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Current Methodologies and Best Practices in Preparing Port Emission Inventories

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Current Methodologies and Best Practices in Preparing Port Emission Inventories

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

This report describes current methodologies and best practices used for preparation of a port emission inventory. An emission inventory is necessary for port authorities, those doing business at ports (such as terminal operators, tenants, and shipping companies), state and local entities, or other interested parties to understand and quantify the air quality impacts of current port operations, and to assess the impacts of port expansion projects or growth in port activity. An inventory provides the baseline from which to create and implement emission mitigation strategies and track performance over time. This report focuses on mobile emission sources at ports, including oceangoing vessels (OGVs), harbor craft, and cargo handling equipment (CHE), as well as other land-side mobile emission sources at ports, such as locomotives and on-highway vehicles. For this report we reviewed current information on port emission inventory preparation and summarized the most current practices.

This report was prepared for the U.S. Environmental Protection Agency's (EPA's) Sector Strategies Program, which works with several industry sectors, including ports, to address the most significant impediments to better environmental performance in each sector. EPA, in partnership with the American Association of Port Authorities (AAPA), is encouraging ports to proactively address air quality issues. This report is intended to help port authorities and others who want to prepare a port mobile source emission inventory and thereby quantify current emissions. The inventory can then be used to develop strategies to minimize current and projected emissions and to quantify progress. An emission inventory can inform regulatory requirements such as those in State Implementation Plans (SIPs), the National Environmental Policy Act (NEPA), and the California Environmental Quality Act (CEQA), and also inform voluntary initiatives such as a collaborative regional air toxics assessment or development of a port environmental management system (EMS).

In the past, port emission inventories were less refined than inventories for other sectors, because port activities were not well defined, and emission factors were based on limited data. Because ports can be large sources of nitrogen oxides (NOx), particulate matter (PM), sulfur oxides (SOx), and toxic emissions, more detailed and accurate emission inventories are needed. Port inventory methodologies have been improving over the last several years, as reflected in the newer port inventories. However, there is still little guidance on preparing port inventories; thus, they can vary by who prepares them and the purpose of the inventory. In addition, emission factors and other operational data on marine vessels continually evolve; plus, the parameters often differ between studies.

Because the rationale and resources to prepare inventories vary between ports, this report provides a range of preparation approaches to provide the appropriate level of detail to meet ports' needs. The three approaches presented in this report are:

- A *detailed approach* in which each ship trip into and out of a port is quantified. Harbor craft and land-side emissions are estimated in detail.
- A *mid-tier approach* in which ship trips are averaged by ship type and dead weight tonnage, and then average trip characteristics are calculated. Harbor craft and land-side emissions also can be averaged by type of ship or equipment.
- A *streamlined approach* in which marine, harbor craft, and land-side emissions are estimated from other detailed inventories.

The report first provides a methodology for detailed emission calculations for OGVs, as this is the best practice. In a detailed inventory, each ship call is analyzed and emission impacts calculated. The report explains how to determine port boundaries, what data sources to use, how to determine ship activity, and how to calculate emissions for propulsion and auxiliary engines. The report also presents the most up-to-date emission factors and load factors. In addition, the report provides best practices for gathering data and calculating emissions from the various classes of harbor craft and CHE, as well as from locomotives and on-highway vehicles servicing the port.

The report then describes a mid-tier approach to estimating emissions at a port, in which average activity information is used rather than detailed information for each ship trip. The mid-tier approach may be appropriate for ports that lack the resources for a detailed inventory approach but do have vessel characteristics and operational data by ship type.

For ports that lack the resources for the mid-tier approach, this report presents a streamlined approach in which other port emission inventories and ratios of activity are used to estimate emissions at a given port.

The report concludes with six recommendations for further study that will lead to improvements in port emission inventory development.

It should be noted that this guidance document reflects current best practices and is not intended to be the last word in port inventory development methodology. To better understand current techniques, the reader should continually look for new inventory methodologies being developed by ports. The AAPA will likely be able to provide contact information for a specific port[1].

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[1] http://www.aapa-ports.org

1 INTRODUCTION

An emission inventory is a quantification of all emissions of criteria and other pollutants (including toxics and greenhouse gases) that occur within a designated area by their source. Emissions sources are categorized broadly as mobile sources, point sources (e.g., a refinery), and area sources (e.g., agricultural tilling). Mobile sources are further categorized as on-road sources (e.g., automobiles, trucks, buses) and non-road sources (e.g., construction equipment, cranes, yard trucks, locomotives, and marine vessels). Mobile source port emissions are generated by marine vessels and by land-based sources at ports. Marine emissions come primarily from diesel engines operating on oceangoing vessels (OGVs), tugs and tows, dredges, and other vessels operating within a port area. Land-based emission sources include cargo handling equipment (CHE) such as terminal tractors, cranes, container handlers, and forklifts, as well as heavy-duty trucks and locomotives operating within a port area. These land-based sources also are likely to have diesel engines. Diesel emissions of concern include nitrogen oxides (NOx), sulfur oxides (SOx), particulate matter (PM), and toxics. Stationary emission sources at ports also need to be counted in total port emissions, but those are beyond the scope of this report.

This report is intended to help port authorities, those doing business at ports (such as terminal operators, tenants, and shipping companies), state and local air quality agencies, and other interested parties who want to prepare mobile source port emission inventories.

Examples of Emission Sources at Ports

Oceangoing vessels	• Container ships • Tanker ships • Bulk carrier ships • Cruise ships • Reefer ships • Roll-on/Roll-off ships • Vehicle carrier ships
Harbor vessels	• Tugboats and pushboats • Ferries • Excursion vessels • Fishing vessels • Dredging equipment
Cargo handling equipment	• Terminal tractors • Top and side loaders • Forklifts • Wharf cranes • Rubber tire gantry cranes • Skid loaders
Locomotives	• Line haul locomotives • Switch yard locomotives
Vehicles	• On-road trucks • Buses • Other port vehicles

1.1 Overview

Historically, port emissions developed by state and local air quality agencies have not been evaluated as a sector but as part of engine classifications. As such, emissions emanating from a port could not be easily quantified. In addition, emission factors for OGVs were developed from very limited data sets. Ports can be a major contributor to regional NOx, SOx, toxics, and PM emissions. Without an inventory of the port as an entity, it is difficult to assess opportunities for emission reductions and to quantify reductions over time. In addition, a port emission inventory is necessary to properly assess the impacts of port improvement projects or growth in marine activity, as well as to plan mitigation strategies.

Estimating emissions generally involves applying emission factors[2] to measures of port activity. Currently, the U.S. Environmental Protection Agency (EPA) offers only limited guidance regarding the

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[2] An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Marine emission factors are usually expressed as the weight (commonly measured in grams) of pollutant divided by the energy (commonly measured in kilowatt-hours (kWh)) of the engine used to produce that emission.

development of port emission inventories, and most small and mid-size ports do not have extensive resources to devote to inventory development. As a consequence, many current emission inventories suffer from poor quantification of port activity and use of outdated emission factors. This report discusses current methods of determining emissions from ports and offers recommendations for improvements.

State Implementation Plans (SIPs)[3] evaluate the emissions within and contributing to a non-attainment area. Because that geographic boundary is typically larger than a port, SIPs do not necessarily call out the geographic boundary of a port and tend to calculate impacts from engines (e.g., trucks or even non-road equipment) in a manner that may not make explicit the port's contribution. The purpose of this report is to lay out a method for doing so, because it is important for the entities that make up a port to be able to understand the current and future emissions associated with their sources. Thus, it is important to capture all of the sources of emissions within the geographic boundary selected for the analysis, including all marine, non-road, on-highway and stationary sources. This report presents a method for estimating emissions from marine, non-road, and on-highway sources. Detailed information on calculating emissions from stationary sources can be found at the EPA Office of Air Quality Planning and Standards website http://www.epa.gov/ttn/chief/.

1.2 Overview of Port Methodologies

There are many different approaches to developing a port emission inventory, and they can vary greatly in terms of the time and resources required. To account for resource disparities, three different approaches are presented in this report:

- *Detailed Inventory* – Highly detailed inventories are typically prepared by the "larger" deep-sea ports in air quality non-attainment areas.[4] This type of inventory requires detailed data on vessels and land-based equipment characteristics and activities, as well as detailed information on port geography and ship paths within the port. This is the best practice for all ports, but its application may be limited by available resources.
- *Mid-Tier Inventory* – A mid-tier inventory approach is often used by "mid-size" and "smaller" seaports and ports that are either not in an ozone or PM non-attainment area or in a maintenance area.[5] Ports on inland waterways or the Great Lakes also might use this approach. Such an inventory requires port-specific activity data but applies "typical" port emission rate averages by ship type.
- *Streamlined Inventory* – A highly streamlined inventory can be developed using extrapolations made from typical port data based on ship calls estimated by the U.S. Army Corps of Engineers (USACE).

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[3] A SIP is the federally approved and enforceable plan by which each state identifies how it will attain and/or maintain the National Ambient Air Quality Standards (NAAQS) described in Section 109 of the Clean Air Act and 40 Code of Federal Regulations (CFR) 50.4 through 50.12.

[4] The Clean Air Act regulates certain air pollutants, called criteria pollutants, which are harmful to human health. EPA sets limits on the amount of these pollutants that can be present in the air before human health may be impaired. If a pollutant limit is consistently exceeded within a certain area, generally defined around urban centers on the county level, or a certain area contributes to an exceedance of the limit in another downwind location, then that area (county or portion of a county) is designated a non-attainment area. For a list of non-attainment areas, visit EPA's website at http://www.epa.gov/oar/oaqps/greenbk/index.html.

[5] Maintenance areas are defined as those areas that were once in non-attainment of the NAAQS, but have cleaned their air to a level below the NAAQS. These areas must be careful to not slip back into non-attainment status.

The purpose of a port emission inventory determines what should be included in the inventory and also may influence the development strategy used.

- For the development of a well-informed emission reduction strategy, all port emissions should be calculated. This will provide a baseline from which performance can be measured over time.
- In developing SIPs, land-based port emission sources are usually combined with other land-based non-road sources of similar type throughout the region. Therefore land-side emissions of non-road equipment at ports are accounted for by running EPA's NONROAD model for the region (California uses its Air Resources Board's (ARB's) OFFROAD model). Similarly, land-side emissions of on-road vehicles at ports are generally calculated using EPA's MOBILE model for the region (California uses ARB's EMFAC model). In a future release of EPA's new emission factor model, **MO**tor **V**ehicle **E**mission **S**imulator (MOVES), ports will be able to estimate all emissions within port boundaries, a practice that may become more commonplace for large ports concerned with emission reduction programs.
- For NEPA[6] (or CEQA[7] in California) or general conformity[8] purposes, land-side emissions, in addition to those from OGVs, need to be estimated. Ports and government agencies also may estimate land-side emissions in order to more effectively develop control strategies for these sources.

There is no right answer to which approach should be followed for each type of port, because each port authority, terminal operator, shipping company, or state or local air quality agency must weight its individual needs and available resources. The factors that should be considered in determining which approach to adopt include the following:

- Purpose of the inventory
- Clean Air Act (CAA) status of the port region (e.g., attainment or non-attainment)
- Location of the port
- Geographic size of port
- Financial size of port (and fiscal resources available to conduct the inventory)
- Current and projected increases in the number of vessel calls, and in cargo volume
- Complexity of port owner/operator relationships

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[6] The National Environmental Policy Act (NEPA) requires federal agencies to integrate environmental values into their decision making processes by considering the environmental impacts of their proposed actions and reasonable alternatives to those actions. To meet this requirement, federal agencies initially prepare an environmental assessment (EA) to determine the extent of environmental impact that may result from a federal action. If the impact is considered to be significant, a more detailed environmental impact statement (EIS) is prepared to fully calculate the environmental effects resulting from a federal action and its alternatives and to offer mitigation strategies, where available. Both documents are subject to public review and comment.

[7] The California Environmental Quality Act (CEQA) is California's equivalent to NEPA and applies to projects proposed to be undertaken or requiring approval by state and local government agencies. An environmental impact report (EIR) details potential environmental impacts from a state or local action and its alternatives. Mitigation strategies also are considered.

[8] General conformity refers to a federal rule established by EPA and the U.S. Department of Transportation (DOT) that requires agency coordination to ensure that the economic, environmental, and social aspects of transportation and air quality planning are considered. All federal plans, programs, and projects must be shown to meet the requirements of the Clean Air Act and any applicable SIPs.

- Social, economic, and political issues surrounding the local and regional communities in which the port is located.

1.3 Recent Port Emission Inventories

A number of port authorities have done detailed inventories in the last several years. Other ports have used a streamlined method for preparing port emission inventories or prepared inventories for a specific terminal or industry. The detailed inventories listed in Table 1-1 represent recent bottom-up activity-driven inventories to the level recommended in this report. Several other ports are in the process of preparing detailed inventories. Additional national inventories worth noting are the National Emissions Inventory (NEI) and the National Air Toxics Assessment (NATA), which include port emissions. Additional references and inventory methods can be found in the references section at the end of this report.

Table 1-1 : Summary of Detailed Port Inventories

Port	Year Published	Data Year	Oceangoing Vessels	Harbor Craft	Land-Side Emissions	Pollutants[a]	Contractor[b]
Beaumont/Port Arthur	2004	2000	Yes	Yes	No	NOx, CO, HC, PM_{10}, SO_2	Starcrest
Corpus Christi	2002	1999	Yes	Yes	Yes[c]	NOx, VOC, CO	ACES
Houston/Galveston	2000	1997	Yes	Yes	No	NOx, VOC, CO, PM_{10}	Starcrest
Houston/Galveston	2003	2001	No	No	Yes	NOx, VOC, CO	Starcrest
Los Angeles	2005	2001	Yes	Yes	Yes	NOx, TOG, CO, PM_{10}, $PM_{2.5}$, SO_2, DPM	Starcrest
Long Beach	2004	2002	No	No	Yes	NOx, TOG, CO, PM_{10}, $PM_{2.5}$, SO_2, DPM	Starcrest
New York/New Jersey	2003	2000	Yes	Yes	No	NOx, VOC, CO, PM_{10}, $PM_{2.5}$, SO_2	Starcrest
New York/New Jersey	2003	2002	No	No	Yes	NOx, VOC, CO, PM_{10}, $PM_{2.5}$, SO_2	Starcrest
Portland	2004	2000	Yes	Yes	Yes	NOx, HC, CO	Bridgewater Consulting

[a] NOx = oxides of nitrogen, TOG = total organic gases, VOC = volatile organic compound, HC = hydrocarbons, CO = carbon monoxide, PM_{10} = particulate matter < 10 microns, $PM_{2.5}$ = particulate matter < 2.5 microns, SO_2 = sulfur dioxide, DPM = diesel particulate matter

[b] Starcrest = Starcrest Consulting Group LLC, ACES = Air Consulting and Engineering Solutions

c Truck and rail only

Many of the recent inventories have been done by Starcrest Consulting Group, LLC. As such, there has been some consistency in methodology for port emission inventories. However, there is no specific guidance on preparing such inventories; thus, methodologies vary. This report attempts to point out the most recent discoveries and best practices regarding port inventory preparation to encourage uniform inventory preparation using the most up-to-date emission and load factors for both propulsion and auxiliary engines.

1.4 Report Organization

The remainder of this report is organized into three sections. Section 2 describes how to prepare a detailed port inventory. Section 3 describes how to streamline inventory calculations for a mid-tier and highly streamlined inventory. Section 4 gives recommendations for further study. A list of the references reviewed to prepare this document is attached at the end of the report.

2 DETAILED EMISSION INVENTORIES

This section describes the necessary steps to prepare a detailed port emissions inventory. It includes (1) the definition of port boundaries, (2) OGV emissions determinations, (3) harbor craft emissions determinations, (4) land-based emissions determinations, and (5) methodology for Great Lake and inland river ports.

2.1 Definition of Port Boundaries

The purpose of the inventory will help define useful port boundaries. In most cases, the land-side boundary should include at least the first intermodal point so that it includes trucks, rail, gates, etc. By doing so, improvements such as reducing wait times into and out of gates and distribution centers, reducing truck vehicle miles traveled (VMT) due to intermodal shifts, and other mitigation strategies can be evaluated. On the ocean side, it should include at least the first 25 miles from where the pilot boards the ship for entry into the port, but this might be extended if wind direction is a factor. For SIP purposes, the non-attainment area boundary(ies) might be used. For other purposes, county boundaries might be used. EPA's marine inventory in the Category 3 engine rulemaking used 175 nautical miles (200 statute miles) from the coast as this represents the boundary of the exclusive economic zone (EEZ)[9] Using the 175 nautical mile boundary will include the effect of transiting ships which are typically considered non-port emissions. It is therefore important to look at the purpose of the inventory to decide on the proper boundaries that it will encompass.

2.2 Oceangoing Vessel Emission Determinations

The current practice to calculate emissions from OGVs is to use energy-based emission factors together with activity profiles for each vessel. The bulk of the work involves determining representative engine power ratings for each vessel and the development of activity profiles for each ship call. Using this information, emissions per ship call and mode can be determined using the equation below.

$$E = P \times LF \times A \times EF$$

Where **E** = Emissions (grams [g])
P = Maximum Continuous Rating Power (kilowatts [kW])
LF = Load Factor (percent of vessel's total power)
A = Activity (hours [h])
EF = Emission Factor (grams per kilowatt-hour [g/kWh])

The emission factor is in terms of emissions per unit of energy from the engine. It is multiplied by the power needed to move the ship in a particular activity.

The next several subsections describe data sources to use and how to determine (1) ship characteristics, (2) activity profiles for each ship call, (3) load factors for each activity during a call, (4) emissions from auxiliary engines and boilers, and (5) appropriate emission factors.

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[9] EPA, *Final Regulatory Support Document: Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder*, EPA420-R-03-004, January 2003.

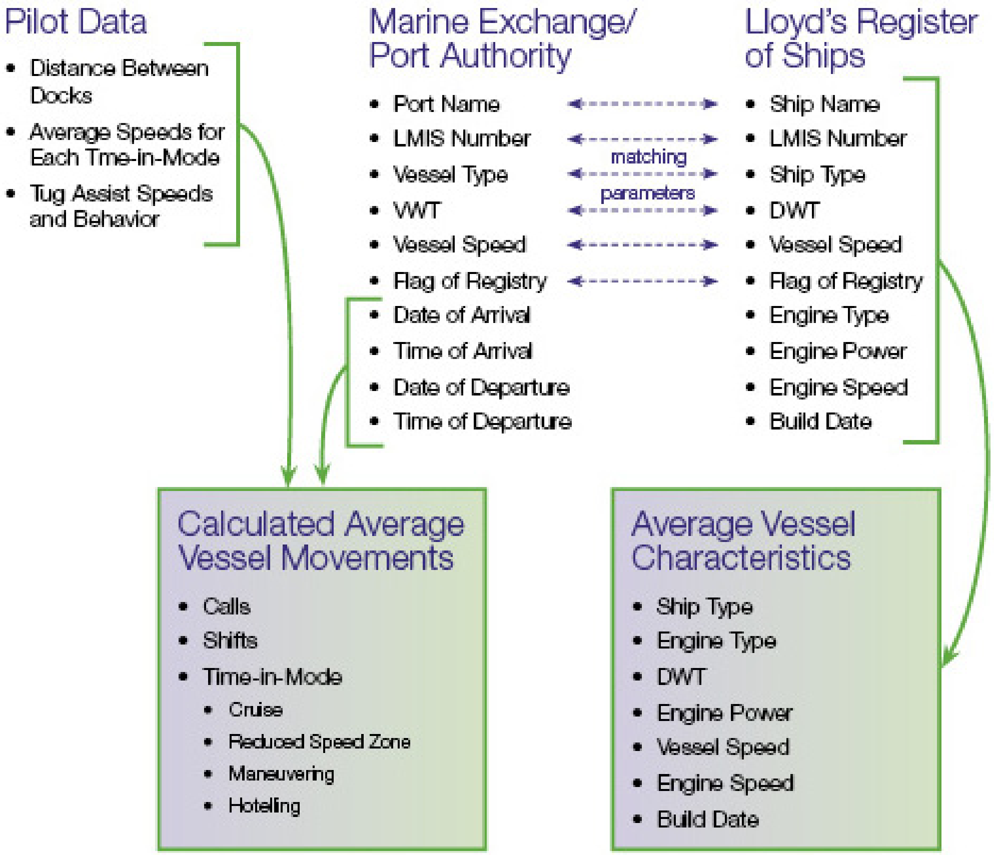
Data Sources

Various data sources are available to those preparing port emission inventories. These include Marine Exchange/Port Authority (MEPA) data, Lloyd's Register of Ships (Lloyd's Data), and Pilot data. The importance and use of each are discussed below and shown in Figure 2-1. The Coast Guard Vessel Traffic System (VTS) also can be used to determine vessel movements. Other data sources that can be found useful are listed in the reference section at the end of this report.

Marine Exchange/Port Authority Data

The data on vessel operations can be obtained from the local port authority, marine exchange, board of trade, or other local organization with reliable information on vessel movements. In most cases, data are in electronic format. Almost all MEPAs record vessel name, date and time of arrival, and date and time of departure. Some MEPAs also record Lloyd's register numbers, flag of registry, ship type, pier/wharf/dock (PWD) names, dates and times of arrival and departure from various PWDs, anchorages, next ports, cargo type, cargo tonnage, activity description, draft, vessel dimensions, and other information. Generally, one record of data corresponds to one call within the MEPA but may include shifts between berths located in the MEPA. MEPAs also can contain more than one port, such as for the Ports of Los Angeles and Long Beach. Because those ports are in close proximity, one MEPA records ship movements into and out of both ports.

Figure 2-1: Data Sources and their Uses



The electronic data received from the MEPAs provide a way to characterize a typical vessel call in each port, using the following elements:

- Total time the vessel was in port
- Port(s) of call within the MEPA
- Vessel characteristics (using Lloyd's vessel characteristic data)

Lloyd's Register of Ships

Lloyd's Data is produced by Lloyd's Register-Fairplay Ltd., headquartered in Surrey, England.[10] They offer the largest database of commercially available maritime data in the world on CD-ROM. The newest version (2004) of Lloyd's Register of Ships CD-ROM has details on 104,161 vessels and 57,000 companies that own, operate, and manage them. It is sold for $1,875 through their website.

Lloyd's Data contains information on ship characteristics that are important for preparing detailed marine vessel inventories including the following:

- Name
- Type
- Age
- Flag
- Dead weight tonnage (DWT)
- Maximum vessel speed
- Engine power plant configuration
- Auxiliary engine characteristics
- Contents of the vessel's fuel tanks

All data are referenced to both ship name and Lloyd's number (LMIS Number), a unique identifier for each ship. Lloyd's insures many of the OGVs on an international basis, and for these vessels, the data are quite complete. For other ships using a different insurance certification authority, the data are less robust.

Pilot Data

Information from pilot associations and tide books can be invaluable to the calculation of time-in-modes.[11] A harbor pilot will often board an OGV near the breakwater. This transfer takes place while the pilot's vessel and the vessel calling on the MEPA are traveling at a reduced speed of 5 to 7 knots. The harbor pilot takes over from the main pilot and coordinates with any tugs that are going to assist the vessel in docking. Many times, it is this boarding by the harbor pilot and the subsequent record keeping that allow the MEPAs to have such detailed records of vessel activity.

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[10] http://www.lrfairplay.com/archway/services/CDRom/RoScdrom.htm

[11] Different modes of concern in determining emissions (based on the amount of time spent in each mode) per a vessel call include cruise, reduced speed zone, maneuvering, and hotelling.

Pilots at all of the MEPA waterways should be contacted and asked about typical operations, including speeds by vessel type. Information on reduced speeds in a typical waterway can be obtained by conversations with knowledgeable personnel at the MEPA and, when possible, directly from the pilots responsible for actually handling the vessels in the waterway. Vessel movements then can be calculated from the MEPA data, and any inconsistencies or lack of data can be resolved by discussions with the pilots. The data provided by pilots can be used to supplement the data received from the MEPA and to form a more complete record of each time-in-mode.

Coast Guard Vessel Tracking System (VTS)

The Coast Guard maintains a vessel tracking system to improve maritime safety as well as national security, and also could enhance port operations. The tracking system provides static information about vessels, including identity, vessel type and size, as well as dynamic information, including its current cargo, destination, course, speed and estimated arrival time. This information can be used to verify and improve upon MEPA data as well as provide statistics of compliance rates for reduced speed zones. It can also be used to determine average speeds by vessel types in the various waterways of a port.

Ship Characteristics

OGVs vary greatly in speed and generating capacity based on ship type. Various studies break out vessel types differently, but it makes most sense to break vessel types out by the cargo they carry. Table 2-1 lists various OGV types that should be described in any detailed inventory.

Table 2-1: Oceangoing Vessel Ship Types

Ship Type	Description
Auto Carrier	Self-propelled dry-cargo vessels that carry containerized automobiles.
Barge Carrier	Self-propelled vessel that tows lashed barges.
Bulk Carrier	Self-propelled dry-cargo ship that carries loose cargo.
Container Ship	Self-propelled dry-cargo vessel that carries containerized cargo.
Cruise Ship	Self-propelled cruise ships.
General Cargo	Self-propelled cargo vessel that carries a variety of dry cargo.
Miscellaneous	Category for those vessels that do not fit into one of the other categories or are unidentified.
Oceangoing Tugs/Tows	Self-propelled tugboats and towboats that tow/push cargo or barges in the open ocean.
Reefer	Self-propelled dry-cargo vessels that often carry perishable items.
Roll-on/Roll-off (RORO)	Self-propelled vessel that handles cargo that is rolled on and off the ship, including ferries.
Tanker	Self-propelled liquid-cargo vessels including chemical tankers, petroleum product tankers, liquid food product tankers, etc.

Other characteristics that should be determined from Lloyd's Data are the propulsion engine power and engine speed, maximum vessel speed, and auxiliary engine power and engine speed. EPA defines marine vessel engines (propulsion and auxiliary) in terms of categories as shown in Table 2-2. These categories relate to land-based engine equivalents. Engine speed designations are shown in Table 2-3. Most ships have diesel engines, although some older ships are steamships.

Table 2-2: EPA Marine Compression Ignition Engine Categories

Category	Specification	Use	Approximate Power Ratings
1	Gross Engine Power ≥ 37 kW[a] Displacement < 5 liters per cylinder	Small harbor craft and recreational propulsion	< 1,000 kW
2	Displacement ≥ 5 and < 30 liters per cylinder	OGV auxiliary engines, harbor craft, and smaller OGV propulsion	1,000 – 3,000 kW
3	Displacement ≥ 30 liters per cylinder	OGV propulsion	> 3,000 kW

[a] EPA assumes that all engines with a gross power below 37 kW are used for recreational applications and are treated separately from the commercial marine category.

Table 2-3: Marine Engine Speed Designations

Speed Category	Engine RPM[a]	Engine Stroke Type
Slow	< 130 RPM	2
Medium	130 – 1,400 RPM	4
High	> 1,400 RPM	4

[a] RPM = revolutions per minute

In the latest emission inventory for the Port of Los Angeles (PoLA), Starcrest shows that Lloyd's Data fairly accurately records both ship power and maximum vessel speed.[12] Previous studies had established that Lloyd's ship power was only 92 percent of maximum continuous rating (MCR) and recommended that the Lloyd's power be divided by 0.92 to obtain MCR. Based on studies done by Starcrest during their vessel boarding program, it is now recommended that Lloyd's ship power be treated as MCR with no adjustment.

Auxiliary engine power also can be determined from Lloyd's Data, but many records are missing this information. Prior practice has been to use a fixed power rating for auxiliaries based on ship type and activity mode or to assume auxiliary power is equivalent to 10 percent of propulsion power.[13] In the PoLA inventory, Starcrest collected information from Lloyd's Data and Starcrest's vessel boarding program. California Air Resources Board (ARB) recently conducted an Oceangoing Ship Survey of 327 ships in January 2005.[14] Table 2-4 shows average auxiliary engine power compared to propulsion power obtained from the ARB survey. While it is important to determine proper ratios for each port because of differences in the types of ships calling on that port, these ratios and engine speeds can be used in mid-tier inventory development as a surrogate for auxiliary power if no other data are available.

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[12] Starcrest Consulting Group LLC, *Port of Los Angeles Baseline Ai Emissions Inventory -2001*, prepared for the Port of Los Angeles, July 2005.

[13] ENVIRON International Corporation, *Commercial Marine Emission Inventory Development*, prepared for the U.S. Environmental Protection Agency, April 2002.

[14] California Air Resources Board, *2005 Oceangoing Ship Survey, Summary of Results,* September 2005.

Table 2-4: Auxiliary Engine Power Ratios (ARB Survey)

Ship Type	Average Propulsion Engine (kW)	Average Auxiliary Engines				Auxiliary to Propulsion Ratio
		Number	Power Each (kW)	Total Power (kW)	Engine Speed	
Auto Carrier	10,700	2.9	983	2,850	Medium	0.266
Bulk Carrier	8,000	2.9	612	1,776	Medium	0.222
Container Ship	30,900	3.6	1,889	6,800	Medium	0.220
Cruise Ship[a]	39,600	4.7	2,340	11,000	Medium	0.278
General Cargo	9,300	2.9	612	1,776	Medium	0.191
RORO	11,000	2.9	983	2,850	Medium	0.259
Reefer	9,600	4.0	975	3,900	Medium	0.406
Tanker	9,400	2.7	735	1,985	Medium	0.211

[a] Cruise ships typically use a different engine configuration known as diesel-electric. These vessels use large generator sets for both propulsion and ship-board electricity. The figures for cruise ships above are estimates taken from the Starcrest Vessel Boarding Program.

Fuel type also is instrumental in determining emission factors and should be determined for each port. Practically all OGVs operate their main propulsion engines on residual oil (RO). Fuel switching while under power is rarely done and is discouraged by the U.S. Coast Guard.[15] However, many ships have two tanks and reserve one for either marine diesel oil (MDO) or marine gas oil (MGO). The later two fuels are refined and used mostly for auxiliary engines and for cleaning and cold start-up of propulsion engines.

Data collected during the ARB survey in January 2005 indicated that approximately 29 percent of auxiliary engines used MDO instead of RO. For cruise vessels, only 8 percent used MDO instead of RO. Generally older ships require MDO in their auxiliary engines while newer ships can tolerate RO. As the price of fuel increases, many ship operators will opt to use RO in their auxiliary engines due to its lower cost. While it is better to determine actual percentages of ships that use MDO instead of RO for their auxiliary engines for a given port, the percentages listed above can be used as a surrogate.

Activity Determinations

The description of a vessel's movements during a typical call is best accomplished by breaking down the call into sections that have similar speed characteristics. Vessel movements for each call are described by using four distinct time-in-mode calculations. A call combines all four modes, while a shift normally occurs as maneuvering. Each time-in-mode is associated with a speed and, therefore, an engine load that has unique emission characteristics. While there will be variability in each vessel's movements within a call, these time-in-modes allow an average description of vessel movements at each port. Time-in-modes should be calculated for each vessel call occurring in the analysis year over the waterway area covered by the corresponding MEPA. The time-in-modes are described in Table 2-5.

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[15] Myles Booth, *CG Perspective—Marine Port Air Quality—Safety and Security Considerations*, Presented at the West Coast Regional Conference, April 21, 2004.

Table 2-5: Vessel Movements and Time-In-Mode Descriptions within the MEPA Areas

Summary Table Field	Description
Call	A call is one entrance and one clearance from the MEPA area.
Shift	A shift is a vessel movement within the MEPA area. Shifts are contained in calls. While many vessels shift at least once, greater than 95 percent of vessels shift three times or less within most MEPA areas. Not all MEPAs record shifts.
Cruise (hr/call)	Time at service speed (also called sea speed or normal cruising speed) usually considered to be 94 percent of maximum speed and 83 percent of MCR. Calculated for each MEPA area from the port boundary to the breakwater or reduced speed zone. The breakwater is the geographic marker for the change from open ocean to inland waterway (usually a bay or river).
Reduced Speed Zone (RSZ) (hr/call)	Time in the MEPA area at a speed less than cruise and greater than maneuvering. This is the maximum safe speed the vessel uses to traverse distances within a waterway leading to a port. Reduced speeds can be as high as 15 knots in the open water of the Chesapeake Bay, but tend to be more in the order of 9 to 12 knots in most other areas. Some ports are instituting RSZs to reduce emissions from OGVs as they enter their port.
Maneuver (hr/call)	Time in the MEPA area between the breakwater and the PWD. Maneuvering within a port generally occurs at 5 to 8 knots on average, with slower speeds maintained as the ship reaches its PWD or anchorage. Even with tug assist, the propulsion engines are still in operation.
Hotelling (hr/call)	Hotelling is the time at pier/wharf/dock (PWD) or anchorage when the vessel is operating auxiliary engines only or is cold ironing. Auxiliary engines are operating at some load conditions the entire time the vessel is manned, but peak loads will occur after the propulsion engines are shut down. The auxiliary engines are then responsible for all onboard power or are used to power off-loading equipment, or both. Cold ironing uses shore power to provide electricity to the ship instead of using the auxiliary engines. Hotelling needs to be divided into cold ironing and active to accurately account for reduced emissions from cold ironing.

Cruise speed is generally taken as 94 percent of the maximum service speed listed in Lloyd's Data. Distances from the maximum port boundary (defined in Section 2.1 above) to either the RSZ or the breakwater[16] are used with the cruise speed to determine cruise times into and out of the port. Some MEPAs record which route was used to enter and leave the port and this information can be used to determine the actual distances the ships travel. Average cruise speeds by ship type from the PoLA inventory are given in Table 2-6. While actual cruise speeds should be calculated in a detailed inventory, these can be used as surrogates for more streamlined analyses.

RSZ time-in-mode also is an estimation based on average ship speed and distance. Pilots generally can report average ship speeds for a precautionary or reduced speed zone. As was found in the PoLA study, ships tend to move at less than the maximum RSZ speed. For instance, in the PoLA, the precautionary zone speed is 12 knots or less. Starcrest found, through conversations with pilots and its vessel boarding program, that auto carriers, container ships, and cruise ships average 11 knots in the RSZ while other ship types average 9 knots in the RSZ. In addition, compliance with RSZ speeds should be determined.

Maneuvering time-in-mode is estimated based on the distance a ship travels from the breakwater to the PWD. Average maneuvering speeds vary from 3 to 8 knots depending on direction and ship type. Generally, outbound speeds are greater because the ship does not need to dock. Ships go from half speed to dead slow to stop during maneuvering. Time-in-mode varies depending on the location of and the approach to the destination terminal and turning requirements of the vessel. Maneuvering speeds should be determined through conversations with the pilots. In the PoLA inventory, inbound auto carriers, container ships, and cruise ships averaged 7 knots during maneuvering, while all other ship types averaged 5 knots. On the outbound route, all vessels averaged 8 knots.

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[16] Not all ports have a physical breakwater. Thus for these ports, an imaginary breakwater needs to be defined.

Table 2-6: Average Cruise Speeds by Ship Type (Port of Los Angeles)

Ship Type	Cruise Speed (knots)
Auto Carrier	13.80
Bulk	17.58
Container Ship	21.26
Cruise Ship	18.06
General Cargo	14.69
Miscellaneous	14.10
OG Tug	9.40
RORO	13.91
Reefer	18.90
Tanker	13.60

One Knot, *or one nautical mile per hour, is equivalent to 1.15 miles per hour.*

Hotelling should be calculated by subtracting time spent maneuvering into and out of a PWD from the departure time minus the arrival time into a port. If possible, anchorage time (time at anchorage within the port but not at a PWD) should be broken out from time at a PWD. Some MEPAs record shifts as well and this will allow for further refinements in maneuvering time. During hotelling, the main propulsion engines are off, and only the auxiliary engines are operating, unless the ship is cold ironing. Hotelling times can also be determined from pilot records of vessel arrival and departure times when other data is not available. Actual hotelling times should be calculated for each individual port, because hotelling is generally a large portion of the emissions at a port. Hotelling times should be separated for those ships that use cold ironing at a port and those that do not. It is important to also look for outliers (ships with extremely long hotelling times) to eliminate those in the average since they may represents ships at a PWD but not with auxiliary engines on.

Many variables affect one or more time-in-mode calculations. These variables cannot be accurately predicted for a ship-type category over an entire year of calls. Traffic conditions, weather, vessel schedule, and current are some of the more important variables that dictate how much time is required at each time-in-mode, especially maneuvering as described below.

- Traffic conditions may make travel in the waterway slower because a wake is more damaging in a congested waterway, forcing vessels to be more careful and travel at slower speeds.
- Bad weather in the form of high winds causes vessels to be more difficult and less predictable to maneuver. Rain and fog obscure visibility and can make a vessel’s maximum speed in the waterway one-third of what it would be on a clear day. Docking at a PWD takes much longer in bad weather and on busy days, resulting in more time spent at maneuvering speeds.
- Vessel schedule also affects time-in-mode. The waterway pilot is at least partially responsible for keeping the vessel on schedule to meet the tug assist for docking, the loading or unloading crews, and/or the bunkering vessel. If a vessel is ahead of schedule, the pilot may use slower speeds in the waterway to conserve fuel and arrive closer to schedule. If the vessel is behind schedule, the pilot may push speeds to the maximum safe limit in an attempt to get back on schedule.

In a detailed inventory where actual speeds are used, these factors will be accounted for. In a mid-tier inventory, these issues cannot be accounted for directly, thus averaging time-in-modes over a year will smooth out some of these issues.

Load Factors

Load factors are expressed as a percent of the vessel's total power. At service or cruise speed, the load factor is 83 percent. At lower speeds, the Propeller Law should be used to estimate ship propulsion loads, based on the theory that propulsion power varies by the cube of speed as shown in the equation below.

$$\mathbf{LF = (AS/MS)^3}$$

Where **LF** = Load Factor (percent)
AS = Actual Speed (knots)
MS = Maximum Speed (knots)

Earlier work by Starcrest and others assumed that this law had a lower limit of approximately 10 percent, representing an assumed stall speed for diesel engines.[17] This assumption was consistent with that used by ENVIRON in their calculations of load factors for ships. In Starcrest's two most recent inventories, they found that load factors as low as 2 percent were possible.[12,18] These lower factors are possible, because ships often cycle their propulsion engine on and off during maneuvering to reduce speeds below the dead slow setting of approximately 5.8 knots. In fact, during its vessel boarding program at the PoLA, Starcrest found container ships had engines stopped 25 to 50 percent of their time during maneuvering. While load factors should be calculated using the above propeller law for each call, load factors below 2 percent should be set to 2 percent as a minimum.

Auxiliary Loads

Load factors for auxiliary engines vary by ship type and time-in-mode. It was previously thought that power generation was provided by propulsion engines in all modes but hotelling. Several studies have shown that auxiliary engines are on all of the time, with the largest loads during hotelling (except when cold ironing[19]). Starcrest determined, through interviews conducted with ship captains, chief engineers, and pilots during its vessel boarding programs, the auxiliary engine load factors shown in Table 2-7. Auxiliary load factors should be used in conjunction with total auxiliary power. For detailed inventories, auxiliary load factors should be determined for the individual port, while mid-tier inventory development could use the values in Table 2-7 together with the total auxiliary engine power from Table 2-4.

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[17] SENES Consultants Limited, *Review of Methods Used in Calculating Marine Vessel Emission Inventories*, prepared for Environment Canada, September 2004.

[18] Starcrest Consulting Group LLC, *Update to the Commercial Marine Inventory for Texas to Review Emission Factors, Consider a Ton-Mile EI Method, and Revised Emissions for the Beaumont-Port Arthur Non-Attainment Area*, prepared for the Houston Advanced Research Center, January 2004.

[19] Cold ironing is a process where shore power is provided to a vessel, allowing it to shut down its auxiliary generators.

Table 2-7: Auxiliary Engine Load Factor Assumptions

Ship-Type	Cruise	RSZ	Maneuver	Hotel
Auto Carrier	0.13	0.30	0.67	0.24
Bulk Carrier	0.17	0.27	0.45	0.22
Container Ship	0.13	0.25	0.50	0.17
Cruise Ship	0.80	0.80	0.80	0.64
General Cargo	0.17	0.27	0.45	0.22
Miscellaneous	0.17	0.27	0.45	0.22
OG Tug	0.17	0.27	0.45	0.22
RORO	0.15	0.30	0.45	0.30
Reefer	0.20	0.34	0.67	0.34
Tanker	0.13	0.27	0.45	0.67

Propulsion Engine Emission Factors

The weakest link in deep sea vessel emission inventories is the emission factors for Category 3 ship engines. Emission factors continue to be derived from limited data. Emission testing of OGVs is an expensive and difficult undertaking; and thus, emissions data are relatively rare. In most cases, the power generated is only estimated, leading to inaccuracies in the overall emission factors.

The most recent study of emission factors was done by Entec, and these factors are generally accepted as the most current set available.[20] Entec analyzed emissions data from 142 propulsion engines and included 2 of the most recent research programs, Lloyd's Register Engineering Services in 1995 and IVL Swedish Environmental Research Institute in 2002. Entec lists individual factors for three speeds of diesel engines (slow-speed diesel (SSD), medium-speed diesel (MSD), and high-speed diesel (HSD)), steam turbines (ST), and three types of fuel (RO, MDO, and MGO). Starcrest used these factors in their PoLA inventory with the following assumptions:

- All main engines operate only on RO (intermediate fuel oil 380 or similar specification with average sulfur content of 2.7 percent).
- Slow speed engines have maximum engine speeds of less than 130 rpm.
- Medium speed engines have a maximum speed of greater than 130 rpm and typically over 400 rpm.
- All turbines are steam boiler turbines.

Currently recommended emission factors are shown in Table 2-8. It should be noted that Entec does not list PM factors for either PM_{10} or $PM_{2.5}$. PM emission factors are the most controversial as measurement of PM emissions on a ship is particularly difficult and there is much variation between sources. Generally

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[20] Entec UK Limited, *Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community*, prepared for the European Commission, July 2002.

the sulfur content of the fuel tends to overshadow other effects. PM_{10} and SO_2 emission factors listed in Table 2-8 were based upon recommendations from ENVIRON.[21]

Table 2-8: Emission Factors for OGV Main Engines using Residual Oil, g/kWh

Engine	NOx	CO	HC	PM_{10}	$PM_{2.5}$	SO_2
SSD	18.1	1.40	0.60	1.08	0.99	10.3
MSD	14.0	1.10	0.50	1.14	1.10	11.1
ST	2.1	0.20	0.10	1.55	0.66	16.1

Another point of contention is how $PM_{2.5}$ is determined. EPA estimates that $PM_{2.5}$ is 97 percent of PM_{10} emissions for all nonroad sources,[22] but this is generally for lower sulfur diesel fuel in high speed engines. Starcrest estimated $PM_{2.5}$ at 80 percent of PM_{10} based upon a report from the *Journal of Aerosol Science*[23], but this relationship is still going through review by the scientific community. As medium and slow speed engines have lower pressure fuel injection systems and residual oil is not refined, it is likely that Category 2 and 3 engines may have a lower ratio of $PM_{2.5}$ emissions to PM_{10} emissions than high speed engines using low sulfur fuel, but 80 percent seems rather low. A more reasonable value of 0.92 is used in the Table 2-8 for marine diesel fuels in slow and medium speed engines. For higher speed engines using lower sulfur diesel fuel, such as harbor craft, cargo handling equipment, and on-highway diesel vehicles, the 97 percent ratio should be used.

In addition, because SO_2 and PM emission factors are directly proportional to the sulfur content of the fuel, SO_2 and PM emission factors should be adjusted if the sulfur content of RO in the ships calling on a port is different from the assumption of 2.7 percent used by Starcrest.

Emission factors are considered to be constant down to about 20 percent load. Below that threshold, emission factors tend to increase as the load decreases. This trend results because diesel engines are less efficient at low loads and the fuel consumption tends to increase. Thus, while mass emissions (grams per hour) decrease with low loads, the engine power tends to decrease more quickly, thereby increasing the emission factor as load decreases. Energy and Environmental Analysis Inc. (EEA) demonstrated this effect in a study prepared for EPA in 2000.[24] Starcrest used the equations developed by EEA to determine emission factor adjustments based on load factor. The emission factor adjustments are given in Table 2-9. These factors should be multiplied by the emission factors given in Table 2-8 to determine emission factors at loads below 20 percent. For diesel-electric systems in which the propulsion is driven by an electric motor, such low load adjustment factors should not be used. This is because several engines are used to generate power, and some can be shut down to allow others to operate at a more efficient setting.

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[21] Memo from Chris Lindhjem of ENVIRON, *PM Emission Factors*, December 15, 2005.

[22] U.S. EPA, *Recommended revision of the fraction of diesel particulate emissions mass less than 2.5 microns in size, m*emo to the docket from Bruce Cantrell. October 17, 2003. (Docket A-2001-28, Document IV-B-21).

[23] Lyyränen, J., Jokiniemi, J., Kauppinen, E. and Joutsensaari, J., *Aerosol characterisation in medium-speed diesel engines operating with heavy fuel oils,* published in the *Journal of Aerosol Science*, Vol. 30., No. 6. pp. 771-784, 1999.

[24] Energy and Environmental Analysis Inc., *Analysis of Commercial Marine Vessels Emissions and Fuel Consumption Data*, EPA420-R-00-002, February 2000.

Table 2-9: Emission Factor Adjustment Factors at Low Loads

Load	NOx	CO	HC	PM	SO_2
1%	11.47	20.00	89.44	19.17	1.00
2%	4.63	10.00	31.62	7.29	1.00
3%	2.92	6.67	17.21	4.33	1.00
4%	2.21	5.00	11.18	3.09	1.00
5%	1.83	4.00	8.00	2.44	1.00
6%	1.60	3.33	6.09	2.04	1.00
7%	1.45	2.86	4.83	1.79	1.00
8%	1.35	2.50	3.95	1.61	1.00
9%	1.27	2.22	3.31	1.48	1.00
10%	1.22	2.00	2.83	1.38	1.00
11%	1.17	1.82	2.45	1.30	1.00
12%	1.14	1.67	2.15	1.24	1.00
13%	1.11	1.54	1.91	1.19	1.00
14%	1.08	1.43	1.71	1.15	1.00
15%	1.06	1.33	1.54	1.11	1.00
16%	1.05	1.25	1.40	1.08	1.00
17%	1.03	1.18	1.28	1.06	1.00
18%	1.02	1.11	1.17	1.04	1.00
19%	1.01	1.05	1.08	1.02	1.00
20%	1.00	1.00	1.00	1.00	1.00

Auxiliary Engine Emission Factors

As with propulsion engines, the most current set of auxiliary engine emission factors comes from Entec. Starcrest used these emission factors for the PoLA inventory, and they are considered the most up to date. Auxiliary engine emission factors are given in Table 2-10. There is no need for a low load adjustment factor for auxiliary engines, because they are generally operated in banks. When only low loads are needed, one or more engines are shut off, allowing the remaining engines to operate at a more efficient level.

It should be noted that Entec used the fuel sulfur content of 2.7 percent for RO, 1.5 percent for MDO, and 0.5 percent for MGO. Therefore, when calculating SO_2 emission factors, SO_2 emission factors should be adjusted accordingly for areas where fuel sulfur content is different. Again PM and SO_2 emission factors were calculated based upon recommendations from ENVIRON.

Table 2-10: Auxiliary Engine Emission Factors, g/kWh

Engine	Fuel	NOx	CO	HC	PM_{10}	$PM_{2.5}$	SO_2
MSD	RO	14.70	1.10	0.40	1.14	1.10	11.1
	MDO	13.90	1.10	0.40	0.75	0.28	6.16
	MGO	13.90	1.10	0.40	0.42	0.23	2.05

Boiler Emission Factors

In addition to the auxiliary engines that are used to generate electricity onboard ships, most OGVs also have boilers used to heat RO to make it fluid enough to use in diesel engines and to produce hot water. Auxiliary boiler emission factors are given in terms of fuel usage, rather than power, so a fuel consumption rate also needs to be determined. During its vessel boarding program, Starcrest gathered enough data to estimate the consumption rate to be 0.0125 tonnes of fuel per hour. In a detailed inventory, data on auxiliary boiler fuel consumption rate should be collected. For mid-tier inventory development, the rate discussed above could be used. Auxiliary boiler emission factors, given in kilograms (kg) of emissions per tonne of fuel used, are given in Table 2-11.

Table 2-11: Auxiliary Boiler Fuel Emission Factors, kg/tonne Fuel Consumed

Pollutant	kg/tonne
NOx	12.30
CO	4.60
HC	0.38
PM_{10}	1.30
$PM_{2.5}$	1.04
SO_2	54.0

Kilograms and Tonnes

One Kilogram *(kg) is equivalent to 2.205 pounds.*

One Tonne, *or metric ton, is equivalent to 1,000 kilograms.*

Aggregation of Results

In a detailed inventory, emissions for each mode (cruise, reduced speed zone, maneuvering, and hotelling with and without cold ironing) during a call should be calculated using ship type, actual speed, engine power, load factor, time in that mode and emission factors for propulsion and auxiliary engines and boilers. It should first be summed by call, then summed emissions by DWT ranges and then by ship type for an entire year of calls. These data can be used by others when developing port emission inventories via the streamlined approach.

2.3 Harbor Craft Emissions

Harbor craft are commercial and recreational vessels that spend the majority of their time within or near a port or harbor. Port harbor vessels types are listed in Table 2-12. To calculate emissions from harbor vessels, the following information needs to be collected from vessel owners and operators:

- Hours of operation (annual and average daily, plus schedules if relevant and available)

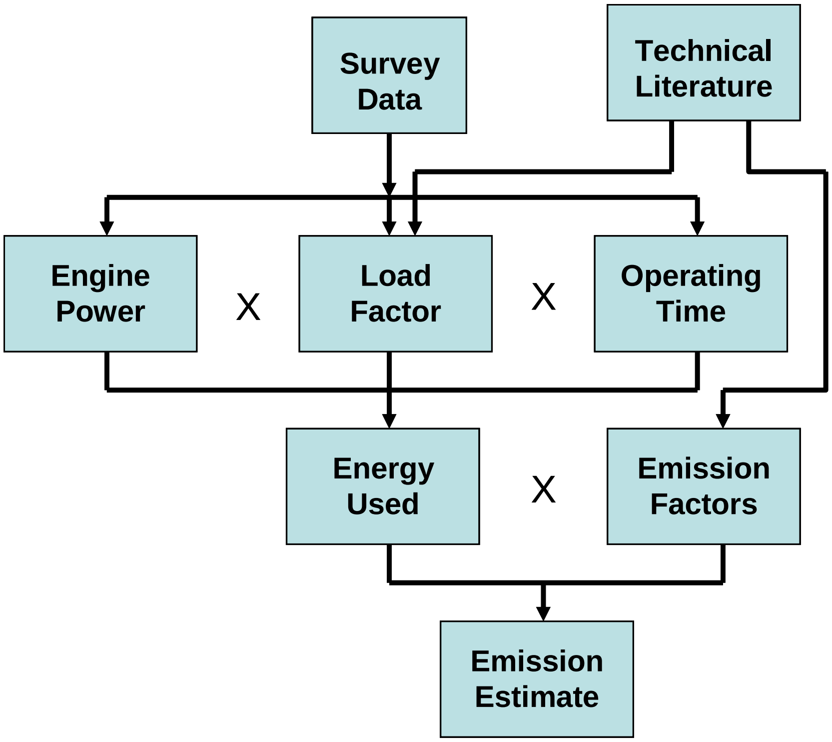
- Percentage of time in operational modes (e.g., idling, half power, full power)
- Vessel characteristics
- Number, type, and horsepower (or kilowatts) of main engine(s)
- Number, type, and horsepower (or kilowatts) of auxiliary engine(s)
- Other operational parameters such as fuel consumption rates and dredging volumes
- Qualitative information regarding how the vessels are used in service

Table 2-12: Harbor Craft Vessel Types

Vessel	Description
Assist tugboats	Help OGVs maneuver in the harbor during arrival and departure and shifts from berth. Also provide “tugboat escort” for tankers. Vessels with a DWT of 20,000 tons or less use one tugboat, greater than 20,000 tons use two tugboats.
Towboats/pushboats/tugboats	Self-propelled vessels that tow or push barges within and outside of the port.
Ferries and excursion vessels	Ferries transport people and property. Excursion boats provide harbor cruises and whale watching.
Crew boats	Carry personnel and supplies to and from off-shore and in-harbor locations.
Work boats	Include utility, inspection, survey, spill/response, research, mining, training, and construction.
Government vessels	Belong to U.S. Coast Guard; U.S. Navy, Fish and Game; and fire, police, and harbor departments. Generally states cannot require emission reductions from federal vessels.
Dredges and dredging support vessels	Perform or assist in performing dredging activities in the harbor.
Commercial fishing vessels	Used for commercial fishing.
Recreational vessels	Privately owned boats, including powerboats and sailboats.

The flow chart in Figure 2-2 summarizes the steps taken to estimate the majority of harbor craft emissions.

Figure 2-2: Harbor Craft Emission Estimation Flow Chart



Average Engine Power and Operating Hours

Most harbor craft have Category 1 marine diesel engines; although, some of the larger assist tugs and most oceangoing towboats have Category 2 marine diesel engines.[25]

Table 2-13 gives average propulsion and auxiliary engine sizes and hours of annual operation by harbor craft type for the PoLA. For detailed inventory preparation, average values should be calculated from the information collected at the specific port. For mid-tier inventory preparation, the information presented in Table 2-13 can be used in developing a streamlined inventory of harbor craft emissions.

One of the hardest categories to get consistent information on is recreational vessels. Most harbors only have data on number of slips, percentage of sailboats versus powerboats, and whether the marinas are at full capacity. Starcrest used data from the California ARB's Pleasure Craft Exhaust Emissions Inventory and the OFFROAD model to determine emissions from recreational vessels. This practice should be used for California ports. Various other states have also done recreational boating surveys. This information could be use together with EPA's NONROAD model for other non-California ports.

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[25] For the purpose of emission regulations, EPA divides marine engines into three categories, where each category represents a different engine technology, based on displacement (swept volume) per cylinder. Category 1 and 2 marine diesel engines range in size from about 700 to 11,000 hp (500 to 8,000 kW). These engines are used to provide propulsion power on many oceangoing vessels and harbor craft or as stand-alone auxiliary engines.

Table 2-13: Average Engine Horsepower and Annual Hours of Operation (Port of Los Angeles)

	Propulsion Engine			Auxiliary Engine	
Vessel Category	Engine Power (kW)	Annual Operating Hours	Percent Category 2 Engines (%)	Engine Power (kW)	Annual Operating Hours
Assist Tug	1,532	1,043	44	82	1,207
Tugboat (Unit Tow)	903	654	25	56	859
Line Haul Towboats	3,357	654	80	82	859
Ferry	803	1,672	0	25	1,616
Excursion	250	1,971	0	41	2,199
Crew Boat	284	606	0	72	700
Work Boat	266	345	0	23	618
Government	237	413	0	176	156
Dredges	1,531	372	0	214	372
Dredge Tenders	450	158	0	19	136
Commercial Fishing	204	1,647	0	51	1,932

Load Factors

Load factors used in the PoLA inventory are shown in Table 2-14. The 43 percent value for other auxiliary vessels comes from EPA's NONROAD model. Starcrest determined the 31 percent for assist tugs from actual vessel load readings and obtained the remaining load factors from other studies, as documented in Starcrest's PoLA inventory report. While best practice is to collect information for a specific port, these load factors could be used for other port emission inventories if no other information is available.

Table 2-14: Load Factors for Harbor Craft (Port of Los Angeles)

Vessel Category	Engine Power (hp)
Assist Tugboat	31%
Dredge Tenders	69%
Recreational	21%
Other Categories	43%
Recreational, Auxiliary	32%
Other Auxiliaries	43%

Emission Factors

Category 1 emission factors for harbor craft come from the 1999 EPA rulemaking for Category 1 and 2 engines and are listed in Table 2-15.[26] $PM_{2.5}$ emission factors are estimated to be 97 percent of PM_{10} emissions for Category 1 engines; 80 percent should be used for Category 2 engines. SO_2 emissions are based on fuel sulfur content of 1.5 percent and should be scaled up or down based on actual fuel sulfur content used for harbor craft at the port. PM emissions also may change based upon sulfur level and also should be scaled.

Table 2-15: Category 1 Harbor Craft Emission Factors

Minimum Power		Emission Factors (g/kWh)				
kW	hp	NOx	CO	HC	PM_{10}	SO_2
37	50	11.0	2.0	0.27	0.9	0.63
75	100	10.0	1.7	0.27	0.4	0.63
130	175	10.0	1.5	0.27	0.4	0.63
225	300	10.0	1.5	0.27	0.3	0.63
450	600	10.0	1.5	0.27	0.3	0.63
560	750	10.0	1.5	0.27	0.3	0.63
1,000	1,341	13.0	2.5	0.27	0.3	0.63

Category 2 emission factors come from the 2002 Entec study and are listed in Table 2-16. Again, the SO_2 and PM_{10} emission factors assume fuel sulfur content of 1.5 percent and, thus, should be scaled accordingly if sulfur levels are different.

Table 2-16: Category 2 Harbor Craft Emission Factors, g/kWh

NOx	CO	HC	PM_{10}	SO_2
13.2	1.10	0.50	0.72	0.63

2.4 Land-Side Emissions

As best practice, those preparing port inventories should estimate CHE emissions using EPA’s NONROAD model (California uses ARB’s OFFROAD model) and on-road trucks, buses and other vehicles using EPA’s MOBILE6.2 model (California uses ARB’s EMFAC2002 model). Rail emissions should be handled separately, as NONROAD does not contain rail emission factors. When the purpose of the inventory is to prepare a SIP, land-side emissions are usually calculated for the non-attainment region and, thus, should not be double counted by ports. However, calculating land-side emissions provides details for possible emission reductions when implementing an emissions mitigation program. NEPA, CEQA, and general conformity analyses also need land-side emissions estimated. There are three categories of land-side emissions that need to be examined: CHE, railroads, and on-road vehicles.

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[26] EPA, *Final Regulatory Impact Analysis: Control of Emissions from Marine Diesel Engines*, EPA420-R-99-026, November 1999.

Cargo Handling Equipment

A wide range of CHE exists at ports due to the diversity of cargo. Container terminals use CHE most extensively. Truck to rail equipment and dry bulk terminals also have high use of CHE. Liquid bulk and auto terminals use CHE the least. Starcrest found that much of CHE is used to load and unload containers.[27] In fact for the PoLA, 99 percent of CHE was associated with container terminals and 88.5 percent at the Port of Long Beach. While only 42 percent of the CHE in the Port of Houston was engaged in container terminal activity, approximately 70 percent of the port-wide NOx emissions came from this equipment. Thus, determining emissions from container terminal CHE is important in any land-side emission inventory.

The majority of CHE can be classified into the equipment types shown in Table 2-17. The table provides EPA's NONROAD model equipment type used to estimate emissions and the corresponding source classification codes (SCC) used in NONROAD. Similar categories are used with California ARB's OFFROAD model.

Table 2-17: Cargo Handling Equipment Types

Equipment Type	NONROAD Model Equipment Type	SCC Code
Aerial Platform	Aerial Lift	2270003010
Bucket Loader	Rubber Tire Loader	2270002060
Chassis Rotator	Other Industrial Equipment	2270003040
Empty Container Handler	Other Industrial Equipment	2270003040
Forklift	Forklift	2270003020
Generator	Light commercial generator set	2270006005
Non-Road Vehicle	Off-highway Trucks	2270002051
Payloader	Skid-Steer Loader	2270002072
Portable Light Set	Signal Board/Light Plant	2270002027
Rubber Tire Gantry Crane	Other Material Handling Equipment	2270003050
Side Loaders	Other Industrial Equipment	2270003040
Straddle Carrier	Other Material Handling Equipment	2270003050
Sweeper	Sweepers/Scrubbers	2270003030
Terminal Tractor	Terminal Tractor	2270003070
Top Loader	Other Industrial Equipment	2270003040
Wharf Crane	Crane	2270002045

To develop a detailed emission inventory of CHE, those preparing port emission inventories should gather the following information for each piece of CHE used at the port:

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[27] Starcrest Consulting Group LLC, *The Port of New York and New Jersey Emission Inventory for Container Terminal Cargo Handling Equipment, Automarine Terminal Vehicles, and Associated Locomotives*, prepared for the Port of New York and New Jersey, June 2003.

- Equipment type
- Rated horsepower
- Model year
- Type of fuel used
- Annual hours of operation
- Equipment load data
- Retrofit devices

To develop inputs for EPA's NONROAD model, the user must define both activity and population of the various categories of equipment shown in Table 2-17. Activity is the number of hours an engine operates during a given analysis year and can be determined from interviews with terminal operators. In general, container terminals use their equipment much more intensively than other terminals. Population is the number of similar engines of a specific equipment type with a similar horsepower rating. EPA's NONROAD model uses a "bin" approach for horsepower as follows:

- 25-40 hp
- 40-50 hp
- 50-75 hp
- 75-100 hp
- 100-175 hp
- 175-300 hp
- 300-600 hp
- 600-750 hp
- 750-1,000 hp
- 1,000-1,200 hp
- 1,200-1500 hp
- 1,500-2,000 hp
- 2,000-3,000 hp
- 3,000+ hp

In preparing inputs, diesel sulfur content in parts per million (ppm) should be determined for the fuels used for CHE at the port. National average non-road fuel has approximately 3,400 ppm sulfur, while national average on-highway diesel fuel has 340 ppm sulfur. By 2010, most non-road diesel fuel will contain only 15 ppm sulfur or less (2006 in California) with a 500 ppm step starting in 2007. Because ambient temperatures do not affect diesel exhaust emissions in NONROAD, an input of 75^{o} F can be used.

Using the data collected on equipment numbers, types, horsepower, model year, hours of operation and load data, inputs can be generated for the various NONROAD equipment types to determine emissions for CHE at the port. It should be noted that the NONROAD model uses 1996 and 1998 baseline populations and then assigns an average growth rate to estimate emissions in subsequent years. As such, growth should be set to zero so that the emissions will not increase over time and the results will be accurate for a given analysis year. For future forecasts, an updated population and activity file will be required.

For alternative fuels such as natural gas or liquefied petroleum gas (LPG), the NONROAD model can estimate emissions by specifying "ALL FUELS" during a run. For retrofit devices such as diesel oxidation catalysts, diesel particulate filters, and PuriNOx, reductions shown on EPA's Verified Retrofit Technology website[28] should be used. In these cases, emission factors should be determined using NONROAD for diesel equipment and then the emission reduction percentages applied.

Rail

Movement of freight into and out of the port via rail should be included in a detailed inventory if land-side emission estimates are sought. Railroad operations are usually described in terms of different types of operation, namely line haul and switching. Line haul refers to the movement of cargo over long distances and would include initiation or termination of a line haul trip in a port. Generally, the first intermodal point should be used in defining the train trips to and from the port. Switching refers to the assembling and dissembling of trains at various locations within a port.

Line haul locomotives are typically large with engines of 2,200 kW or more, while switching locomotives have engines of 900 to 2,200 kW. Information on locomotives and their operation should be gathered from the railroad companies that service a port. Information from the railroad companies should be used in concert with EPA's guidance on locomotive emissions.[29, 30]

For ports near U.S. border areas, the effect of different emission standards for foreign trains entering the U.S. should be taken into account.

On-Road Vehicles

There are three types of on-road vehicles that service ports: on-road diesel trucks, diesel passenger buses, and other vehicles such as passenger cars used by port staff and maintenance trucks. EPA's MOBILE6.2 (California uses EMFAC2002) should be used for calculating emissions from these vehicles.

On-Road Diesel Trucks

On-road diesel trucks are used extensively to move cargo into and out of ports. Again, the first intermodal point should be considered when calculating truck emissions related to a port. On-road truck emissions should be modeled using MOBILE6.2 (California uses EMFAC2002). Several issues should be examined in modeling truck traffic at ports, including the following:

- Fleet age
- Idling time
- Truck speeds within the port
- Truck speeds on arterials and freeways accessing the port
- Retrofit devices, repowers, and alternative fuels

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[28] http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm

[29] EPA, *Technical Highlights – Emission Factors for Locomotives*, EPA420-F-97-051, December 1997.

[30] EPA, *Guidance for Quantifying and Using Long Duration Switch Yard Locomotive Idling Emission Reductions in State Implementation Plans*, EPA420-B-04-002, January 2004.

Because trucks manufactured before 1991 produce higher emissions, the truck fleet age profile is an important variable in preparing emission inventories. Most trucks serving ports are operated by independent owner-operators or as part of a short haul drayage fleet of a trucking company. Port-serving trucks usually pick up containers and cargo at the port and drop them at a central facility outside of the port. From there, long haul trucks will pick up loads for other parts of the state and country and drop off loads. The port-serving fleet is typically much older than the long haul trucking fleet. According to the 1997 Vehicle Inventory and Use Survey (VIUS) data,[31] combination tractor-trailer Class 8B trucks that traveled less than 50 miles from the home base had an average age of 11.7 years, while long haul trucks that traveled over 200 miles from the home base had an average age of 4.7 years.

Alternative fuel trucks should be modeled as compressed natural gas (CNG) trucks as described in EPA MOBILE6 guidance.[32] For PuriNOx and retrofit devices such as diesel oxidation catalysts and diesel particulate filters, diesel emission factors should be discounted by the reduction percentages given for the devices on EPA's Verified Technology List website.

During delays at ports, trucks spend large amounts of time idling, which is not directly accounted for in MOBILE6.2. EPA cautions that curb idle rates calculated using MOBILE6.2 is too low to represent extended idling of commercial class 8B diesel trucks. For extended idle, EPA guidance suggests using average idle emission rates of 135 grams per hour for NOx and 3.68 grams per hour for PM .[33] These idle rates represent fleet average values at high idle speed.[34] Idle times should be calculated both inside and outside the port gates as well as entering and leaving distribution centers and other intermodal points.

California ARB developed a methodology for calculating idle emissions from commercial class 8B diesel trucks during extended idling periods in their initial statement of reasoning for a proposed California anti-idling regulation.[35] In this document, California ARB developed idle emission factors for curb idle and for high idle with accessory loads based on test data. These emission factors provide emission factors by truck model year and provide a more accurate assessment of class 8B diesel truck idle emissions.

Truck speeds also are important for estimating truck emissions within the port and outside the port. Emissions of NOx, VOC, and CO tend to vary with speed (PM emission rates do not vary with speed in the MOBILE model). Average roadway speed data can be obtained from local government traffic engineers or the region's metropolitan planning organization (MPO).

For ports near border areas, the effect of foreign trucks meeting different emission standards and servicing the port should also be taken into account.

Diesel Passenger Buses

Diesel passenger buses transport cruise passengers into and out of the port. Generally these buses would be considered intercity buses, but MOBILE6.2 does not provide emission factors for intercity buses. Therefore, transit buses should be used when modeling diesel buses into and out of a port. Best practice is to collect age distributions and mileage accumulation rates for these buses that service a specific port. However, it that information is not available, MOBILE6.2 defaults for transit buses can be used. In

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[31] U.S. Census Bureau, *Vehicle Inventory and Use Survey, 1997*, CD-EC97-VIUS, January 2000.

[32] EPA, *MOBILE6 Emission Factors for Natural Gas Vehicles*, EPA420-R-01-033, April 2001.

[33] EPA, *Guidance for Quantifying and Using Long Duration Truck Idling Emission Reductions in State Implementation Plans and Transportation Conformity*, EPA420-B-04-001, January 2004.

[34] Communication with David Brzezinski of EPA Office of Transportation and Air Quality, February 11, 2004.

[35] California Air Resources Board, *Public Hearing To Consider The Adoption Of Heavy-Duty Vehicle Idling Emission Reduction Requirements – Staff Report: Initial Statement of Reasoning*," December 5, 2003.

addition, there is no guidance for bus idle emission factors, so the model should be run at 2.5 mph and the resulting emission factors in grams per mile should be multiplied by 2.5 miles per hour to get gram per hour emission rates at idle. Retrofits and alternative fuels should be handled similar to the methodology described above for on-road trucks. Foreign buses meeting different emissions standards should be accounted for near border areas.

Other Port Vehicles

Other port vehicles include passenger cars and light trucks used by port staff and maintenance trucks. General light-duty car and truck emission factors can be used for modeling staff cars and trucks, while maintenance trucks can be modeled as Class 3 or 4 heavy-duty trucks.

2.5 Great Lake and Inland River Ports

The port boundaries and ships that call on Great Lake and inland river ports differ from deep sea ports. Those preparing emission inventories for Great Lake and inland river ports also should calculate land-side emissions similar to the methods described in Section 2.4. Calculation of emissions from vessels operating in Great Lakes and inland rivers are discussed below.

Great Lake Ports

There are several ship types common to the Great Lakes. Most Great Lake ports have a combination of cargo ships called “Lakers” and “Salties,” as well as a substantial amount of barge traffic. Excursion vessels are also common on the Great Lakes.

Lakers are dry cargo ships that operate only on the Great Lakes and have self-unloading equipment. Most Lakers are bulk carriers or cement carriers. Salties are foreign-flagged ships entering and leaving the Great Lakes using the St. Lawrence Seaway. Salties may include bulk dry cargo, general cargo, tankers, and container ship types.

Barge traffic in the Great Lakes falls into two categories. Flat-bottomed river barges (scows) enter the Great Lakes through the Illinois River at Chicago, Illinois and near Hammond, Indiana. The river barges share one to four barges per tug and generally do not have self-unloading equipment. Notch barges are larger lake barges that are more common at Great Lake ports distant from Chicago. Notch barges frequently have self-unloading equipment.

Generally, Great Lake port boundaries extend 10 miles into the lake from the breakwater. As with deep sea ports, Great Lake ports usually have MEPAs that collect data on ships that enter and leave their port. This information can be used with the Lloyd’s Data to determine ship time-in-mode and power.

Methodology for determining activity at Great Lake ports has been developed in an EPA guidance document.[36] Those preparing emission inventories for Great Lake ports should use the guidance for typical ports together with the emission factors for OGVs and harbor craft tugboats/pushboats/towboats. This approach was followed by ENVIRON in developing a recent emission inventory for Lake Michigan ports.[37]

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[36] ARCADIS, *Commercial Marine Activity for Great Lake and Inland River Ports in the United States*, EPA420-R-99-019, September 1999.

[37] ENVIRON International Corporation, *LADCO Nonroad Emission Inventory Project for Locomotive, Commercial Marine, and Recreational Marine Emission Sources*, prepared for Lake Michigan Air Director Consortium, December 2004.

Inland River Ports

Commercial traffic on rivers consists almost exclusively of tug and barge movements. There are some excursion vessels, such as paddle boats, dinner cruises, or other entertainment-centered river traffic, but the majority of trips and vast majority of tonnage recorded by USACE are centered on tug/barge movements. The tug/barge combination often is referred to as a "tow." The following is a discussion of excursion vessels, tugs, and barges that operate on rivers.

Excursion vessels are passenger boats of all kinds that normally operate on repetitive routes that last a set length of time. Each excursion boat usually has a cruise that lasts from one to several hours, returning and departing from the same port. A few excursion cruises may be overnight or several days and cover several ports. Excursion vessels will have only a short time at the dock between cruises and will rarely leave their auxiliary engines on for more than an hour of hotelling time at the dock. Gambling boats are likely to have large hotelling emissions from auxiliary engines but are expected to be a small percentage of the overall excursion vessel population.

There are different types of tugs and different types of barges that commonly operate on the rivers. The two main types of tugs are towboats and pushboats. A river tug, or pushboat, is generally a flat-bottomed boat with a flat bow. The bow meets up against the flat stern of a river barge, the two are secured to each other, and the tug pushes the barge (or barges) up or down the river. In one variation, the pushboat has a rounded or pointed bow that fits into a notch on the stern of a barge (notch barge) and then commences to push the barge. Less commonly seen on rivers are towboats. Unlike a pushboat, the hull of the towboat does not, generally speaking, touch the barge. Instead a long line passes between the towboat and the barge as the towboat pulls the barge forward. Towboats are more commonly used for oceangoing barges and on the Great Lakes than they are in rivers.

The two main types of barges are dry cargo and liquid cargo barges. Dry cargo barges include flat deck, open hopper, covered, and lash barges. Liquid cargo barges include single-hull, double-hull, and double-sided. Liquid cargo barges have an average of 40 percent greater cargo capacity and are an average of 15 percent longer and 30 percent wider than a dry cargo barge. Variations exist within the liquid and dry cargo barge categories.

Barges are assembled into tows at fleeting areas. Within the fleeting area, tows are made and broken down by harbor tugs. Higher horsepower tugs also may meet the completed tow in the fleeting area for the trip up- or down-river. Barges are secured together according to their delivery destination. Sometimes the entire tow may be delivered to a fleeting area within a port. Other times a harbor tug will meet the tow and remove one or more of the outermost barges, while leaving the rest of the tow intact to continue its voyage.

Unlike deep sea ports, a vessel passing through a river port does not necessarily stop at the port. However, the passage of this vessel will be an emission event for the surrounding port area. For example, a vessel leaving from Memphis, Tennessee, and destined for St. Paul, Minnesota, would pass through the Port of St. Louis. Likewise, a vessel leaving St. Louis, Missouri, and destined for Pittsburgh, Pennsylvania, would pass through the Port of Cincinnati. Thus, traffic passing through a river port can be equally important as traffic calling on the port. Indeed, passing traffic is often more significant in tonnage and trips than the calling traffic.

The EPA guidance document for Great Lakes and inland river ports provides a methodology for determining activity, power, and speed of tugs. This methodology should be followed and used with harbor craft emission factors to determine an inventory of inland river ports. Additional guidance can be found in ENVIRON’s Lake Michigan Air Directors Consortium (LADCO) report.

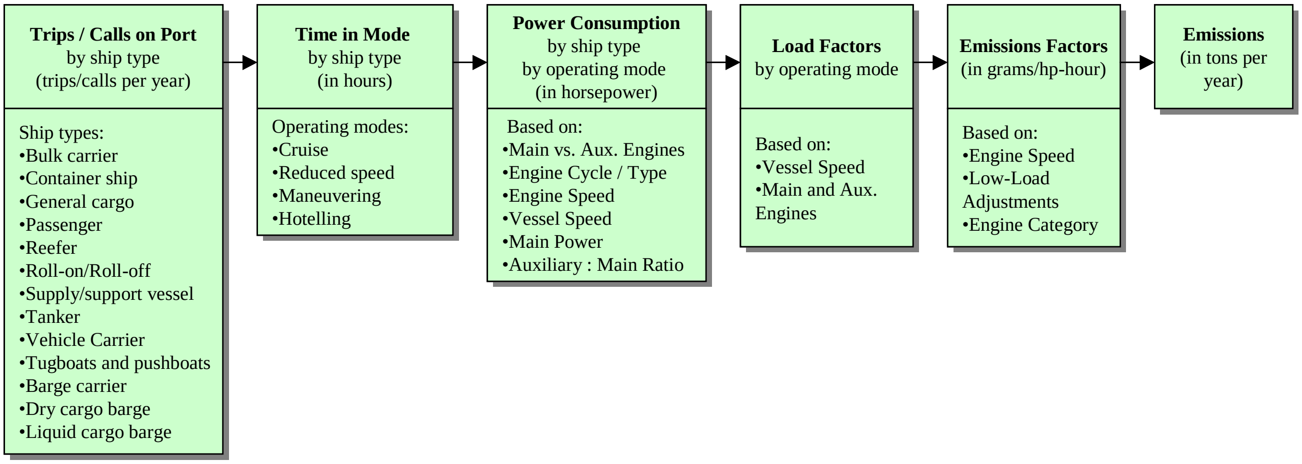
3 MID-TIER AND STREAMLINED EMISSION INVENTORY PREPARATION

While a detailed inventory is the most accurate methodology for determining emission impacts at ports, many mid-size and smaller ports do not have the resources to accomplish such a task. This section discusses both a mid-tier and streamlined approach.

3.1 Mid-Tier Approach

Some mid-size ports, or those preparing emission inventories with mid-sized resources, could prepare a simplified version of the detailed inventory by averaging vessel characteristics and operational data by ship type. Even better resolution can be gained if the average information also includes a DWT range. Load factors and emission factors then can be applied to average vessel characteristics for a given ship type and DWT range and multiplied by the number of calls that all vessels of a given type of vessel and DWT range made in a year at the port. Each call should be divided into the various modes of operation and each mode also averaged for the vessel type and DWT range. Detailed guidance for typical ports is provided in the two EPA documents for deep sea ports[38] and Great Lake and inland river ports. ENVIRON offers additional guidance in its report. A flow chart for preparation of marine vessel inventories using the mid-tier approach is shown in Figure 3-1.

Figure 3-1: Flow Chart for Mid-Tier Inventory Preparation



By combining vessels in ship type and DWT categories and summing the calls, an averaged approach can be used to determine time-in-mode and load factors for a set of vessel calls instead of each individual call. This pared down method should reduce the amount of time and information needed to prepare an inventory.

3.2 Streamlined Approach

A streamlined approach can be applied if those preparing port inventories do not have sufficient resources to follow the mid-tier approach outlined above. In this approach, those preparing port inventories should use an existing emission inventory from another similar port, scaling the emissions up or down based on the ratio of vessel operation data between the two ports. The two EPA activity guidance documents

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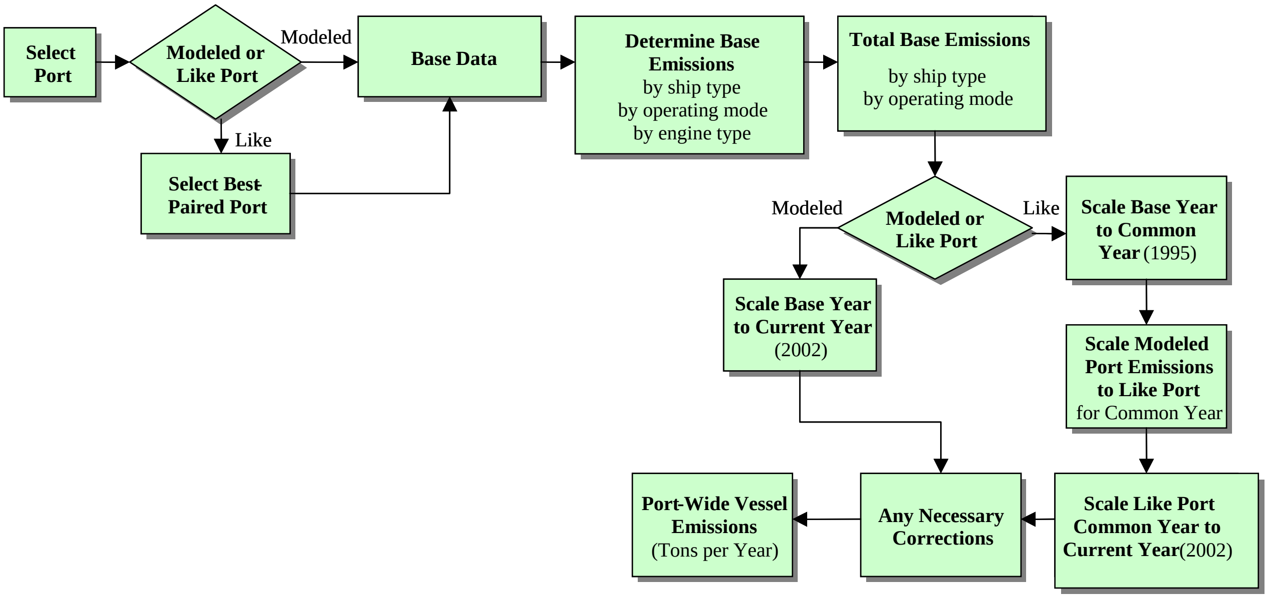
[38] ARCADIS, *Commercial Marine Activity for Deep Sea Ports in the United States*, EPA420-R-99-020, September 1999.

provide details on estimating emission inventories from other ports.[36, 38] The documents use USACE data to scale emissions based on the ratio of ship trips from a "like" port that has an existing inventory compared to the port in question.[39] ENVIRON used this method to prepare a national inventory for an EPA rulemaking. While there are significant issues with this sort of approach, it does provide a first cut inventory for ports to use in SIPs and for other purposes. A flow chart of this method is shown in Figure 3-2.

Figure 3-2: Flow Chart for Streamlined Inventory Preparation



3.3 Cargo Handling Equipment Estimation

Few preparers of port inventories have developed estimates of CHE emissions. In the development of SIPs, port CHE is considered together with other non-road sources, and emissions are calculated using EPA's NONROAD model (California uses ARB's OFFROAD model). Generally, SIP documents assign these sources to the counties or air districts in which these emissions occur, rather than to a port. A small number of the nation's largest ports have developed estimates of CHE emissions, sometimes for an EIS/EIR or in an attempt to help identify effective mitigation strategies. These ports include the Ports of Los Angeles, Long Beach, Houston, and New York/New Jersey.

Unlike vessel emissions, there is no EPA guidance or other standardized methodology for developing estimates of port CHE emissions. Developing a CHE inventory from scratch requires extensive time and resources in order to survey all port tenants regarding their equipment. Such an effort is not always feasible. As an alternative, CHE emissions can be estimated from other CHE inventories prepared for other ports. The method described below is recommended for both mid-tier and streamlined inventory preparation.

Of the ports that have developed CHE inventories, the Ports of Long Beach and Los Angeles are the only ports with emissions estimates from land-side activity provided with sufficient detail to allow application of ratios to other ports. To estimate the CHE emissions at other ports of interest, one can scale the 2002

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[39] U.S. Army Corps of Engineers, *Waterborne Commerce of the United States*, 2002.

CHE emissions for the Ports of Long Beach and Los Angeles by the ratio of freight activity. For three of the four cargo categories – liquid bulk, dry and break bulk, and vehicles – this ratio is determined by the total tonnage handled in each category. For the fourth category – container cargo – the ratio is determined by the number of boxes handled at each facility. The emissions at each of the four possible terminal types then can be determined from scaling both the Long Beach and Los Angeles values to those of the port under consideration and averaging the two results. Using an average of these two values provides more reasonable emissions estimates than scaling off either one of the ports alone. The total emissions at each port then can be determined by summing over each of the four terminal types.

The total 2002 tonnage at a given port in each of the four cargo categories can be determined from USACE data. Total petroleum minus petroleum coke should be taken as a surrogate for liquid cargo. “Vehicles and Parts” should be taken as a surrogate for automobiles. Number of boxes should be taken to best represent containerized cargo. The scaling ratios used to determine emissions then are determined for the port in question.

There are some reservations on using this method as the Ports of Long Beach and Los Angeles are unique from the rest of the country. In particular, they handle mostly container traffic and larger ships so the CHE might have higher horsepower engines, be newer, operate on different fuels, etc. While not as detailed, information from the New York/New Jersey and the Houston CHE inventories also can be scaled to check the results from the PoLA or Port of Long Beach emission scaling exercise.

4 RECOMMENDATIONS FOR FURTHER STUDY

There are a variety of opportunities to improve on the port emission inventory development procedures described in this document. Below are recommendations for future research and improvement.

Recommendation 1 – There is a need for the development of updated and more accurate marine vessel emission factors and load factors. The current emission factors are still based on limited test data and do not fully represent newer vessels that meet the IMO Annex VI NOx standard. A test program by EPA to determine more accurate emission factors for all engine categories would greatly improve emission inventories. Utilizing international standards will resolve some of the current technical/legal problems and provide consistent requirements for OGVs as they participate in worldwide commerce. In addition, the PM emission factors for slow and medium speed ships needs further review. The recent difficulty in measuring PM emissions raises concerns with earlier measurements used in the Entec dataset. Finally, there is a need to develop emission factors specific to $PM_{2.5}$. Currently, emission factors for $PM_{2.5}$ are an approximation based on PM_{10} emission factors.

Recommendation 2 – There is little information on the number and size of auxiliary engines on Category 3 ships. Because hotelling emissions can be a substantial part of port emissions, better information on the size and number of auxiliary engines on ships calling on U.S. ports is needed. While the 1999 EPA rulemaking has made estimates of these engines, more accurate information is needed to improve emission estimates, including information on load, type of operation, and fuel. It is recommended that emission factors also be developed for incinerators and boilers.

Recommendation 3 – Some emission inventories include assumptions regarding the amount of time that Category 2 vessels, such as tugs and pushboats, operate within a port's boundaries. In many cases these vessels travel from one port to another along the coastline, and this travel may not be properly accounted for in the inventory. Furthermore, some inventories assume that all Category 2 vessels operate within the 48-state U.S. airshed. This may be inaccurate in areas near U.S. borders where tugs and pushboats might push cargo into Alaska, Hawaii, Canada, or Mexico. Therefore, an improved methodology is needed to determine the amount of activity of Category 2 vessels in port areas and the U.S. airshed.

Recommendation 4 – For NEPA (or CEQA) and general conformity purposes, the emission inventory process could be improved by the development of emission factors for on-dock equipment that better represent their in-use duty cycle. It is recommended that EPA spearhead the development of test cycles for dock equipment that realistically represent the operating patterns of this equipment.

Recommendation 5 – For those preparing port emission inventories using the streamlined approach, EPA needs to update the emissions from ports using the method prescribed in this document. The 1999 marine inventory document prepared by ENVIRON uses older emission factors and methodology.[13] Therefore, it is recommended that the national inventory be redone using the methodology and emission factors suggested in this report. It is recommended that this revised inventory be used as the basis for emission factors provided by the future release of EPA's new emission factor model, MOVES.

Recommendation 6 – The U.S. Coast Guard (USCG) has begun operating in most major ports an upgraded version of its Vessel Tracking System (VTS) that could substantially improve emission inventories for ocean going vessels. This new system allows for real time tracking of all ocean going vessels beginning approximately twenty miles outside of the port. It can measure distance traveled and speed. The EPA and USCG believe that the upgraded VTS system could be used to help generate real-time air pollution emission inventories. While a substantial amount of work would have to be done to convert the distance and speed information to NOx, PM 2.5, VOC, SOx, CO, and CO2 emissions, there do not appear to be any major technical challenges. It is recommended that EPA and USCG collaborate with Canada, ports, terminal operators, and shipping companies to adapt VTS for the calculation calculating ship emissions.

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ACRONYMS

AAPA	American Association of Port Authorities
ACES	Air Consulting and Engineering Solutions
ARB	(California) Air Resources Board
AS	Actual Speed
CAA	Clean Air Act
CEQA	California Environmental Quality Act
CHE	cargo handling equipment
CNG	compressed natural gas
CO	carbon monoxide
DOT	(United States) Department of Transportation
DWT	dead weight tonnage
DPM	diesel particulate matter
EEA	Energy and Environmental Analysis Inc.
EEZ	exclusive economic zone
EPA	(United States) Environmental Protection Agency
g/kWh	grams per kilowatt-hour
HC	hydrocarbons
HP	horsepower
HSD	high-speed diesel
IMO	International Maritime Organization
kg	kilograms
kW	kilowatts
LADCO	Lake Michigan Air Directors Consortium
LF	Load Factor
LPG	liquefied petroleum gas
MCR	maximum continuous rating
MDO	marine diesel oil
MEPA	Marine Exchange/Port Authority
MGO	marine gas oil
MOVES	MOtor Vehicle Emission Simulator
MPO	metropolitan planning organization
MS	maximum speed
MSD	medium-speed diesel
NAAQS	National Ambient Air Quality Standard
NATA	National Air Toxics Assessment
NEI	National Emissions Inventory
NEPA	National Environmental Policy Act
NOx	nitrogen oxides
OGVs	oceangoing vessels
PM	particulate matter
PoLA	Port of Los Angeles
ppm	parts per million
PWD	pier/wharf/dock
RO	residual oil
RORO	Roll-on/Roll-off (ships)
SCC	Source Classification Codes
SIPs	State Implementation Plans
SOx	sulfur oxides

SSD	slow-speed diesel
ST	steam turbines
TOG	total organic gases
USACE	United States Army Corp of Engineers
USCG	United States Coast Guard
VIUS	Vehicle Inventory and Use Survey
VMT	vehicle miles traveled
VOC	volatile organic compound
VTS	Vessel Traffic System