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Documentation for the Commercial Marine Vessel Component of the National Emissions Inventory

Methodology

Prepared by:

Eastern Research Group
1600 Perimeter Park Drive
Morrisville, North Carolina 27560

Under Contract to:

E.H. Pechan & Associates, Inc.
3622 Lyckan Parkway
Suite 2002
Durham, North Carolina 27707

For Submittal to:

Laurel Driver
Emissions, Monitoring and Analysis Division
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

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1.0 INTRODUCTION

1.1 What is the National Emission Inventory?

The National Emission Inventory (NEI) is a comprehensive inventory covering all anthropogenic sources of criteria pollutants and hazardous air pollutants (HAPs) for all areas of the United States. The NEI was created by the U.S. Environmental Protection Agency's Emission Inventory and Analysis Group (EIAG) in Research Triangle Park, North Carolina. The NEI will be used to support air quality modeling and other activities. To this end, the EPA established a goal to compile comprehensive emissions data in the NEI for criteria and HAPs for mobile, point, and nonpoint sources. This report presents an overview of how emission estimates for the commercial marine vessel (CMV) component of the 2008 NEI was compiled.

1.2 Why Did the EPA Create the NEI?

The Clean Air Act (CAA), as amended in 1990, includes mandates for the EPA related to criteria and hazardous air pollutants. The CAA defines criteria pollutants as being one of the following air pollutants:

- Carbon monoxide (CO);
- Sulfur oxides (SO_x);
- Nitrogen oxides (NO_x);
- Ozone; and
- Particulate matter (PM).

Where emission factors and activity data permit, ammonia (NH_3) estimates are also included as an important precursor to PM. Hazardous air pollutants are also delineated in the CAA, see *http://www.epa.gov/ttn/atw/188polls.html* for a complete list of regulated pollutants and their chemical abstract service [CAS] numbers.

The CAA requires the EPA to identify emission sources of these pollutants, quantify emissions, develop regulations for the identified source categories, and assess the public health and environmental impacts after the regulations are put into effect. The NEI is a tool that EPA can use to meet the CAA mandates. In this report, criteria and HAP emission estimates are discussed for CMV sources.

1.3 How is the EPA Going to Use This Version of the NEI?

It is anticipated that the emission inventory developed from this effort will have multiple end uses. The data have been formatted according to protocols established for the EPA's NEI submittals. The common data structure on which the NEI platform is based will allow the NEI emission data to be transferred to multiple end-users for a variety of purposes.

The criteria and HAP emission estimates developed for the NEI will be used to evaluate air pollution trends, air quality modeling analysis and impacts of potential regulations.

1.4 Report Organization

Following this introduction, Section 2.0 provides information on how the national CMV, emission estimates were developed. This inventory effort was coordinated by the EPA's Office of Transportation and Air Quality (OTAQ) and EIAG.

The appendix were created to provide technical details on how the national emissions were developed and how state and local inventory data (when provided) were incorporated into the national estimates. Appendix A provides a copy of the report documenting how the 2002 data were adjusted to reflect marine vessel activity and emissions for 2008.

2.0 DEVELOPMENT OF THE COMMERCIAL MARINE VESSEL COMPONENT FOR THE NEI

2.1 How Does This CMV Study Fit into the NEI?

The NEI was developed to include all point, nonpoint (sometimes referenced as “area”), and mobile sources. The approaches used in the point and nonpoint source categories are documented in other reports. Table 1 summarizes the approaches used to estimate emissions from all nonroad sources included in the NEI program. Those source categories and years that are included in this report are noted in bold.

The scope of this inventory component of the NEI was to compile criteria and HAP emissions data for CMVs operating in United States waters and federal waters extending 200 nautical miles from the United States’ coastline. In this effort, national emission estimates were often developed and allocated to counties based on available Geographic Information System (GIS) data. The methodologies used to estimate emissions and the procedures used to spatially allocate them to the county-level are discussed in this report.

Table 2-1. Methods Used to Develop Annual Emission Estimates for Nonroad Mobile Sources
(Categories included in this report are noted in bold print)

Category	Base Year	Pollutant(s)	Estimation Method*
NONROAD Categories			
Nonroad Gasoline, Diesel, LPG, CNG	2002	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$, NH_3, & HAPs	Emission estimates for NONROAD model engines were developed using EPA’s National Mobile Inventory Model (NMIM), which incorporates NONROAD2004. Where states provided alternate nonroad inputs, these data replaced EPA default inputs. State-supplied emissions data also replaced default EPA emission estimates.

Table 2-1. Methods Used to Develop Annual Emission Estimates for Nonroad Mobile Sources (Continued)
(Categories included in this report are noted in bold print)

Category	Base Year	Pollutant(s)	Estimation Method*
	1999	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$	Using emission estimates from two emission inventories including: 1) a 1996 county-level inventory, developed using EPA's October 2001 draft NONROAD model; and 2) an updated 1999 national inventory, based on EPA's draft Lockdown C NONROAD model (dated May 2002). Using the 1996 county-level emission estimates, seasonal and daily county-to-national ratios were then developed for application to updated national estimates per season estimated from the Lockdown C model. Replaced State-submitted data for California for all NONROAD model categories; Pennsylvania for recreational marine and aircraft ground support equipment, and Texas for select equipment categories.
	1996, 1997, 1998, 2000 & 2001	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$	Using emission estimates from two emission inventories including: 1) a 1996 county-level inventory, developed using EPA's October 2001 draft NONROAD model; and 2) updated year-specific national and California inventories, based on EPA's draft Lockdown C NONROAD model (dated May 2002). Using the 1996 county-level emission estimates, seasonal and daily county-to-national ratios and California county-to-state ratios were then developed for application to updated national estimates per season estimated from the Lockdown C model. California results replace the diesel equipment emissions generated from prior application of county-to-national ratios.

Table 2-1. Methods Used to Develop Annual Emission Estimates for Nonroad Mobile Sources (Continued)
(Categories included in this report are noted in bold print)

Category	Base Year	Pollutant(s)	Estimation Method*
Nonroad Gasoline, Diesel, LPG, and CNG (Continued)	1991-1995	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$, NH_3	Using 1990 and 1996 county-level emissions inventories, estimated emissions using linear interpolation of national emissions between 1990 and 1996. From these emissions, calculated the average annual growth rate for each pollutant/SCC combination for each year, and then applied the growth factors to 1990 county-level emissions to estimate 1991-1995 emissions.
	1990	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$	Using emission estimates from two emission inventories including: 1) a 1996 county-level inventory, developed using EPA's October 2001 draft NONROAD model; and 2) updated 1990 national inventory, based on EPA's draft Lockdown C NONROAD model (dated May 2002). Using the 1996 county-level emission estimates, seasonal and daily county-to-national ratios were then developed for application to updated national estimates per season estimated from the Lockdown C model.
	1986, 1988, & 1989	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$, NH_3	Using 1985 and 1990 county-level emissions inventories, estimated emissions using linear interpolation of national emissions between 1985 and 1990. From these emissions, calculated the average annual growth rate for each pollutant/SCC combination for each year, and then applied the growth factors to 1985 county-level emissions to estimate 1986-1989 emissions.
	1987	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$	Using EPA's draft Lockdown C NONROAD model (dated May 2002), developed updated national emissions for 1987 by running 4 seasonal NONROAD model runs to estimate annual criteria pollutant emissions. Also performed national NONROAD model runs to estimate typical summer weekday emissions.

Table 2-1. Methods Used to Develop Annual Emission Estimates for Nonroad Mobile Sources (Continued)
(Categories included in this report are noted in bold print)

Category	Base Year	Pollutant(s)	Estimation Method*
Nonroad Gasoline, Diesel, LPG, and CNG (Continued)	1985	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$	Using emission estimates from two emission inventories including: 1) a 1996 county-level inventory, developed using EPA's October 2001 draft NONROAD model; and 2) updated 1985 national inventory, based on EPA's draft Lockdown C NONROAD model (dated May 2002). Using the 1996 county-level emission estimates, seasonal and daily county-to-national ratios were then developed for application to updated national estimates per season estimated from the Lockdown C model.
	1970, 1975, 1978, & 1980	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$	Using EPA's draft Lockdown C NONROAD model (dated May 2002), developed updated national emissions for all years by running 4 seasonal NONROAD model runs to estimate annual criteria pollutant emissions. Also performed national NONROAD model runs to estimate typical summer weekday emissions.
	1996, 1997, 1998, 1999, 2000, & 2001	NH_3	Obtaining national fuel consumption estimates from the Lockdown C NONROAD model, multiplying by NH_3 emission factors, and distributing to counties using 1996 inventory, based on October 2001 draft NONROAD. NH_3 emissions for California were also recalculated using updated diesel fuel consumption values generated for California-specific runs, and assuming the 1996 county-level distribution.
	1985 & 1990	NH_3	Obtaining national fuel consumption estimates from the Lockdown C NONROAD model, multiplying by NH_3 emission factors, and distributing to counties using 1996 inventory, based on October 2001 draft NONROAD.
	1987	NH_3	Obtaining 1987 national fuel consumption estimates from Lockdown C NONROAD model and multiplying by NH_3 emission factors.

Table 2-1. Methods Used to Develop Annual Emission Estimates for Nonroad Mobile Sources (Continued)
(Categories included in this report are noted in bold print)

Category	Base Year	Pollutant(s)	Estimation Method*
Nonroad Gasoline, Diesel, LPG, and CNG (Continued)	1970, 1975, 1978, & 1980	NH_3	Obtaining national fuel consumption estimates from the Lockdown C NONROAD model and multiplying by NH_3 emission factors.
	1990, 1996, & 1999	HAPs	Speciation profiles applied to county VOC and PM estimates. Metal HAPs were calculated using fuel and activity-based emission factors. Some state data were provided and replaced national estimates. (2003)
Aircraft			
Commercial Aircraft	2008	Criteria and HAPs	Federal Aviation Administration (FAA) Emissions and Dispersion and Modeling System (EDMS) - Version 5.1.was run using BTS T-100 LTO data. (2009)
	2002	Criteria and HAPs	Federal Aviation Administration (FAA) Emissions and Dispersion and Modeling System (EDMS) was run for criteria pollutants, VOC and PM emissions were speciated into HAP components. (2004)
	1990, 1996, 1999, 2000, 2001	VOC, NO_x, CO, SO_x	Input landing and take-off (LTO) data into FAA EDMS. National emissions were assigned to airports based on airport specific LTO data and BTS GIS data. State data replaced national estimates. (2003)
	1970-1998	VOC, NO_x, CO, SO_x	Estimated emissions for interim years using linear interpolation between available base years. (2003)
	1990, 1996, 1999	HAPs	Speciation profiles were applied to VOC estimates to get national HAP estimates. State data replaced national estimates. (2003)
General Aviation, Air Taxis	2008	Criteria and HAPs	Used FAA LTO data from TAF and OTAQ provided activity data for smaller airports derived from FAA 5010 master plans. EPA approved generic emission factors for criteria estimates. Speciation profiles were applied to VOC and PM estimates to get national HAP estimates. (2009)

Table 2-1. Methods Used to Develop Annual Emission Estimates for Nonroad Mobile Sources (Continued)

(Categories included in this report are noted in bold print)

Category	Base Year	Pollutant(s)	Estimation Method*
General Aviation, Air Taxis (Continued)	1978, 1987, 1990, 1996, 1999, 2000, 2001, & 2002	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$	Used FAA LTO data and EPA approved emission factors for criteria estimates. Speciation profiles were applied to VOC estimates to get national HAP estimates. State data replaced national estimates. (2004)
	1970-1998	VOC, NO_x, CO, SO_x, PM_{10}, $PM_{2.5}$	Estimated emissions for interim years using linear interpolation between available base years. (2003)
	1990, 1996, 1999, & 2002	HAPs	Used FAA LTO data and EPA approved emission factors for criteria estimates. Speciation profiles were applied to VOC estimates to develop national HAP estimates. (2004)
	1990, 1996, 1999, & 2002	Pb	Used Department of Energy (DOE) aviation gasoline usage data with lead concentration of aviation gasoline. (2004)
	1996	NH_3	Applied NH_3 emissions factors to 1996 national jet fuel and aviation gasoline consumption estimates.
Military Aircraft	1978, 1987, 1990, 1996, 1999, 2000, 2001, 2002, 2008	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$	Used FAA LTO data as reported in TAF and EPA approved emission factors for criteria estimates. Representative HAP profiles were not readily available, therefore HAP estimates were not developed. (2009)
	1970-1998	VOC, NO_x, CO, SO_X, PM_{10}, $PM_{2.5}$	Estimated emissions for interim years using linear interpolation between available base years. (2003)
Auxiliary Power Units	2008	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$	Federal Aviation Administration (FAA) Emissions and Dispersion and Modeling System (EDMS) - Version 5.1.was run using BTS T-100 LTO data. (2009)
	1985-2001	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$	Grew 1996 emissions to each year using LTO operations data from the FAA. Estimation methods prior to 1996 reported in EPA, 1998.

Table 2-1. Methods Used to Develop Annual Emission Estimates for Nonroad Mobile Sources (Continued)

(Categories included in this report are noted in bold print)

Category	Base Year	Pollutant(s)	Estimation Method*
Unpaved Airstrips[1]	1985-2001	PM_{10}, $PM_{2.5}$	Grew 1996 emissions to each year using SIC 45-Air Transportation growth factors, consistent with the current draft version of EGAS. Estimation methods prior to 1996 reported in EPA, 1998.
Aircraft Refueling[1]	1985-2001	VOC	Grew 1996 emissions to each year using SIC 45-Air Transportation growth factors, consistent with the current draft version of EGAS. Estimation methods prior to 1996 reported in EPA, 1998.
Commercial Marine Vessel (CMV)			
All CMV Categories	**2008**	**VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$**	**2002 estimates were adjusted by OTAQ to reflect 2008 activity levels., note that the SCCs for this category have changed such that the Diesel category refers to smaller vessels (Category 1 and 2) using distillate fuels and the Residual category refers to larger (Category 3) vessel using a blend of residual fuels (2009)**
	2008	**HAPs**	**OTAQ's 2008 estimates were speciated into HAP components using SEPA profiles**
	2002	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$	2001 Estimates carried over. Used state data when provided. (2004)
		HAPs	1999 Estimates carried over. Used state data when provided. (2004)
CMV Diesel	1978, 1987, 1990, 1996, 1999, 2000, & 2001	VOC, NO_x, CO, SO_x, PM_{10}, & $PM_{2.5}$	Used criteria emission estimates in the background document for marine diesel regulations for 2000. Adjusted 2000 criteria emission estimates for other used based on fuel usage. Emissions were disaggregated into port traffic and underway activities. Port emissions were assigned to specific ports based on amount of cargo handled. Underway emissions were allocated based on Army Corp of Engineering waterway data. State data replaced national estimates. (2003)
	1970-1998	VOC, NO_x, CO, SO_x, PM_{10}, $PM_{2.5}$	Estimated emissions for interim years using linear interpolation between available base years. (2003)
	1990, 1996, 1999	HAPs	VOC and PM emission estimates were speciated into HAP components. State data replaced national estimates. (2003)

Table 2-1. Methods Used to Develop Annual Emission Estimates for Nonroad Mobile Sources (Continued)
(Categories included in this report are noted in bold print)

Category	Base Year	Pollutant(s)	Estimation Method*
	1996	NH_3	Applied NH_3 emissions factors to 1996 distillate and residual fuel oil estimates (i.e., as reported in EIA, 1996).
	1990-1995	NH_3	Estimation methods reported in EPA, 1998.
CMV Steam Powered	1978, 1987, 1990, 1996, 1999, 2000, & 2001	VOC, NO_x, CO, SO_x, PM_{10}, & $PM_{2.5}$	Calculated criteria emissions based on EPA SIP guidance. Emissions were disaggregated into port traffic and under way activities. Port emissions were assigned to specific ports based on amount of cargo handled. Underway emissions were allocated based on Army Corp of Engineering waterway data. State data replaced national estimates. (2003)
	1970-1998	VOC, NO_x, CO, SO_x, PM_{10}, $PM_{2.5}$	Estimated emissions for interim years using linear interpolation between available base years. (2003)
	1990, 1996, & 1999	HAPs	VOC and PM emission estimates were speciated into HAP components. State data replaced national estimates. (2003)
Military Marine	1997-2001	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$	Applied EGAS growth factors to 1996 emissions estimates for this category.
CMV Coal,[2] CMV, Steam powered, CMV Gasoline[2]	1997-1998	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$	Applied EGAS growth factors to 1996 emissions estimates for this category.
CM Coal, CMV, Steam powered, CMV Gasoline, Military Marine	1991-1995	VOC, NO_x, CO, SO_2, PM_{10}, $PM_{2.5}$	Estimation methods reported in EPA, 1998.
Locomotives			
Class I, Class II, Commuter, Passenger, and Yard Locomotives	1978, 1987, 1990, 1996, 1999, 2000, 2000, & 2002	VOC, NO_x, CO, PM_{10}, $PM_{2.5}$	Criteria pollutants were estimated by using locomotive fuel use data from DOE EIA and available emission factors. County-level estimates were obtained by scaling the national estimates with the rail GIS data from DOT. State data replaced national estimates. (2004)

Table 2-1. Methods Used to Develop Annual Emission Estimates for Nonroad Mobile Sources (Continued)
(Categories included in this report are noted in bold print)

Category	Base Year	Pollutant(s)	Estimation Method*
Class I, Class II, Commuter, Passenger, and Yard Locomotives (Continued)	1978, 1987, 1990, 1996, 1999, 2000, 2001, & 2002	SO_2	SO_x emissions were calculated by using locomotive fuel use and fuel sulfur concentration data from EIA. County-level estimates were obtained by scaling the national estimates with the county level rail activity data from DOT. State data replaced national estimates. (2004)
	1970-1998	VOC, NO_x, CO, SO_x, PM_{10}, $PM_{2.5}$	Estimated emissions for interim years using linear interpolation between available base years. (2003)
	1990, 1996, 1999, & 2002	HAPs	HAP emissions were calculated by applying speciation profiles to VOC and PM estimates. County-level estimates were obtained by scaling the national estimates with the county level rail activity from DOT. State data replaced national estimates. (2004)
	1997-1998	NH_3	Grew 1996 base year emissions using EGAS growth indicators.
	1996	NH_3	Applied NH_3 emissions factors to diesel consumption estimates for 1996.
	1990-1995	NH_3	Estimation methods reported in EPA, 1998.

Notes:
* Dates included at the end of Estimation Method represent the year that the section was revised.
1 Emission estimates for unpaved airstrips and aircraft refueling are included in the area source NEI, since they represent non-engine emissions.
2 National Emission estimates for CMV Coal and CMV Gasoline were not developed though states and local agencies may have submitted estimates for these source categories.
EPA, 1998. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emission Factors and Inventory Group, National Air Pollutant Emission Trends, Procedures Document, 1900–1996, EPA-454/R-98-008. May 1998.

The target inventory area includes every state in the United States and every county within a state. There are no boundary limitations pertaining to traditional criteria pollutant nonattainment areas or to designated urban areas. The pollutants inventoried included all criteria pollutants (except for the other nonroad source category which addressed only HAPs in this report) and the 188 HAPs identified in Section 112(b) of the CAA. Some state or local agencies provided emissions information on more HAPs than those delineated in the CAA, only the federally regulated HAPs are included in the NEI.

In addition to numerous specific chemical compounds, the list of 188 HAPs includes several compound groups [e.g., individual metals and their compounds, polycyclic organic matter (POM)]; the NEI includes emission estimates for the individual compounds wherever possible. Many of the uses of the NEI depend upon data (e.g., toxicity) for individual compounds within these groups rather than aggregated data on each group as a whole.

The intent in presenting the following emission inventory approach is to provide sufficient and transparent documentation such that states and local agencies can use these approaches, in conjunction with their specific local activity data to develop more accurate and comparable emission estimates in future submittals.

2.2 What are Commercial Marine Vessels?

The CMV source category includes all boats and ships used either directly or indirectly in the conduct of commerce or military activity. These vessels range from 20-foot charter boats to large tankers which can exceed 1,000 feet in length (EPA, 1989). In spite of the broad range of vessels represented by this category, a number of common characteristics allow for the use of simple emission estimation methods. The majority of vessels in this category are powered by diesel engines that are either fueled with distillate or residual fuel oil blends. For the purpose of this inventory it is assumed that Category 3 vessels primarily use residual blends while Category 1 and 2 vessels typically used distillate fuels.

The Category 3 (C3) inventory developed by OTAQ includes vessels which use C3 engines for propulsion. C3 engines are defined as having displacement above 30 liters per cylinder (U.S. EPA, 2003). The resulting inventory includes emissions from both propulsion and auxiliary engines used on these vessels, as well as those on gas and steam turbine vessels. Geographically, the inventories include port and interport emissions that occur within the area that extends 200 nautical miles (nm) from the official U.S. baseline, which is roughly equivalent to the border of the U.S. Exclusive Economic Zone (EEZ).

Category 1 and 2 vessels tend to be smaller ships that operate closer to shore, and along inland and intercoastal waterways. Naval vessels are not included in this inventory, though Coast Guard vessels are included as Category 1 and 2 vessels.

The CMV source category does not include recreational marine vessels, which are generally less than 100 feet in length, most being less than 30 feet, and powered by either inboard or outboard engines (EPA, 1989). Emissions from recreational marine vessels are included in the nonroad source category.

2.3 What Pollutants are Included in the National Emission Estimates for CMVs?

The EPA's Office of Transportation and Air Quality (OTAQ) provided estimates for all criteria pollutants including volatile organic compounds (VOC), nitrogen oxides (NO_x), carbon monoxide (CO), sulfur oxides (SO_x), particulate matter less than 10 microns (PM_{10}), particulate matter less than 2.5 microns ($PM_{2.5}$) and carbon dioxide (CO_2). Criteria emissions were provided for Category 1 and 2 vessels (Carey, 2009b); Category 3 port, reduced speed zone, and cruising activities (Carey, 2009a and Carey, 2009c); and Category 3 interport activities (Carey, 2009d).

The VOC and PM estimates were speciated into hazardous air pollutants (HAP) components based on available data sources. The Swedish Environmental Protection Agency (SEPA) document *Methodology for Calculating Emissions from Ships: 1. Update of emission factors* served as the primary source of HAP emission factors which were converted into speciation profiles (Cooper and Gustafsson, 2004). Ammonia emission factors were also obtained from the SEPA, but as these factors require activity data, and such data were not available for Category 3 vessels operating in Federal waters, ammonia was estimated as a ratio of PM_{10} using the SEPA emission factors. Similar ratios were developed for Category 1 and 2 vessels, assuming that this fleet primarily operates on marine diesel fuel with 80.5 percent of the fleet equipped with medium speed engines and the remaining 19.5 percent were high speed engines. This provided a weighted NH_3 emission factor of 4.61E-03 g/kw-hr for operations at-sea and in-port. The PM_{10} factors vary for at-sea (0.2 g/kw-hr) and in-port (0.4 g/kw-hr), so our NH_3 / PM_{10} ratios were different for at-sea (2.31E-02) and in-port (1.15E-02).

While the SEPA document was used as the primary speciation source, other resources were investigated for potential inclusion in this effort. Recent BTEX data from Moldanova et al. were examined, but it included inconsistent benzene factors, some over 20% of hydrocarbon (HC) factors, were much higher than others found in recent publications and, as a result, were not included (Cook, 2009). CE-CERT metals data was also reviewed as it pertained to slow speed residual fuel engines (Cook, 2009). The CE-CERT emission factors were in line with the Swedish factors for nickel and lead, but they were an order of magnitude different for chromium, cadmium, and selenium. As a result, the Swedish factors were retained over the CE-CERT data based on the larger study sample size, while CE-CERT's manganese emission factors were added as these factors were not included in the Swedish study (Cook, 2009).

The complete pollutant list for CMVs is shown in Table 2-2.

2.4 How Were the CMV Emissions Estimated?

As noted above, the CMV criteria and CO_2 emission estimates were provided for this inventory by OTAQ. Category 3 commercial marine inventories were developed for a base year of 2002 then projected to 2008 applying regional adjustment factors to account for growth. In addition, NO_X adjustment factors were applied to account for implementation of the NO_X Tier 1 standard. Details about adjustments and growth factors can be found in the Category 3 documentation (Appendix A). For Category 1 and 2 marine diesel engines, the emission estimates were consistent with the 2008 Locomotive and Marine federal rule making (Carey, 2009b).

Table 2-2. Commercial Marine Vessel Pollutant List

2,2,4 Trimethylpentane	Carbon Monoxide*	Naphthalene
Acenaphthene	Chromium(VI)	Nickel
Acenaphthylene	Chromium (III)	Nitrogen Oxides*
Acetaldehyde	Chrysene	PAH, total
Acrolein	Cobalt	Phenanthrene
Ammonia	Dibenzo[a,h]Anthracene	Phosphorus
Anthracene	Dioxins/Furans	PM10 Primary*
Arsenic	Ethyl benzene	PM2.5 Primary+
Benz(a)anthracene	Fluoranthene	Polychlorinated Biphenyls
Benzene	Fluorene	Propionaldehyde
Benzo(a)pyrene	Formaldehyde	Pyrene
Benzo(b)fluoranthene	Hexachlorobenzene	Selenium
Benzo(g,h,i)perylene	Hexane	Styrene
Benzo(k)fluoranthene	Indeno(1,2,3-cd)pyrene	Sulfur Dioxide*
Beryllium	Lead	Toluene
Cadmium	Manganese	VOCs*
Carbon Dioxide*	Mercury	Xylene

* Provided by OTAQ

\+ $PM_{2.5}$ was provided by OTAQ for all vessels and modes except for Category 3 Interport, where it was calculated using OTAQ guidance.

OTAQ's emissions were then allocated to individual GIS polygons using appropriate methods that varied by operating mode (i.e., hotelling, maneuvering, reduced speed zone, and underway). HAP emissions were estimated by applying speciation profiles to each polygon's VOC and PM estimates. Figure 2-1 provides an overview of the approach used to estimate and spatially allocate CMV emissions.

Speciation profiles were applied to the VOC, PM_{10}, and $PM_{2.5}$ emission estimates to calculate the associated HAP emissions using the following equation.

$$VOC\text{-}PM_{10/2.5} * speciation\ profile_i = HAP\ emission\ estimate:$$

Where:

HAP emission estimate	= HAP Emission estimate (tons/year) for pollutant:
$VOC\text{-}PM_{10/2.5}$	= VOC or PM emission estimate (tons/year)
Speciation $Profile_i$	= VOC or PM speciation fraction for HAP i

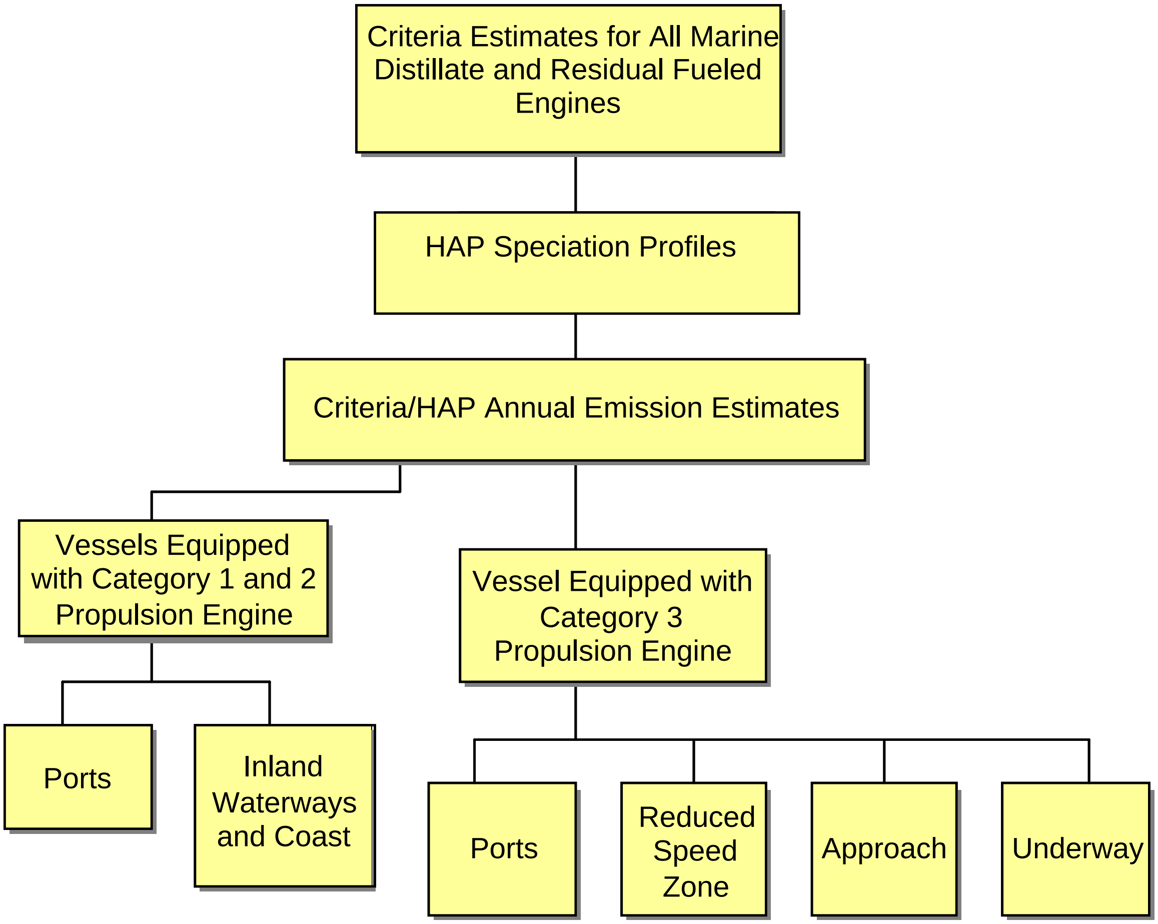

Figure 2-1. General Approach Used to Develop Marine Vessel Component of the 2008 National Emission Inventory

For Category I diesel-powered vessels, the speciation profiles were based on high-speed diesel vehicle (HSDV) factors obtained from information in the SEPA's *Methodology for Calculating Emissions from Ships: 1. Update of emission factors* (Cooper and Gustafsson, 2004). For Category 2 diesel-powered vessels, the speciation profiles were developed from medium-speed diesel vehicles (MSDV). Since emissions and activity data were provided as a combined value for all Category 1 and 2 vessels, the Category 1 and Category 2 emission factors were averaged to obtain a single emission factor for all diesel vessels. All port activities for Category 1 and 2 vessels were assumed to be maneuvering.

For Category 3 vessels, speciation profiles were developed using data from *Methodology for Calculating Emissions from Ships: 1. Update of emission factors* and assuming 80.5% of Category 3 vessels were equipped with slow-speed engines and 19.5% of vessels were equipped with medium speed engines based on vessel census data reported in the International Maritime Organization's (IMO) recent greenhouse gas (GHG) study (IMO 2009). Separate speciation profiles were created for Category 3 vessels for underway, maneuvering, and hotelling activities. Chromium emissions were split into hexavalent and trivalent chromium based on an assumption that 34% of total chromium was hexavalent and the remaining 66% was trivalent.

2.5 How Were Emissions Allocated?

Previous emissions allocations were based on waterway length and port county assignment. In this effort, spatial accuracy was greatly enhanced via the creation of GIS polygons representing port and waterway boundaries. GIS polygons allowed the estimation/allocation of emissions to defined port, waterway, and coastal areas, leading to improved spatial resolution compared to 2002's county-level emissions. Methodologies for both port and underway emissions are described in detail in the sections that follow.

2.6 How Were Port Emissions Allocated?

Port boundaries were developed using a variety of resources to identify the most accurate port boundaries. First, GIS data or maps provided directly from the port were used. Next, maps or port descriptions from local port authorities, port districts, etc. were used in combination with existing GIS data to identify port boundaries. Finally, satellite imagery from tools such as Google Earth and street layers from StreetMap USA were used to delineate port areas. Emphasis was placed on mapping the 117 ports with Category 3 vessel activity using available shape files of the port area. The Port of Huntington was developed differently given its large extent and limited available map data. The state of West Virginia provided a revised file of US Army Corps of Engineers *port terminals* reported to be part of the Port of Huntington-Tristate area. A 200 meter buffer of the water features near these port terminals was created to identify port area.

In all cases, polygons were created on land, bordering waterways and coastal areas, and were split by county boundary. Each polygon was identified by the port name and state and county FIPS in addition to a unique ShapeID. Smaller ports with Category 1 and 2 activities were mapped as small circles. Note that no Category 3 emissions were mapped to small circles. The final shapefile contained 159 ports and 196 polygons.

OTAQ provided Category 1 and 2 criteria emissions and activity as a single national number. These emissions and activity were allocated to ports based on total commodity tonnage data obtained from the U.S. Army Corps of Engineers (USACE) Principal Ports file for 2007 (U.S. ACE, 2009). Emissions were then assigned to polygons within a port based on port area.

OTAQ developed port-level emissions for 117 of the largest U.S. ports with Category 3 activity. Activity in megawatt hours (MWh) and resulting criteria and CO_2 emissions were provided by port for maneuvering and hotelling modes. Emissions were then assigned to polygons within a port based on port area. HAP emissions were then speciated from VOC and PM estimates for each polygon using the methodology described in Section 3.0.

2.7 How Were Underway Emissions Allocated?

For this inventory, a GIS polygon layer was created to more accurately represent the location of CMV-related activity and emissions. Inland waterway polygons were obtained from the Bureau of Transportation Statistics' National Transportation Atlas Database hydro polygon layer (U.S. DOT, 2007). These polygons were further divided by county boundary and waterway ID. Coastal waters were drawn using Mineral Management Service state-federal boundary files and were also divided to indicate county boundaries. Federal waters were included as large area blocks outlined by the Exclusive Economic Zone (EEZ) boundary provided by EPA, which extends to approximately 200 nautical miles from the coastline. The final product is a polygon layer that includes all inland and coastal state waters and federal waters along with FIP, polygon area, and a unique ShapeID. Underway emissions were allocated differently by vessel category and mode, as outlined below.

2.7.1 *Category 1 and 2 Underway*

OTAQ provided Category 1 and 2 criteria emissions and activity as a single national number. These emissions and activity were allocated to underway polygons in state waters based on total commodity movements (in tons) data obtained from USACE (U.S. ACE, 2001). These data were waterway-specific, so waterways that crossed into multiple FIPs had emissions assigned by waterway length in each polygon. HAP emissions were then speciated from VOC and PM estimates using the methodology described in Section 3.0 for each polygon.

2.7.2 *Category 3 Reduced Speed Zones (RSZ)*

OTAQ provided polyline shapefiles indicating location of RSZ activities along with port-specific RSZ emissions and activity. These polylines were intersected with existing shipping lane polygons, and emissions were allocated to polygons based on the approach segment length on a per-port basis. HAP emissions were then speciated from VOC and PM estimates using the methodology described in Section 3.0 for each polygon.

2.7.3 *Category 3 Approach*

OTAQ provided polyline shapefiles indicating location of cruising activities along with port-specific cruising emissions and activity. These polylines were intersected with our existing polygons, and emissions were allocated to polygons based on the approach segment length on a per-port basis. HAP emissions were then speciated from VOC and PM estimates using the methodology described in Section 3.0 for each polygon.

2.7.4 *Category 3 Interport*

OTAQ provided 4km grids for interport-only emissions for CO, CO_2, HC, NO_x, SO_x, and PM_{10}. These grids were provided in a customized projection which, without a custom geographic transformation, could not be converted to match the polygon layer's projection. Furthermore, the emission estimates provided by OTAQ were developed using EEZs which were in the GCS Arc Sphere projection. Per OTAQ's direction, the interport polygons were converted from North American Equidistant Conic to GCS Arc Sphere by using the data frame projections tool as the a transformation method. This approach was recommended by OTAQ in order to mirror previous methodology and provide emission estimates consistent with the recent Category 3 Commercial Marine Inventory. Zonal statistics tools were used to sum the gridded emissions within each underway polygon**.** HAP emissions were then speciated from VOC and PM estimates using the methodology described in Section 3.0 for each polygon.

2.8 QA/QC

Given the significant methodological changes over previous inventory efforts, several quality checks were implemented to ensure that these data were developed and allocated in a clear and reproducible manner. Some of the quality checks implemented include the following:

GIS shapefiles

- Topology was created and validated through several rounds or revisions to remove gaps or overlapping features both within and between polygon layers.
- Boundaries derived from Google Earth imagery were validated against Street Map network, port-provided map images, USACE ports points, and other online mapping resources to improve boundary accuracy.
- All final shapefiles and polygon characteristics (such as area, etc.) were managed and evaluated in a single projection to ensure quality area and distance measurements, consistent results across CMV activity types, and maximum accuracy across the study area. The only exception to this was in the case of the interport criteria emissions, as described in Section 4.2.4.

Emissions allocations and estimations

- Emission factors were compiled from a variety of sources, and emission factor development methodologies evaluated to identify the most accurate emission factor for use in this inventory effort.
- National emission sums were checked both before and after allocation to ensure no emissions were dropped or grown.
- HAP speciation profiles were checked for accuracy, and speciated emissions were checked on both the polygon and national level to ensure accuracy.
- All unit conversions were double-checked for errors.
- Emission sums were evaluated across activity types (i.e., hotelling, maneuvering, cruising, reduced speed zones, and interport) to ensure they consistently mirror activity levels.
- Port and underway emissions were examined across SCCs to ensure consistency with activity levels and vessel populations.

- 2008 pollutants and emissions were checked against the 2005 inventory to identify any missing pollutants or major changes compared to previous inventories. Discrepancies were investigated and revisions were made as needed.

2.9 What are the Results?

Table 2-3 summarizes the emission estimates for CMVs for criteria pollutants. Table 2-4 summarizes the emission estimates for individual HAPs. Note that for the purposes of this inventory vessels equipped with category 1 and 2 propulsion engines are assumed to operate on Distillate diesel, while vessels equipped with Category 3 propulsion engines are assumed to used a residual blend. Both tables provide data for all states; these 2008 estimates do not include state submitted data.

Table 2-3. Commercial Marine Vessel Criteria and Greenhouse Gas Emission Estimates 2008 (TPY)

Pollutant	Diesel Port	Diesel Underway	Diesel Total	Residual Port	Residual Underway	Residual Total	CMV Total
CO	113,452	37,817	151,269	5,871	68,588	74,459	**225,728**
CO_2	39,221,848	13,073,950	52,295,798	3,703,169	30,986,332	34,689,501	**86,985,299**
NH_3	210	140	350	64	323	387	**737**
NO_X	588,844	196,281	785,125	70,044	813,908	883,952	**1,669,077**
PM10-PRI	20,954	6,985	27,939	6,730	67,702	74,432	**102,371**
PM25-PRI	20,325	6,775	27,100	6,081	62,318	68,399	**95,499**
SO_2	34,803	11,601	46,404	52,512	522,327	574,839	**621,243**
VOC	12,752	4,251	17,003	2,412	28,711	31,123	**48,126**

* Note that for the purposes of this inventory vessels equipped with category 1 and 2 propulsion engines are assumed to operate on Distillate diesel, while vessels equipped with Category 3 propulsion engines are assumed to used a residual blend.

Table 2-4. Commercial Marine Vessel HAP Emission Estimates 2008 (TPY)

Pollutant	Diesel Port	Residual Port	Diesel Underway	Residual Underway
2,2,4-Trimethylpentane	3.825675	NA	1.062688	NA
Acenaphthene	0.36585	0.002068	0.101625	0.021188
Acenaphthylene	0.564019	0.003193	0.156672	0.032717
Acetaldehyde	710.6	0.552315	197.388896	6.574751
Acrolein	33.47466	NA	9.298516	NA
Anthracene	0.564019	0.003193	0.156672	0.032717
Arsenic	0.366686	2.358644	0.209535	11.836005
Benz[a]Anthracene	0.60975	0.003448	0.169375	0.035334
Benzene	194.5738	0.023636	54.048288	0.281365
Benzo[a]Pyrene	0.052384	0.011793	0.034923	0.059180
Benzo[b]Fluoranthene	0.104768	0.023586	0.069845	0.118360
Benzo[g,h,i,]Perylene	0.137194	0.000778	0.038109	0.007977
Benzo[k]Fluoranthene	0.052384	0.011793	0.034923	0.059180
Beryllium	NA	0.003674	NA	0.036965
Cadmium	0.059298	0.057506	0.035970	1.530064
Chromium (VI)	0.178105	1.224973	0.118737	4.419583
Chromium III	0.345733	2.377888	0.230489	8.579191
Chrysene	0.106706	0.000604	0.029641	0.006188
Cobalt	NA	1.717108	NA	10.426100
Dioxins/Furans as 2,3,7,8-TCDD TEQs	1.57E-06	1.18E-06	0.000001	0.000006
Ethyl Benzene	19.12838	NA	5.313438	NA
Fluoranthene	0.335363	0.001897	0.093156	0.019443
Fluorene	0.746944	0.004227	0.207484	0.043311
Formaldehyde	1430.802	3.786611	397.445137	45.075801
Hexachlorobenzene	0.000419	9.43E-05	0.000279	0.000473
Hexane	52.60303	NA	14.611954	NA
Indeno[1,2,3-c,d]Pyrene	0.104768	0.023586	0.069845	0.118360
Lead	1.571513	0.354705	1.047675	1.773791
Manganese	0.032059	0.385606	0.008905	3.879322
Mercury	0.000524	0.008218	0.000349	0.035508
Naphthalene	21.35649	0.121021	5.932360	1.240126
Nickel	10.47675	90.68502	6.984500	398.764466
PAH, total	26.5488	0.154501	7.496895	1.584859
Phenanthrene	0.85365	0.004829	0.237125	0.049480
Phosphorus		26.71489	NA	387.932155
Polychlorinated Biphenyls	0.005238	0.001179	0.003492	0.005918
Propionaldehyde	58.34154	NA	16.205985	NA
Pyrene	0.594506	0.003363	0.165141	0.034462
Selenium	0.000593	0.053465	0.000360	0.235603
Styrene	20.08479	NA	5.579110	NA
Toluene	30.6054	NA	8.501500	NA
Xylenes (Mixed Isomers)	45.9081	NA	12.752250	NA

* Note that for the purposes of this inventory vessels equipped with category 1 and 2 propulsion engines are assumed to operate on Distillate diesel, while vessels equipped with Category 3 propulsion engines are assumed to used a residual blend.
NA – Not Applicable.

2.10 Commercial Marine Vessel References

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Appendix A
2008 Category 3 Commercial Marine Vessel Inventory Methodology

Citation: U.S. Environmental Protection Agency. *Development of 2008CY Category 3 Commercial Marine Inventory*. Office of Transportation and Air Quality, Ann Arbor, MI. 2009.

Development of 2008CY Category 3 Commercial Marine Inventory

The Category 3 (C3) inventory includes vessels which use C3 engines for propulsion. C3 engines are defined as having displacement above 30 liters per cylinder. The resulting inventory includes emissions from both propulsion and auxiliary engines used on these vessels, as well as those on gas and steam turbine vessels.

Geographically, the inventories include port and interport emissions that occur within the area that extends 200 nautical miles (nm) from the official U.S. baseline, which is roughly equivalent to the border of the U.S. Exclusive Economic Zone (EEZ). The U.S. region was clipped to the boundaries of the U.S. EEZ in areas where the 200nm boundary extended beyond the EEZ.

Category 3 commercial marine inventories were developed for a base year of 2002. [1] These were then projected to 2008. Regional adjustment factors were applied to account for growth. In addition, NO_X adjustment factors were applied to account for implementation of the NO_X Tier 1 standard. The methodology for each type of adjustment is described below.

Growth Factors by Geographic Region

The emissions inventory is calculated for nine geographic regions: Alaska East, Alaska West, East Coast, Gulf Coast, Hawaii East, Hawaii West, North Pacific, South Pacific, and the Great Lakes. Average annual growth rates from 2002-2020 were calculated for five regions: East Coast, Gulf Coast, North Pacific, South Pacific, and the Great Lakes. The Alaska regions were assigned the growth factor for the North Pacific region, while the Hawaii regions were assigned the growth factor for the South Pacific region. Each regional growth rate was then compounded over the inventory projection time period for 2008 (i.e., 6 years). The average annual growth rates and resulting multiplicative growth factors for each emission inventory region is presented in Table 1 below.

Table 1. Regional Emission Inventory Growth Factors for 2008

Emission Inventory Region	2002-2020 Average Annualized Growth Rate (%)	Multiplicative Growth Factor for 2008 Relative to 2002
Alaska East (AE)	3.3	1.2151
Alaska West (AW)	3.3	1.2151
East Coast (EC)	4.5	1.3023
Gulf Coast (GC)	2.9	1.1871
Hawaii East (HE)	5.0	1.3401
Hawaii West (HW)	5.0	1.3401
North Pacific (NP)	3.3	1.2151
South Pacific (SP)	5.0	1.3401
Great Lakes (GL)	1.7	1.1064

NO_X Adjustment Factors

The 2008 calendar year baseline inventory includes pre-control (Tier 0) engines and those subject to the NO_X Tier 1 standard that became effective in 2000. The NO_X emission factors (EFs) by tier and engine/ship type are given in Table 2.

Table 2. NO_X Emission Factors by Tier

Engine/Ship Type	NO_X EF (g/kW-hr)	
	Tier 0	Tier 1
Main		
Slow-Speed Diesel (SSD)	18.1	16.1
Medium-Speed Diesel (MSD)	14	12.5
Steam Turbine (ST)	2.1	n/a
Gas Turbine	6.1	n/a
Auxiliary		
Passenger Ship	14.6	13.0
Other Ships	14.5	12.9

The NO_X EFs by tier were then used with age distributions to generate calendar year NO_X EFs by engine/ship type for 2008. For 2002, Tier 0 EFs were used for simplicity. These calendar year NO_X EFs are provided in Table 3. Since the age distributions are different for vessels in the Great Lakes, NO_X EFs were determined separately for the Great Lakes.

Table 3. NO_X Emission Factors by Calendar Year

Engine/Ship Type	CY NO_X EF (g/kW-hr)		
		2008	
	2002	DSP[a]	GL[b]
Main			
Slow-Speed Diesel (SSD)	18.1	17.07	17.50
Medium-Speed Diesel (MSD)	14	13.01	13.74
Steam Turbine (ST)	2.1	2.1	2.1
Gas Turbine	6.1	6.1	n/a
Auxiliary			
Passenger Ship	14.6	13.76	14.32
Other Ships	14.5	13.60	14.16

[a]DSP = Deep sea ports and areas other than the Great Lakes
[b]GL = Great Lakes

Emission adjustment factors for NO_X were then calculated. Adjustment factors are ratios of the 2008 calendar year EFs to the 2002 calendar year EFs. The adjustment factors by engine/ship type are provided in Table 4.

Table 4. NO_X EF Adjustment Factors for 2008CY

Engine/Ship Type	2008 NO_X Adj (unitless)	
	DSP[a]	GL[b]
Main		
Slow-Speed Diesel (SSD)	0.9433	0.9670
Medium-Speed Diesel (MSD)	0.9293	0.9815
Steam Turbine (ST)	1.0000	1.0000
Gas Turbine	1.0000	n/a
Auxiliary		
Passenger Ship	0.9403	0.9784
Other Ships	0.9403	0.9784

<u>Methodology for Development of 2008CY Port Inventories</u>

For the non-California ports, 2002 emissions for each port are summed by engine/ship type. Propulsion and auxiliary emissions are summed separately, since the EF adjustment factors differ. The appropriate regional growth factor, as provided in Table 1, is then applied, along with the NO_X EF adjustment factors by engine/ship type in Table 4 to calculate the 2008 port inventories.

For the California ports, 2002 emissions for each port are summed by ship type. Propulsion and auxiliary emissions are summed separately, since the EF adjustment factors differ. The EF adjustment factors by engine/ship type in Table 4 are consolidated by ship type, using the CARB assumption that engines on all ships except passenger ships are 95 percent slow speed diesel (SSD) engines and 5 percent medium speed diesel engines (MSD) based upon a 2005 CARB survey. All passenger ships were assumed to be MSD engines. Steam turbines (ST) and gas turbines (GT) are not included in the CARB inventory. The NO_X EF adjustment factors by ship type are then applied, along with ship-specific growth factors used by CARB, to calculate the 2008 California port inventories. The ship-specific growth factors for 2008 relative to 2002 are provided in Table 5 below.

Table 5. Growth Factors by Ship Type for California Ports

Ship Type	Calendar Year	
	2002	2008
Auto	1.0000	1.1525
Bulk	1.0000	0.7412
Container	1.0000	1.4023
General	1.0000	0.9071
Passenger	1.0000	1.9823
Reefer	1.0000	1.0112
RoRo	1.0000	1.1525
Tanker	1.0000	1.3005

Methodology for Development of 2008CY Interport Inventories

The interport portion of the inventory is not segregated by engine or ship type. As a result, regional NO_X EF adjustment factors were developed based on the assumed mix of main (propulsion) engine types in each region. The mix of main engine types by region was developed using the ship call and power data and is presented in Table 6. Main engines are considered a good surrogate for interport emissions, since the majority of emissions while underway are due to the main engines. The NO_X EF adjustment factors by main engine type in Table 4 were used together with the mix of main engine types by region in Table 6 to develop the regional adjustment factors. The resulting NO_X EF regional adjustment factors are provided in Table 7. These NO_X EF regional adjustment factors, together with the regional growth factors in Table 1, were applied to calculate the 2008 interport inventories.

Table 6. Installed Power by Main Engine Type

Region	2008 Installed Power (%)			
	MSD	SSD	GT	ST
Alaska East (AE)	19.1%	18.4%	0.3%	62.2%
Alaska West (AW)	19.1%	18.4%	0.3%	62.2%
East Coast (EC)	25.6%	72.5%	0.9%	1.0%
Gulf Coast (GC)	13.7%	85.5%	0.0%	0.8%
Hawaii East (HE)	66.2%	18.5%	7.4%	8.0%
Hawaii West (HW)	66.2%	18.5%	7.4%	8.0%
North Pacific (NP)	5.1%	83.5%	1.6%	9.7%
South Pacific (SP)	17.8%	82.2%	0.0%	0.0%
Great Lakes (GL)	47.9%	43.7%	0.0%	8.4%

Table 7. NO_X EF Regional Adjustment Factors

Region	2002	2008
Alaska East (AE)	1.0000	0.9761
Alaska West (AW)	1.0000	0.9761
East Coast (EC)	1.0000	0.9408
Gulf Coast (GC)	1.0000	0.9419
Hawaii East (HE)	1.0000	0.9428
Hawaii West (HW)	1.0000	0.9428
North Pacific (NP)	1.0000	0.9490
South Pacific (SP)	1.0000	0.9408
Great Lakes (GL)	1.0000	0.9767

The resulting 2008 Category 3 emission inventories are shown in Table 8 for each of the nine geographic regions and the nation.

Table 8. 2008 Regional and National Emissions from Category 3 Vessel Main and Auxiliary Engines

Region	Metric Tonnes						
	NO_X	PM_{10}	$PM_{2.5}$ [a]	HC	CO	SO_2	CO_2
Alaska East (AE)	21,590	1,749	1,609	733	1,730	13,032	807,159
Alaska West (AW)	71,901	5,755	5,294	2,441	5,750	42,694	2,631,081
East Coast (EC)	271,707	23,021	21,180	9,573	22,665	190,767	10,696,360
Gulf Coast (GC)	195,240	16,839	15,492	6,903	16,990	125,728	7,604,870
Hawaii East (HE)	28,837	2,403	2,211	1,013	2,390	17,843	1,108,047
Hawaii West (HW)	40,573	3,381	3,110	1,426	3,362	25,105	1,559,016
North Pacific (NP)	30,248	2,647	2,435	1,153	2,568	18,790	1,216,723
South Pacific (SP)	132,669	10,982	10,103	4,692	11,368	81,896	5,145,632
Great Lakes (GL)	16,395	1,318	1,212	557	1,312	9,797	605,001
Total Metric Tonnes	**809,160**	**68,094**	**62,646**	**28,492**	**68,136**	**525,651**	**31,373,889**
Total Short Tons [b]	**891,946**	**75,061**	**69,056**	**31,407**	**75,107**	**579,431**	**34,583,792**

[a] Estimated from PM_{10} using a multiplicative adjustment factor of 0.92.

Reference (for 2002 inventory development)

1) U.S. Environmental Protection Agency, "Draft Regulatory Impact Analysis: Control of Emissions of Air Pollution from Category 3 Marine Diesel Engines," Office of Transportation and Air Quality, EPA-420-D-09-002, June 2009.

Appendix B

2008 Commercial Marine Vessel Hazardous Air Pollutant Speciation Profiles

Table 1. Category 1 and 2 Hazardous Air Pollutant Speciation Profile for Port Activities

Pollutant Code	Pollutant	Speciation Basis	2008 Emission Factor
540841	2,2,4-trimethylpentane	VOC	3.00E-04
83329	Acenaphthene	$PM_{2.5}$	1.80E-05
208968	Acenaphthylene	$PM_{2.5}$	2.78E-05
75070	Acetaldehyde	VOC	5.57E-02
107028	Acrolein	VOC	2.63E-03
NH3	Ammonia	PM_{10}	1.15E-02
120127	Anthracene	$PM_{2.5}$	2.78E-05
7440382	Arsenic	PM_{10}	1.75E-05
56553	Benz[a]Anthracene	$PM_{2.5}$	3.00E-05
71432	Benzene	VOC	1.53E-02
50328	Benzo[a]Pyrene	PM_{10}	2.50E-06
205992	Benzo[b]Fluoranthene	PM_{10}	5.00E-06
191242	Benzo[g,h,I,]Perylene	$PM_{2.5}$	6.75E-06
207089	Benzo[k]Fluoranthene	PM_{10}	2.50E-06
7440439	Cadmium	PM_{10}	2.83E-06
16065831	Chromium III	PM_{10}	1.65E-05
18540299	Chromium VI	PM_{10}	8.50E-06
218019	Chrysene	$PM_{2.5}$	5.25E-06
600	Dioxin	PM_{10}	2.50E-09
100414	Ethylbenzene	VOC	1.50E-03
206440	Fluoranthene	$PM_{2.5}$	1.65E-05
86737	Fluorene	$PM_{2.5}$	3.68E-05
50000	Formaldehyde	VOC	1.12E-01
118741	Hexachlorobenzene	PM_{10}	2.00E-08
193395	Indeno[1,2,3-c,d]Pyrene	PM_{10}	5.00E-06
439921	Lead	PM_{10}	7.50E-05
7439965	Manganese	PM_{10}	1.53E-06
7439976	Mercury	PM_{10}	2.50E-08
91203	Naphthalene	$PM_{2.5}$	1.05E-03
110543	n-Hexane	VOC	4.13E-03
7440020	Nickel	PM_{10}	5.00E-04
1336363	Polychlorinated Biphenyls	PM_{10}	2.50E-07
85018	Phenanthrene	$PM_{2.5}$	4.20E-05
123386	Propionaldehyde	VOC	4.58E-03
129000	Pyrene	$PM_{2.5}$	2.93E-05
7782492	Selenium	PM_{10}	2.83E-08
100425	Styrene	VOC	1.58E-03
108883	Toluene	VOC	2.40E-03

Table 2. Category 1 and 2 Hazardous Air Pollutant Speciation Profile for Underway Activities

Pollutant Code	Pollutant	Speciation Basis	2008 Emission Factor
1330207	Xylene	VOC	3.60E-03
540841	2,2,4-trimethylpentane	VOC	2.50E-04
83329	Acenaphthene	$PM_{2.5}$	1.50E-05
208968	Acenaphthylene	$PM_{2.5}$	2.31E-05
75070	Acetaldehyde	VOC	4.64E-02
107028	Acrolein	VOC	2.19E-03
NH3	Ammonia	PM_{10}	2.31E-02
120127	Anthracene	$PM_{2.5}$	2.31E-05
7440382	Arsenic	PM_{10}	3.00E-05
56553	Benz[a]Anthracene	$PM_{2.5}$	2.50E-05
71432	Benzene	VOC	1.27E-02
50328	Benzo[a]Pyrene	PM_{10}	5.00E-06
205992	Benzo[b]Fluoranthene	PM_{10}	1.00E-05
191242	Benzo[g,h,I,]Perylene	$PM_{2.5}$	5.63E-06
207089	Benzo[k]Fluoranthene	PM_{10}	5.00E-06
7440439	Cadmium	PM_{10}	5.15E-06
16065831	Chromium III	PM_{10}	3.30E-05
18540299	Chromium VI	PM_{10}	1.70E-05
218019	Chrysene	$PM_{2.5}$	4.38E-06
600	Dioxin	PM_{10}	5.00E-09
100414	Ethylbenzene	VOC	1.25E-03
206440	Fluoranthene	$PM_{2.5}$	1.38E-05
86737	Fluorene	$PM_{2.5}$	3.06E-05
50000	Formaldehyde	VOC	9.35E-02
118741	Hexachlorobenzene	PM_{10}	4.00E-08
193395	Indeno[1,2,3-c,d]Pyrene	PM_{10}	1.00E-05
7439921	Lead	PM_{10}	1.50E-04
7439965	Manganese	PM_{10}	1.28E-06
7439976	Mercury	PM_{10}	5.00E-08
91203	Naphthalene	$PM_{2.5}$	8.76E-04
110543	n-Hexane	VOC	3.44E-03
7440020	Nickel	PM_{10}	1.00E-03
1336363	Polychlorinated Biphenyls	PM_{10}	5.00E-07

Table 2. Category 1 and 2 Hazardous Air Pollutant Speciation Profile for Underway Activities (Continued)

Pollutant Code	Pollutant	Speciation Basis	2008 Emission Factor
85018	Phenanthrene	$PM_{2.5}$	3.50E-05
123386	Propionaldehyde	VOC	3.81E-03
129000	Pyrene	$PM_{2.5}$	2.44E-05
7782492	Selenium	PM_{10}	5.15E-08
100425	Styrene	VOC	1.31E-03
108883	Toluene	VOC	2.00E-03
1330207	Xylene	VOC	3.00E-03

Table 3. Category 3 Hazardous Air Pollutant Speciation Profile for Hotelling Activities

Pollutant Code	Pollutant	Speciation Basis	2008 Emission Factor
83329	Acenaphthene	$PM_{2.5}$	3.40E-07
208968	Acenaphthylene	$PM_{2.5}$	5.25E-07
75070	Acetaldehyde	VOC	2.29E-04
NH3	Ammonia	PM_{10}	1.08E-02
120127	Anthracene	$PM_{2.5}$	5.25E-07
7440382	Arsenic	PM_{10}	4.00E-04
56553	Benz[a]Anthracene	$PM_{2.5}$	5.67E-07
71432	Benzene	VOC	9.80E-06
50328	Benzo[a]Pyrene	PM_{10}	2.00E-06
205992	Benzo[b]Fluoranthene	PM_{10}	4.00E-06
191242	Benzo[g,h,I,]Perylene	$PM_{2.5}$	1.28E-07
207089	Benzo[k]Fluoranthene	PM_{10}	2.00E-06
7440417	Beryllium	PM_{10}	5.46E-07
7440439	Cadmium	PM_{10}	5.90E-06
16065831	Chromium III	PM_{10}	3.96E-04
18540299	Chromium VI	PM_{10}	2.04E-04
218019	Chrysene	$PM_{2.5}$	9.93E-08
7440484	Cobalt	PM_{10}	2.92E-04
53703	Dibenzo[a,h]Anthracene	$PM_{2.5}$	0.00E+00
600	Dioxin	PM_{10}	2.00E-09

Table 3. Category 3 Hazardous Air Pollutant Speciation Profile for Hotelling Activities (Continued)

Pollutant Code	Pollutant	Speciation Basis	2008 Emission Factor
206440	Fluoranthene	$PM_{2.5}$	3.12E-07
86737	Fluorene	$PM_{2.5}$	6.95E-07
50000	Formaldehyde	VOC	1.57E-03
118741	Hexachlorobenzene	PM_{10}	1.60E-08
193395	Indeno[1,2,3-c,d]Pyrene	PM_{10}	4.00E-06
7439921	Lead	PM_{10}	6.00E-05
7439965	Manganese	PM_{10}	5.73E-05
7439976	Mercury	PM_{10}	1.40E-06
91203	Naphthalene	$PM_{2.5}$	1.99E-05
7440020	Nickel	PM_{10}	1.54E-02
1336363	Polychlorinated Biphenyls	PM_{10}	2.00E-07
85018	Phenanthrene	$PM_{2.5}$	7.94E-07
7723140	Phosphorous	PM_{10}	4.38E-03
130498292	POM as 16-PAH	$PM_{2.5}$	2.49E-05
130498292	POM as 7-PAH	PM_{10}	4.50E-07
129000	Pyrene	$PM_{2.5}$	5.53E-07
7782492	Selenium	PM_{10}	9.08E-06

Table 4. Category 3 Hazardous Air Pollutant Speciation Profile for Maneuvering Activities

Pollutant Code	Pollutant	Speciation Basis	2008 Emission Factor
83329	Acenaphthene	$PM_{2.5}$	3.40E-07
208968	Acenaphthylene	$PM_{2.5}$	5.25E-07
75070	Acetaldehyde	VOC	2.29E-04
NH3	Ammonia	PM_{10}	2.38E-03
120127	Anthracene	$PM_{2.5}$	5.25E-07
7440382	Arsenic	PM_{10}	8.74E-05
56553	Benz[a]Anthracene	$PM_{2.5}$	5.67E-07
71432	Benzene	VOC	9.80E-06
50328	Benzo[a]Pyrene	PM_{10}	4.37E-07
205992	Benzo[b]Fluoranthene	PM_{10}	8.74E-07

Table 4. Category 3 Hazardous Air Pollutant Speciation Profile for Maneuvering Activities (Continued)

Pollutant Code	Pollutant	Speciation Basis	2008 Emission Factor
191242	Benzo[g,h,I,]Perylene	$PM_{2.5}$	1.28E-07
207089	Benzo[k]Fluoranthene	PM_{10}	4.37E-07
7440417	Beryllium	PM_{10}	5.46E-07
7440439	Cadmium	PM_{10}	2.26E-05
16065831	Chromium III	PM_{10}	1.27E-04
18540299	Chromium VI	PM_{10}	6.53E-05
218019	Chrysene	$PM_{2.5}$	9.93E-08
7440484	Cobalt	PM_{10}	5.94E-05
53703	Dibenzo[a,h]Anthracene	$PM_{2.5}$	0.00E+00
600	Dioxin	PM_{10}	4.37E-10
206440	Fluoranthene	$PM_{2.5}$	3.12E-07
86737	Fluorene	$PM_{2.5}$	6.95E-07
50000	Formaldehyde	VOC	1.57E-03
118741	Hexachlorobenzene	PM_{10}	3.50E-09
193395	Indeno[1,2,3-c,d]Pyrene	PM_{10}	8.74E-07
7439921	Lead	PM_{10}	1.40E-05
7439965	Manganese	PM_{10}	5.73E-05
7439976	Mercury	PM_{10}	2.71E-07
91203	Naphthalene	$PM_{2.5}$	1.99E-05
7440020	Nickel	PM_{10}	3.25E-03
1336363	Polychlorinated Biphenyls	PM_{10}	4.37E-08
85018	Phenanthrene	$PM_{2.5}$	7.94E-07
7723140	Phosphorous	PM_{10}	1.79E-03
130498292	POM as 16-PAH	$PM_{2.5}$	2.49E-05
130498292	POM as 7-PAH	PM_{10}	4.90E-07
129000	Pyrene	$PM_{2.5}$	5.53E-07
7782492	Selenium	PM_{10}	1.91E-06

Table 5. Category 3 Hazardous Air Pollutant Speciation Profile for Underway Activities

Pollutant Code	Pollutant	Speciation Basis	2008 Emission Factor
83329	Acenaphthene	$PM_{2.5}$	3.40E-07
208968	Acenaphthylene	$PM_{2.5}$	5.25E-07

Table 5. Category 3 Hazardous Air Pollutant Speciation Profile for Underway Activities (Continued)

Pollutant Code	Pollutant	Speciation Basis	2008 Emission Factor
75070	Acetaldehyde	VOC	2.29E-04
NH3	Ammonia	PM_{10}	4.77E-03
120127	Anthracene	$PM_{2.5}$	5.25E-07
7440382	Arsenic	PM_{10}	1.75E-04
56553	Benz[a]Anthracene	$PM_{2.5}$	5.67E-07
71432	Benzene	VOC	9.80E-06
50328	Benzo[a]Pyrene	PM_{10}	8.74E-07
205992	Benzo[b]Fluoranthene	PM_{10}	1.75E-06
191242	Benzo[g,h,I,]Perylene	$PM_{2.5}$	1.28E-07
207089	Benzo[k]Fluoranthene	PM_{10}	8.74E-07
7440417	Beryllium	PM_{10}	5.46E-07
7440439	Cadmium	PM_{10}	2.26E-05
7440473	Chromium	PM_{10}	1.92E-04
16065831	Chromium III	PM_{10}	1.27E-04
18540299	Chromium VI	PM_{10}	6.53E-05
218019	Chrysene	$PM_{2.5}$	9.93E-08
7440484	Cobalt	PM_{10}	1.54E-04
53703	Dibenzo[a,h]Anthracene	$PM_{2.5}$	0.00E+00
600	Dioxin	PM_{10}	8.74E-10
206440	Fluoranthene	$PM_{2.5}$	3.12E-07
86737	Fluorene	$PM_{2.5}$	6.95E-07
50000	Formaldehyde	VOC	1.57E-03
118741	Hexachlorobenzene	PM_{10}	6.99E-09
193395	Indeno[1,2,3-c,d]Pyrene	PM_{10}	1.75E-06
7439921	Lead	PM_{10}	2.62E-05
7439965	Manganese	PM_{10}	5.73E-05
7439976	Mercury	PM_{10}	5.24E-07
91203	Naphthalene	$PM_{2.5}$	1.99E-05
7440020	Nickel	PM_{10}	5.89E-03
1336363	Polychlorinated Biphenyls	PM_{10}	8.74E-08
85018	Phenanthrene	$PM_{2.5}$	7.94E-07
7723140	Phosphorus	PM_{10}	5.73E-03
130498292	POM as 16-PAH	$PM_{2.5}$	2.49E-05
130498292	POM as 7-PAH	PM_{10}	4.90E-07
129000	Pyrene	$PM_{2.5}$	5.53E-07
7782492	Selenium	PM_{10}	3.48E-06