The Need to Reduce Marine Shipping Emissions: A Santa Barbara County Case Study

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ABSTRACT

Marine shipping, the largest unregulated source of oxides of nitrogen (NOx) emissions, represents a significant long-term obstacle to achieving ozone standards in coastal areas, as documented in the example of Santa Barbara County in California.

According to the Santa Barbara County Air Pollution Control District (APCD) 2001 Clean Air Plan, 1999 base year NOx emissions from marine vessels were more than those from all on-road motor vehicles, and comprised just over a third of the total NOx emissions inventory. By 2015, the Plan projects that NOx emissions from ships will be almost five times greater than those from on-road motor vehicles, and comprise more than 60 percent of the total NOx emissions inventory.

The projected increase in marine shipping emissions essentially negates all the NOx emissions reductions expected to occur onshore, and brings the 2015 inventory to levels close to those experienced in 1999, the year Santa Barbara County attained the federal one-hour ozone standard. This jeopardizes the county's ability to maintain the ozone standard. Achieving reductions in marine shipping emissions is critically important for the county's long-term air quality, especially as it is increasingly difficult to obtain cost-effective onshore emission reductions.

Since more than ninety percent of the NOx emissions from vessels transiting offshore the county fly foreign flags, and the existing fleet has a slow rate of turnover, the task of reducing marine shipping emissions is a challenging one. While regulatory approaches may achieve NOx emission reductions over the long term (10-30 years), incentive programs and partnerships to reduce emissions from existing vessels are essential for continued air quality improvements in the near term (1-10 years).

This paper provides information about the Santa Barbara County emissions inventories, places this information in a national and international context, outlines the existing regulatory framework, identifies opportunities for near-term cost-effective emission reductions, and highlights the need for incentives and partnerships to gain momentum in reducing marine shipping emissions through demonstration programs. Much of what we have learned and will present is thanks to the work of others who have been researching this issue for many years. And while this paper presents Santa Barbara County specific data, we believe that the information is germane to other areas of the nation and internationally.

INTRODUCTION

There is a growing awareness internationally of the significance of shipping emissions. Ships are increasing in number, size, carrying capacity and speed, while fuel use is increasing proportionally.[1,2,3,4] In addition, residual heavy fuel oil – the most common fuel used in large ship engines – is decreasing in quality, while a greater number of engines are being designed to use this lower-quality fuel.[5]

There is also an increasing awareness of the impacts of shipping emissions on onshore air quality. An estimated 85 percent of international shipping traffic occurs in the northern hemisphere, and 70 percent of that is within 400 km (240 miles) of land.[6] Much of the shipping activity and associated emissions occur near major urban areas, many of which are already struggling with air quality problems.

There is a range of estimates for NOx emissions from marine shipping activities. The United States Environmental Protection Agency (USEPA) estimates that approximately 4.4 percent of total NOx emissions in the United States come from compression ignition marine engines.[7] One study estimates that NOx emissions from US ships are 127,000 tons/year (inland rivers) and 317,000 tons/year (ocean-going).[8] According to a study conducted for USEPA in 1991, ocean-going marine vessel emissions contributed more than 11 tons per day of NOx in New York/New Jersey and 19 tons per day of NOx in the Houston/Galveston area.[9] A recent estimate of year 2000 NOx emissions from ocean-going vessels in the Vancouver, B.C. region is close to 15 tons per day of NOx.[10] NOx emissions from ocean-going ships in the South Coast Air Basin for the year 2000 are estimated at 35 tons per day.[11]

Santa Barbara County is situated on the west coast of California between San Luis Obispo County to the north and Ventura County to the east. Even though Santa Barbara County does not have a port, more than 33 tons per day of NOx were produced by marine shipping activities offshore the county in 2000 – a figure more comparable to those estimated for Los Angeles and San Francisco. This is due to several factors. There is a very high volume of vessels transiting along the Santa Barbara County coastline, and most of these vessels use large, higher polluting, two-stroke engines. The county also has 130 miles of coastline, so these vessels are traversing a relatively long distance. In addition, much of the emissions associated with shipping activities occur between 10 to 20 miles from shore, as ships traverse the California coastline and/or use great circle routes throughout the Pacific Rim.

Santa Barbara County is currently classified by USEPA as a "serious" nonattainment area for the federal 1-hour ozone standard but has applied for redesignation as an attainment area. APCD developed a 2001 Clean Air Plan to support the application for redesignation, and to demonstrate continued attainment of the 1-hour standard for at least 10 years after redesignation.[12]

Based on accepted methodologies for estimating marine vessel emissions, primarily as detailed in the 1999 ARCADIS emissions inventory report,[13] inventories developed for Santa Barbara County's 2001 Clean Air Plan showed that marine shipping emissions represented approximately one-third of estimated NOx emissions for 1999. Marine shipping was thus the single largest source of NOx emissions, contributing an amount comparable to the NOx emissions from all trucks, cars, and buses operating onshore. In the 2015 emissions forecast, marine shipping emissions represent more than 60 percent of NOx emissions and are almost five times greater than those from on-road motor vehicles. The dramatic increase in NOx emissions from this source through the planning horizon essentially negates anticipated NOx reductions onshore from local, state and federal air programs. This also jeopardizes APCD's ability to show continued attainment of the federal 1-hour standard through 2015.

Data collected to calculate marine shipping emissions offshore Santa Barbara County during 2000 reveal several specific points of interest: [14]

- 6,424 total transits occurred offshore the county (an average of almost 18 transits every day of the year)
- 1,363 different individual vessels transited the coastline
- 91 percent of the emissions were from foreign-flagged vessels
- 10 percent of the individual vessels contributed 50% of the emissions
- 44 of the vessels each emitted more than 50 tons per year of NOx.

In Santa Barbara, we have assigned the moniker "frequent flyers" to those vessels that create the most emissions each year, due to a combination of the emissions characteristics of their engines, the fuel they burn, and the number of transits they make each year. One very interesting feature is that 10 percent of the ships make up 50 percent of the marine shipping emissions offshore Santa Barbara. The fact that a relatively small number of ships contributes a large percentage of emissions provides a unique opportunity to obtain significant emission reductions with retrofit technologies.

Efforts to regulate the emissions from marine shipping have been largely ineffective to date. More stringent regulations, and a more intensive focus on international implementation, are needed to encourage the development of engines that will be substantially cleaner than those already on the market today.

While regulatory efforts are of critical importance to reducing emissions in the long term, near-term strategies must also be pursued. The California Air Resources Board (CARB) has initiated the Maritime Working Group to provide a forum for discussion of air quality issues and concerns pertaining to maritime activities in California. This group draws upon a large group of interested parties including USEPA, local California air districts, port representatives, ship owner/operators, the Maritime Administration, engine manufacturers and emission control technology providers. Preliminary estimates indicate that implementing retrofit emission control technologies on existing ocean-going vessels could provide very cost-effective emission reductions relative to those already implemented onshore. The status of current efforts to reduce emissions from the existing vessels, and the need to continue to build partnerships to address this large source of emissions, will be discussed in this paper.

MARINE SHIPPING EMISSIONS INVENTORY

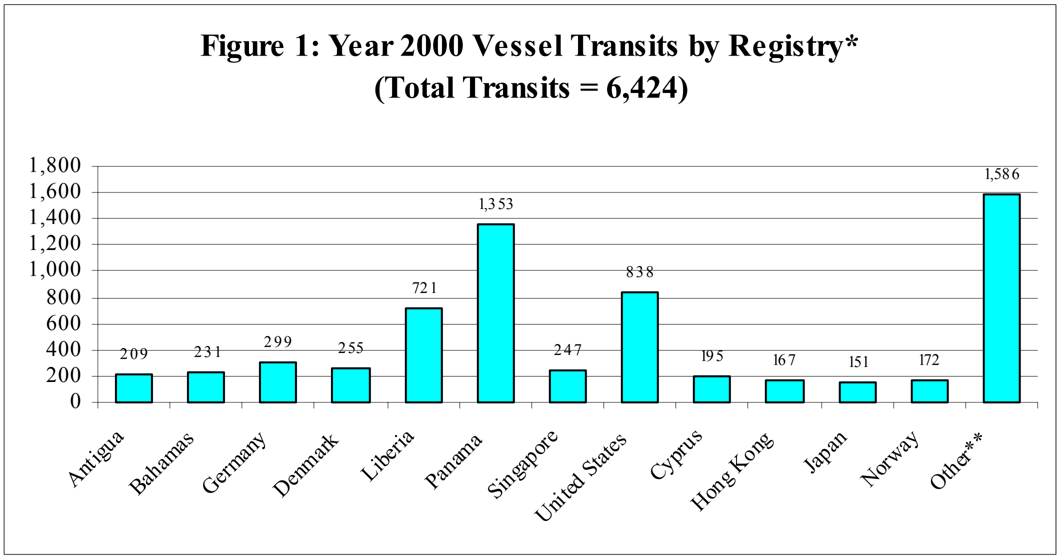
The NOx emissions from marine shipping activities offshore Santa Barbara County are largely due to three principal factors:

- There is a high volume of transits along the Santa Barbara County coastline.
- The majority of the vessels use large, higher polluting, two-stroke engines.
- The county has 130 miles of coastline, so these vessels are traversing a relative long distance. Much of this travel is through the Santa Barbara Channel, which is only 10-20 miles from the shore.

A detailed, ship-by-ship review was used to estimate emissions from ships transiting offshore Santa Barbara. The inventory process gathered information on ship names, arrival and departure dates and direction, ship type (e.g., container, bulk carrier), flag, dead-weight tonnage, and average cruise speed. Port Hueneme[15] and the Marine Exchange of Los Angeles - Long Beach Harbor, Inc.[16] were the main sources of these data.

All ships that arrived from the north to Port Hueneme, the Port of Los Angeles or the Port of Long Beach, or departed to the north from any of these ports, were included in the estimates. Duplicates were eliminated. The average cruising horsepower for each ship's main engine(s) was determined using methods detailed in the ARCADIS report, or by consulting the Lloyd's Registry of Ships.[17] Emissions from auxiliary engines were included. We determined the Santa Barbara coastline transit time for each ship, and applied NOx emission factors from the ARCADIS report. The factors used were based on ARCADIS' analysis of NOx emissions limits finalized in late 1997 at the International Maritime Organization, and considered emissions testing of ships performed as part of Lloyd's Marine Exhaust Emissions Research Programme.[18]

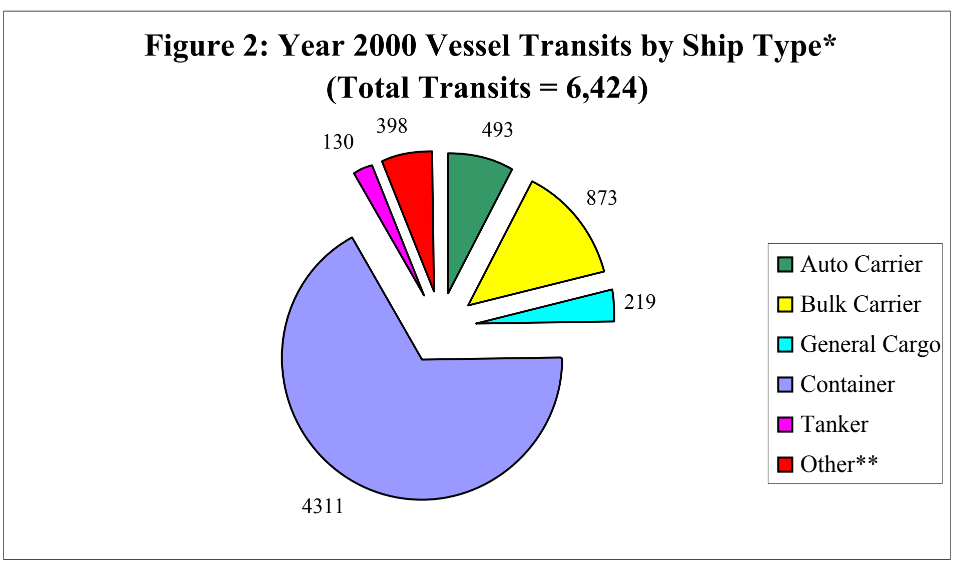
Figure 1 presents a summary of the number of transits along Santa Barbara during 2000 by vessel registry.



* 2000 Marine Exchange Data – Ports of Los Angeles/Long Beach.
** Comprised of 37 other countries.

During the year 2000, there were 6,424 vessel transits along Santa Barbara County from 49 different countries. The country with the greatest number of vessel transits was Panama (1,353 transits), followed by the United States (838 transits), and Liberia (721 transits). More than 87 percent of the total transits along this coastline were by foreign-flagged vessels.

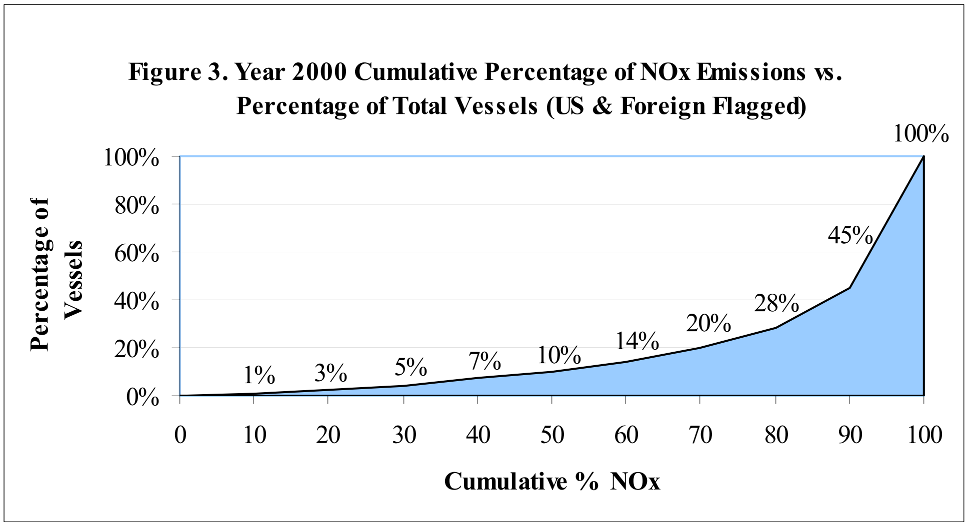
Figure 2 itemizes the types of vessels that traversed our coastline during 2000.



* 2000 Marine Exchange Data – Ports of Los Angeles/Long Beach.
** Other vessels include Passenger, Reefer, and Ro-Ro vessels.

Figure 2 shows that 67 percent of the 6,424 traverses along our coastline in the year 2000 were by container vessels, followed by bulk carriers (14 percent), auto carriers (8 percent), general cargo vessels (3 percent), and tankers (2 percent).

Figure 3 shows a comparison of the cumulative percentage of NOx emissions versus the percentage of vessels for 2000 offshore Santa Barbara.



Source: 2000 Marine Exchange Data, Ports of Los Angeles/Long Beach

This figure shows that by focusing our retrofit efforts on only 10 percent of the vessels that transit along our coastline, we can target 50 percent of the NOx emissions associated with shipping activities impacting our air quality.

Table 1 presents the maximum and average horsepower ratings by vessel type for those vessels that traversed our coastline during 2001.

Table 1: Maximum and Average Horsepower Ratings by Vessel Type[19]

Vessel Type	Maximum Horsepower	Average Horsepower
Auto Carrier	20,940	10,430
Bulk Carrier	20,874	7,742
Container Ship	109,600	32,322
General Cargo	57,089	7,738
Passenger	62,370	30,913
Reefer	15,079	11,267
Ro-Ro	26,921	11,056
Tanker	29,422	8,778

Table 1 shows that the container vessel fleet averaged 32,000 horsepower with a maximum horsepower rating of 109,000. General cargo and passenger vessels had maximum horsepower ratings around 60,000 with the remaining vessels maximum horsepower ratings ranging from 20,000 to 30,000.

The combination of the large number of vessel transits along our 130-mile coastline and the high percentage of container vessels that have the highest average and maximum horsepower ratings (equating to higher emissions) resulted in more than 33 tons per day of NOx emissions in the area in 2000. Foreign-flagged vessels accounted for 87 percent of the total transits, but accounted for 91 percent of the total NOx emissions, since these vessels are predominantly large, higher emission container ships.

SHIPPING EMISSIONS IN THE CONTEXT OF SANTA BARARA COUNTY AIR QUALITY PLANNING

APCD has prepared several air quality plans for Santa Barbara County to comply with state and federal ozone standards, and offshore emissions have been considered significant in these documents for some time. The first two plans, the 1979 Air Quality Attainment Plan and the 1982 update were prepared in response to mandates established by the federal Clean Air Act Amendments of 1977. The 1982 update predicted attainment of the federal ozone standard by 1984, but acknowledged that the county's ability to attain the federal ozone standard was uncertain because pollution generated offshore was not considered.

In the 1994 Clean Air Plan, photochemical air quality modeling was performed for the region. This modeling showed that emissions from marine shipping activities contributed to ozone formation, and found that Santa Barbara County would attain the federal 1-hour ozone standard by the mandated 1996 attainment date but for the emissions generated off the coast by marine shipping activities.[20]

Santa Barbara County was unable to attain the federal 1-hour ozone standard by the 1996 attainment deadline, and was reclassified in 1997 as a "serious" nonattainment area by the USEPA. The new classification required additional regulatory requirements and the development of another air quality plan to show attainment by a new deadline of November 15, 1999.

Subsequent to the development and submission of the next air quality plan (1998 Clean Air Plan) required to comply with the "serious" nonattainment area mandates, air quality monitoring data showed that the county met the federal 1-hour ozone standard by the 1999 attainment deadline. This prompted the development of a "Maintenance Plan," which became the 2001 Clean Air Plan.

The Maintenance Plan required APCD to determine an "attainment inventory" for Santa Barbara County against which to compare future predicted emissions through 2015. Since the federal 1-hour ozone standard was attained from 1997 through 1999, emission inventories were developed for 1999 for both reactive organic compounds (ROC) and NOx.

The attainment inventory methodology assumes that the emission levels experienced in Santa Barbara County during 1999 are adequate to keep measured ozone concentrations below the federal 1-hour ozone standard. The maintenance demonstration must show that predicted future year emission levels through 2015 are below the attainment inventory established for 1999.

2001 Clean Air Plan Emission Inventory

This section describes the baseline emission inventory used in the development of the 2001 Clean Air Plan. The emission inventory accounts for the types and amounts of pollutants emitted from a wide variety of sources, including on-road motor vehicles and other mobile sources, fuel combustion at industrial facilities, solvent and surface coating usage, consumer product usage, and emissions from natural sources. Emission inventories are used to describe and compare contributions from air pollution sources, evaluate control measures, schedule rule adoptions, forecast future pollution, and demonstrate attainment and maintenance of air quality standards.

Emission Inventory Development

The emission inventory is organized in a three-tier hierarchy that categorizes all air pollution sources. The first tier of this hierarchy contains four divisions:

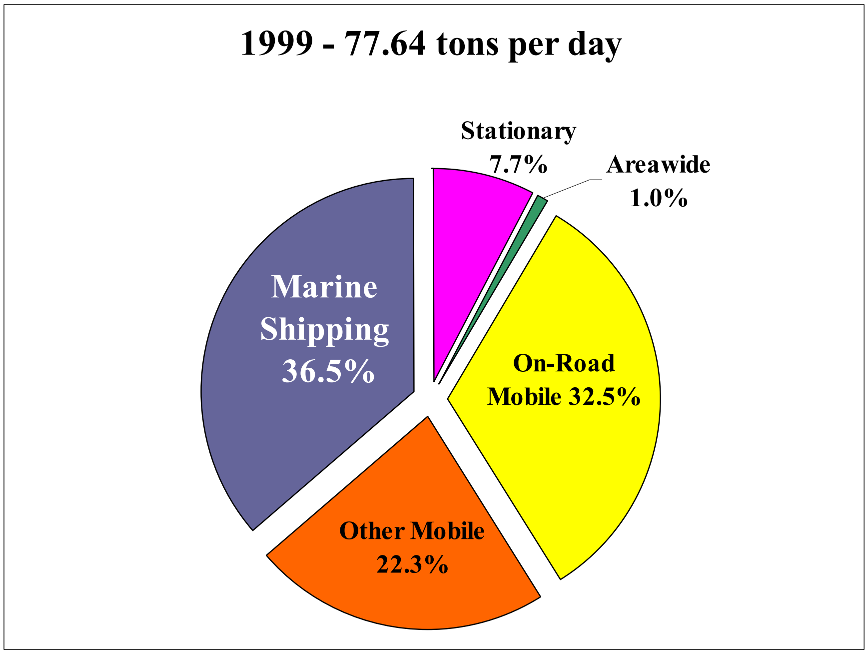
- Stationary sources (e.g., internal combustion engines, boilers, mineral processing)
- Area-Wide sources (e.g., consumer products, paints and solvents)
- Mobile sources (e.g., cars, trucks, planes, trains, ships)
- Natural sources (e.g., vegetation, oil and gas seeps).

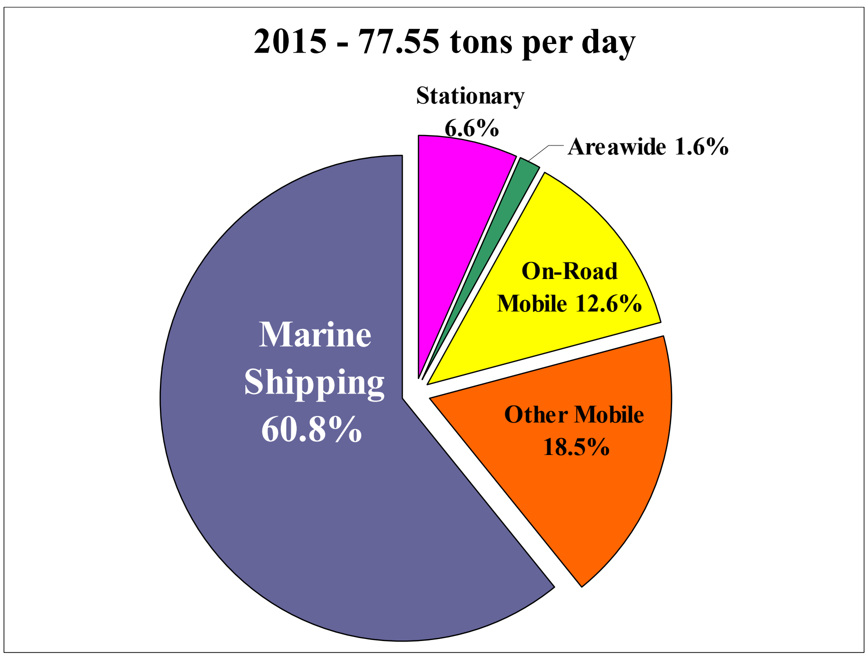
In the second tier, each of the four divisions is sub-divided into major source categories. The third tier divides the major source categories into summary categories. For the purposes of this paper, we present NOx emissions by first tier emission divisions for stationary, area-wide, and mobile sources both onshore and offshore of Santa Barbara County, with marine shipping emissions distinguished from the "other mobile" sources. Natural sources are not included in this paper as those emissions are not human-generated.

1999 and 2015 Emission Inventories

Once the 1999 emission inventory was developed using the most current data, it was forecast out to 2015 using both growth and control assumptions. Growth assumptions include changes in population, employment, vehicle miles traveled, agricultural acres in use, and many others. Control assumptions predict the expected emission controls that will result from local, state and federal air programs. The combination of both growth and control data assumptions are applied to the 1999 inventory in order to develop the 2015 forecast. Figure 4 presents the emission inventories developed for 1999 and forecast for 2015.

Figure 4: Santa Barbara County NOx Emissions Comparison

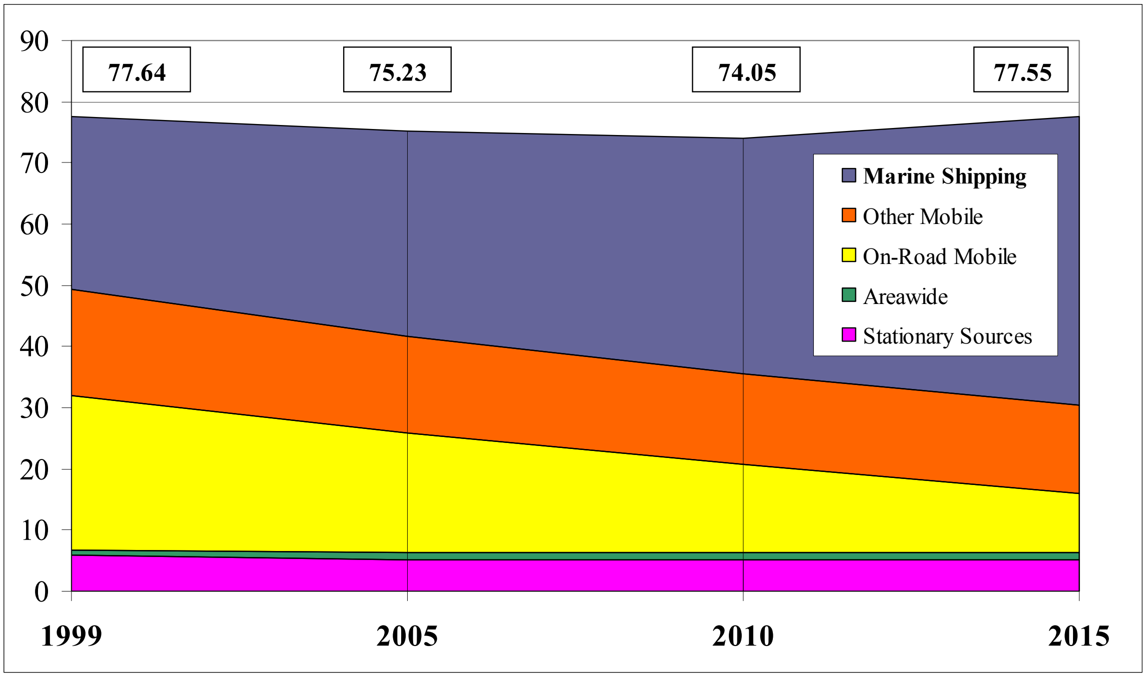




As seen in Figure 4, marine shipping activities contribute more NOx emissions to Santa Barbara County than all the cars, trucks, and buses operating onshore, and represent 36 percent of the total NOx emissions in 1999. The figure also shows that marine shipping emits more NOx than all the "other mobile" sources in the county, including trains, planes, off-road vehicles, farm and construction equipment and many other sources. In addition, Figure 4 shows that the anticipated growth of marine shipping emissions results in a NOx emission contribution of 60 percent of the total inventory by 2015, almost five times the emissions associated with on-road motor vehicles.

Figure 5 presents the forecast for NOx emissions from 1999 through 2015.

Figure 5: Santa Barbara County Forecast NOx Emissions (tons per day)



This figure shows that total NOx emissions decline slightly from 1999 through 2010 and then increase through 2015 to levels that approach those experienced during 1999. This figure also documents that the projected increase in marine shipping emissions essentially negates all the NOx emissions reductions expected to occur onshore from local, state and federal air programs.

IMPLICATIONS FOR MEETING AIR QUALITY STANDARDS

Since forecasted NOx emission levels in 2015 are approaching those experienced in 1999, the county's maintenance demonstration to USEPA comes under increasing scrutiny. If marine shipping emissions continue at the projected rates without any additional controls, Santa Barbara County's long-term trend of improving air quality and ability to maintain attainment of standards could be jeopardized.

Marine shipping activities are the most significant source of emissions that impact our local air quality. And the fact that the growth of marine shipping emissions is counteracting the emission reductions achieved onshore via regulatory controls is of greatest concern. Local, state and federal air programs, in existence for more than 30 years, have resulted in significant emission reductions to date and are anticipated to provide additional emission reductions into the future, as Figure 5 illustrates.

However, the issue at hand is that the majority of the cost-effective emission controls available onshore have been implemented or are already scheduled for implementation. Additional onshore controls will be difficult to obtain and expensive to implement. Reducing emissions from marine shipping activities is of critical importance to the long-term air quality of Santa Barbara County.

REGULATORY FRAMEWORK

Although the shipping industry is highly regulated in some environmental areas such as sewage and waste, and ballast water, regulatory efforts to date to reduce air emissions from marine shipping have not kept pace with emission reduction programs onshore. MARPOL 73/78 is the International Convention for the Prevention of Pollution from Ships. Annex VI, adopted by the Parties to MARPOL in 1997, has NOx requirements for the Category 3 engines typically used in ocean-going vessels, beginning January 1, 2000. This Annex has not been ratified by the required minimum of 15 member countries representing 50 percent of the world's merchant shipping.

However, since the NOx emission standards contained in Annex VI are retroactive to January 1, 2000 once the Annex is ratified, virtually all ship engine manufacturers already build engines that meet these standards. No additional emission reductions from ratification of Annex VI are expected, although ratification does represent a first step toward the implementation of additional technology-forcing standards and requirements in the future.

The USEPA Final Rule on Control of Air Pollution from New Marine Compression-Ignition Engines at or Above 37 kW (50 hp), effective 1/28/2000, applies to Category 1 and 2 engines, and recommends that the IMO adopt regulations for Category 3 engines that are more stringent than the Annex VI requirements. In 2000, the Bluewater Network settled a lawsuit against the USEPA for failure to establish standards for Category 3 engines. The settlement required USEPA to establish standards for these engines by January 2003. The resultant regulation recently promulgated by USEPA establishes standards that are no more stringent than those established in Annex VI.[21]

CARB is currently developing proposed emission control strategies for commercial marine vessels and ports that are expected to become part of the South Coast Air Quality Management District's State Implementation Plan.[22] These strategies will provide emission reductions statewide. Measures under consideration include:

- setting more stringent emission standards for new harbor craft and ocean-going ships;
- developing ways for existing harbor craft fleet to use cleaner engines and fuels;
- designing strategies to clean up the existing ocean-going fleet; and
- taking steps to reduce land-based emissions at ports.

Action on the state's proposed measures is expected between 2003 and 2005, with implementation in the 2003-2010 timeframe.

Even in the best-case scenario—if new regulations are adopted by CARB and USEPA, and the IMO moves to strengthen standards under Annex VI— it could be many years before significant emission reductions are realized through the regulatory process, particularly for the larger ocean-going vessels that traverse the Santa Barbara coastline. Most of the USEPA and IMO regulations only apply to newly manufactured vessels. Since the turnover of vessels is very slow, coastal and port areas will be living with pollution from existing vessels for many years. Therefore, it is imperative to develop partnerships and incentive programs like those being evaluated by CARB, and to initiate demonstration projects to reduce emissions from the existing vessels that transit our area.

TECHNOLOGIES

Until recently, many have viewed shipping industry emissions as fairly minor, of lesser impact to onshore air quality, and difficult, if not impossible, to control. Over time, these views have changed in recognition of the facts that a significant percentage of total man-made emissions are from ships, these emissions have both near-shore and regional air quality impacts, and feasible technologies are available at reasonable costs to clean up ship emissions.[23]

Most NOx emissions in exhaust gases are produced due to high temperatures during the combustion process. There are primary methods to reduce NOx formed during combustion, most of which attempt to reduce the maximum temperatures during combustion, as well as secondary methods that treat the post-combustion exhaust gas stream to reduce NOx. Examples of each method are shown below:

Primary:

- Engine related: injection timing retard, higher compression ratios, increased charge air
- Fuel injection: nozzle changes and injection rate shaping
- Addition of water: fuel-water emulsion, direct water injection, pre-treatment of combustion air (humid air motor or combustion air saturation systems)
- Exhaust gas recirculation

Secondary:

- Selective catalytic reduction (SCR) mixes exhaust gas with ammonia or urea before it passes through a catalytic bed
- Electrostatic precipitators to reduce PM emissions
- Oxidation catalysts to reduce CO and HC
- Low-sulfur content fuel that allows catalytic converters

In addition to the noted control technologies, operational limits that reduce emissions can also be implemented. The voluntary speed reduction program that limits the speed of ships entering the Ports of Los Angeles and Long Beach is an example of setting operational limits to achieve emission reductions.

Both primary and secondary control technologies are applied most easily to a specific ship during the ship's design stage. Application of these technologies as retrofit controls (i.e., not as part of a ship's original design) has potential downsides, including: high unit cost; ship downtime for installation of the new controls; increased fuel use (typical for timing retard and water injection or emulsion systems); the need for large amounts of deionized water production and storage (typical for water injection, emulsion, and humid air motor systems); potential engine damage from the control system (possible with exhaust gas recirculation that routes exhaust gas particulate matter through the charge air system); and lack of space on the existing ship (e.g., installing SCRs on 2-stroke engines).

In addition, significant modifications to an engine not previously subject to the NOx Technical Code of MARPOL 73/78 of Annex VI may make the engine subject to the Annex VI requirement to demonstrate that the modifications did not cause an increase in emissions. This means that pre- and post-modification emissions tests may be required, even for engines not previously subject to Annex VI requirements.

Table 2 presents a summary of various retrofit control technologies that could be installed on large vessel engines.[24]

Table 2: Performance Attributes Summary of NOx Control Technologies for Existing Engines.

Control Technology	Nominal NOx Reduction (%)	Nominal Reduction in PM and other Pollutants (%)	Nominal Increased Fuel Use (%)	Net Present Value ($)	Global Cost Effectiveness ($/ton NOx)
Aftercooler upgrade	10	-1	2	$184,000	$620
Engine derating	14	-10	4	$386,000	$933
Fuel pressure increase	14	-21	2	$220,000	$523
Injector upgrade	16	-21	2	$192,000	$410
Injection Timing Retard	19	-11	4	$363,000	$618
Water in combustion air	28	1	3	$365,000	$468
Exhaust gas recirculation	34	-51	0	$16,900,000	$16,377
Water/fuel emulsion	42	15	2	$325,000	$284
Selective catalytic reduction	81	0	0	$475,000	$227

As this table shows, a range of control technologies can be evaluated as retrofits to existing vessels in order to reduce NOx emissions, and these controls potentially carry a lower cost per ton of emission reduction than most typical onshore emission controls. In addition, focusing retrofit efforts on the "frequent flyer" vessels that create the most emissions will provide the most cost-effective emissions reduction projects.

A review of cost-effectiveness calculations for incentive programs,[25] generation of emission reduction credits,[26] and emission control measures[27] shows a range of cost from $660 to more than $40,000 per ton of NOx reduced. By way of comparison, the average cost per ton for industrial NOx emission reduction credits used in Santa Barbara County from 1999 through 2003 was more than $9,000, and the average cost per ton from California's Carl Moyer Program (Years 1 and 2) was $5,000.

Comparatively, emission reduction programs for marine shipping applications have the potential to produce significant levels of emission reductions on a more cost-effective basis. This is due to the fact that onshore emission reduction programs have matured, while marine shipping emissions have been largely unregulated to date.

However, the cost-effective emission reductions from marine shipping require a large capital expenditure as indicated by the Net Present Value costs associated with the technologies identified in Table 2 that range from $184,000 to several million dollars. A broad-based partnership/incentive approach will be necessary to support capital expenditures of this magnitude, and provide for the evaluation, implementation and verification of these technologies though demonstration programs. Once a technology or set of technologies is proven, additional funding partnerships and incentives will be needed to expand implementation programs to other existing vessels.

Table 2 also highlights the potential for increases in other pollutants (e.g., particulate matter, greenhouse gases) and decreased fuel efficiency. These trade-offs need to be clearly identified and minimized to the greatest extent feasible. For example, injection timing retard generally reduces NOx emissions, but increases PM, and increases fuel use with an associated increase in greenhouse gas emissions. A thorough review of each emissions reduction technology must be conducted for each application to avoid emission trade-offs that may be counter to broader clean air goals.

Fuel characteristics can also be modified to reduce pollution, primarily by reducing sulfur content, thereby reducing SOx emissions, and allowing the use of catalytic treatment of exhaust gases to reduce NOx. SOx emissions reduction is a major concern in much of Europe, due to the impacts of acid rain.[28, 29]

There is a tremendous opportunity to reduce both SOx and NOx emissions by reducing the sulfur content of fuels used in shipping. The current average sulfur content of heavy fuel oils used by large marine vessels is about 2.5% (25,000 ppm). The fuel sulfur content limits of the impending IMO Annex VI are set at 4.5% (45,000 ppm), with a 1.5% (15,000 ppm) limit for SOx Emissions Control Areas (SECA) such as the Baltic Sea. Upon application to IMO after Annex VI is implemented, other areas (e.g., coastal areas of the United States) may be declared SECA areas with the 1.5% sulfur limit. These sulfur content values contrast with the current California on-road diesel limit of 0.05% (500 ppm), especially as the sulfur content of typical on-road diesel fuel is usually well below this limit, generally in the 130-150 ppm range. Also, ultra low sulfur diesel (15 ppm sulfur) is now becoming available, and will soon be required on both urban buses and solid waste collection vehicles in California. This ultra low sulfur diesel requirement will also apply nationwide for on-road diesel fuel starting in 2007, so it is clear that there are opportunities to improve the quality of the fuels used by the shipping industry.

The above tables and information document the fact that many opportunities exist to achieve emission reductions from existing marine vessels. Steps towards implementation of a demonstration program targeting reductions from existing vessels could include:

- Identification of funding sources, and securing of funding;
- Design of emissions-testing protocols to validate emission reductions;
- Selection of candidate vessels for demonstration projects;
- Development of criteria for judging the success of a demonstration retrofit program;
- Testing of emission-control technologies in real-world use;
- Evaluation of these technologies for widespread use;
- Formulation of a plan for widespread implementation.

However, as previously outlined, due to the significant capital investment required, the development of creative partnerships and innovative strategies is necessary to build momentum for the implementation of retrofit technologies and cleaner-fuels strategies.

PARTNERSHIPS AND INCENTIVES

The Maritime Air Quality Working Group (MWG), led by CARB, is an industry-wide group of stakeholders including air agencies (CARB, USEPA, and local air districts), environmental groups, and shipping industry representatives (owner operators, ship captains, major engine manufacturers, technology vendors and marine consultants). The group's goal is to gain a basic understanding of the shipping industry, identify control technologies that can reduce NOx and PM emissions from ship engines, and determine how to make these technologies attractive for both retrofit and new implementation by carriers.

The MWG has had several meetings over the last year that have incorporated presentations on available and developing control technologies, and the group is currently reviewing vendor proposals to demonstrate retrofit control technologies on ship engines at sea. The APCD participates in this working group and is interested in seeing cost-effective control technologies successfully installed on one or two ships over the next year.

The US Department of Transportation Maritime Administration (MARAD) is pursuing in parallel a program to review, select, install, demonstrate and test emissions of retrofit control technologies for reducing NOx emissions of large ship engines. MARAD is investigating possible incentive programs to encourage control technology installation on coastal vessels, and will determine if these technologies increase combustion efficiency, thereby saving fuel and reducing greenhouse gases. It is likely that the MARAD demonstration will be the first partnership project for the MWG stakeholders.

Business for Social Responsibility (BSR) is a consortium of businesses interested in improving the environmental and social impact of their operations, and of their suppliers. Among many other programs, BSR has formed a Clean Cargo Program to encourage the ship owner operators – their “carriers”- to reduce emissions from their sea transport operations.

A range of incentive programs that could be evaluated include:

- Emission reduction credits – A system in which credits are provided for reducing vessel emissions that can be traded within a market-based system.
- Differential port fees – A system where cleaner vessels pay lower fees and dirtier vessels pay higher fees with a net result equal to the existing fee structure.
- Government incentives – Similar to California’s Carl Moyer Program in which funds are allocated to cost-effective projects, based on the merits of the project and the level of cost share funding.
- Environmental award programs – A system in which cleaner vessels are provided the recognition and positive publicity for being the cleanest of the fleet.
- Preferential port access – A system in which the cleanest vessels have the best access to port facilities.

These types of incentive programs need to be carefully evaluated as part of the effort to reduce emissions from the existing fleet. Without some type of incentive program, the information and experience gained in retrofit demonstration projects may not be realized due to the large capital costs associated with many of the technologies discussed in this paper.

It is important to coordinate efforts toward understanding the dynamics of the shipping industry, and researching and demonstrating control technologies by building partnerships, evaluating incentive programs, and sharing results. Only with a cooperative, partnership-based approach will we realize emission reductions from the existing vessels that transit along the Santa Barbara coastline and other areas nationally and globally.

CONCLUSIONS

As documented in the Santa Barbara County emissions inventories, marine shipping emissions currently impact onshore air quality, and, if left uncontrolled, will be of increasing concern in the future. Conclusion points of interest are listed below.

- Marine shipping emissions are significant and largely unregulated locally, nationally and globally.
- If marine shipping emissions continue to increase without controls, they may threaten attainment strategies of coastal (and inland) areas. This could increase the need to reduce emissions onshore, where many of the most achievable and cost-effective reductions have either already been obtained or are in process.
- International and national regulatory efforts have been largely ineffective to date, and should be strengthened to set targets for development of new engine technologies.
- While regulatory strategies are important to reducing these emissions in the long term, a near-term strategy is needed for existing vessels.

- Many control technologies are available that can potentially reduce emissions in the near term from existing marine vessels at a relatively low cost per ton of NOx reduced. In fact, these technologies are significantly more cost-effective than typical onshore emission controls.
- Retrofit of existing vessels with emission controls will demand a high capital expenditure.
- A coordinated partnership-based approach will be necessary to support the capital expenditure, and provide for the evaluation, implementation and verification of retrofit technologies though demonstration programs.
- Once a technology or set of technologies is proven, additional funding partnerships and incentives programs will be needed to expand implementation programs with existing vessels.

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KEY WORDS

Marine Shipping, Marine Shipping Emissions, Compression Ignition Engines, Air Pollution Control, Santa Barbara County, Annex VI, Emission Control Technologies, Clean Air Plans, Container Ships

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