[30] (See Appendix B.) In the area of fuel logistics, ports face some uncertainties with respect to the technical feasibility and constraints on-board ships to store and use two different grades of fuel. Modern ships may not have two separate fuel tanks. Some can use only the lower-sulfur fuel; some must be retrofitted for second fuel grade capabilities. Historically, distillate fuels, not heavy fuel oil, have been used in harbors for maneuvering and start-ups of marine engines. Marine distillate fuels were more reliable and did not require preheating for start-ups.

The United States should follow suit by requiring 2,000 ppm or less sulfur content fuel for all oceangoing vessels while berthed at ports nationwide.

Oceangoing vessels average three engines, with one to two main engines and one to two auxiliary engines per ship.[31] In anticipation of the EU directive, one company has developed an automatic system for switching between fuels. The design protects the integrity and efficiency of fuel pumps and fuel valve injection nozzles from the change in viscosity and also addresses the risk of fuel pumps sticking because of temperature variations.[32]

In addition, because most marine vessels have more than one engine, they should be able to carry and use two grades of fuel. According to an EU report on the subject, "There are still a significant number of vessels built with the capacity to switch to distillates for the purposes of starting engines as well as maneuvering in port."[33]

Cleaner Ships

Although ports cannot require oceangoing ships to meet more stringent emission standards, ports should set up incentives for ships making frequent calls at a port to use emission controls. Incentives should take the form of differentiated harbor fees or direct cash grants to shipping lines.

Oceangoing ship emissions are virtually unregulated because they traverse international boundaries. Moreover, international standards will not come into force until next year, and these standards will be quite weak and will apply only to newer ships.

Therefore, creative local and national incentives or requirements are necessary if ship emissions are to be reduced in coastal areas.

Sweden's differentiated harbor fees are a good example of what can be done by way of incentives (see "Swedish Harbor Fees Deter Dirty Ships," page 32). When ships enter Swedish harbors, discounts are given to those using lower-sulfur fuel or NO_x emission controls. California is evaluating this strategy, along with economic incentives for cleaner ships through the addition of pollution controls or the replacement of engines with cleaner models.[34]

Available Technologies Selective catalytic reduction (SCR) can achieve NO_x reductions of 80 percent or more. Although it was developed for such stationary sources as power plants, it has been successfully adapted to large marine vessels. The evidence indicates, however, that the cost of this technology can be prohibitive and that, in some instances, use of existing marine SCR systems has been discontinued due to cost. Furthermore,

TABLE 2-6
Control Technologies for Marine Vessels

Control Technology	Percent NO_x Reductions	Percent PM Reductions	Cost of Equipment	Cost of Operation and Maintenance	Comments
Selective Catalytic Reduction (SCR)	80–90		$260,000 to $1.23 million ($40–$94 per HP)	$24,000 to $144,000 per year	Available; requires significant space and storage for urea
Direct Water Injection	50–60		$20–$40 per HP	$1–$4 per 1,000 HP	Still under development; possible corrosion problems; may require lower-sulfur fuel
Continuous Water Injection	20–30	Up to 25	~$33,000	~$530/year	Still under development; possible demo; on ferry vessel in British Columbia
Fuel Injection Modifications	5–30	25–50	*Note: Only possible for new engines, therefore cost cannot be determined*		Available; may reduce VOCs and improve fuel economy
Humid Air Motor	40–80	N/A	N/A	N/A	Transitioning from development to market
Combustion Air Saturation Systems (CASS)	70	N/A	N/A	N/A	Under development
Emulsified Fuels	15–50	50-63	Up to $217,000	Up to $36,000	Transitioning from development to market; used in Port of Houston tour boat but discontinued due to power loss; possible increase in VOCs and CO and reduction in power
Diesel Oxidation Catalyst (DOC)	N/A	15-30	$3–$15 per HP	N/A	Available; must use lower-sulfur fuel
Diesel Particulate Filter (DPF)	N/A	70-90	$14–$30 per HP	$150 to $300 per year	Under development for marine use; requires ultra low sulfur diesel

Sources: Draft Oceangoing Marine Vessel Emission Control Technology Matrix, California Air Resources Board, Maritime Working Group, 30 Oct. 2002. Various presentations during 26 July 2002 made to the Maritime Air Quality Technical Working Group and Incentives Subgroup; and CARB.

SCR technology still has several problems to overcome before it can be a fully successful NO_x control strategy for marine diesel engines. Urea, the chemical relied on by SCR to reduce NO_x emissions, can become a problem pollutant itself. Without the use of low-sulfur diesel and additional controls—oxidation catalysts, for example—the problem is worsened. Finally, it is difficult to enforce the actual use, instead of bypass, of these systems because engines operate whether or not an installed SCR system is functioning.

Other promising NO_x reduction technologies are currently under development for marine diesel engines. Direct water injection can reduce NO_x by as much as 60 percent, and humid air motors can reduce NO_x by 40 to 80 percent. Both technologies are based on a similar principle—lowering engine temperatures—and have been tested on a number of ferries running in the Baltic Sea. Several variations on the technology have been developed, such as continuous water injection and combustion air saturation systems, reducing NO_x up to 30 percent and 70 percent, respectively. Some of these technologies have the added benefit of reducing some other pollutants as well. Various engine modifications can achieve additional NO_x reductions of up to 30 percent and PM reductions of up to 50 percent.

Many of the particulate matter controls discussed in the measures for cargo-handling equipment and trucks may also be practical for use on large ships. The California Air Resources Board is funding a U.S. Navy study of one such control, diesel particulate filters on marine military craft. It is also possible to install DOCs on ships; however, both DOCs and DPFs require much lower sulfur levels than current marine-grade fuels.

Oceangoing ship emissions are virtually unregulated because they traverse international boundaries.

Pollutants Reduced and Cost As outlined earlier, pollutants reduced include NO_x and diesel PM, depending on the control technology. Some controls also reduce such other pollutants as VOCs and SO_x. The CARB maritime working group has compiled a matrix of controls and cost data, summarized in Table 2-6.

Cost-Effectiveness Not enough information is available at the time of this report to estimate cost-effectiveness.

EXAMPLES ▶ More than 100 large ships, mostly in the Baltic Sea area, have installed selective catalytic reduction (SCR) to reduce drastically the smog-forming nitrogen oxides (NO_x) coming out of their smokestacks. Several U.S. ships have done the same. In California, for example, four large oceangoing vessels and one dredging vessel use SCR systems.

In addition to the Swedish harbor fee system, Finnish and Norwegian ports have either proposed or implemented similar programs to reduce port fees or taxes for cleaner vessels.

DISCUSSION ▶ In addition to the emission controls outlined earlier, many other steps can be taken to reduce visible emissions or smoke and other pollutants through maintenance, operational controls, and local ordinances. Smoke from ship stacks can be controlled and reduced through the following engine maintenance efforts:[35]

- Regular cleaning of the engine turbo charging system
- Regular cleaning of the fuel injection system
- Maintenance to limit lube oil consumption in piston rings and cylinder liners
- Limiting the amount of used lube oil in marine fuels
- Regular cleaning and maintenance of the automated fuel viscosity control system
- Limiting fuel consumption during acceleration mode in cold climates
- Limiting heat removal from the waste heat boilers

Operational behavior can also be changed to reduce emissions, especially in coastal areas. For example, ships often "blow" their stacks to remove soot buildup within the stacks to run more efficiently and prevent fires. But to prevent the release of excess soot emissions, ships should avoid blowing their stacks near shore. Many port areas have instituted "smoking ship" programs to enforce this. Other operational control measures, such as voluntary speed reductions, can also reduce NO_x emissions. However, speed reductions are difficult to enforce and can lead to increased emissions in other areas if ships attempt to make up lost time.

The state of Alaska requires cruise ships within three miles of the coastline to keep their visible emissions below a threshold of 20 percent opacity. Other areas, such as Southern California and Savannah, Georgia, have less stringent smoking

SWEDISH HARBOR FEES DETER DIRTY SHIPS

In 1996, the Swedish Maritime Administration, the Swedish Shipowners' Association, and the Swedish ports made an agreement to implement stringent pollution reduction measures, which aimed to reduce emissions by 75 percent by the year 2000. In an attempt to achieve this goal, the organizations decided to provide economic incentives in the way of differentiated fairway and port dues. Ships that used lower-sulfur bunker fuel and controls to decrease NO_x emissions would pay smaller shipping costs.

For example, an oil tanker carrying a cargo of mineral oil products in bulk, that has attained an emission level of a maximum 2 grams per kilowatt-hour (g/kWh) is charged the minimum amount. Following a linear scale, with an increasing rate of 6 percent per g/kWh, the amount for an emission level exceeding 12 g/kWh will increase by 60 percent. For other vessel types, the amounts increase at a rate of about 7 percent per g/kWh.

Additionally, to promote the installation of emission controls, the Swedish Maritime Administration reimburses the fairway dues that are paid for a five-year period. The cost of installations, that qualify for the reimbursement can be as high as 40 percent of the investment cost if emission controls are installed before the year 2000, and up to 30 percent for installations thereafter. Finally, ships are given an additional rebate per unit of the ship's gross tonnage if the sulfur content of the bunker fuel is lower than 0.5 percent (5,000 parts per million) for passenger ships and 1 percent (10,000 parts per million) for other ships. Following Sweden's lead, Finnish and Norwegian ports have proposed or implemented similar programs, reducing port fees or taxes for cleaner vessels.

Source: www.sjofartsverket.se/tabla-b-eng/pdf/b142.pdf.

ship programs. Southern California also has a speed-reduction program, as detailed in Chapter 3.

CARGO-HANDLING EQUIPMENT

Ports should pursue three major cleanup strategies for cargo-handling equipment, depending on the age of the equipment. First, equipment more than ten years old should be replaced with either alternative-fuel engines that run on propane or natural gas, or with battery-electric hybrid systems. Second, existing equipment less than ten years old should be repowered or retrofitted with the best available control technology, such as diesel particulate filters (DPFs) with lean NO_x catalysts (LNCs) where possible, and diesel oxidation catalysts (DOCs) where DPFs are not practical. Third,

QUIET, CLEAN, HYBRID MARINE POWER

Just as Honda and Toyota are leading the automotive industry in the transition to hybrid passenger vehicles, an Australian-based company called Solar Sailor is working to take the lead for marine vessel applications. By creating electricity from solar power, using available wind energy, and combining this with backup power from modern batteries and fossil fuel generators, Solar Sailor has produced vessels with zero water pollution, low noise, and minimal emissions.

These boats, which have a proven track record in Australia, are ideal for low-speed applications, less than 25 knots, and can be used in tourism, patrolling land, recreational, and transport markets.

In addition, Solar Sailor can retrofit boats running on fossil fuels to function on hybrid marine power. Solar Sailor can customize a retrofit to suit nearly all marine applications where constant high-speed operations are not required. For higher speeds, a generator can be used to power the electric drive directly. The vessels constructed and retrofitted by Solar Sailor can hold up to 250 passengers and produce up to 1,000 horsepower. These hybrid vessels will serve as an immediate platform for the use of fuel cells when they become commercially available.

Source: www.solarsailor.com.au/aboutus.htm.

WWW.SOLARSAILOR.COM

existing equipment should be switched to cleaner diesel fuels, such as low-sulfur fuel with DPFs or diesel emulsions with DOCs.

Purchase New Equipment That Uses Alternative Fuels

Ports should replace older diesel-powered cargo-handling equipment at container terminals with equipment powered by alternative fuel, where possible. Specifically, natural gas, propane, or battery-electric systems would be required for all new purchases.[36] Where possible, ports should also adopt policies that require the purchase of new alternative-fuel cargo-handling equipment as a condition of all new leases and significant lease renegotiations.[37] Diesel equipment that is ten years old or older should be targeted for replacement. These recommendations might necessitate the installation of fueling stations for alternative fuels throughout port terminals.

Certified natural gas engines are available and are used widely in transit bus fleets operating throughout the country. In fact, the same manufacturers that make natural gas bus engines produce conventional diesel engines for cargo-handling equipment.[38]

The vehicles and equipment in this category are powered by off-road engines, ranging from 100 to 500 horsepower (HP), depending on the application. Equipment with known alternative-fuel, electric, or electric hybrid models available are outlined in Table 2-7. The four types of yard equipment in this table—terminal tractors, straddle carriers, rubber-tired gantry cranes (RTGs), and forklifts—make up the majority of cargo-handling equipment and also account for the majority of pollution from equipment at ports.[39] It should be noted that other pre-1996 cargo-handling equipment, for which alternative-fuel, electric, or hybrid-electric options are not available, should still be retired and replaced with cleaner new models. Where possible, those new diesel models should incorporate cleaner on-road, instead of nonroad, engines. Also, where possible, vehicles and equipment that predate standards but are not quite ten years old (for example, eight years old or pre-1996), should be slated for replacement.

Much of the cargo-handling equipment at the Port of Los Angeles runs on diesel emulsions, a cleaner diesel fuel, with simple emission controls that reduce pollution.

Tom Plenys

Pollutants Reduced Replacing older equipment with equipment powered by alternative fuels significantly reduces emissions of toxic diesel PM, NO_x, and other pollutants. The South Coast Air Quality Management District recently reported that, compared with conventional diesel technology, natural gas technology can reduce more than 60 percent more NO_x and 30 percent more PM in terminal tractors.[40] Although natural gas engines have significantly lower NO_x and PM emissions, they will likely have slightly higher CO and VOC emissions. However, the increase in CO and VOC emissions is small compared with the decrease in NO_x and PM emissions.[41]

Table 2-8 shows the total pollutant reductions obtained in three Southern California demonstration projects where non-road diesel vehicles were converted (either by new purchase or repower) from diesel to propane-fueled engines.[42] One new propane engine reduced NO_x emissions in this equipment by an average of 0.3 tons per year, and a repower of one engine eliminated more than half a ton per year.

Unit Cost The incremental cost of a new, alternative-fuel terminal tractor ranges from \$17,000 to \$29,600.[43] Table 2-8 summarizes unit costs for the replacement of diesel engines with propane engines. Terminal tractors are currently available for compressed (CNG) and liquefied (LNG) natural gas, as well as for propane.[44] Although an electric hybrid straddle carrier costs roughly 10 percent more than a standard diesel model, it reduces fuel and other operating costs.[45] A rubber-tired gantry crane that is completely electric also costs roughly 10 percent more than comparable models.

Electric forklifts currently constitute one-quarter of the market for moderate-size forklifts.[46] They would be appropriate for smaller-capacity uses at terminals, where the charging infrastructure can be installed and there is adequate time to allow for recharging. The Carl Moyer Program in California has funded more than 200 electric forklifts at a cost of roughly \$10,000 each.[47] California inventories

TABLE 2-7
Types of Alternative Cargo-Handling Vehicles and Equipment

Category	Usage	Engine Horse Power	Available Alternatives
Terminal Tractors	Shuttle containers around; the most prevalent type of equipment	150–250	Propane, LNG, CNG
Straddle Carriers	Transfer containers between stacks and trailers	Up to 500	Diesel-electric hybrid
Rubber Tired Gantry Cranes	Stacks containers	400–600	Electric
Forklifts	Lift various cargo	50–250	Electric, propane, CNG[a]

Sources: "Marine Terminal Design to Minimize Diesel Emissions" presentation given by Richard A. Woodman, P.E. at the Diesel Air Emissions Seminar on 24 October 2001. *The Port of New York and New Jersey Emissions Inventory for Container Terminal Cargo Handling Equipment, Automarine Terminal Vehicles and Associated Locomotives,* prepared by Starcrest Consulting Group, LLC, for the Port Authority of New York & New Jersey, June 2003.

a Sold by Yale, northamerica.yale.com/lift_trucks/pneumatictires/index.asp; and Clark Material Handling Company, www.clarkmhc.com

TABLE 2-8
Emissions Reduced from New Purchases and Repowers of Off-Road Engines with Propane

Project Type	Equipment Type	Engine HP	No. of Engines (Tons/yr)	Project NO_x Reduction	Project NO_x Reduction (Tons over 7-year Life)	Baseline Engine Cost (\$)	Cost of Cleaner Engine (\$)
New	Yard Hostler	195	5	1.5	18.3	**N/A**	**N/A**
New	Yard Spotting Tractor	195	2	0.6	8.3	**\$53,000**	**\$60,000–\$70,000**
Repower	Yard Spotting Tractor	195	5	2.7	39.9	**0**	**\$20,000**

Source: The Carl Moyer Program Status Report, 13 April 2001.

show that all forklifts greater than 175 horsepower are diesel; however, natural gas and propane models make up the majority of forklifts between 50 and 175 horsepower.[48]

The cost of a moderate-sized, full-service, natural gas fueling station ranges from $500,000 to $1,000,000.[49] The cost difference between an LNG and a CNG refueling infrastructure is not significant. A $250,000 to $500,000 additional investment will allow for CNG availability at an existing LNG fueling station (i.e., LNG/LCNG Station). In many cases, a fuel supplier will provide infrastructure equipment at no cost to the user in return for a substantial fuel-supply agreement and a guaranteed throughput of vehicles.[50,51] In contrast, refueling infrastructure for LPG (propane) is relatively inexpensive when compared with NG. In exchange for a long-term fuel contract of three to five years, fuel suppliers often absorb the cost of infrastructure, requiring the fleet operator or user to pay only the cost of necessary electrical upgrades ranging from $1,000 to $5,000.[52]

The Port of Barcelona reports driver satisfaction and a 30 percent drop in fuel use with its electric-hybrid equipment.

Cost-Effectiveness Alternative-fuel yard tractors have a cost-effectiveness of $3,500 to $6,600 per ton of NO_x reduced, making them a fairly cost-effective way to reduce NO_x emissions.[53] This figure is based on capital expenditures for the incremental cost of the alternative-fuel engines over their diesel counterparts. This does not, however, include the installation of a fueling station for alternative fuels. Grants, such as those from California's Carl Moyer Program, often cover at least three-quarters of the incremental costs of the alternative-fuel vehicle. The average cost-effectiveness for such alternative-fuel programs is estimated at $4,000 per ton, not including infrastructure costs. According to the Carl Moyer Program, electric forklifts reduce an average of three-quarters of a ton of NO_x per year per forklift at a cost-effectiveness of roughly $5,000 per ton.[54] We were unable to estimate cost-effectiveness of alternative-fuel forklifts and hybrid-electric straddle carriers.

EXAMPLES ▶ In 1999, a terminal operator at the Port of Los Angeles was awarded funds that facilitated the purchase of five LPG yard tractors through the Carl Moyer Program. Despite reduced efficiency and the need for more frequent fueling, the tractors have been able to do the work at the terminal.

Additionally, as a result of the lawsuit against the Port of Los Angeles (see *The Dirty Truth About U.S. Ports*), the China Shipping Terminal is expected to have all alternative-fuel yard tractors by the end of 2004.

The Port of Barcelona reports driver satisfaction and a 30 percent drop in fuel use with its hybrid straddle carrier demonstration project.[55] In the United States, the Port of Virginia is also testing several hybrid straddle carriers.[56]

A number of ports, including the Port of New York and New Jersey and the Port of Houston, report using propane or electric forklifts.

DISCUSSION ▶ Technological advancements, including lean burn, closed loop, and electronic fuel management, have improved the fuel economy and performance of alternative fuel engines. Although alternative fuel engines are still slightly less efficient than their diesel counterparts, they emit significantly less NO_x and PM.

Natural gas is a lighter-than-air gas, and therefore modifications to existing maintenance facilities are often necessary. The modifications usually consist of a methane-detection system, an improved ventilation system, and new lighting. Employee training and containment practices and procedures are also required.

Propane or liquefied petroleum gas (LPG), a byproduct of natural gas processing or petroleum refining, is a mixture of at least 90 percent propane, 2.5 percent butane and higher VOCs, and a balance of ethane and propylene. At room temperature, it is a gas, but it returns to liquid form when compressed. Unlike natural gas, LPG is heavier than air and therefore tends to accumulate toward the floor. LPG vehicles can be serviced at maintenance facilities that meet standards for use with gasoline or diesel vehicles, based on the number of air changes required per hour.

Retrofits and Repowers for Existing Equipment

Although the superior approach to cleaning up older equipment is to replace it with new, cleaner models, existing equipment with remaining useful life can be significantly cleaned up through retrofits and repowers. Under this approach, ports would fund an incentive program for marine terminal operators (MTOs) to repower and retrofit and to use cleaner fuel in cargo-handling equipment to reduce NO_x and diesel particulate emissions. MTOs that choose to repower their equipment would install newer, lower-emitting diesel engines to replace existing diesel engines. MTOs that retrofit would install add-on equipment to their existing engines or to their new repowered engines.

For repowering, the program should target existing "middle-aged" or recently purchased engines that are used extensively and that have relatively long remaining useful lives—generally speaking, engines manufactured between 1994 and 2003. Numerous new certified nonroad diesel engines in the appropriate size categories may be installed in place of older, dirtier engines. Target equipment would include

ALTERNATIVE FUEL SUCCESS STORY

The California grocery chain Stater Bros. has a fleet of 41 alternative-fuel vehicles, including six propane yard tractors. In 2001, Stater Bros. began operating the yard tractors, used primarily to arrange empty trailers after they are unloaded. Typical units log 5,150 hours of operation per year. The units are Ottawa Commando 30, powered by a 195-horsepower dedicated LPG engine that is available as an OEM product from Cummins Stater Bros., who report an overall fuel cost to savings on these units. Management has reported that the LPG units have performed satisfactorily under any legal load. Compared with new off-road diesel units, each of these yard spotters reduces NO_x emission by 2.75 tons per year. The average fuel cost per hour for diesel units was $2.38 per hour. During the same time period and under comparable operating conditions, the LPG units averaged $1.96 per hour. This is based on a fuel economy of 2.3 gph for LPG and 1.7 gph for the diesel units. The operational savings was realized from the different fuel cost of $1.42 for diesel and $0.92 for LPG.

Sources: Personal communication, Karen Sagen, Gladstein & Associates, December 2003.

regularly used yard hostlers, top-picks, side-picks, and straddle carriers. Several technologies have been shown to be cost-effective whether the engine repowers are installed on new or middle-aged equipment.

Diesel particulate filters (DPFs) and diesel oxidation catalysts (DOCs) are available in various configurations from a number of manufacturers and are used to reduce harmful particulate matter as well as CO and VOCs. Ports should favor retrofit equipment that has been "verified" or "certified" for effectiveness by the CARB or the U.S. EPA. However, because very few controls have been verified or certified specifically for use in off-road equipment, controls demonstrated in other applications or verified/certified for on-road use should also be considered, with consultation and approval from the manufacturer. Cleaner diesel fuels, necessary for many controls to function, are available in much of the country. For more information on control technologies, see Appendix B.

Pollutants Reduced Table 2-9 lists several common types of retrofit technologies, estimated pollutant reductions, fuel requirements, fuel penalty, and costs using the various technologies available.[57,58]

Unit Cost Estimated costs of various retrofit options are listed in Table 2-9. Estimates are based on 150–350 horsepower diesel engines. The cost of engine replacements,

TABLE 2-9
Pollutant Emissions Reductions Using Retrofit Technologies Available for Off-Road Sources

	PERCENTAGE REDUCTIONS				Fuel Sulfur	Fuel	
Technology	**NO_x**	**PM**	**CO**	**VOC**	**Tolerance**	**Penalty**	**Cost**
Active Diesel Particulate Filter (DPF) & Lean NO_x Catalyst (LNC)[a]	25–35	50–90	50–90	50–90	Up to 15 ppm	3 to 7%	\$15,000–\$18,000
Electrically Regenerated DPF	—	80–95	[b]	[b]	Up to 15 ppm	1 to 2%	\$4,450–\$14,000, scaled to engine size
Flow-Through Filter (FTF)[c]	—	> 40	> 40	> 40	Up to 500 ppm	10%	\$700–\$7,000, most likely ~\$1,500–\$2,000
Diesel Oxidation Catalysts (DOC)	-	25[d]	30–90	40–90	Up to 500 ppm	0 to 2%	\$2,500–\$3,000
Exhaust Gas Recirculation (EGR)[e]	20–50	N/A[5]	N/A	N/A	Up to 500 ppm	0 to 5%	\$13,000–\$17,000
Lean NO_x Catalyst (LNC)[f]	10–20	N/A	N/A	N/A	Up to 250 ppm	4 to 7%	\$6,500–\$10,000

Sources: Cleaire; MECA; *CARB Diesel Risk Reduction Plan*, App. IX, October 2000; Clean Air Systems; Donaldson Corporation; and *EPA Technical Summary of Retrofit Technologies*, available at www.epa.gov/otaq/retrofit/retropotentialtech.htm.

Note: Emission reductions listed in this table may be less than those listed for on-road applications due to differing duty cycles. Where no information was available specific to off-road applications, emission reduction data from on-road applications were substituted.

a This retrofit, called "Longview" by trade name, has been verified by CARB for use on select on-road vehicles. The technology has been used by construction and other off-road vehicles; however, specific reductions for off-road applications are not yet available. Emission reductions are as reported by CLEAiREe, the manufacturer.

b Highly variable; may depend on fuel sulfur levels.

c Not yet commercially available; CARB verification is expected in 2004.

d DOCs have been verified for off-road use by CARB at this level. However, PM emissions reductions can be improved with very low sulfur levels. It should also be noted that when DOCs are used with regular EPA grade off-road diesel, which averages more than 3,000 ppm sulfur, PM emissions are likely to increase, according to MECA, *Exhaust Emission Controls Available to Reduce Emission from Nonroad Diesel Engines*, April 2003.

e PM emissions may increase slightly, especially with higher NO_x reductions; EGR should not be used without particulate controls.

f Not yet commercially available, unless bundled with a DPF or DOC. A DOC paired with an LNC currently costs \$10,000.

or repowers, ranges from $11,000 for the smaller yard hostler engines to $28,000 for larger equipment. Engine installation can be an additional $1,500 to $3,500 per unit.[59]

Cost-Effectiveness Cost-effectiveness for retrofitting or repowering existing cargo-handling equipment varies widely. The Port of Oakland reported that its program had achieved a $2,000 to $3,000 per ton cost for NO_x and PM reductions combined.[60]

Table 2-10 contains a summary of the ranges of cost-effectiveness control strategies for existing off-road equipment that is not yet ready to be retired and replaced. All of the NO_x control strategies, engine repowers, NO_x catalysts, and exhaust gas recirculation (EGR) are relatively competitive in terms of cost-effectiveness. The range of cost-effectiveness for PM controls is wider. Flow-through filters, when available, may offer one of the most affordable and effective solutions. In the meantime, active DPFs, DOCs, and repowers offer cost-effective PM reductions. Engine repowers and combination active DPFs with NO_x reduction catalysts offer cost-effective NO_x and PM reductions at the same time. Together, these two strategies offer an effective fleetwide solution, given that engine repowers are ideal on slightly older vehicles and active DPFs are compatible only with newer vehicles.

EXAMPLES ▶ In addition to the Port of Oakland, the Ports of Los Angeles and Long Beach have programs to retrofit or repower yard equipment. The Port of Long Beach expects by the end of summer 2004 to have installed more than 600 DOCs on its yard equipment at its seven major container terminals.[61] Similarly, the Port of Los Angeles has taken initial steps to clean up its approximately 800 pieces of mobile diesel yard equipment. The port has ordered and received 585 DOCs for installation on a variety of yard equipment, including yard tractors, side- and top-picks, and forklifts.[62]

The Port of Göteborg fitted all its terminal tractors and roughly one-third of its straddle carriers with DPFs, greatly reducing particulate emissions from cargo-handling operations and ensuring the use of very low-sulfur diesel, as needed for the DPFs.

TABLE 2-10
Cost-Effectiveness of Various Off-Road Control Strategies

Control Strategy	NO_x (Cost Per Ton)	PM (Cost Per Pound)
Engine Repower	$1,100–4,900	$8.40–17.40
Active DPF and NO_x Reduction Catalyst	$1,900–3,200	$6.40–9.30
Electrically Regenerated DPF	N/A	$1.80–7.20
Diesel Oxidation catalysts (DOC)	N/A	$2.40–4.60
Exhaust Gas Recirculation (EGR)	$1,100–3,800	N/A
Lean NO_x Catalyst	$1,400–4,500	N/A
Flow-Through Filter	N/A	$0.50–6.80

Assumptions: (1) Pollutant reduction percent and costs were taken from Table 2-9. (2) Baseline emission factors taken from 2003 Carl Moyer Guidelines, Table 3.1 and 3.4; emission factors for repower were assumed to be a 1988–1994 diesel engine with 176–250 HP replaced with a 2003 model; baseline EFs for all others were estimated as model years 1996–2002. (3) Project life was estimated as 8 years. (4) Operating hours of equipment was assumed to be 3,640 hours per year. (5) Load factor was assumed to be 50 percent.

DISCUSSION ▶ Many choices of exhaust controls for equipment are commercially available. The EPA and CARB have certified numerous replacement engines, and CARB has verified numerous control devices for various retrofit applications. Although most devices are verified for use only with on-road applications, many will also work well on cargo-handling equipment, depending on the fuel used and other factors such as engine temperature.

The Port of Oakland has acquired valuable field experience that can be applied at other ports to make an overall program more effective and cost-efficient. The Port of Oakland program is funded through a settlement that the port reached with the surrounding community over a recent expansion. Terminal operators can use the funds of this voluntary program to retrofit, repower, or purchase new and cleaner terminal equipment.

The Oakland experience indicates that the program must be well funded to achieve a high rate of voluntary participation from marine terminal operators. Sound administration is also a key to cost-effectiveness, and to the provision of adequate technical assistance. Some MTOs need technical assistance to sort out the claims of vendors competing for business. It may also be necessary to require retrofits or new purchases of older vehicles via new lease agreements or renegotiations.

Although Sweden's Port of Göteborg has successfully used "passive" diesel particulate filters on some cargo-handling equipment, not all equipment at the port regularly operates at exhaust temperatures high enough for DPFs to properly regenerate (i.e., burn off the particles they collect). Testing at the Port of Oakland indicates that most yard hostlers cannot use passive DPFs for this reason. It should be noted that "active" DPFs rely on different technology and are known to be compatible for use on yard equipment, regardless of operation.[63] Most DPFs, however, active or passive, do not work on the old two-stroke, mechanically controlled engines typical of model years before 1994. That is why an alternative-fuel approach for yard hostler applications in combination with a diesel oxidation catalyst system is a superior emissions reduction strategy.

Finally, converting existing diesel equipment to alternative-fuel use may now be possible with new technology. One company has developed a cost-effective method to convert older diesel trucks and buses to clean-burning natural gas. The process involves removing the cylinder head, removing diesel components, remachining the head and pistons for spark plug ignition, and adding a new system for fuel delivery, along with a close-coupled diesel oxidation catalyst in the exhaust system.[64,65]

Cleaner Diesel Fuels for Existing Equipment

The use of cleaner fuels is essential for certain pollution control devices to function properly. Cleaner fuels should be used throughout port facilities to prevent contamination of sensitive controls and for the additional, though modest, emission reductions from the fuels. Several options are available that are compatible with existing diesel engines in most nonroad vehicles and equipment, including low-sulfur diesel (15 ppm sulfur), diesel emulsions, biodiesel, Fischer-Tropsch diesel, and "E-diesel." Although low-sulfur diesel is the most widely available and the cheapest, the other four options offer higher emission reductions for certain pollutants if used alone without after-treatment equipment, as Table 2-11 indicates. Low-sulfur diesel is generally used in combination with a DPF or other pollution control device.

Pollutants Reduced and Costs Table 2-11 summarizes the various pollution reductions achieved by cleaner diesel fuels, as well as the fuel penalty and cost.

The CARB estimates that 20 percent of the diesel sold in California for on-road heavy-duty diesel vehicles has a sulfur content of 15 ppm or less. This low-sulfur diesel is currently manufactured in large quantities and is available throughout California, the Northeast, and most major metropolitan areas in the Northwest, Upper Midwest, and Texas.[66] The entire nation will be required to use low-sulfur diesel fuel for on-road vehicles by mid-2006.[67] In the meantime, where low-sulfur diesel is unavailable or terminal operators are unwilling to use it, on-road grade diesel can be substituted for nonroad grade diesel, which contains 10 times as much sulfur. The minimal cost difference, estimated at $0.01 to $0.02 per gallon, also allows the use of certain control technologies, such as diesel oxidation catalysts.[68]

Diesel emulsions are sold under several trade names, including Aquazole, Lubrizol, and Aquadyn, all of which have been verified by the CARB or the EPA.[69] Typically, the characteristics of diesel emulsions depend upon the type of diesel used as a base fuel, which may or may not be low sulfur depending on the specifications of the user. Low-sulfur diesel, however, must be specified as a base for diesel emulsions to ensure compatibility with emission controls and to maximize emission reductions. Emulsified diesel combined with DOCs is becoming a popular control strategy. Although it is on the high end of cost-effectiveness compared with other emission control strategies ($5,400 to $8,700 per ton of NO_x, and $15 to $25 per pound of PM), capital investments are modest, and the fuel can be used in any vehicle regardless of age.[70]

The Port of Houston has been running part of its cargo-handling equipment fleet on diesel emulsions for several years. The only problem reported has been that some equipment with extremely high power demands has been unable to generate sufficient

TABLE 2-11
Emission Reductions Achieved by Use of Various Cleaner Diesels[a]

Technologies	NO_x	PM	SO_x	CO	VOC	Fuel Penalty	Extra Cost (per gallon)
Low-sulfur diesel (LSD) fuel	3–11%	3–15%	>90%	6–10%	8–13%	~3%	$0.05
Diesel emulsions[b]	9–20%	16–64%				15–20%	$0.24–0.29[c]
Biodiesel (100%)	10–15% Increase	30–70%	>90%	50%	40–90%	4–10%	~ $1
Fischer-Tropsch diesel	4–12%	≈25%		18–36%	20–40%	2–4%	~$0.30
e-diesel	1–6%	20–40%		20–28%		~ None	$0.02–0.05

Sources: CARB, *Diesel Risk Reduction Plan*, Appendix IV, October 2000; CARB, *Verification of Fuels*, www.arb.ca.gov/fuels/diesel/diesel.htm; EPA Verified Technology list, www.epa.gov/otaq/retrofit/retroverifiedlist.htm; www.o2diesel.net/faqs.php.

a D Blume, Port of Houston, personal communication, August 2002.
b Emission reductions are in comparison to CARB diesel (<150ppm sulfur).
c CO and VOC emissions vary widely. Some tests show substantial increases, and others show great decreases.

power under certain circumstances. The port advises against its use for such equipment as "loaded container handlers," which lift and move containers and move them simultaneously. Other diesel emulsion users have reported similar problems with power loss in certain equipment, as well as a few other minor problems, including increased fuel-filter plugging, problems in cold weather, and the need to keep the fuel in constant use or regularly stirred to avoid separation.[71] However, diesel emulsions combined with a diesel oxidation catalyst offers extremely cost-effective and significant PM and NO_x reductions.

Diesel emulsions combined with a diesel oxidation catalyst can offer cost-effective and significant PM and NO_x reductions.

Biodiesel should be considered only in its pure form as opposed to a diesel blend. Although biodiesel is most commonly blended with 80 percent or more conventional diesel, the emission benefits of these blends are minimal and costs are not competitive. Pure biodiesel offers substantial PM and CO_2 reductions but increases NO_x (by as much as 15 percent). Unfortunately, most engine manufacturers do not warrant their products for use with pure biodiesel because it can cause problems in some engines.[72]

Biodiesel fuel is distributed in many parts of the United States, although prices vary widely, as does the feedstock used to produce it. Used oils and grease are preferable to farmed oils, where feedstock can be specified. The biodegradability and low toxicity of biodiesel makes it well suited for marine use.

Fischer-Tropsch diesel is usually made from coal but is sometimes made from natural gas, leading to the recent acronym GTL (gas to liquids) fuel. Much of the Fischer-Tropsch diesel in the United States is imported from Malaysia; however, new plants are likely to be built in the United States soon. In fact, several pilot plants are already operating, including one in Washington state. Costs are contingent on transport and feedstocks, and are not yet well-known.

E-diesel, also known as Oxydiesel, is a blend of conventional diesel and as much as 15 percent ethanol.[73] The ethanol, usually produced from corn, adds oxygen to the fuel, thus allowing it to burn slightly cleaner. Although this fuel recently received verification for use in California, emission reductions are modest, and safety concerns, such as flammability, remain to be addressed.[74]

A recent CARB study concluded that alternative diesel fuels provide relatively cost-effective reductions of PM, NO_x, and petroleum use. Fischer-Tropsch diesel and biodiesel offered some of the most cost-effective PM and petroleum use reductions, while NO_x reductions were demonstrated best by LNG and propane.[75,76]

EXAMPLES ▶

Northern Europe has led the way on use of cleaner diesel fuels and exhaust controls on marine terminal equipment.[77] The Port of Helsinki uses lower-sulfur diesel (30 ppm) in its own equipment and several marine vessels as an example to terminal operators. The port has proposed the use of cleaner fuels in cargo-handling equipment, heavy trucks, and marine vessels for its large new Vousaari Container Terminal Complex. The Port of Copenhagen Malmö in Denmark and Sweden also uses low-sulfur diesel (50 ppm) in cargo-handling equipment, which has also been fitted with diesel oxidation catalysts.

In the United States, the Port of Oakland has convinced most of its terminal operators to adopt low-sulfur diesel (15 ppm) for cargo-handling equipment. Addition-

AUTOMATED CARGO-HANDLING SYSTEMS:
The ports of Singapore and Rotterdam have led the way in improving efficiency of cargo handling and reducing associated pollution. The Port of Rotterdam, on the North Sea in the Netherlands, serves roughly 380 million European consumers. Rotterdam has several cutting-edge programs, including an effort to lessen environmental impacts through the use of inland barges instead of trucks and trains. However, the port's multitrailer system for moving containers in Europe's largest container terminal, the ECT, is truly noteworthy. Over the past two decades the multitrailer system has been refined to combine five yard tractors into one flexible trailer that can tow five containers at a time. Other major ports, such as Felixstowe in the U.K., the Port of Singapore, and the Port of Vancouver, have now studied and installed similar systems.

The Port of Singapore set a world standard for cargo-handling efficiency at its Pasir Panang Terminal in 2000, incorporating the latest in containerized cargo-handling technologies. The terminal is outfitted with nine-story tall, freestanding concrete structures supporting automated bridge cranes. These remotely operated cranes mark a major shift in container-handling yard systems because they are capable of very fast and flexible operations with a minimum number of operators. The terminal virtually eliminated diesel exhaust from cargo handling because the automated system is electrically powered. The cranes are controlled remotely from a crane operating center in the main terminal building, employing artificial intelligence to semiautomate the stacking andunstacking process.

Sources: Vernon E. Hall, V.E. Hall & Associates, personal communication, 1 July 2003; "Future Small Inland Vessels," by Richard Savenije, October 2000 edition of the *International Navigation Association's Bulletin* No. 105. PSA Corporation, Ltd. Appearing in the August 2000 issue of *Port Technology International* published by ICG Publishing Ltd., London, U.K.

ally, the Port of Houston has conducted the first demonstration of diesel emulsions on various cargo-handling equipment and one tour boat; indeed, the port now uses diesel emulsions in roughly 40 pieces of equipment. The Port of Long Beach is currently using emulsified diesel to fuel its yard equipment at two of its terminals. At one point, the Port of Los Angeles was running 600 pieces of yard equipment on emulsified diesel at four of its terminals. Due to water accumulation in storage systems caused by significant switching between and mixing of emulsified diesel and traditional diesel, two terminals have terminated their use of emulsified diesel. The Port of Los Angeles believes this issue has been resolved.[78]

ON-ROAD TRUCKS

Ports should pursue three major emissions reduction strategies, tailored to the age of the on-road trucks. First, pre-1984 trucks should be *replaced* with 1994 model year and newer trucks, which can then be equipped with after-treatment control devices. Second, model year 1994 and newer trucks should be *retrofitted* with a diesel particulate filter; older trucks (1984–1993) should be retrofitted with diesel oxidation catalysts. Third, all trucks should use cleaner fuels, such as diesel emulsions or low-sulfur diesel fuel, to further reduce emissions and ensure that after-treatment devices function properly. Ports should create incentive programs for the replacement or retrofit of older trucks to carry out these measures. Ports can reduce emissions further still by enforcing limits that require reduced engine idling.

Purchase New, Cleaner Trucks to Replace Pre-1984 Models

This program would encourage independent truck owners who perform the majority of their contractual work at a given port and operate pre-1984 model year trucks to voluntarily replace them with 1994 model year or newer trucks. The measure is an extremely cost-effective way to reduce truck emissions at ports, particularly because most truck models from 1983 and earlier have no emissions controls whatsoever.

Newer vehicles would also be equipped with an appropriate after-treatment system to further reduce particulate matter (PM) emissions and air toxics, described in more detail in the cargo-handling equipment section, with the priority of replacing pre-1984 heavy trucks. After identifying the applicant pool with the oldest heavy trucks, preference should be given to applicants willing to replace their trucks with the cleanest available options. Incremental funding should also be disbursed for low-sulfur diesel to those applicants who opt to install a higher-efficiency DPF system on their new trucks until mid-2006, when federal requirements for low-sulfur diesel phase in. The program should encourage the replacement of the oldest vehicles with the newest, cleanest engines, including after-treatments.

A recent CARB study concluded that alternative diesel fuels provide relatively cost-effective reductions of PM, NO_x, and petroleum use.

Pollutants Reduced Similar to the recommendation to purchase new cargo-handling equipment, this measure would reduce toxic diesel PM, NO_x, and other pollutants associated with diesel engine exhaust.

Unit Cost Used model year 1994 heavy-duty diesel trucks cost $25,000 to $45,000.[79]

Cost-Effectiveness Focusing on the replacement of the oldest and dirtiest trucks in the port with newer used trucks can provide a cost-effective means of reducing both NO_x and PM emissions. On average, replacing a pre-1984 engine with a post-1993 engine will result in an average cost-effectiveness of $8,200 per ton of NO_x reduced and $28 per pound of PM reduced. In addition to these significant NO_x and PM benefits, the strategy of replacing older trucks and employing DOCs or DPFs on the newer trucks results in an 82 to 96 percent overall PM emission benefit (including the benefit of the new engine). The DPFs provide greater PM emission reductions (96 percent), for a total unit price, including fuel, of $31,000 to $53,500.

One benefit not included in cost-effectiveness estimates is the increased fuel efficiency of new engines. Mechanical engines, typical of pre-1991 model years, in general, have much lower fuel efficiencies than electronically fuel-injected engines: two to three miles per gallon versus three and a half to four miles per gallon for a new engine.[80]

EXAMPLES ▶ Although only in its second year, the Gateway Cities program has proved very successful in Southern California as a way to retire pre-1984 heavy-duty trucks. The program is funded mainly by a coalition of approximately 30 local cities and government agencies. The program has amassed roughly $14 million to remove aging and largely uncontrolled diesel trucks operating in the port area with 1994 model year or newer diesel-powered trucks. And the program has allocated approximately $4 million for aging heavy-duty trucks that meet certain conditions and generally operate in and around the Port of Long Beach as well as the surrounding area.[81] The China Shipping settlement mandated the Port of Los Angeles to provide an additional $10 million, earmarked specifically for the replacement of diesel trucks servicing the Port of Los Angeles.

Regularly oversubscribed, the program shares expenses with the recipient trucker. More than 200 pre-1984 model year trucks serving the ports of Long Beach and Los Angeles have been retired and replaced with newer, lower-emitting trucks.[82] So far, an estimated 0.8 tons of NO_x and 0.2 tons of PM will be reduced per year for each truck over their next five years of operation, totaling more than 160 tons per year of NO_x and 40 tons per year of PM reductions.[83] Of the total to date, more than 80 of the trucks have been replaced with funds from the China Shipping settlement.[84] Although not yet implemented, the Gateway Cities program also includes potential elements to (1) install diesel DOCs on the "modernized" trucks of independent owner operators and (2) install DPFs or other after-treatment devices on appropriate fleet-operated trucks that would require the use of low-sulfur diesel at 15 ppm.[85]

Focusing on the replacement of the oldest and dirtiest trucks in the port with newer used trucks can provide a cost-effective means of reducing both NO_x and PM emissions.

DISCUSSION ▶ A number of programs, including the Gateway Cities program just discussed, use variations of this strategy to reduce NO_x, PM, and toxic pollution emitted by aging diesel trucks in regular operation at ports.

AB 2650, a relatively recent California law introduced by Assembly Member Alan Lowenthal, will generate penalty funds from marine terminals in major metropolitan areas that allow trucks to idle for more than 30 minutes. The funds will be used to replace aging diesel trucks that operate in and around the port area with 1994 model year or newer trucks equipped with after-treatments that can achieve a 90 percent reduction, or 0.01 grams per brake horsepower-hour (g/bhp-hr) PM standard. Such alternative fuels as natural gas would also be funded under this program.

Many other programs in the United States offer incentive funding for the replacement of older vehicles, equipment, or engines. The Carl Moyer Program, also in California, can be used for incentive funding for cleaner new purchases. Many metropolitan areas have their own programs, through local branches of the U.S. Department of Energy's Clean Cities Program, local air quality management districts, or regional government authorities. Two other notable programs are the Texas Emission Reduction Plan (TERP) and the Sacramento Emergency Clean Air Transportation (SECAT) Program.[86]

These types of programs can be fairly labor- and resource-intensive to administer. However, the potential emission benefits are large. The cost-effectiveness of this step is slightly higher than that of other control strategies for heavy-duty trucks. However, for very old trucks that smoke, called gross polluters, the step is competitive with others, particularly because old trucks have few retrofit options, none of which reduce as much pollution. Additionally, even though cost-effectiveness assessed for the cost of full replacement is high, we recommend a partial subsidy, which would greatly improve cost-effectiveness.

Programs must be tailored to the age and type of truck fleet serving a specific port. For example, roughly 10 percent of trucks serving the Port of Oakland are pre-1987 model year, all of which should be eligible for replacement under this type of program.[87] Roughly one-third of trucks serving the Port of Oakland are from the 1987 through 1993 model years. A repower, instead of a replacement, program would be better suited for this middle-aged group of trucks.

As with the SECAT and Gateway Cities programs, contracts must be designed so that new truck purchases funded by this program stay in service in a specified geographic area for a specified time. Without contractual obligations tied to the funding, "drayage" truckers, those hauling loads on short trips, may be tempted to use their more reliable new rigs on long-haul business instead of remaining in local service to the port. In that event, new owner/operator trucks, operating old rigs on thin margins, could easily take up the slack, again increasing emissions at and near the port.

Retrofits for Existing 1984 Model Year and Newer Vehicles

This program would encourage, but not require, independent truck owner contractors who perform the majority of their contractual work at the port and operate a 1984 or later model year truck to install an appropriate after-treatment system to reduce emissions. The approach would be very similar to the previously described approach of replacing older trucks with newer models, allowing incentive funding for after-treatments on 1984 and newer trucks.

After-treatments, such as diesel particulate filters (DPF) and diesel oxidation catalysts (DOCs), can reduce diesel exhaust emissions by varying amounts depending on the specific technology employed. The CARB and the EPA have so far verified five DPF emission-control devices for 1994 model year or newer heavy trucks, as well as many other retrofit devices.[88] Of all the retrofit devices available, DOCs have the longest history of certification and use on both diesel and natural gas-powered heavy-duty vehicle configurations. Where trucks cannot be replaced with 1994 or newer engines, retrofits with DOCs would be required.[89]

Where compatible, incentives should favor the use of the cleanest possible retrofit controls available. Extra fuel stipends should be offered to cover the incremental

Diesel particulate filters can be put in place of the muffler on modern trucks, reducing particulates in exhaust by more than 85 percent.

JOE KUBSCH/MECA

cost of low-sulfur diesel for after-treatments that specify the cleaner fuel. This extra incentive should expire in mid-2006, when federal requirements for low-sulfur diesel phase in. All applicants who receive awards from the proposed measure should be required to attend free maintenance and training courses to help ensure proper care for the vehicle and after-treatment systems.

Pollutants Reduced Table 2-12 lists the various after-treatment technologies available, estimated pollutant reductions, fuel requirements, and fuel penalties.

Unit Cost Cost estimates for retrofit controls are also listed in Table 2-12. Many of these controls require low-sulfur diesel, which costs approximately 5 to 20 cents more per gallon than regular on-road grade diesel, depending on location.[90]

Cost-Effectiveness Cost-effectiveness for retrofitting trucks varies widely, depending on the number of miles driven, the availability and cost of fuels and controls, and the age of the retrofitted truck. Table 2-13 summarizes the ranges of cost-effectiveness for various retrofits that can be applied to off-site container trucks.

Both of the NO_x control strategies—NO_x catalysts and EGR—are relatively competitive in terms of cost-effectiveness. But the range of cost-effectiveness for PM

TABLE 2-12
Pollutants Reduced by Various Retrofit Technologies

	PERCENTAGE REDUCTIONS						
Technologies	**NO_x**	**PM**	**CO**	**VOC**	**Fuel Sulfur Tolerance**	**Fuel Penalty**	**Cost**
Active Diesel Particulate Filter (DPF) & Lean NO_x Catalyst (LNC)[a]	25	85	60–80	40–60	Up to 15 ppm	3–7%	\$15,000–\$18,000
Passive Diesel Particulate Filter (DPF)[b]	—	85	60–90+	60–90+	Up to 15 ppm	2–4%	\$5,000–\$7,000
Flow-Through Filter (FTF)[c]	—	> 40	> 40	> 40	Up to 500 ppm	10%	\$700–\$7,000, most likely ~\$1,500–\$2,000
Diesel Oxidation Catalyst (DOC)[d]	—	25	40–90	40–90	Up to 500 ppm	0–2%	\$1,000–\$3,000
Exhaust Gas Recirculation (EGR)[e]	40–50	N/A	N/A	N/A	Up to 500 ppm	0–5%	\$13,000–\$17,000
Lean NO_x Catalyst[f]	10–20	N/A	N/A	N/A	Up to 250 ppm	4–7%	\$6,500–\$10,000

Sources: *EPA Technical Summary of Potential Capabilities of Currently Available Retrofit Technologies,* www.epa.gov/otaq/retrofit/retropotentialtech.htm; CLeaire; Clean Air Systems; CARB, *Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Airborne Toxic Control Measure for in-use Diesel Fuel Transport Refrigeration Units (TRU) and TRU Generator Sets, and Facilities where TRUs Operate,* Oct. 28, 2003 and *Diesel Risk Reduction Plan,* Oct. 2000; Memo from Dale McKinnon, Manufacturers of Emission Controls Association, Dec. 5, 2000; and MECA, *Retrofitting Emission Controls on Diesel-Powered Vehicles,* March 2002.

Note: This table differs from the table listing retrofit technologies for off-road applications, which often have different duty cycles and activity factors.

a NO_x and PM reductions as verified by CARB; CO and VOC reductions as reported by CLEAIRE, currently the only manufacturer that has verified this type of retrofit technology.
b Verified DPFs are prone to produce more nitrogen dioxide, as its creation is required for proper regeneration of the system. CARB believes the NO_x increase is offset by NO_x benefits achieved by the DPF systems.
c FTFs are not yet commercially available; they are expected to complete CARB verification in 2004.
d DOCs may achieve higher PM reductions, especially with very low sulfur fuels; however, they are verified only at 25% by CARB.
e EGR increases PM emissions slightly, and therefore should not be used without a PM control.
f LNCs are not yet commercially available alone, although they are available as a package with a DPF or DOC. The cost of DOC-LNC retrofit is roughly \$10,000.

TABLE 2-13
Ranges of Cost-Effectiveness of Various On-Road Control Strategies

Control Strategy	NO_x (Per Ton)	PM (Per Pound)
Active DPF and NO_x Reduction Catalyst[a]	$ 6,000–35,700	$ 78–117
Passive DPF[a]	N/A	$ 31–57
Diesel Oxidation catalysts (DOC)[b]	N/A	$ 5–35
Exhaust Gas Recirculation (EGR)[a]	$ 3,300–37,000	N/A
Lean NO_x Catalyst[a]	$ 4,100–43,500	N/A
Flow-Through Filter[b]	N/A	$ 2–51

Assumptions: (1) Pollutant reduction percent and costs were taken from Table 2-12. (2) Baseline emission factors taken from 2003 Carl Moyer Guidelines, Table 2.6 & 9.3. (3) Project life ranges from 7 to 15 years, per Carl Moyer Guidelines, Sept. 2003, p. 23. (4) The incremental cost of ULSD is based on [fuel cost per gallon] x [annual mileage/ 6 mpg]. The best cost scenario was estimated at $0.05/gallon, and the worst case scenario was estimated at $0.20 per gallon. (5) Annual vehicle mileage was assumed to range from 30,000 to 65,000 miles.

a These retrofits were assumed to apply to MY 1994 trucks for the best case and 2004 worst case.
b These retrofits were assumed to apply to MY 1984–1990 trucks for the best case and 1991–1993 worst case.

controls varies considerably because control strategies vary with the age of the truck. For example, both DPF options appear much less cost-effective because they must be applied to 1994 and newer trucks (due to engine compatibility), which are much cleaner than earlier models. The result is that control strategies, such as DOCs and flow-through filters, can reduce a smaller percentage of PM, but from much dirtier older trucks, therefore yielding greater overall PM reductions.

EXAMPLES ▶ The Port of Oakland is currently designing an incentive program for off-site trucks. The $2 million program appears to be focused on incentives for new purchases and retrofits and is slated to begin in 2004.

DISCUSSION ▶ The incentive programs noted earlier—Gateway Cities, SECAT, TERP, and Carl Moyer—also serve as precedents for retrofitting diesel trucks. In addition, two other regional California programs, funded by vehicle registration fees, offer similar incentive funding. The mobile source air pollution reduction review committee's MSRC discretionary funds receives 30 percent of funds collected each year from a $4 surcharge on vehicle registration in the Los Angeles area. MSRC incentive funding targets programs that reduce mobile source emissions, including alternative-fuel infrastructure, alternative-fuel school buses, and cleaner on- and off-road heavy-duty vehicles. The San Francisco Bay area transportation fund for clean air also disburses roughly $20 million per year for the cleanup of existing vehicles and equipment and funds cleaner new purchases.

After-treatments should be tailored to the local air shed, focusing on more expensive NO_x reductions in urban areas suffering from smog. PM reductions remain a priority in every air shed, because PM, especially diesel PM, has a severe effect on local health. We do not recommend the use of after-treatments that require low-sulfur diesel where appropriate fuel is not available, except in the case of centrally fueled fleet applications, where cleaner fuel can be delivered. When low-sulfur diesel becomes available nationwide in mid-2006, these sensitive after-treatments can be more widely used. Unfortunately, in the absence of available low-sulfur diesel, PM controls are limited to DOCs and flow-through filters, which are much less efficient at removing PM.

The more efficient DPF after-treatments are also limited by other factors. They can be applied only to 1994 model year or newer heavy trucks, are vulnerable to failure if maintenance is not timely or if vehicle use does not consistently generate high enough temperatures, and misfueling with diesel fuel containing sulfur levels greater than 30 ppm is a possibility—an error that could impair performance and contaminate and destroy DPF systems.

Many new technologies are emerging, providing more options for different levels of PM and NO_x reductions in older versus newer model year vehicles with varying fuel types. As California continues to implement a series of diesel PM control rules, we expect more control technology options to be verified and become available for use nationwide.

Finally, it should be noted that we do not recommend repowers in this measure because of the logistical constraints on owner/operator truckers and small truck fleets. Repowers are a cost-effective pollution control measure, when truck owners or operators can afford to have their trucks out of service for several weeks while the engines are replaced. However, that may not be feasible for many trucks serving marine terminals because time in service for each individual truck is so important. Large fleets, such as terminal tractors (see cargo-handling equipment covered in previous section), appear to be better equipped to cycle a few vehicles out of use for a few weeks at a time.

The Port of Oakland has identified a local trucking company with a centrally fueled fleet that will demonstrate the use of diesel emulsions.

Cleaner Diesel Fuels

This measure is appropriate for centrally fueled truck fleets. A fleet manager would have to commit to a cleaner fuel and arrange for on-site delivery and fueling. The various available clean fuels, pollutant reductions, costs, and other effects are described in the cleaner diesel fuels discussion for existing equipment. The fuels listed in that measure are all appropriate for use in off-site trucks and cargo-handling equipment.

The Port of Oakland has identified a local trucking company with a centrally fueled fleet that plans to demonstrate the use of diesel emulsions. Some of the company's trucks will also have DOCs installed, followed by limited testing to compare the performance of trucks with and without DOCs. This demonstration has only recently begun, so impact estimates are premature.

Reduced Idling

Ports should restrict idling inside and outside the terminal to no more than 10 minutes for all container trucks. Idling limits should apply in all terminal areas throughout the port, as well as in queuing areas near entry gates. Marine terminal operators (MTO) and port authority personnel should be responsible for ensuring that idling limits are met, but enforcement should be conducted by the port, air quality agency staff, or such local officials as police officers. Finally, MTOs must provide sufficient electrical power hookups for refrigeration units and any other heavy-duty truck power needs in all terminals and queuing areas.

Finally, MTOs should be responsible for ensuring that lines do not form inside the terminal instead of outside the gates—a problem some drivers have reported at the ports of Oakland and Los Angeles. It is more difficult to enforce idling limits when long lines of trucks are waiting inside the terminal because they must constantly start up to advance the line and compete for attention in receiving or dropping off their loads.[91] MTOs should consider implementing a scheduling system so that drivers arrive at appointed times and that containers are ready when drivers arrive.

One promising solution is a statewide mandate requiring idling restrictions, with enforcement through local regulatory agencies. However, without a regulation in place, this measure should still be encouraged by individual ports.

At the Port of Los Angeles, 10-minute idling restrictions would translate to more than 800 tons per year of NO_x reductions, more than 14 tons per year of toxic PM reductions, and reduced emissions of the primary greenhouse gas, carbon dioxide, of more than 46,000 tons per year.

Pollutants Reduced A 10-minute idling limit could save hundreds of gallons of fuel annually for each truck that regularly visits the port. In addition, it would likely reduce emissions of priority pollutants by dozens of tons. The fuel savings and emission reductions are directly related to the reduction in idling time. The pollution reductions are most significant for diesel PM and NO_x; however, reductions in other pollutants, such as CO_2, CO, SO_2, and VOCs provide additional benefits.

Emission rates during idling do not consistently go down with newer model years; therefore, new trucks must also adhere to the idling limits as long as they are powered by fossil fuels. Although VOC emissions during idling steadily decline with newer model year vehicles, NO_x, CO, and CO_2 have increased with newer models.[92]

Unit Cost Some costs are associated with this measure. Each terminal operator in a port would have to hire personnel to monitor compliance. In addition, terminal operators would need to post signs and train both their new and existing personnel for enforcement. This could cost terminal operators on the order of $100,000 a year (possibly more during the first year, but subsequent years will cost much less).[93]

Cost-Effectiveness At the Port of Los Angeles, reducing idling could reduce more than 800 tons of NO_x every year, for an average cost-effectiveness of $990 per ton. Compared with other measures, that is an extremely cost-effective pollution control measure. Moreover, that estimate does not include all of the other pollutants that would be reduced by this measure, including the reduction of 14.4 tons of toxic diesel particulate and more than 46,000 tons of greenhouse gases.

In addition, this measure would result in significant cost savings from the reduced use of fuel—more than 4 million gallons at the Port of Los Angeles, for example. At this writing, the U.S. Department of Energy reports that a gallon of diesel in the United States costs on average $1.50, so the millions of gallons of diesel fuel consumed annually that this measure would reduce could translate to millions of dollars in collective savings to port truckers.[94]

Finally, truck owners should also benefit from reduced maintenance on their trucks. Experts estimate that engine wear on trucks due to idling for one hour per day is the equivalent of 6,400 miles of travel annually. That is roughly equivalent to an additional $300 per year in added maintenance on a vehicle.[95]

EXAMPLES ▶ California implemented a statewide idling law in 2003 (see Chapter 3), limiting truck idling at ports in major metropolitan areas to 30 minutes. The law appears to have significantly reduced idling outside of port terminals, but some truck drivers at the ports of Oakland and Los Angeles report long lines and idling inside terminals, thus offsetting the benefits. Other ports, including the Port of Seattle, are beginning to post no-idling signs and implement idling restrictions, but enforcement is questionable.

DISCUSSION ▶ The enforcement of an idle-reduction measure should significantly reduce pollution, result in substantial fuel savings, and reduce noise pollution around the terminals and in local neighborhoods. The cost-effectiveness of this measure rivals the least-expensive emission reduction strategies available today. The benefits are enormous to the terminal operators, truckers, and the community. The one serious drawback is that enforcement

PARKING PLACES WITH AMENITIES

At least one company is developing travel center electrification products intended to provide in-cab heating and air conditioning for heavy diesel freight-hauling trucks, where they would otherwise idle for extended periods. Advanced travel center electrification systems provide each installed parking space with an individual heating, ventilation, and air conditioning (HVAC) unit mounted outside and above the truck. With the swipe of a credit card, a console unit is tethered to the HVAC and mounts into a truck's cab window, delivering heat or air conditioning along with television, Internet, local phone connections, and a 110-volt outlet for appliances. Outside, separate plugs power refrigerated trailers and engine block heaters.

This type of system can be used at port facilities, truck stops, terminals, border crossings, and many other areas. Systems are already in place in 11 travel centers or parking facilities in New York, Texas, California, Georgia, Arkansas, and Tennessee, with many more locations planned throughout the country.

The electrification system benefits community members, truckers, and entrepreneurs by

- Reducing toxic diesel emissions
- Eliminating idling noise nuisance to nearby community
- Saving truckers fuel and the extra costs of engine wear associated with prolonged idling while parked
- Providing added revenue to local commercial travel center or parking site owners
- Increasing driver comfort and rest

More than 250 trucking fleets provide their drivers with discounts to these plug-in facilities.

Source: www.idleaire.com.

may be difficult for port and MTO personnel unaccustomed to taking on enforcement roles.

Use of appointment, scheduling, or other truck or container management systems would also help reduce idling. Ultimately, however, enforcement is needed to curtail idling in many instances. For example, residents in neighborhoods close to terminals often complain that trucks idle outside terminal gates through the night. Lengthening gate hours may also disturb nearby communities, encouraging more traffic early in the morning or late at night. Ports, terminal operators, drivers, and community

RAIL VERSUS ROAD

Freight companies face a choice when shipping their goods to or from coastal ports: Should they send freight by rail or by road? To minimize emissions, fuel consumption, cost, accidents, and traffic congestion, the resounding answer is rail, according to a number of studies.

A study jointly commissioned by the Environmental Protection Agency, the Federal Railroad Administration, and the Federal Highway Administration, for example, found that transferring freight from today's average truck fleet to rail would reduce NO_x, CO, PM_{10}, and VOC emissions and that pollution reductions can be realized at even greater rates as more freight is transferred in the future. NO_x emission rates measured in grams emitted per ton-mile (ton-miles measure the movement of one ton of cargo one mile) are three times as high for long-distance freight trucks as for double-stack trains. PM_{10} emission rates can be as much as ten times as high for trucks as for rail, and the release of VOCs from trucks can be an astounding 17 times the rate from rail.

Moreover, case studies in Los Angeles, Philadelphia, and Chicago have shown that truck emissions make up a disproportionately high percentage of total regional transportation emissions of NO_x, VOCs, and CO. For example, in Chicago, trucks account for only 7.2 percent of all vehicle miles traveled but are responsible for 39.1 percent of all mobile source NO_x emissions and 20.7 percent of total regional NO_x emissions. In the same region, a national rail transportation hub emits only 2.3 percent of total NO_x emissions. Improving emission standards for trucks will eventually narrow the gap between diesel rail and diesel trucks. Therefore, trains must also be cleaned up or switched to electric power instead of diesel fuel, in order to maintain advantages in emission reductions.

Rail also outpaces road in fuel efficiency. For every gallon of fuel, rail lasts 455 ton-miles, whereas trucks last only 105, meaning that trucks burn at least four times as much fuel as rail. Another study found similarly that truck fuel use ranges from 1.4 to 9 times that of rail.

Over and above the significant environmental benefits, rail reduces costs both for freight companies and society.

Private freight transport costs range from 1 to 3 cents per ton-mile for rail freight, whereas each ton-mile costs about 5 to 8.5 cents if delivered by truck. These costs do not include the many external costs left unpaid by trucking companies. For example, the societal costs directly associated with air pollution are estimated as eight times as high for truck use as for rail. Additionally, extra costs are incurred from accidents involving trucks, and a switch to rail could lessen increased roadway congestion, resulting in additional fuel use as well as travel time. One forecast for the Norfolk-Newport News-Virginia Beach area shows that transferring 25 percent of projected 2010 truck traffic to freight would save 69 gallons of diesel fuel and gasoline per capita that year, if increased fuel efficiency and reduced traffic congestion are accounted for. Similarly, citizens of Houston would each save 64 gallons, and New Yorkers would save 46 gallons.

Today, ports can speed the conversion to rail by formulating proactive policies that encourage on-dock intermodal rail and rail infrastructure improvements and discourage existing dependence of freight transport by truck.

Sources: Cambridge Systematics, Inc. (1997), *Air Quality Issues in Intercity Freight: Final Report,* prepared for Federal Railroad Administration, Federal Highway Administration, and Environmental Protection Agency; D Forkenbrock (1998), *External Costs of Truck and Rail Freight Transportation,* the University of Iowa: Public Policy Center, 55 pp. and (2001), "Comparison of external costs of rail and truck freight transportation," Transportation Research, Part A 35:321-337; Air Pollution Prevention Directorate, Environmental Protection Service, Environment Canada (2001), *Trucks and Air Emissions: Final Report;* H Van Essen, et.al. (2003), "To shift or not to shift, that's the question: The environmental performance of freight and passenger transport modes in the light of policy making," CE Delft; T Brown, A Hatch (2003), "Intermodal: on the fast track," available at www.tomorrowsrailroads.com/industry/intermodal.cfm; and W Cox (2003), "Gridlock relief: freight rail's role in reducing gridlock," available at www.tomorrowsrailroads.com/industry/gridlock.cfm.

residents need to work together to find solutions that keep terminals open longer without disturbing local communities.

The creation of extra truck parking with electrical hookups or technology similar to Idle Aire (see "Parking Places with Amenities," page 51) is critical to any comprehensive truck-idling reduction program. Many trucks, especially those traveling long distances, arrive at port terminals during off hours when gates are closed, prompting drivers to leave engines idling while waiting in order to have heat, air conditioning, or other amenities. In addition, many trucks servicing ports carry refrigerated cargo that requires extra engines to keep the cargo cool. These extra refrigeration engines, called reefers, create additional pollution over and above that from the main truck engine. Most, if not all, ports provide reefer hookups into which refrigerated containers may plug. However, it appears that these reefer hookups are not always available to trucks carrying refrigerated containers, especially those waiting outside terminal gates, leading to increased idling. By providing parking areas with electrical power or services so that these trucks can turn engines off, ports can reduce pollution from both reefer and truck engines.

Natural gas powered locomotives provide fuel diversity and significantly reduce emissions. However, specialized maintenance facilities are required.

LOCOMOTIVES

Ports should reduce air pollution from switching locomotives by making three major changes: (1) replace or repower older locomotives at rail yards and container terminals; (2) install idling control devices on switching locomotives; and (3) use cleaner fuels such as lower-sulfur diesel fuel or diesel emulsions in locomotives.

Cleaner New Purchases and Repowers[96]

This measure would require the replacement or repower of older locomotives, both at the container terminals and at other major rail yards serving a port. Appropriate technologies for engine replacements include new, low-emitting engines fueled either by natural gas or other alternative fuels, or hybrid engines relying on battery-electric and turbine power. In particular, the replacement of pre-1973 locomotive engines, or those engines not yet meeting federal standards, with new alternative fuel or electric-hybrid equipment would provide significant emission benefits. This strategy may require the installation of alternative-fueling stations at the associated rail yards and terminals.

This program would target switching locomotives as opposed to line-haul locomotives because they typically idle for long periods, tend to be quite old, and are known as the workhorses in most rail yards. Among the criteria that should be considered in deciding which locomotives to replace or repower are the emission rates of older engines, the hours normally spent running, the age of the engines, and the willingness of the owner/operator to operate in or near a port after replacement of the engine.

Several alternative-fuel and hybrid-electric locomotives are on the market and available for purchase; others are under development. The "Green Goat," a new hybrid electric switching locomotive, retails for roughly half the cost of a new

PUTTING AN END TO EMPTY CONTAINER TRAFFIC

The Port of Oakland is working with a private company to develop software to coordinate truck trips, thus eliminating unnecessary trips and mileage. Truckers usually drive to ports to pick up empty containers, or "empties," take them to the shipper to pick up merchandise, and then make a return trip to bring the full container back to the port for export. Because shippers and trucking companies are often located some distance away from the port, the distance that trucks haul empties to the shipper creates significant air truck miles. These wasted miles lead to extra roadway congestion and pollution and can be eliminated with well-planned coordination.

When complete, the service will allow trucking companies to interchange containers through an Internet site at a virtual container yard, improving productivity and reducing lines at terminal gates. For example, a trucker in Sacramento could go to Stockton to pick up an empty container, get it filled, and go to the Port of Oakland, saving a trip to Oakland to get an empty container. Bill Aboudi, whose 40-truck company was one of three to test the system, says, "It definitely will reduce congestion big time if everybody gets behind it." The system will soon be available for a small monthly fee to the more than 800 trucking firms serving the Port of Oakland.

Sources: Personal communication with Paul Larking, SynchroNet; and Alec Rosenberg, "The SynchroMet service lets trucking companies interchange containers through one Internet site, increasing productivity and trimming waits at terminal gates", *Oakland Tribune*, 23 April 2002.

conventional locomotive and reduces both PM and NO_x by roughly 85 percent (see "The Green Goat," page 57). It uses a 100 horsepower generator, as compared to 2,000 horsepower locomotive engines, to replenish power to a bank of lead-acid batteries, significantly cutting fuel use by at least one-third and also lowering noise. The least-expensive option uses a Tier II certified diesel generator, although natural gas micro-turbines and fuel cell power are also possible.

Pollutants Reduced The emission benefits of this approach are expected to consist of reduced diesel PM, NO_x, and other pollutants. Depending on the technology selected, NO_x emission reductions are generally reported to be between 50 and 85 percent for electric-hybrid or natural gas powered switching engines.

Unit Cost Locomotives used in switching service are generally older units that have been retired from short-line or line-haul service. Depending on the condition of a used locomotive, the resale unit cost can range from $100,000 to as high as $1 million. Currently, it is not possible to purchase a new natural gas locomotive from an original equipment manufacturer. The several projects completed to date where natural gas fuel was used to power a locomotive have been retrofit projects where the existing engine was overhauled and converted to run on natural gas. Cost for such a conversion, including a new natural gas fuel system, ranges from $400,000 to $800,000 per locomotive.

With production volume increases, the new Green Goat hybrid electric switching locomotive is projected to cost $750,000.[97] Other undetermined costs that must also be considered when investing in such a technology include disposal costs for the lead-acid batteries and the replacement costs of the new battery system at the end of its useful life.[98]

Cost-Effectiveness Although alternative-fuel and electric-hybrid locomotives have significant incremental costs, seeking applications with high usage make these projects a cost-effective option for reducing emissions within port operations. Conservative estimates place the projected annual fuel consumption of a switching locomotive at 25,000 gallons of diesel per year. Retrofitting the locomotive with a low-emission LNG engine would reduce NO_x by more than 9 tons per year and PM by more than 300 pounds per year. The average cost-effectiveness of an alternative-fuel switching locomotive is roughly $12,900 per ton of NO_x and $430 per pound of PM reduced.

Projects opting for the electric-hybrid technology can be more cost-effective because the project life would be longer. That is because the units are new and because the percentage of emissions reduced can be greater. Electric-hybrid switch tractors can achieve 85 percent emission reductions, annually reducing more than 11 tons of NO_x and 800 pounds of PM emissions. The average cost-effectiveness is slightly lower than an LNG switcher, or roughly $11,800 per ton of NO_x and $200 per pound of PM reduced.

The average cost-effectiveness of an alternative-fuel switching locomotive is roughly $12,900 per ton of NO_x and $430 per pound of PM reduced.

EXAMPLES ▶ Burlington Northern ran two LNG line-haul locomotives transporting coal inside Wyoming from 1991 to 1995.[99] From 1994 through 1997, several companies demonstrated LNG switching trains in the Los Angeles area. Two of the four LNG switching trains remain in use in local yards; it is unclear why the other two were discontinued, as the demonstrations were successful. A number of LNG locomotive applications are in use abroad as well, including projects in Russia, Germany, Japan, Finland, and the Czech Republic.[100] In the late 1990s, the Napa Valley Wine Train, a passenger train, was converted to CNG. (See "The Green Goat," page 57, for examples of electric-hybrid use.)

DISCUSSION ▶ Natural gas provides fuel diversity. However, because it is lighter than air and therefore rises, modifications to existing maintenance facilities are generally necessary in order to prevent leaks from going undetected. The modifications usually consist of a methane detection system, an improved ventilation system, new lighting, employee training, and containment procedures.

Electric-hybrid locomotives would also save significant amounts of fuel, so cost-effectiveness for this technology is competitive.

Other clean locomotive options are under development. Railpower Technologies Corporation, the company marketing the Green Goat, also has a natural gas locomotive under development. General Motors is working on a fuel cell locomotive, and General Electric is trying to integrate simpler emission reductions into locomotives, including cleaner diesel fuel, regenerative braking, and automatic idling controls.

Although after-treatments are not yet known to be in widespread use on locomotives, the CARB is exploring use on locomotives of some of the same retrofit controls available for other heavy-duty engines. Many of these retrofit controls, such as diesel oxidation catalysts, diesel particulate filters, and selective catalytic reduction, are likely to work well on locomotives with the right grade of fuel. Finally, locomotives could also be fully electrified, an approach used for passenger rail in many locations. Freight rail, however, presents tougher challenges for electrification. The Port of Göteborg, Sweden, is currently investigating this issue.[101]

Idling Controls

All existing conventional locomotive engines should be required to have automatic idling controls installed. An automatic idling control is a device that automatically controls the locomotive engine so that it turns off when not in use and then turns on when the unit is needed, when the system needs to warm up to maintain a certain operating temperature for readiness, or when battery power needs to be replenished. The controls would be installed on any existing diesel locomotives not slated for replacement, with the oldest switching locomotives the priority. Switching trains are generally quite old and dirty and tend to idle about 75 percent of the time, accounting for 27 percent of their total fuel use.[102] Idling controls reduce fuel use and emissions, and cut down on noise. This measure is widely available and has been used successfully in many locations.

Switching trains are generally quite old and dirty and tend to idle about 75 percent of the time, accounting for 27 percent of their total fuel use.

Pollutants Reduced Pollution reductions are most significant for diesel PM and NO_x; however, reductions in other pollutants, such as CO_2, CO, SO_2, and VOCs provide additional benefits. Idling controls also save hundreds of gallons of fuel in addition to the pollution avoided.

Unit Cost Most automatic idling controls for locomotives cost roughly $6,000 to $10,000, with more elaborate devices costing up to $40,000.[103] Locomotive idling controls typically take several days to install—lost time that constitutes a cost.[104]

Cost-Effectiveness Several companies make these controls and claim that the cost is paid back in a year or two through fuel savings. Locomotive idling controls are extremely competitive on cost-effectiveness of emission reductions. The controls can achieve an average of almost 4 tons of NO_x and 270 pounds of PM reductions per year. Cost-effectiveness is on average $3,000 per ton of NO_x reduced and $50 per pound of PM reduced.

EXAMPLES ▶ Under a Canadian-funded freight sustainability demonstration project, Southern Railways of British Columbia installed the ZTR Control System's SmartStart Technology to automatically shut down and restart locomotives on demand.[105] Under a green transport initiative, the EPA created a grant program in 2002 for the demonstration of locomotive and truck idling controls.[106] The EPA cosponsored a successful locomotive idling control project in Chicago more than a year ago with Burlington Northern Santa Fe (BNSF), Wisconsin Southern Railroad, and the City of Chicago.[107] The EPA has also recently funded a similar project in Vancouver, Washington. Several current state implementation plans for complying with federal air quality standards include measures to explore locomotive idling controls.

DISCUSSION ▶ Several companies make these controls in various configurations for different locomotive types. The use of idling control devices can cut down on noise and can result in significant fuel savings. The EPA estimates that 10 percent of all rail fuel could be saved, translating into 366 million gallons and $240 million.[108] Operators of on- and off-site rail yards where port cargo is handled must agree to this measure; however, potential fuel savings would be a substantial incentive in itself.

THE GREEN GOAT

A company based in Vancouver, Canada, has rolled out a hybrid-electric switching locomotive, the Green Goat, that is competitively priced with conventional locomotives. The Green Goat combines a small and efficient 100 horsepower (HP) generator with a custom-made large bank of batteries. Currently the generator is diesel; however, the company is exploring micro-turbine gas and fuel cell options. The 2,000 HP Green Goat, fitted with an auto-shutoff device to reduce idling, achieves fuel savings of at least 30 percent, NO_x and PM reductions of 80 to 90 percent, and reduced operating noise. Because it is digital, remote-control operation can be integrated.

The Green Goat recently finished a one-year demonstration at a Union Pacific rail yard in Roseville, California, and is now in use at the Marine Corps Logistics Base in Barstow. A smaller, 1,000 HP version, called the Green Kid, is being demonstrated at Chevron's El Segundo refinery in Los Angeles. A number of orders for new Green Goats have recently been placed in Texas.

Sources: Simon Clarke, Executive VP Corporate Development, Railpower Technologies Corp., personal communication, December 2002, and Executive Summary document, November 2002, sclarke@railpower.com. Pat Maio, "Train Makers Race Clock to Find Ways to Cut Locomotive Pollution," *The Wall Street Journal*, 23 Oct 2003.

NIGEL HORSLEY/RAILPOWER

Cleaner Fuels

This measure would be appropriate for all centrally fueled switching and short-haul locomotives. A rail company would have to commit to a cleaner fuel and arrange for on-site delivery and fueling; however, in many areas incentive funding may be available. Details on the various clean fuels available, pollutant reductions, costs, and other impacts are in the first section regarding cleaner fuels at the beginning of the chapter. All of the fuels listed in that measure would technically be compatible with locomotives, but diesel emulsions and low-sulfur diesel (15 ppm sulfur) are the two most likely options. These fuels would also allow the use of such after-treatment controls as diesel particulate filters.

STORMWATER POLLUTION PREVENTION[109]

A model aquatic resources protection program for ports should encompass all potential sources of water pollution and other damage to aquatic resources that are associated with port operations, with the exception of industrial-processed wastewater and domestic wastewater that may be generated onshore within port jurisdiction. Although this section does not cover the construction of port facilities, we encourage ports to follow the guidance provided by the EPA and other authorities, because serious water quality problems can occur during construction (e.g., soil erosion and contamination from construction materials and activities).

The principal water quality issues at ports include the following: stormwater runoff; ship liquid and solid waste handling; fueling; activities in, over, or adjacent to water (e.g., dredging, pile driving, ship maintenance); and stewardship of ecological resources under port auspices.

Broadly speaking, these issues divide into two categories: onshore areas (stormwater), and offshore areas (shoreside and harbor).

A model stormwater program for ports should include the most successful, state-of-the-art general stormwater practices applicable to marine terminals. Shoreside and harbor water quality programs should include best practices that have been successfully implemented in the shipping industry. In both cases, the model programs require no new technological advances for effective application.

Port Guidance on Model Programs for Port Tenants

To have an effective program, the port should provide guidance to its tenants, including development of model stormwater programs, oversight of individual terminal programs, inspections of individual terminals to confirm implementation of an acceptable program, and education and training of terminal staff.

Environmental responsibilities at ports are generally split among the port authority body, the port's tenants, contractors for both parties, and visiting ships. It is essential to distinguish these responsibilities for the purpose of identifying where educational efforts for the various parties should be directed. Ultimately, the parties who actually hold government permits are responsible for meeting water quality standards. For stormwater, the port authority is generally a permittee and has the principal responsibility for preparing a stormwater pollution prevention plan (SWPPP). The permits and SWPPPs in some cases cover tenants, whereas in others tenants produce their own SWPPPs under port auspices as co-permittees or as separately permitted entities. It is preferable that port authorities maintain the permit and SWPPP for all facilities, including tenant-operated terminals, to ensure an efficient and effective water quality protection program.

Documenting and Analyzing Potential Water Pollution

Ports should carefully document and analyze potential water pollution problems as a requirement of any comprehensive stormwater plan.

The analysis should map each terminal and describe how runoff flows through the terminal. It should also assess the risks of pollution, prior instances of pollutant spills and leaks, and best management practices (BMPs) that can be implemented to minimize pollutant runoff. Monitoring data should also be collected to determine existing water quality around the terminal.

Developing a Stormwater Program

Each port terminal should develop a stormwater program that includes best management practices for the control of stormwater runoff in operational, source control, and treatment areas.

A model stormwater program for ports should include the most successful, state-of-the-art general stormwater practices applicable to marine terminals.

The plans should establish operational and source control BMPs that prevent the initial development of water quality problems. However, because source controls will not, in general, fully isolate pollutants from the environment, BMPs to capture and treat water pollutants are also necessary. Because treatment can never provide better water quality than prevention, thorough application of the first two categories of preventive BMPs is always preferred.

The following operational BMPs are critical to an effective stormwater program:

Pollution Prevention Personnel Specific personnel should be assigned responsibility for each aspect of the stormwater management program.

Preventive Maintenance A formal program of preventive maintenance should be implemented to avoid equipment deterioration and failure that cause spills and leaks of pollutants.

Good Housekeeping Each facility should adopt a written policy for maintaining a clean facility, including regular sweeping, drain inlet stenciling to prohibit discharge of pollutants into storm drains, employee education about how to maintain a clean facility, employee incentives, and publication of the good housekeeping policy for employees.

Spill Response A clear, comprehensive, organized program to respond properly if and when a spill occurs should include (1) whom to notify, (2) who is in charge, (3) specific instructions for different materials that could be spilled, (4) spill containment procedures,

(5) easy-to-find-and-use spill cleanup kits, (6) procedures for preventing a spill from getting into a drainage system, (7) a disposal plan, and (8) a worker training program.

Illicit Connection and Illegal Discharge Control Each facility should adopt a written program that analyzes the storm drain system to find and remove connections that would introduce harmful non-stormwater (e.g., sewage) discharges into the stormwater system. There should be an ongoing program to avoid such illicit connections and the illegal discharge of wastes into the storm drain system.

Improved Materials and Waste Management Management strategies should be adopted to substitute less polluting products for more contaminating ones and to decrease waste through recycling and reuse of materials.

Inspection An inspection program is a critical component of any stormwater program and should include two components. The first is an annual comprehensive facility compliance evaluation; as part of this evaluation, an experienced supervisory inspector should walk through and evaluate the entire site, review all stormwater documentation, complete a comprehensive checklist designed to ensure that all protocols and stormwater policies are being followed, and follow up on any deficiencies found at the facility. Second, there should be a regular and ongoing program to find potential problems before they occur. Facility staff must be trained to look for deteriorating equipment that may leak or spill and for stormwater control devices that need maintenance.

Ports should carefully document and analyze potential water pollution problems as a requirement of any comprehensive stormwater plan.

Record-Keeping Each facility must implement a comprehensive system for recording and retrieving information gathered from carrying out all aspects of the stormwater management program. Copies of all records should be maintained at the facility and as part of a central port stormwater control program.

Employee Training Proper training is essential for any stormwater management program to be effective. Ports should implement formal and documented training programs for all personnel who perform or supervise any function that could affect runoff water quality appropriate to the level and responsibilities of the employees. For example, outdoor workers might get "tailgate training" to explain why stormwater control is important and how the release of pollution can be avoided in their work. Supervisors might get classroom training on how to assign maintenance tasks for stormwater treatment controls.

Each facility must also implement source control practices that prevent pollutants from coming into contact with rainfall or runoff. Examples include covering a potentially polluting activity, such as a petroleum coke (or other material) stockpile and providing secondary containment for storage of potentially polluting liquids on site. Control practices implemented at a particular site will depend on the facilities and activities at the facility. Examples of source control practices are included in Appendix C, Section B.2.

Where implementation of operational and source control practices at a facility cannot fully prevent contact between pollutants and rainfall or runoff, treatment BMPs must be implemented. Specific treatment BMPs must be selected based on the individual aspects of a facility designed to prevent the discharge of pollutants into the receiving waterbody. Examples of treatment BMPs include the use of porous pavement to allow runoff to infiltrate into the pavement and then into the underlying soil (instead of flowing from the area) and an oil/water separator to separate and treat oil discharges. Examples of treatment BMPs are included in Appendix C, Section B.3.

In addition, a stormwater program must be designed to prevent non-stormwater discharges into the stormwater runoff. For example, polluted water or sewage from other sources could reach a facility through an illegal connection to the stormwater system or by dumping into a storm drain. Holders of a stormwater permit are required to certify that they have implemented a program of observation and testing of potential discharges and have eliminated any discharges.

Finally, the stormwater permit requires implementation of a monitoring program, including observation of visible signs of pollution and sampling of stormwater runoff. Although the stormwater permit requires limited monitoring, an effective program must include comprehensive monitoring both of stormwater runoff onsite and of the receiving waterbody to ensure that the BMPs implemented by the port facilities are effective at preventing pollutants from flowing to the receiving waters. A more complete description of a stormwater monitoring program is included in Appendix C, Section B.5.

In many cases, the surrounding community, environment, and region would be better served if the port improved its land use efficiency instead of expanding its footprint.

It should be noted that circumstances vary greatly from port to port, and this, in turn, has a strong effect on the applicability of specific practices. Users should select practices that best meet overall goals beyond permit compliance, not only preventing discharge from causing or contributing to a violation of water quality standards but also preserving or improving the natural resource values of waters under port jurisdiction. Because BMP effectiveness and feasibility depend on a good match between methods and real-world circumstances at the site, careful selection of approaches is critical.

CONSTRUCTION DESIGN FEATURES TO CONTROL POLLUTION AT PORTS

Design choices can play an important role in reducing pollution from port operations, ranging from a precautionary approach to new port development to targeted pollution control measures employed at existing terminals. At a minimum, to the extent ports expand their operations, they should employ special design features and state-of-the-art technologies to mitigate impacts on the local environment.

Multiple pollution prevention measures should be incorporated into the planning stages of any new port terminal development. Some of the most important mitigation measures for new port terminal development include locating the new terminal near the mouth of the harbor, close to existing transportation infrastructure and far from residential areas. It should be noted, however, that developing on pristine land, and especially filling in waterbodies, should never be sacrificed to meet these criteria. In fact, before expanding, ports must first evaluate whether it is truly necessary. In many cases, the surrounding community, environment, and region would be better served if the port improved its land use efficiency instead of expanding its footprint.

At the very least new terminals should be located away from residential areas to protect communities from the pollution, noise, and other stressful effects of ports' heavy industrial activities. Other measures that must be included in new development include incorporation of infrastructure for cleaner fuels, such as natural gas or even fuel cells; inclusion of on-dock rail in terminal designs; and planning for sufficient electrical power to run equipment and ships that ordinarily run on diesel or bunker fuel.

The location of new terminals near a harbor entrance is a simple way to avoid significant amounts of pollution from ships traveling extra distances from the shipping lanes in the open ocean. For example, the largest single-terminal container complex on the East Coast, at the Port of Savannah, is located 36 miles from the harbor entrance, more than half of which is up a river.[110] The Port of Miami, on the other hand, is located just a few miles from the open ocean.

Multiple pollution prevention measures should be incorporated into the planning stages of any new port terminal developments.

Proximity of new terminals to land transportation infrastructure is also extremely important. Developments that reuse abandoned industrial properties or former military installations are often close to existing highways and main rail lines, and at the same time avoid new construction on a more pristine site. Sufficient roadway infrastructure is important in order to prevent persistent traffic and safety problems on smaller roads. Residents of neighborhoods near busy ports have long complained about trucks cutting through their narrow streets, getting stuck, creating noise and pollution, and causing safety threats to pedestrians and children.

Well-planned railroad infrastructure is particularly important at new port terminals. Although rail transport is environmentally preferable to truck transport, it is still a significant pollution source, and longer, less direct rail lines result in more pollution. Recognizing these issues, the Port Authority of New York and New Jersey is investing $500 million in rail infrastructure to serve its terminals.[111] However, the Port of Charleston failed to consider the impacts of a lengthy rail connection in a recent proposal to build a new container terminal on Daniel Island, a location that would require a circuitous 50-mile rail loop merely to cross a river.[112] Finally, after the state Senate denied the expansion plan, the port was forced to choose a new site for development, on the other side of the river from Daniel Island and close to the existing transportation infrastructure.

On-dock rail, or rails that go all the way onto the docks where ships are unloaded, can significantly reduce pollution by eliminating the need for truck trips to shuttle containers from the docks to a rail yard. Increasingly, ports are embracing on-dock rail as a means to increase efficiency. The recent container terminal development at the Port of Seattle was built with on-dock rail, routing the majority of containers out via rail rather than truck. The Port of Seattle reports that on-dock rail, combined with other rail improvements, has replaced 200,000 miles of truck trips in Seattle annually.[113]

OTHER MEASURES TO ALLEVIATE IMPACTS FROM PORT OPERATIONS

Ports need to consider many other measures in addition to those that mitigate air and water quality impacts. Following are short descriptions of measures that abate traffic, noise, and aesthetic impacts. This list is not intended to be comprehensive. Many more mitigation measures may be necessary to address impacts on specific communities near marine ports. However, this list is representative of the concerns commonly raised by nearby communities.

Traffic Mitigation Plan

Ports should create and implement a traffic mitigation plan. Ports should conduct a study of traffic on roads and highways in and around the port and then create and implement a meaningful traffic plan based on the findings to reduce congestion and impacts from the port on local roads and highways. Although traffic studies are required for expansion projects, it is important that ports study existing traffic to reduce the impacts from prior port growth. Public comment and input should be a priority throughout the process.

Minimize Noise and Light Pollution

Ports should minimize noise and light pollution. Because ports are often close to residential areas, their highly industrialized operations create a number of hazards and nuisances for nearby communities. Ports should make every effort possible to

A FINNISH MODEL: THE VUOSAARI HARBOR PROJECT

The Vuosaari Harbor Project is an ambitious new development that will move all of Helsinki's port operations out of the downtown area to the Vuossari Harbor. The project may be the best example of a new port development that employs precautionary measures.

Construction recently began on the new terminals, at a total cost of more than $550 million to relieve downtown Helsinki from the pollution, noise, and traffic from its port operations. The core operations of the harbor will be 2 kilometers from the nearest residential area. The new development, however, is very close to designated natural habitat areas, and therefore a number of mitigation measures have been employed.

Most notably, plans call for rail and road tunnels, and a special bridge to be built, in order to avoid disturbing certain sensitive wildlife areas. Bridge and tunnel designs incorporate various elements that will minimize noise, vibration, and the potential for hazardous spills and water contamination. The rail tunnel will be electrified, and the rail bridge will incorporate warning devices to prevent birds from flying into the cables. Outside of the tunnels and bridges, the rail and road corridor will be adjacent to noise barriers and native landscaping. Other measures include bicycle paths and footpaths, several foot bridges, noise shielding and native landscaping of the rail yard and harbor road, and groundwater monitoring.

Sources: Port of Helsinki, *Vuosaari Harbour is Important for the Foreign Trade of the Whole of Finland,* Port of Helsinki: Helsinki available at http://www.vuosaarensatama.fi/fi/index.html. Port of Helsinki, *Harbour centre-vitality for the development of Vuosaari and its environs. Sustainable Port Development: case: Port of Helsinki/Vuosaari harbour,* in Sustainable Port Development. 2002, Genoa.

avoid expanding near residential areas. Where existing terminals are already close to residences, ports must make every effort to minimize noise and light pollution. For example, bright lights used at night should be minimized to the extent possible to avoid glare in the local community.

On-dock rail, or rails that go all the way onto the docks where ships are unloaded, can significantly reduce pollution by eliminating the need for truck trips to shuttle containers from the docks to a rail yard.

Low-Profile Cranes

Ports should use low-profile cranes at marine terminals to improve aesthetics. Gantry cranes, because of their structural size and girth, can greatly impair and degrade the community's view of the harbor. Cranes of a lower profile can be designed upon request to the crane manufacturers, resulting in a product that significantly reduces the aesthetic impact created by conventional gantry cranes. Low-profile cranes can be designed to the same load-lifting capacity and performance standards as conventional gantry cranes, making low-profile cranes as efficient and productive as their conventional counterparts. Currently, there are approximately 33 low-profile cranes in use throughout the world; the largest low-profile crane currently in operation is capable of servicing 16-wide container ships.[114] The Port of Los Angeles is in the process of ordering and purchasing two low-profile cranes capable of servicing post-Panamax 22-wide container ships. The conventional gantry cranes required to service these ships are 300 feet tall when in the stowed position and 360 feet tall when they are extended for occasional maintenance.[115] By contrast, a low-profile crane that would service the same ship can be designed to be no more than 185 feet when in the stowed position and when maintained.

CHAPTER 3

Improving Laws and Regulations Governing Ports

The large, industrial, and high-polluting operations at marine ports have an enormous effect on human health and the environment. Ordinarily, such activities would be subject to stringent regulation, but for the most part, oversight of ports falls between the regulatory cracks—defeated by confusion over jurisdictional authority and a strong industry lobby. A patchwork of international, federal, state, and local rules applies to various pollution sources at ports, and most are weak and poorly enforced. This chapter highlights the major rules that apply to port-related activity and offers recommendations for strengthening existing rules and for laying the groundwork for new rules to help clean up U.S. ports.

INTERNATIONAL TREATIES

Created in 1958, the International Maritime Organization (IMO) promotes and coordinates international maritime safety and ship pollution prevention.[1] The IMO has adopted roughly 40 conventions and protocols to date, covering such topics as preventing oil spill and air pollution from ships. The IMO has 162 member states and serves as an agency under the United Nations. Two noteworthy IMO treaties are a 2001 agreement prohibiting the use of toxic chemical coatings on ship hulls, called the Anti-Fouling Systems (AFS) Convention, and a pollution prevention treaty covering a broad range of marine pollution issues called MARPOL.

MARPOL is the main international convention covering pollution prevention of the marine environment by ships from operational or accidental causes. Updated by additional amendments since its adoption in 1973, MARPOL comprises six "annexes" covering oil pollution (Annex I), noxious liquid substances (Annex II), harmful substances in packaged form (Annex III), sewage pollution (Annex IV), garbage (Annex V), and air pollution (Annex VI). In May 2004, Annex VI of the convention, covering air pollution and cleaner marine fuels, garnered the requisite number of international signatories to lead to its "entry into force" in May 2005. These MARPOL Annexes, the AFS convention, and other treaties, as well as a number of international programs, European Union (EU) directives, the European Union (EU) sustainability policy on transportation, and the ECOPORTS project, are discussed in Appendix D.

Recommendation: The U.S. government should ratify MARPOL Annex VI, thereby retroactively holding January 1, 2000, and later ships to Tier 1 standards.

Recommendation: The EPA should expedite efforts to establish the entire East, West, and Gulf coasts as control zones subject to stricter emission standards equivalent to Annex VI's "Sulfur Emission Control Areas," regardless of a marine vessel's flag.

Recommendation: The U.S. government should officially ratify MARPOL Annex IV, which prevents sewage pollution from ships, and the Antifouling Systems (AFS) Convention, which bans toxic chemical coatings on ship hulls.

U.S. REGULATIONS, RULES, AND POLICIES

In the United States, state and local governments establish port authorities to manage individual or multiple ports.[2] A complex layering of federal, state, and local laws and regulations governs these port authorities.

Although the federal government has complete jurisdiction over the navigable waters of the United States, its exclusive authority stops at the coastline.

Although the federal government has complete jurisdiction over the navigable waters of the United States, its exclusive authority stops at the coastline.[3] In general, port authorities are therefore subject to state laws and regulations, with several important exceptions.[4] Additionally, some local government entities—air districts in California, for example—also have authority to regulate ports in certain ways, such as an "indirect source" of pollution. Jurisdictional issues are further complicated because ports vary widely in their organizational structure, which may take the form of a port authority, a special district, or a department within various levels of government, each presenting its own legal issues.

The following describes the primary federal, state, and local laws and regulations governing pollution sources at ports in the United States.

Air Emissions from Marine Vessels

The EPA first issued emission standards for new marine diesel engines in 1996 and revised them in 1999. As part of the 1999 regulation, the EPA adopted voluntary emission standards for small and medium-sized marine vessels (known as Category 1 and 2 vessels) such as tugboats, pushboats, and supply vessels with a 700- to 11,000-horsepower range. The EPA then set more stringent standards to be implemented by 2007.[5,6] However, the 1999 marine rule set no mandatory standards for larger vessels (Category 3 vessels), prompting the Bluewater Network, an independent nonprofit organization, to sue the EPA.[7,8]

In early 2003, the EPA finally adopted mandatory emission standards, known as Tier 1 standards, for Category 3 vessel engines (container ships, oil tankers, bulk carriers, and cruise ships, among others),[9,10] settling on standards equivalent to the internationally negotiated NO_x limits in MARPOL. Although these standards are a step in the right direction, they are weak and do not address particulate matter, carbon monoxide, or VOCs.[11] Beginning January 1, 2004, the standards will apply to small and medium-sized marine vessels, as well as to the larger oceangoing

Category 3 marine vessels.[12] Ratification of Annex VI retroactively holds January 1, 2000, and later ships to Tier 1 standards.

Tier 1 standards, expected to reduce NO_x emissions by 20 percent, apply only to new marine diesel engines installed on U.S.-flagged or registered vessels and will do nothing to clean up existing ships.[13] However, in anticipation of global ratification of this portion (Annex VI) of the MARPOL treaty, many manufacturers worldwide have been achieving these standards.[14,15]

The EPA's 2003 ruling also sets the maximum sulfur content of marine diesel fuel at 45,000 parts per million and commits the EPA to the 2007 implementation of more stringent, Tier 2 standards for Category 1 and 2 marine vessels, as well as the adoption of Tier 2 standards for Category 3 marine vessels by mid-2007.[16] The Tier 2 standards will include emissions standards on particulate matter (PM), carbon monoxide (CO), and volatile organic compounds (VOCs).[17] (See the Table of Emission Standards in Appendix B.)

Recommendation: The EPA should expedite implementation of Tier 2 emission standards for Category 1, 2, and 3 marine vessels within two years, and the new standards should be applied to all vessels.

Air Emissions from Locomotives

In 1998, the EPA finalized new emission standards for newly manufactured locomotives and remanufactured locomotives from model year 1973 and later.[18] The rule sets requirements for NO_x, VOCs, CO, PM, and smoke, as required under the Clean Air Act. The rule has been criticized by environmental and public health groups for requiring only minimal reductions in NO_x and PM for highly polluting locomotives built before 2000, given available emission reduction technologies.[19] (See the Table of Emission Standards in Appendix B for locomotive standards and estimated emission factors.)

Recommendation: The EPA should implement the next tier of emission standards (Tier 3) for locomotives within one year.

Air Emissions from On-Road Trucks

The EPA's "2007 on-highway" emission standards for heavy-duty vehicles and engines will require diesel transport trucks to be roughly 90 to 95 percent cleaner than today's models by 2010.[20] Impressive though these percentages sound, the regulation applies only to new trucks in model years 2007 and later. Given the longevity of diesel heavy-duty trucks, which have a useful life of at least ten years, the reality is that the regulation does not address the older, heavily polluting diesel trucks predominantly serving ports nationwide. (See the Table of Emission Standards in Appendix B.)

Recommendation: The EPA must follow through with full implementation of its 2007 emissions standards for on-road heavy-duty trucks.

Air Emissions from Nonroad Engines

In May 2004, the EPA adopted a rule that would clamp down further on diesel engine emissions by setting tough engine standards for nonroad vehicles, including industrial, farm, and construction equipment. The nonroad rule extends the model of the EPA's most recent on-road truck rule to the nonroad sector—requiring ultra-low-sulfur diesel fuel nationwide, followed eventually by stringent, after-treatment-based PM and NO_x standards. Nonroad engines are used in cargo-handling equipment at ports, such as yard hostlers, top-picks, and side-picks, and are a major source of polluting emissions. The new regulations are sorely needed. Until 1996, emissions from this category of equipment were entirely unregulated—several decades after the first standards for on-road trucks and buses took effect.[21]

The new EPA rule will reduce the sulfur levels in nonroad diesel fuel from today's average of more than 3,400 parts per million (ppm) to 500 ppm in 2007, and then to 15 ppm in 2010.[22] Lowering sulfur levels is crucial to cleaning up diesel because sulfur inhibits—and can even destroy—advanced emission control systems for diesel engines, just as lead in gasoline disables catalytic converters. In addition to the considerable near-term savings in polluting emissions, the proposal will require engine manufacturers to meet increasingly stringent engine emissions standards over the 2008–2015 timeframe using a variety of advanced emission control strategies. Table 3-1 lists the new emissions standards.

The new rule will also reduce sulfur levels in diesel fuel used in locomotives and all but the largest marine diesel engines to 500 ppm in 2007 and to 15 ppm by 2012, and this in turn will reduce sulfate PM from the existing fleet of these engines by

TABLE 3-1
Estimated Pollutant Reductions from the Proposed Tier 4 Emission Standards, g/bhp·hr

Engine Power	Year	NMHC	NMHC+NO_x	NO_x	PM
HP < 25	2008	—	—	-	0.30[a]
25 ≤ HP < 75	2013	—	3.5	-	0.022[b]
75 ≤ HP < 175	2012–2014[c]	0.14	—	0.30	0.015
175 ≤ HP ≤ 750	2011–2014[d]	0.14	—	0.30	0.015
HP > 750	2015[e]	0.14	—	0.5/2.6[f]	0.022/0.03[g]

Source: Diesel Net, "Emission Standards: USA: Nonroad Diesel Engines," 2004, www.dieselnet.com/standards/us/offroad.html (26 May 2004).

Note: These standards will drastically clean up nonroad equipment. Compared with on-road heavy-duty vehicle standards, they are almost as stringent.

NMHCs are non-methane hydrocarbons similar to VOCs.

a Hand-startable, air-cooled, DI engines below 11 HP can continue to meet Tier 2 PM standards in 2008 and an optional standard of 0.45 g/bhp-hr in 2010.
b Interim PM standard of 0.22 g/bhp-hr effective 2008; interim standard is 0.3 g/bhp-hr for manufacturers that meet the 2013 standard one year early.
c 2012–2013: full PM compliance, 50% phase-in engines meet NO_x/VOCs (phase-out NMHC+NO_x < 3.0 g/bhp-hr).
d 2011–2013: full PM compliance, 50% phase-in engines meet NO_x/VOCs (phase-out NMHC+NO_x < 3.0 g/bhp-hr).
e Interim NMHC standard of 0.3 g/bhp-hr from 2011–2014.
f Generator sets must meet the 0.5 g/bhp-hr NO_x standard and all other engines in this size range must meet the 2.6 g/bhp-hr NO_x standard; all engines > 1200 HP must meet their respective standard from 2011–2014.
g Generator sets must meet the 0.22 g/bhp-hr PM standard and all other engines in this size range must meet the 0.03 g/bhp-hr PM standard; all engines > 1200 HP must meet an interim standard of 0.07 from 2011–2014.

more than 80 percent.[23] Currently, locomotives run on diesel fuel with sulfur levels that often exceed the 3,400 ppm nonroad national average.

The benefits of the new rule are significant. The EPA estimates the rule will provide nearly $80 billion in net benefits when the program is fully implemented. The EPA further estimates that the cost of adding advanced emission controls to a 175-horsepower bulldozer will be roughly 1 percent of the $230,000 purchase price. Without these controls, the same bulldozer would emit as much soot and smog-forming pollutants as 26 new cars. Most notably, this rule will prevent 9,600 premature deaths each year.[24]

Recommendation: The EPA must follow through with full implementation of its recent nonroad emissions and fuel standards, including all locomotive and marine fuel requirements.

Stormwater Pollution

Under the federal Clean Water Act, operators of marine port terminals are required to obtain national pollution discharge elimination system (NPDES) permits for what are considered point source discharges to waterbodies, or pollution emanating from a confined, discrete source, such as a pipe, ditch, tunnel, well, or floating craft.[25] These regulated point sources primarily include stormwater runoff from paved terminals and facilities. In 1987, nonpoint sources—those water discharges that do not come from an identifiable pipe or outfall—became subject to a revised regulatory approach as well.

Stormwater permits are issued either through one of the EPA's 10 regions or through an authorized state or territorial authority. Permits must, at a minimum, meet federal standards, although individual state programs are permitted to be more stringent or to alter certain procedures.[26] Stormwater permit holders must monitor pollution levels in receiving waters to prove that they are within allowable levels, implement a stormwater pollution prevention plan (SWPPP), and perform facility inspections, among other requirements. Appendix C contains a comprehensive description of a model water quality program under an NPDES permit and describes elements beyond permit requirements.

The EPA's nonroad rule will prevent 9,600 premature deaths each year.

Recommendation: The EPA should issue effluent guidelines to require a general baseline level of pollutant reduction for port facilities or for those pollutants typically found in port runoff.

Recommendation: States should ensure that anti-degradation provisions of federal and state law are fully implemented in stormwater permits.

Recommendation: States should give special attention to the development of total maximum daily loads (TMDLs) for impaired waters around many ports.

Recommendation: Local governments should prioritize port facilities when designing inspection protocols in conjunction with local regulatory programs and implementation of municipal stormwater permits.

Ballast Water

The federal government maintains no mandatory ballast water discharge requirements other than that ships entering U.S. waters must file a report detailing their ballast water management practices. [27] What those practices entail is not regulated, and a regimen of voluntary guidelines has proved largely inadequate.[28] The EPA recently announced it would not regulate ballast water discharges from ships, deferring to the U.S. Coast Guard, and in the summer of 2003, the Coast Guard began developing a nationwide rule.[29] A final, mandatory national ballast water management program rule is expected by summer 2004.[30]

Recommendation: The U.S. Coast Guard must finalize mandatory national ballast water regulations as quickly as possible and no later than the expected summer 2004 completion date.

Waste Discharge

Various state and federal regulations prohibit marine vessels from dumping sewage, toxics, and oil in U.S. waters. For example, all ships with toilets must have sewage-treatment equipment, called marine sanitation devices. Within three miles of the U.S. coast, ships may then either discharge the treated sewage or store it for later disposal at a shoreside pumpout facility.[31] Outside the three-mile coastal U.S. territorial water limit, ships are allowed to discharge untreated sewage. In addition, the EPA has designated more than 50 "no discharge zones" (NDZs), in which all sewage discharge, treated or not, is prohibited. About half of these NDZs are located in salt or estuarine waters, which are important to marine habitats.[32]

Outside the three-mile coastal U.S. territorial water limit, ships are allowed to discharge untreated sewage.

Recommendation: The EPA should consider more stringent requirements on the dumping of wastes containing oxygen-depleting nitrogen and phosphorous, as well as persistent toxic compounds, that continue to threaten marine life.

Spill Prevention

Under a national contingency plan for oil spills, the EPA is the lead federal response agency for spills in inland waters, and the U.S. Coast Guard is the lead response agency for spills in coastal waters and deepwater ports. After the 1989 *Exxon Valdez* accident, Congress enacted the Oil Pollution Act of 1990, mandating the phase-in of requirements for double-hulled protection for all tankers in U.S. waters between 1995 and 2015.[33]

In 2003, U.S. Representative Lois Capps (D-CA) introduced the Stop Oil Spills Act (H.R. 880), which would accelerate the phase-in of double-hulled tankers in U.S. waters by 2007, create a 100-mile coastal safety zone, and implement financial incentives for double-hulled tanker use.[34] The bill has been referred to the House Committee on Transportation and Infrastructure's Subcommittee on Coast Guard and Maritime Transportation but has seen no action since February 2003.

Additionally, to prevent oil spills on land, the EPA conducts on-site facility inspections and requires owners or operators of certain port-based oil storage facilities to prepare and implement spill prevention control and countermeasure plans.[35] One important misconception about oil spills is that the majority is the result of collisions or grounding accidents. Studies have shown that more than 70 percent of oil spills occur during such routine, day-to-day operations in ports and harbors as loading, discharging, bunkering, and various industrial processes. These spills include those caused by human error, such as not ensuring correct hose connections, or mechanical failures.

Recommendation: Congress should pass the Stop Oil Spills Act (H.R. 880) to accelerate the phase-in of double-hulled tankers in U.S. waters by 2007.

Oily Bilge Water

National and international regulations prohibit the dumping of water that contains 15 parts per million or more of oil, or that has an oily sheen.[36] Instead, the Clean Water Act requires ships to retain on-board the oily mixtures that collect from engine rooms, called bilge water, then and discharge it at onshore reception facilities.[37] Most ships either have a bilge pipe system for this purpose or an on-board oil-water separator.[38]

More than 70 percent of oil spills occur during such routine, day-to-day operations in ports and harbors as loading, discharging, bunkering, and various industrial processes.

Toxic Waste Disposal

The Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972 bans the ocean disposal of many harmful wastes, including radiological, medical, and industrial wastes. Other materials may be dumped with permits, including wastes that contain oxygen-depleting nitrogen and phosphorous, as well as persistent toxic compounds, both of which are a threat to marine life.[39,40]

Other Federal Programs

In January 2003, the EPA and the National Oceanic and Atmospheric Administration (NOAA) signed a memorandum of understanding (MOU) expediting the cleanup of local brownfields to revitalize the aging port city of New Bedford, Massachusetts.[41] The memorandum laid the groundwork for the two agencies to work together to clean up brownfields in coastal communities. Later in 2003, NOAA announced the "Portfields" initiative, partnering with a number of federal agencies, including the EPA, working with port communities to revitalize waterfront areas to improve marine transportation such as barges and restore and protect habitat.[42] In addition to New Bedford, two other port cities will receive federal support for brownfield cleanup: Bellingham, Washington, and Tampa, Florida.

The EPA also started the port environmental management system (EMS) assistance project in 2003, in collaboration with the American Association of Port Authorities (AAPA) and the Global Environment and Technology Foundation (GETF).[43] Eleven ports—including the ports of Houston, Hampton Roads, New York and New Jersey, and Los Angeles—will receive two years of EMS training and technical assistance. Each participant is expected to "analyze, control, and improve the environmental consequences of its activities" in order to improve overall environmental performance.

The Marine Mammal Protection Act was first enacted in 1972 to protect and manage marine mammals.[44] Since then, various governmental agency programs and regulations have addressed the subject.[45] For example, in an effort to reduce the number of collisions between ships and the critically endangered northern right whale, NOAA and the U.S. Coast Guard implemented Mandatory Ship Reporting Systems in 1999 to prevent future strikes.[46]

Recommended Actions Warranting Further Investigation

In addition to the recommendations listed earlier, many other avenues exist to address pollution from port operations at the national level. Following is a short list of additional actions that warrant further investigation, some of which have already demonstrated success in other parts of the world.

Recommendation: The U.S. government should adopt and support a sustainable transportation system program, similar to the EU program, facilitating the shift of cargo transport from more polluting modes such as trucking to cleaner locomotive and barge transport.

Recommendation: The EPA should implement a graduated harbor fee system similar to a program in Sweden that requires polluting ships to pay on a sliding scale (the more polluting, the higher the fees upon entering a port).

California and Washington have ballast water programs that are much more stringent than the federal voluntary practices.

Recommendation: The EPA and individual states should consider charging fees on each container entering a port, and use these funds to mitigate the environmental effect of moving those containers.

Recommendation: All levels of government—federal, state, regional, and local, including environmental agencies—should encourage the utilization of rail instead of less efficient trucks, particularly for long-distance landside cargo movement.

STATE LAWS, REGULATIONS, AND INCENTIVE PROGRAMS

Some states maintain and enforce regulations for their ports that go beyond federal requirements.

Ballast Water

California, Hawaii, Maryland, Michigan, Oregon, Virginia, and Washington have taken the initiative to expand ballast water regulations beyond the federal requirements. In particular, California and Washington have programs that are much more stringent than the federal voluntary practices.[47] California requires ships coming from more than 200 miles off U.S. coasts—that is, from outside the nation’s exclusive economic zone (EEZ)—to replace ballast water in tanks while still outside the EEZ (a practice called “open ocean exchange”) or to retain ballast inside the EEZ (in other words, banning dumping of ballast water within 200 miles of the coast). The state also requires ships to avoid taking on ballast water in polluted areas, to clean ballast tanks and anchors, and to minimize discharge.[48] Similarly, Washington state makes the requirements in the voluntary federal program mandatory and requires open ocean exchange of ballast water prior to discharging ballast in state waters. California and Washington have ballast water programs that are much more stringent than the federal voluntary practices.[49]

Recommendation: States should adopt ballast water regulations similar to those in place in California and Washington, ensuring a 200-mile buffer from the U.S. coast and making the voluntary federal program mandatory.

Truck Idling Limits

A number of states and cities have rules or ordinances limiting vehicle idling, a source of unnecessary pollution from diesel engines. A 2002 California law limits idling outside marine terminals to 30 minutes unless the terminal implements an appointment system for trucks or extends open gate hours significantly.[50] Since implementation of this program in July 2003, however, complaints have arisen about queues being moved inside terminal gates to circumvent the law and avoid penalties.

Most of the 45 tugboats operating at the ports of Long Beach and Los Angeles have been repowered with cleaner diesel engines, reportedly reducing aggregate NO_x emissions by more than 80 tons per year, about what 4,600 passenger vehicles emit each year.

Recommendation: The EPA should set uniform federal idling limits for all diesel engines. In the absence of federal action, states or local authorities should require idling limits.

Air Emissions Reduction Incentive Programs

California's Carl Moyer Program provides incentives for the reduction of NO_x and PM from heavy-duty diesel engines. These incentives—$98 million worth to date—are in the form of grants for private companies, public agencies, or individuals operating heavy-duty diesel engines, and they cover an incremental portion of retrofitting or repowering on-road, off-road, marine, locomotive, and agricultural irrigation pump engines. Under the program, most of the 45 tugboats operating at the ports of Long Beach and Los Angeles have been repowered with cleaner diesel engines, reportedly reducing aggregate NO_x emissions by more than 80 tons per year, about what 4,600 passenger vehicles emit each year.[51,52,53]

Several other states and the EPA maintain similar programs.[54] The Texas Emission Reduction Program (TERP) is an incentive program, begun in 2001, to reduce emissions from diesel engines by funding the incremental cost associated with cleaner engines, engine repowers, addition of control technology, use of cleaner fuels, infrastructure for cleaner fuels, and the demonstration of new technology.[55] The roughly $20 million per year program is funded through various fees and surcharges on motor vehicle sales, leases, inspections, and registrations.

Recommendation: States should provide incentive programs to reduce pollution from heavy-duty diesel engines, similar to the Carl Moyer and TERP programs. In the absence of state action, regional authorities should sponsor such programs.

The California Diesel Risk Reduction Plan: In-Use Diesel Engine Cleanup

After identifying diesel PM as a toxic air contaminant in 1998, the CARB produced a diesel risk reduction plan two years later to outline the steps necessary to control diesel PM from engines and vehicles throughout the state. The plan called not only for cleaner engine and fuel standards but also for the cleanup of existing or in-use engines, through early retirement, retrofits, repowers, or conversions to alternative fuels. Rules passed under the plan so far have covered transit buses, refuse haulers, transportation refrigeration units, portable diesel engines, and stationary diesel engines. However, a number of rules are expected in 2004 and 2005 that will help clean up port-related activities. These include proposed rules for cleaner harbor craft, oceangoing vessels, and cargo-handling equipment, as well as various idling restrictions. A maritime working group is currently investigating various methods to reduce pollution from oceangoing vessels, including a demonstration project of a retrofit technology added to an oceangoing vessel in 2004.

Recommendation: The EPA should adopt a series of diesel retrofit rules, similar to those proposed in the California Risk Reduction Program, to establish a cleanup schedule for existing polluting diesel engines. In the absence of federal action, states or local authorities should adopt these programs.

California's ARB is slated to propose rules for cleaner harbor craft, oceangoing vessels, and cargo-handling equipment, as well as various idling restrictions.

West Coast Governors' Initiative

In September 2003, the governors of California, Oregon, and Washington announced the West Coast Governors' Initiative, a collaborative effort to combat greenhouse gas emission.[56] This initiative could serve as a platform for the West Coast to harmonize air quality efforts around interstate trade issues. Uniform requirements across multiple ports would eliminate economic competitive advantages from less stringent requirements.

Discussions are under way with British Columbia, and many are hopeful that Mexico will consider joining as well, creating a full Pacific Coast Initiative. California, Oregon, and Washington meet quarterly with the goal of producing a status report by September 2004. At the time of this writing, there was a significant chance that the maritime component of the governors' initiative would roll into a program initiated by the U.S. EPA Regions 9 and 10 to clean up diesel pollution on the West Coast. This initiative, called the West Coast Diesel Emission Reduction Collaborative, began in June 2004 to identify projects, which could include shoreside power and diesel truck-stop electrification.

Recommendation: Neighboring states should work together in coastal alliances to protect their marine natural resources, share information on programs and technologies, and work together to jointly shoulder the neglected responsibility to neighboring communities and their surrounding environment.

LOCAL ORDINANCES AND FUNDING

Some local jurisdictions have ordinances of their own governing pollution at their ports.

Oil Pollution

Congress adopted the Oil Pollution Act of 1990 to improve prevention and response to catastrophic oil spills. The act requires detailed facility and regional oil spill contingency plans and sets aside funds for emergency cleanup, financed by a tax on oil. Some individual ports have joined in this effort as well. For example, the Port of Oakland's Clean Water Program establishes training programs for monitoring stormwater runoff and for preventing oil pollution from becoming a part of runoff. Several ports have also established oil-recycling programs.[57]

Recommendation: Regional authorities should require ports to ensure that oil pollution does not become a part of runoff and that portwide oil-recycling programs are in place. Even more effort should be focused on oil spill prevention, in addition to response, in order to prevent irreversible damage to ecosystems.

Locomotive Memorandum of Understanding

Although the Clean Air Act prohibits certain state and local governments from adopting or enforcing requirements controlling emissions from new locomotives or new engines used in locomotives, nothing prohibits local or state agencies from entering into agreements or memoranda of understanding to provide incentives for locomotive companies to operate cleaner engines in a given region.[58] In California, CARB and participating railroads entered into one such MOU in 1998 with the goal of accelerating introduction into the South Coast Nonattainment Area[59] (Los Angeles, Orange County, and parts of San Bernardino and Riverside counties) newer, lower-emitting locomotives by establishing a locomotive fleet average emissions program. The MOU will result in an additional 35 percent reduction in NO_x emissions beyond the federal regulation and a 100 percent scrappage or replacement with lower-emitting locomotives by 2010.[60,61]

The City of Los Angeles recently signed multiple agreements with shipping lines to promote the use of cleaner, lower-sulfur marine fuel for ships docked or hoteling at the Port of Los Angeles.

Recommendation: States should negotiate MOUs that create incentives for cleaner locomotives. In the absence of state action, regional authorities should pursue this.

Voluntary Commercial Cargo Ship Speed Reductions Memorandum of Understanding

In an effort to address the significant public health concern from air pollution in the South Coast Air Basin and to assist in attainment of air quality pollution goals, the ports of Long Beach and Los Angeles in 2000 entered into an MOU with local, state, and federal regulatory agencies and participating steamship associations.[62] The agreement sets a 12-knot speed limit within 20 nautical miles of the coast, which the Port of Los Angeles claims has reduced emissions of NO_x by approximately 1 ton per day at the port.

Recommendation: Regional authorities should monitor and enforce ship speed reduction programs.

City of Los Angeles Alternative Maritime Power Memorandum of Understanding

In 2002, the City of Los Angeles signed MOUs with six shipping lines to participate in the development of the Alternative Maritime Power (AMP) program at the Port of Los Angeles. These MOUs acknowledge the signatories' intent to research and develop an electric infrastructure that would allow vessels to plug in to electric power while at berth (shoreside power). This program is just getting started with implementation at the China Shipping terminal as a result of litigation relating to the expansion. In fact, the first container ship in the world plugged in to electric power at the China Shipping terminal as this report was going to print (see “China Shipping Plugs In,” page 25).

Recommendation: States should require that ships plug in to shoreside power while docked. In the absence of state action, regional authorities should build infrastructure for and require that ships plug in to shoreside power while docked.

City of Los Angeles Cleaner Marine Fuels Initiative

The City of Los Angeles recently signed multiple agreements with shipping lines to promote the use of cleaner, lower-sulfur marine fuel for ships docked or hoteling at the Port of Los Angeles. The agreements are in lieu of full-scale implementation of an alternative maritime power program. According to the Port of Los Angeles, one shipping line is currently using lower-sulfur diesel with a 2,000 parts per million sulfur content.[63]

A December 2003 rule in New York City will require most construction equipment in that city to use low-sulfur diesel (15 ppm) and the best available pollution control technology.

Recommendation: States should require that ships use low-sulfur diesel while in coastal waters and at berth (until electric power is made available). In the absence of state action, regional authorities should require this.

New York City Clean Construction Rule

A December 2003 rule in New York City will require most construction equipment in that city to use low-sulfur diesel (15 ppm) and the best available pollution control technology. Although this rule does not cover the Port Authority of New York and New Jersey because it is a bistate authority, the port voluntarily agreed to abide by it during construction activities. Under this rule, pollution from diesel construction equipment is reduced by as much as 90 percent.

Fleet Rules

The South Coast Air Quality Management District (SCAQMD) is in the process of developing a rule (Proposed Rule 1198—Intermodal Equipment) that would reduce emissions from yard tractors at South Coast ports.[64] The rule is still in development and the SCAQMD is considering different options for regulation, including limits on operations, required use of cleaner fuels, and a requirement that fleet operators purchase only new, alternative-fuel tractors.

Recommendation: States and regional authorities should adopt fleet rules to clean up and require cleaner new purchases of all heavy-duty engines, similar to those in place in the Los Angeles area.

Gateway Cities Incentive Program

The Gateway Cities program in Southern California, funded by federal, regional, and state dollars, provides funding to operators who replace pre-1984 model year trucks with 1994 model year or newer trucks equipped with a diesel oxidation catalyst.[65] The expense is shared by the program and drivers. Regularly oversubscribed, this program has provided approximately $15 million to local companies and is responsible for the modernization of more than 200 trucks servicing the ports of Long Beach and Los Angeles. This effort has resulted in an annual reduction of 160 tons of NO_x and 40 tons of particulate matter.[66] The program is an extremely cost-effective way to reduce truck emissions at ports, particularly because most 1983 and earlier trucks have no emissions controls whatsoever.

In addition to the recommendations listed earlier, local and regional governments can adopt the following recommendations to further reduce or prevent degradation from port operations.

Recommendation: Regional authorities should improve efforts to protect marine habitats from further infill due to port developments.

Recommendation: Regional authorities should improve efficiency and land use in order to alleviate the need to expand facilities.

Recommendation: Regional authorities should minimize the effects of terminals on local communities, by rerouting or otherwise mitigating terminal-related traffic.

In summary, the recommendations in this report, if implemented, could reduce port-related pollution affecting seaside communities and marine environments.

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53 Total passenger car emissions from U.S. EPA, "National Emission Trends," 13 August 2003, http://www.epa.gov/ttn/chief/trends/index.html (27 May 2004).

54 For more information on similar voluntary retrofit programs, see http://www.epa.gov/otaq/retrofit/.

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58 Clean Air Act, Section 209(e), 42 USC § 7543.

59 Areas of the country where air pollution persistently exceeds the national ambient air quality standards are designated as "nonattainment" areas. The greater Los Angeles area is currently designated as an "extreme" nonattainment area; it fails to attain federal ozone, particulate matter, and carbon monoxide air quality standards.

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61 CARB, "Update on Locomotives and Marine Vessels," Informational Item, California Air Resources Board hearing, 23 October 2003.

62 Port of Los Angeles, Port of Long Beach, Steamship Association of Southern California, the Pacific Merchant Shipping Association, the Marine Exchange of Los Angeles and Long Beach Harbor, Inc., the U.S. Environmental Protection Agency, the California Air Resources Board, the South Coast Air Quality Management District, "Memorandum of Understanding for the Use of Emission Reductions from Voluntary Commercial Cargo Ship Speed Reductions," 22 Nov 2000 and amended on 11 April 2001.

63 TL Garrett, Port of Los Angeles, Presentation at the Maritime Air Quality Technical Working Group meeting at the Port of Los Angeles, 3 December 2003.

64 The rules apply to Los Angeles, San Bernardino, Riverside, and Orange counties.

65 Gateway Cities Council of Governments, "Clean Air Program Guidelines," http://www.gatewaycog.org/cleanairprogram/documents/documents.html (27 May 2004).

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