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Report on the Recommended Method to Measure the Carbon Footprint of a USCG Vessel

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16. Abstract Executive Order (E.O.) 13514 directs Federal agencies to lead by example in improving energy efficiency and managing greenhouse gas (GHG) emissions. In response to this directive, the U.S. Coast Guard embarked on developing an initial defensible methodology to quantify the annual GHG emissions and resulting carbon footprint of the U.S. Coast Guard (USCG) vessel fleet. The initial methodology (as outlined in the Appendix) was developed for specific emission sources to provide for the effective evaluation of management decisions. The initial methodology was assessed and, due to data limitations and the evolving science behind GHG inventory, modified to consider only the consumption of hydrocarbons (i.e. fuels) and shore-side electrical power. This change was necessary in order to conform to other ongoing Agency efforts in GHG inventory and reporting efforts. For example, emissions from employee commute were excluded awaiting results from DHS agency-wide survey. Consumables and supply chain emissions were excluded awaiting the release of Federal guidance and recommendations. Therefore, the current methodology may be enhanced as new research and data become available. This methodology development is presented and recommendations for future work are made.					
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EXECUTIVE SUMMARY

Executive Order (E.O.) 13514 directs Federal agencies to lead by example in improving energy efficiency and managing greenhouse gas (GHG) emissions. The U.S. Coast Guard (USCG), with its valued reputation as a protector of the marine environment, desires to be in the forefront of this initiative by evaluating and adapting solutions that serve to assess and reduce its carbon footprint. The purpose of this study is to develop an initial defensible methodology to quantify the annual greenhouse gas (GHG) emissions that are attributable to the operations and major recurring maintenance of the USCG fleet.

Executive Order 13514, issued in October 2009, directs Federal agencies to improve energy efficiency and reduce GHG emissions. The Council on Environmental Quality (CEQ) and the Department of Energy's Federal Energy Management Program (FEMP) provide Federal Agencies with guidance to calculate and report their direct (Scope 1), indirect (Scope 2) and other indirect (Scope 3) GHG emissions at the Agency level, e.g. through the FEMP Annual GHG and Sustainability Data Reporting Portal. Federal GHG guidance and reporting are expected to be continually updated to improve the methodology and to incorporate additional requirements.

Although the portal is the Federal mandatory reporting tool, the CEQ Guidance does not preclude agencies from developing additional methodologies and tools for determining their GHG emissions. The USCG desires the ability to conduct an independent assessment of the carbon footprint of all USCG vessels. The development of a detailed, adaptive methodology will enable the USCG to evaluate the impact of management decisions and technical changes to the fleet's carbon footprint.

GHG emissions from a vessel include a variety of emission sources, such as direct emissions from engine and generator operations and indirect emissions from purchased electricity, employee commuting, and the supply chain. The preliminary GHG estimation methodology was organized by individual source categories, such as engine, generator, and boiler emissions. It also included upstream and downstream activities and processes associated with operations, including such items as employee commute and waste disposal ashore. After the data collection effort and usability review (target vessels included the 270' Medium Endurance Cutter and Response Boat Small [RB-S]), the preliminary methodology was assessed and reorganized.

The resultant final methodology retains only four of the thirteen emission categories included in the preliminary methodology. Five sections (vessel propulsion, vessel electrical generation, boiler, helicopter, and cutter boat emissions) were combined into one section (vessel hydrocarbon emissions). The consolidation is necessary because the existing USCG vessel operating and maintenance documentation system requires only a high level documentation of fuel/hydrocarbon and shore-side electrical power consumption. The major recurring maintenance category is excluded because fuel consumption associated with this category is accounted for by fuel procurement data. Two sections: Towing Vehicle and Employee Commute were removed from the calculation to avoid overlap with other ongoing Agency efforts (e.g. the FEMP reporting portal requires the use of the Federal Automotive Statistical Tool for reporting General Services Administration-leased vehicle emissions, DHS agency-wide commuting survey, etc.). Consumables and supply chain emissions are excluded pending the release of Federal guidance and



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recommendations. Four sections: solid waste shore disposal, liquid waste shore disposal, refrigerant, and fire suppressant emissions, were determined to be *de minimis* contributors sources and excluded.

In general, results indicated that fuel consumption (e.g. vessel engine and generator power consumption) is the single largest source of GHG emissions for a major USCG cutter, representing 75-90 percent of the total carbon footprint. Shore-side electrical power consumption accounts for approximately 10-15 percent. The RB-S does not use shore power; therefore, fuel consumption is the only contributor to the carbon footprint of the RB-S class. All other emission sources contribute less than a few percent to the vessel's overall carbon footprint. It is important to note that the estimates discussed in this report serve as a snapshot of the GHG contributor for the target vessel studied. They may not represent a uniform and common trend across different classes of USCG vessels or even across similar vessels of a class in different homeports.

The primary sources of data being used are the USCG's financial procurement database and data collected from individual vessels and homeports. It is important to note that the reliability of the carbon footprint calculation is a direct function of the accuracy of the source data. It is recommended that the USCG should continue to improve the accuracy of the source data while maintaining the current carbon footprint methodology based on annual fuel and shore-side energy consumption. Data quality can be dramatically enhanced through the installation of vessel switchboard or pier side shore-tie monitoring equipment. Additionally, installation of vessel fuel meters and automated data logging capabilities aboard a small sample of USCG classes (such as those capable of monitoring and recording information such as the WMSL) can have a significant impact on refining the methodology.

Although the current methodology does not provide for effective evaluation of management decisions, it provides a baseline for emission mitigation strategies, while performance can be tracked through future improvement in data collection techniques. Results from the preliminary GHG estimation are used to determine the significance of emission sources. Therefore, energy efficiency measures and technologies can be identified and prioritized based on the relative impact on the total carbon footprint.

The report concludes with recommendations for further studies that will lead to improvements in the vessel carbon footprint estimation. It should be noted that this report reflects current best practices and provides a framework for expansion; it is not intended to be the conclusion of methodology development. To better understand and meet future GHG reporting needs, the USCG should continually update the methodology to incorporate and ensure consistency with current Federal GHG guidance.



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DEFINITIONS

- **Boat** – Any type of Coast Guard vessel not considered a cutter. Coast Guard boats are unnamed vessels under 65' in length.
- **Carbon Footprint** – An assessment of the greenhouse gas emissions associated with the operation, major recurring maintenance of Coast Guard vessels, expressed in units of CO₂ equivalence.
- **Consumables** – An ancillary input necessary for a process to occur but not present in the end result and/or items which have an expected lifespan of 1 year or less.
- **Defendable Methodology** – A methodology which recognizes, but is not constrained by international best practice, records any assumptions made, and is transparent in its manipulation of data.
- **Deployable Assets (Helicopters and Small Boats)** – Operational units (personnel and hardware) that deploy with a Coast Guard vessel (under control of the operational command).
- **Direct Emissions** – Direct emissions are from sources that are owned or controlled by the organization, e.g., emissions from combustion in owned or controlled engine, boilers, air conditioning equipment, etc.
- **Fugitive Emissions** – An intentional or unintentional release of greenhouse gases through events such as leaks, spills and evaporation. An example of fugitive emissions is refrigerant leaked during the operation and maintenance of refrigerant equipment.
- **Greenhouse Gases** – The four greenhouse gases and two groups of gases defined within the Kyoto protocol, namely: Carbon Dioxide (CO₂), Nitrous Oxide (N₂O), Methane (CH₄), Sulfur Hexafluoride (SF₆), Hydrofluorocarbons (HFCs) and Perfluorocarbons (PFCs).
- **Indirect Emissions** - Emissions that are a consequence of the activities of the organization, but occur at sources owned or controlled by another company or organization. Indirect emissions for the purchaser are characterized as direct emissions for the facility where the emissions are generated. An example of indirect emissions is the emissions from the generation of purchased electricity consumed by an organization.
- **Material Contribution** – (For this methodology) an emission source that, at a minimum, accounts for one percent of the total carbon footprint of a vessel.
- **Major Recurring Maintenance** - (For this methodology) planned maintenance activities likely to make a material contribution.
- **Operational Control** – Exists when an organization or one of its subsidiaries has the full authority to introduce and implement its operating policies at the operation.
- **Scope 1 Emissions** – All direct GHG emissions from sources that are owned or controlled by the entity, in this case, a USCG vessel.
- **Scope 2 Emissions** – Indirect GHG emissions from the consumption of purchased electricity, heat or steam.
- **Scope 3 Emissions** – All other indirect emissions that are not Scope 2. Scope 3 emissions are a consequence of the activities of the organization, but come from sources not owned or controlled by that organization. Examples includes: the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g., transmission and distribution losses) not covered under Scope 2, outsourced activities, waste disposal, etc.



LIST OF ACRONYMS AND ABBREVIATIONS

ALMIS	Asset Logistics Management Information System (US Coast Guard)
BSU	Base Support Unit
BTU	British Thermal Unit
CAFÉ	Corporate Average Fuel Economy
CARROT	Climate Action Registry Reporting Online Tool
CEQ	Council on Environmental Quality
CH ₄	Methane
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
CO ₂ -e	Carbon Dioxide equivalent
DHS	Department of Homeland Security
DOC	Degradable Organic Compound
DOD	Department of Defense
eGRID	Emissions & Generation Resource Integrated Database
EIA	Energy Information Administration
EISA	Energy Independence and Security Act
E.O.	Executive Order
EPA	Environmental Protection Agency
EPAct	Energy Policy Act
EPCA	Energy Policy and Conservation Act
FAST	Federal Automotive Statistical Tool
FEMP	Federal Energy Management Program
FOD	First Order Decay
FY	Fiscal Year
GHG	Greenhouse gas
GRP	General Reporting Protocol
GSA	General Services Administration
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbons
HHV	Higher Heating Value
ICLEI	ICLEI - Local Governments for Sustainability (formerly the “International Council for Local Environmental Initiatives”)
IEAP	International Emissions Analysis Protocol
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
kWh	Kilowatt Hour
LGO	Local Government Operations
LTO	Landing/Take-off



LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

MARPOL	International Convention for the Prevention of Pollution from Ships
MBTU	Million British Thermal Units
MCF	Methane Correction Factor
MPG	Miles Per Gallon
MY	Model Year
N ₂ O	Nitrous Oxide
NHTSA	National Highway Traffic Safety Administration
NO _x	Nitrogen Oxide - NO and NO ₂
ODS	Ozone Depleting Substance
PFC	Perfluorocarbons
PM	Particulate Matter
PTO	Power Take-off
RB-S	Response Boat - Small
RB-M	Response Boat- Medium
RGGI	Regional Greenhouse Gas Initiative
SF ₆	Sulfur Hexafluoride
SO ₂	Sulfur Dioxide
SW	Solid Waste
SWBS	Ship Work Breakdown Structure
T&D	Transmission and Distribution
USCG	U.S. Coast Guard
VOC	Volatile Organic Compound
WBCSD	World Business Council for Sustainable Development
WMEC	Medium Endurance Cutter
WPB	Coastal Patrol Boat
WRI	World Resource Institute
WTGB	Icebreaking Tug



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1 INTRODUCTION

1.1 Background and Objective

The Federal government has indicated that it will be placing an emphasis on environmentally friendly and sustainable energy solutions for national initiatives and federal government operations. Executive Order (E.O.) 13514, directs Federal Agencies to lead by example in improving energy efficiency and managing greenhouse gas (GHG) emissions. The requirements specified within the E.O., along with the reputation of the U.S. Coast Guard (USCG) as a protector of the marine environment, are the driving force for the USCG to address GHG emissions. The USCG is in the process of evaluating and adopting solutions that serve to reduce its carbon footprint.

The primary objective of this study is to develop a defensible methodology to measure the annual carbon footprint of USCG vessels, both underway and in port. The method established will allow the USCG to identify GHG reduction opportunities where investments in equipment, procedures, and training would yield the greatest reductions. Finally, the methodology and associated methodology assessment workbook can be updated and applied to all classes of USCG cutters and all USCG boats.

1.2 Scope of Study

This methodology is restricted to the GHGs defined by the Kyoto Protocol, which are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), sulfur hexafluoride (SF₆), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs). While recognizing ozone depleting substances (ODS) also contribute to global warming, this study does not address ODS as they are covered by the 2000 Montreal Protocol on Substances that Deplete the Ozone Layer¹. Moreover, other environmental pollutants such as particulate matter (PM) and nitrogen oxides (NO_x) are not covered in this study.

The first phase of this effort was to establish a preliminary methodology to measure the carbon footprint of a USCG vessel. The preliminary methodology included all Scope 1 (direct GHG emissions), Scope 2 (indirect GHG emissions from purchased electricity), and Scope 3 (all other indirect GHG emissions) emission sources. The methodology is revised in the second phase of the project, after assessing the usability of the preliminary methodology through data collection and practical application on a 270' Medium Endurance Cutter (WMEC) and Response Boat Small (RB-S). Data collection and methodology refinement are expected to continue as the USCG, along with the rest of the Federal government, further develops and refines the processes and standards through which GHG emissions will be measured, reported, and ultimately reduced. This report consolidates results from both phases of this study.

¹ The treaty was signed on September 16, 1987, and entered into force on January 1, 1989. It was adjusted and/or amended in 1990, 1992, 1995, 1997, 1999, and published in 2000.



2 TECHNICAL APPROACH

2.1 Organizational and Operational Boundaries

Establishing organizational and operational boundaries is critical for identifying the sources of GHG emissions. The organizational and operational boundaries were used to determine the emission sources that the USCG controls. Operational boundaries further categorize emissions resulting either directly (Scope 1) or indirectly (Scope 2 and 3) from vessel activities. Boundaries for this carbon footprint assessment were based on an agreed set of guidelines rather than a list of specific processes, with all processes evaluated against these guidelines. This reduces the likelihood that a process is identified in the future which can be considered both within and outside the boundary. The following criteria determine the boundaries of the activities and processes considered:

- All processes that occur during the operation of a Coast Guard vessel and its deployed assets either underway or at pier;
- All processes from mobile assets;
- All processes from major recurring maintenance;
- Only processes that can be controlled or influenced by the vessel's operational or maintenance command; and
- Only factors that make a material contribution (account for one percent or more of the total carbon footprint of a vessel).

The project team held a one-day workshop in March 2010 to define terms, set boundaries and map the systems and processes for determining the carbon footprint of USCG vessels and boats. The key goals of the workshop and the initial steps of defining the process map are as follows:

- Producing a map of headline processes within the system boundary.
- Producing a map of sub-processes behind each headline.
- Identifying inputs and outputs of energy and materials for these processes.

The final product of the workshop was a preliminary process map, including process inputs and outputs, to be used in creating a GHG inventory. The resulting process map is provided in Appendix A.

2.2 GHG Legislation and Guidance

Federal agencies are required to inventory and manage GHG emissions to meet Federal goals and mitigate climate change. This section focuses on summarizing key Federal GHG legislation and programs for the management and reporting of GHG emissions. Appendix B provides additional detailed information on GHG emissions and other relevant energy legislation and programs.

Although the current legislation does not specifically call for the reduction of GHG emission from marine vessels, the legislation may influence strategic objectives and actions at the agency level for reducing vessel emissions. According to the Department of Homeland Security (DHS) Sustainability Plan, Scope 1 and 2



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emissions include mobile sources such as vehicles, aircraft, and marine vessels. As a result, vessel GHG emissions are an integral part of the DHS GHG inventory.

2.2.1 GHG Legislation (E.O. 13514)

On October 5, 2009, President Obama signed E.O. 13514 to require Federal agencies to measure, manage, and reduce GHG emissions. The E.O. requires agencies to set agency-wide reduction targets and provides a number of overall reduction goals for energy, water, and waste. Specifically, Section 8 requires agencies to develop integrated Strategic Sustainability Performance Plans (Sustainability Plan) to implement and achieve the goals and GHG reduction targets of the E.O.

In response to E.O. 13514, the government-wide GHG reduction goal is 28 percent for Scope 1 and 2 emissions and 13 percent for Scope 3 emissions by 2020 relative to the 2008 baseline. The DHS's goal is to reduce Scope 1 and 2 GHG emissions by 25 percent² from the fiscal year (FY) 2008 baseline inventory. The DHS Sustainability Plan sets the USCG's Scope 1 and 2 reduction goals at 25 percent. Additionally, DHS components (including the USCG) are responsible for preparing Operational Sustainability Performance Plans to implement the goals, targets and objectives of the DHS Sustainability Plan. DHS has not announced the Scope 3 reduction target, however, three emission categories³ will be included in the initial Scope 3 target.

Section 18 of the E.O. provides exemption for tactical operations such as aircraft, ships, and armored vehicles, however, it is important to recognize that while certain sources of GHG emissions are excluded from agency's reduction targets, these sources are not excluded from the agency's inventory or reporting requirements.

2.2.2 GHG Guidance

2.2.2.1 Council on Environmental Quality (CEQ) Guidance

The CEQ's Federal Greenhouse Gas Accounting and Reporting Guidance (CEQ Guidance) provides the procedures for Federal agencies to comply with Section 2 of E.O. 13514. It follows the basic guidelines found in the U.S. Public Sector Protocol. The Technical Support Document to the CEQ Guidance provides detailed information on the inventory reporting process and accepted calculation methodologies. Under the CEQ Guidance, agencies can develop agency-specific tools for GHG estimation. However, agencies must ensure that any agency-specific tools are appropriately aligned with the Guidance and the Technical Support Document. Moreover, CEQ requires that no *de minimis* reporting threshold exists for required emission categories. To exclude reporting of small or trace quantities of emissions for which full accounting may be particularly difficult or costly, the agency must explicitly detail and report its rationale for excluding the emission source. The CEQ Guidance is expected to be continually revised to improve the methods and incorporate additional requirements for calculating GHG emissions.

² DHS Strategic Sustainability Performance Plan, June 2010.

³ Category 1 - Transmission and distribution (T&D) losses from purchased energy. Category 2 - Federal employee travel. Category 3 - Contracted waste disposal



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2.2.2.2 *Federal Energy Management Program (FEMP) Reporting Portal*

The FEMP Reporting Portal was developed in compliance with Section 9 of E.O. 13514. Although all agencies are required to report their GHG inventory through the centralized reporting portal, E.O. 13514 does not preclude the use of other tools to support the agency's GHG inventory development. The FEMP Reporting Portal contains an Excel workbook that provides electronic reporting capability for the Federal agencies to compile and report comprehensive GHG inventory for fiscal year 2010 and the base-year 2008 GHG inventory. It collects agency-aggregated data for calculating Scope 1, 2, and 3 GHG emissions. The FEMP Reporting Portal aligns with the CEQ Guidance and transparently incorporates all of the approved methodologies and conversion factors contained in the Technical Support Document. FEMP expects to release subsequent versions of the GHG and Sustainability Data Report (FEMP Reporting Portal) to increase usability and functionality and, if necessary, correct any errors in calculating emissions or other performance metric outputs. This study analyzed the latest FEMP Reporting Portal that was released on November 9, 2010. For vessel specific emissions, only a few of the tabs apply and require data input from a USCG vessel.

2.2.2.3 *Public Sector Standard*

Also known as the Public Sector Protocol, the Public Sector Standard was developed by the World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI). It provides guidance for Federal, State, and local agencies for accounting and reporting GHG emissions. Based on the Corporate Standard, the Public Sector Standard covers six GHG from the Kyoto Protocol. The Public Sector Standard applies the principles of financial accounting and reporting to ensure the accurate account of an agency's GHG emissions. These principles include relevance, completeness, consistency, transparency, and accuracy. They have been widely adopted by U.S. and international programs such as the Climate Registry and ICLEI - Local Governments for Sustainability (formerly the "International Council for Local Environmental Initiatives").

2.2.2.4 *2006 IPCC Guidelines for National Greenhouse Gas Inventories*

The 2006 Guidelines are built on the revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines and the subsequent Good Practice reports. The guidelines are designed to assist countries in compiling national inventories of greenhouse gases. Default values for various parameters and emission factors are provided based on sectors. The IPCC also manages the IPCC Emission Factor Database (EFDB). The EFDB, a repository of emission factors and other relevant parameters, was launched in 2002 and is regularly updated. However, country-specific emission factors and parameters are recommended for more accurate emission estimates.

2.3 Development of the Preliminary Methodology

The preliminary methodology for calculating a USCG vessel's carbon footprint was developed from the headline processes identified during the March 2010 workshop brainstorming exercise (see Appendix A). Two constraints had significant impact on the preliminary methodology development. First, the expected lack of data drove the team to start this methodology from theoretical vessel design information. Second, in order to provide the ability to evaluate future management decisions and technical changes to the vessels, each independent section of the methodology was built such that the carbon footprint impact of potential future changes could be evaluated against the current carbon footprint baseline. Specific details of the preliminary methodology are contained in Appendix C.



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2.4 Assessing the Preliminary Methodology

Methodology development and its subsequent usability assessment are part of an iterative process. Figure 1 outlines the usability assessment process undertaken during this study. In order to provide a better understanding of the methodology's capabilities, limitations, and uncertainties, the team developed a Microsoft Excel Methodology Assessment Workbook using the preliminary methodology. Two USCG target vessels, the 270' Medium Endurance Cutter (WMEC) and the 25' Response Boat Small (RB-S)⁴, were used to develop this workbook. The Methodology Assessment Workbook relies on both actual and theoretical/analytical data in estimating the vessel's carbon footprint. See Appendix D for a brief description of the Methodology Assessment Workbook.

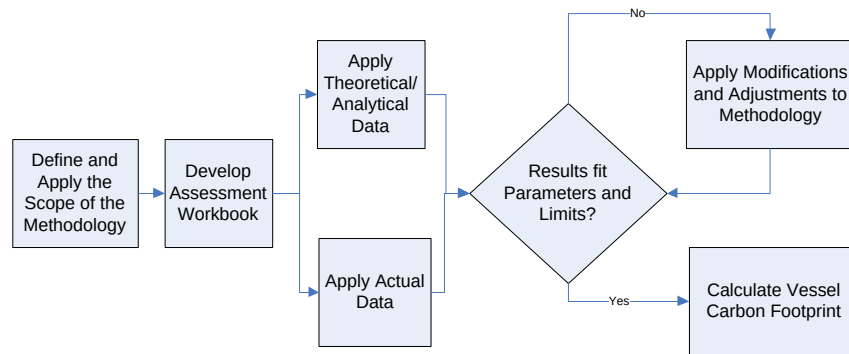


Figure 1. Methodology usability assessment process.

The usability assessment process identified areas of concern and enabled incorporation of appropriate adjustments to the preliminary methodology. For example, in estimating the vessel's shore power electrical consumption, actual shore tie electrical metering information provided by the Base Support Unit Portsmouth, Virginia, was used and compared to the analytical electrical power consumption calculated based on cutter characteristics and estimated electrical loading. When the methodology was assessed, it was found that the original planned in-port estimation was significantly different from the actual data collected due to differences in assumptions as well as technical changes to the vessel. As a result, a correction factor was derived to account for the data limitations and to improve the overall accuracy of the workbook. The usability analysis provides an assessment of the influence of data quality on the performance of the methodology. Specific usability assessment results are summarized in Section 3.2.3.

⁴ The Response Boat Medium (RB-M) was initially chosen as the target small boat. However, the desire was to use a small boat that was trailerable in order to investigate the sources of trailering information. Thus for the usability analysis the target small boat was shifted to the RB-S.



3 RESULTS (METHODOLOGY ASSESSMENT)

3.1 Assumptions

3.1.1 FEMP Reporting Portal

As explained in Section 2.2.2, the FEMP Reporting Portal is the Excel-based file in which all Federal agencies must submit their GHG emission information. Although the FEMP portal does not preclude any agency from calculating their carbon footprint independently, following the suggested input procedures and assumptions inherent in the FEMP Reporting Portal is conducive to comparing vessel emissions across Agencies (USCG versus National Oceanic and Atmospheric Administration versus the U.S. Navy, et cetera). The following assumptions made by the FEMP Reporting Portal affect the ongoing development of the USCG's Carbon Footprint Methodology and associated assessment workbook:

1. All movable resources that are not automobiles tracked by the General Services Administration (GSA) Federal Automotive Statistical Tool (FAST) are considered mobile resources. The fuel consumed by these mobile resources must be assigned generic fuel types.
2. The FEMP Reporting Portal requires output from the FAST system for all automobiles captured under it.
3. For contracted liquid waste disposal, the FEMP tool applies waste generation rates.
4. For purchased electricity, the amount of electricity consumed (organized by zip code) must be entered according to building energy status.

Specific effects of these assumptions on the USCG Vessel Carbon Footprint Methodology are addressed in applicable parts of Section 3.2.3.

3.1.2 Exclusion of the Supply Chain

During the early methodology scoping process, the supply chain emissions were considered outside the boundary. Primarily, this was due to the E.O. tasking GSA, along with the Department of Defense (DOD) and the Environmental Protection Agency (EPA), to specifically provide recommendations "regarding the feasibility of working with the Federal vendor and contractor community to provide information that will assist Federal agencies in tracking and reducing Scope 3 greenhouse gas emissions related to the supply of products and services"⁵. Additionally, in order to determine the carbon footprint for a particular product, the vendor and distributor will be required to determine their emissions related to the production and distribution of that product. It would be more cost-beneficial to focus on the emission sources within the scope and control of the USCG at this time and to postpone further development until GSA and DOD propose to incorporate the GHG emissions from the Federal supply chain.

⁵ Executive Order 13514- Federal Leadership in Environmental, Energy, and Economic Performance, Section 13, Recommendations for Vendor and Contractor Emissions



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3.1.3 Exclusion of Major Recurring Maintenance

It was anticipated that major recurring maintenance could make a material contribution to the vessel's GHG emissions and resulting carbon footprint. This may still be the case, however at this time, major maintenance items are not included in the current methodology for the following reasons.

3.1.3.1 *Supply Chain Exclusion*

A significant portion of the carbon footprint of the vessel maintenance emissions is expected to come from the supply chain. For example, the condition-based overhaul of a major piece of equipment may require use of several hundred replacement parts and consumables, where each part and consumable has an associated carbon footprint. Without proper accounting of the supply chain emissions, GHG emissions from maintenance activities may not be accurately assessed. Thus, the maintenance emissions may be investigated in the future when supply chain guidance and recommendations become available

3.1.3.2 *Hydrocarbon Consumption*

The consumption of hydrocarbons may be a significant component of vessel maintenance emissions. Many maintenance activities and the subsequent equipment test require the combustion of fuels or hydrocarbons. For example, in the case of major engine overhaul, engine lube oil is normally replaced and the engine also undergoes a test run upon completion of the maintenance. Both of these actions have a direct scope 1 emission impact. However, lube oil and fuel oil consumption is already taken into account when using hydrocarbon procurement information as the data source. Any attempt to allocate hydrocarbon consumption to major maintenance actions may result in a duplication and overestimation of the footprint.

3.1.3.3 *Shipyard / Vessel Boundary*

After numerous discussions among the team and the USCG during the workshop, preliminary methodology development and again during the mid-period progress meeting, the USCG agreed that only major maintenance actions actually performed onboard the vessels would be within the boundary of the vessel. This precluded many of the major maintenance activities that are conducted at the shipyard. Major maintenance activities may be an area to be explored in the future.

3.1.3.4 *Conditional Maintenance Impact*

The USCG has a bi-level maintenance philosophy and a majority of the maintenance activities occur on a conditional basis. The Cutter Class Maintenance Plans were reviewed in an attempt to allocate major maintenance tasks to specific time periods. This would have enabled the calculation of a carbon footprint on a periodic (annual) basis. Unfortunately, the majority of the major maintenance tasks are conditional (as was expected), and the conditions do not lend themselves to any sort of periodic accounting.

3.1.4 Application of *de minimis*

De minimis refers to a minimum emission threshold below which reporting is not required. According to the CEQ Guidance, Federal agency GHG inventories have no *de minimis* reporting threshold for required emission categories. The current vessel carbon footprint methodology applied a one percent threshold to exclude emissions that do not make a "material contribution" to the overall footprint. This assumption was made prior to the publishing of the CEQ guidance.



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Although this assumption is contrary to the current CEQ Guidance, the current methodology is focused on accounting for emission sources for which reliable and accessible data are available, and for which more detailed and accepted calculation methodology have been established. Due to data limitations, and the USCG's ongoing effort to improve the ability to collect and synthesize data, *de minimis* emissions are not evaluated at this time. It is important to note that the CEQ Guidance does stipulate that if an agency desires to exclude trace emissions from reporting and no alternatives exist, the agency must explicitly detail and report its rationale for excluding the emission source.

In order to appropriately reflect the true impact of fugitive emissions from refrigeration equipment aboard the vessel, an accurate inventory of the equipment and charge capacity are required. Currently, the USCG does not have a comprehensive inventory of the refrigeration equipment; therefore, the inclusion of the fugitive emissions would have negative impact on the accuracy of the vessel carbon footprint. Moreover, a large fraction of *de minimis* emissions are Scope 3 emissions (such as contractor waste disposal). As accepted methods for calculating Scope 3 emissions are evolving, these emissions are excluded from the current vessel carbon footprint. The goal of this approach is to continually improve data quality, while incorporating new procedures in future methodology development. Specific *de minimis* assumptions are detailed in Section 3.3.

3.2 Limitations

3.2.1 Fuel Temperature Uncertainty

Fuel consumption is the largest contributor to the vessels carbon footprint. Any error in the determination of the amount of fuel consumed by a vessel will have a significant effect on the overall carbon footprint of the vessel. The fuel consumption data currently being used to assess the carbon footprint of a USCG vessel comes from the USCG procurement database. The data for this database comes from the monthly fuel reports of each vessel. These fuel reports do not indicate temperature corrections when reporting the volume of fuel used. To determine the potential magnitude of this temperature uncertainty, the effect of onloading fuel at one temperature and then reporting that fuel at another temperature was investigated. Details of this calculation are provided in Appendix E.

For the purpose of calculating fuel temperature uncertainty, a worst case scenario was investigated. It was assumed that F-76 was onloaded at 35°F (for example, winter in Kittery, Maine) and then measured at 90°F water for the monthly fuel report (after transiting to Key West, Florida to start a patrol). The average percent change in fuel volume due to temperature alone is over 2.5 percent. Assuming 70 percent of the vessels carbon footprint can be attributed to fuel consumption, this temperature correction will influence the overall carbon footprint of the vessel by as much as 1.8 percent. Thus, this fuel temperature uncertainty makes a material contribution to the carbon footprint of the vessel.

3.2.2 Higher Heating Value Uncertainty

The higher heating value (HHV) of a fuel refers to the amount of heat released by a defined quantity of the fuel (initially at 25°C) when it is combusted and allowed to cool to its original temperature. The HHV (as opposed to the lower heating value) assumes that all water in combustion products is in the liquid state. The common units representing the HHV of a substance are British thermal units (BTU)/lb. It is important to



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note that the HHV of a fuel does not change with temperature (e.g., a fuel stored at 5°C will have the same HHV as that same fuel stored at 35°C).

The FEMP Reporting Portal (issued November 9, 2010) provides a list of fuels and specifies their HHV. In order to stay in alignment with the CEQ guidance and the FEMP portal, these HHVs were utilized in the methodology assessment workbook. Additionally, for the purposes of calculating the carbon footprint, the HHV of a liquid fuel is given in terms of BTU/gal, meaning that a density of the fuel was assumed in the CEQ guidance and FEMP portal. The CEQ and the FEMP portal do not include the specific fuels used by the USCG vessels. As a result, many of the widely-used fuels are assigned a generic HHV in the methodology assessment workbook. The difference between using a generic factor as opposed to a more specific one was a concern; therefore, this discrepancy was investigated.

In the case of the fuel F-76, other data sources⁶ are available to provide the HHV of that particular fuel. Using the specific HHV for F-76 would yield a carbon footprint nearly 7 percent smaller than if the generic HHV provided from the CEQ guidance is used (assuming the usage of the same emission factors). See Appendix E for the calculations of HHV uncertainty.

3.2.3 Emission Factor Uncertainty

The current CEQ Guidance and the FEMP Reporting Portal do not document the uncertainties associated with emission factors; however, the IPCC Guidelines describe the uncertainties of CO₂, N₂O, and CH₄ emission factors. The CO₂ emission factors for fuels are generally well-determined as they are primarily dependent on the carbon content of the fuel. For example, the default uncertainty value for diesel fuel is about ± 1.5 percent. The uncertainty for non-CO₂ emissions, however, is much greater because the factors not only depend on the fuel type but also the combustion process (engine versus turbine). The uncertainty of the CH₄ emission factor may range as high as 50 percent, and the uncertainty of the N₂O emission factor may range from about 40 percent below to about 140 percent above the default value.

3.3 Usability of the Preliminary Methodology

Table 1 summarizes the preliminary methodology development with details provided in Appendix C. This methodology served as the basis for the creation of the Methodology Assessment Workbook. The preliminary methodology sections were revised and updated to incorporate the results of the usability analysis. This section outlines the details of these changes, and Section 4 summarizes the final methodology. As the usability of the preliminary methodology sections was assessed, it became apparent that the carbon footprint of the RB-S is primarily tied to hydrocarbon consumption, much more so than the

⁶ Katikaneni, S., C. Yuh, S. Abens, and M. Farooque. "The Direct carbonate Fuel Cell Technology: Advances in Multi-fuel Processing and Internal Reforming." *Catalysis Today* 77 (2002) 99–106.

Tosh, J.D., D.S. Moulton, and C.A. Moses. "Navy Fuel Specification Standardization, Interim Report BFLRF No. 225." April 1992.

United States. Dept. of Defense. Detail Specification: Turbine Fuel, Aviation, Grades JP-4 and JP-5. MIL-DTL-5624U. 5 January 2004.

Bowden, J.N., S.R. Westbrook, M.E. LePera. "A Survey of JP-8 and JP-5 Properties, Interim Report BFLRF No. 253." September 1988.



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footprint of a major cutter. As such, the following sections primarily address the WMEC and the attempts to differentiate between different sources of carbon on the WMEC.

Table 1. Preliminary carbon footprint methodology.

Emission Source	GHG Emission	Scope (1, 2, 3)	Section #
Vessel Propulsion Emissions	CO ₂ , CH ₄ , N ₂ O	1	3.3.1
Vessel Electrical Generation Emissions	CO ₂ , CH ₄ , N ₂ O	1	3.3.2
Boiler Emissions	CO ₂ , CH ₄ , N ₂ O	1	3.3.3
Helicopter Emissions	CO ₂ , CH ₄ , N ₂ O	1	3.3.4
Cutter Boat Emissions	CO ₂ , CH ₄ , N ₂ O	1	3.3.5
Refrigerant Emissions	HFC	1	3.3.6
Fire Suppressant Emissions	CO ₂ , HFC	1	3.3.7
Incinerator Emissions	CO ₂ , CH ₄ , N ₂ O	1	3.3.8
Purchased Shore Power Emissions	CO ₂ , CH ₄ , N ₂ O	2 or 3	3.3.9
Towing Vehicle Emissions	CO ₂ , CH ₄ , N ₂ O	1 or 3*	3.3.10
Employee Commute Emissions	CO ₂ , CH ₄ , N ₂ O	3	3.3.11
Ashore Solid Waste Disposal Emissions	CH ₄ (Landfill)	3	3.3.12
Ashore Liquid Waste Disposal Emissions	CH ₄	3	3.3.13
* Scope 1 if the vehicle is under the operational control of the vessel. Scope 3 if the vessel is controlled and owned by the shore facility.			

3.3.1 Vessel Propulsion Emissions

3.3.1.1 Preliminary Methodology

The preliminary methodology for calculating the GHG emissions attributed to the vessel's main propulsion engines is contained in Appendix C. A major assumption of the preliminary methodology was that the raw fuel consumption information for the main engines could be coupled with the detailed operation profile data to determine the amount of annual fuel consumed. From that point, using the heating content and emission factors of the fuel, and application of the global warming potentials, the resultant equivalent metric tons of CO₂ (CO₂-e) could then be calculated. Tying the footprint to the operational profile would provide the ability to evaluate management decisions regarding vessel speed.

3.3.1.2 Assumptions, Limitations, and Analysis of Data

The inability to discern the load at which the engines were operating while at specific speeds became the significant limiting factor in utilizing this preliminary methodology. Sufficient data was available to detail the main engine operating hours. The theoretical operating profile provided a high-level correlation between vessel speed and time, and the vessel's fuel consumption curves provided the necessary information to which would relate engine load to fuel consumption. However, there was insufficient information available for relating vessel speed to engine load over time. In other words, the lack of "handle position" or specific engine speed data prevented the successful use of this preliminary methodology.

It was possible to determine lube oil consumption factors based on the engine operating hour logs from the data provided by the target WMECs. These engine hour logs provided the amount of lube oil added to each piece of main equipment (both propulsion diesel engine and generator prime mover), and they correspond to



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the number of operating hours for each piece of equipment. An engine lube oil consumption factor was created by averaging the lube oil consumption of each main engine on the three 270-WMECs during the reporting period. The same process was used for the generator prime movers. See Appendix E for those calculations.

3.3.1.3 *Changes from Preliminary Methodology*

Without the ability to determine fuel consumption based on the operations of the vessel, a higher-level approach must be taken to determine the annual fuel consumed by the vessel. Unfortunately, across the USCG fleet, once fuel has been loaded on board the vessels, there is currently no accurate method of tracking how much fuel is consumed by specific pieces of equipment without the installation of fuel flow meters and monitoring systems onboard the vessel to capture the fuel flow data. Without having the ability to differentiate how much fuel is used by each piece of equipment, the current methodology was significantly changed. The individual sections relating to specific pieces of equipment were removed and hydrocarbon consumption was consolidated into one section.

3.3.2 Vessel Electrical Generation

3.3.2.1 *Preliminary Methodology*

The preliminary methodology for calculating the GHG emissions attributed to operating the generators aboard a vessel is detailed in Appendix C. In order to aid the user in making management decisions regarding the use of electricity aboard the vessel, the team used the original vessel electrical load analysis as the source of electrical load information. Based on the design load analysis and the generator fuel consumption curves, an estimated amount of fuel consumed is calculated. From the total amount of fuel consumed, emission factors and global warming potentials are applied to calculate the amount of CO₂-e produced by the generator plant.

3.3.2.2 *Assumptions, Limitations, and Analysis of Data*

For the purposes of assessing usability, actual generator loads recorded over the month of September 2010 by the U.S. Coast Guard Cutter ESCANABA were utilized. Switchboard readings recorded by the watch section at two-hour intervals for the entire month enabled the creation of two correction factors based on the actual average load of a generator when in parallel and the actual average load of a generator when singled-up. The data indicates that the load on the generators are 3.6 times less when operating in parallel and 1.96 times less when operating singled up compared to the predicted average continuous cruise load from the electrical load analysis. See Appendix E for calculations.

The most-likely reason for the discrepancy comes from the nature of the design load analysis. By definition, the design load analysis is a prediction of what the original design team designed for the electrical load of the cutter based on estimated duty cycles of individual pieces of equipment. The primary purpose of the design load analysis is to size the electrical generation and distribution plant onboard the vessel. In addition, the design load analysis was created prior to the construction of the first ship of the class. The equipment on board the vessels has changed over the last thirty years and the load analysis is typically not maintained.

Once the power demand from each generator is determined, the fuel consumption curve was used to attain the gallons of fuel burned per hour to achieve that power. It was assumed that the fuel consumption curve



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remained constant throughout its maintenance cycle. Additional instrumentation of the vessel would be required to verify this assumption.

3.3.2.3 *Changes from Preliminary Methodology*

The design load analysis was used as the starting point of the methodology; however, a factor was applied to the design load to allow for a better estimate of the electricity consumption. Regardless, due to the inability to track fuel consumption to specific pieces of equipment, this section of the preliminary methodology was consolidated with the other hydrocarbon consumers in the current methodology.

3.3.3 **Boiler Emissions**

The preliminary methodology for calculating the GHG emissions attributed to operating a vessel's boilers is described in Appendix C. No boilers are installed on the WMEC and RB-S classes of vessels so the usability of this methodology could not be evaluated. Additionally, the fuel used to operate the boiler (on the 140' Icebreaking Tug for example) has already been captured by the fuel procurement data for the entire vessel. Including a separate methodology would result in double counting of this fuel. Finally, due to the inability to track fuel consumption to specific pieces of equipment, this section of the preliminary methodology was consolidated with the other hydrocarbon consumers in the current methodology.

3.3.4 **Helicopter Emissions**

3.3.4.1 *Preliminary Methodology*

The preliminary methodology for calculating the GHG emissions attributed to operating a deployed helicopter is in Appendix C. It was assumed that fuel consumption information could be directly ascertained from the vessel log books.

3.3.4.2 *Assumptions, Limitations, and Analysis of Data*

The RB-S does not have the capability to transfer JP-5 to a helicopter. Therefore helicopter emissions are not part of the RB-S carbon footprint. The helicopter resources aboard all USCG cutters use the kerosene-type fuel JP-5⁷. The fuel in the tanks must be refreshed every 42 days. To avoid offloading the JP-5 unused by the helicopters, JP-5 is typically transferred to the fuel service tanks and burned in the propulsion engines and generator sets. The monthly cutter JP-5 report messages document how much fuel is transferred to the helicopter, as well as how much JP-5 is burned by the vessel.

According to the CEQ Guidance, N₂O and CH₄ emission factors depend on the type of combustion equipment (engine, turbine, et cetera) used. Properly allocating the amount of JP-5 to the helicopters versus the usual diesel consumers on the vessel influences the overall vessel carbon footprint by less than one one-hundredth of a percent. It should be noted that there is no difference in the CO₂ emission factors when combusting JP-5 in a shipboard diesel or helicopter turbine engine because CO₂ emission factors depend mostly on the carbon content of the fuel, not the combustor. Furthermore, the FEMP Reporting Portal uses the same N₂O and CH₄ emission factors on all mobile resource fuels except biodiesel and ethanol. Consequently, there is no benefit to keeping track of the difference in how JP-5 has been consumed.

⁷ USCG COMDTINST M3710.2D, Shipboard-Helicopter Operational Procedures Manual



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3.3.4.3 *Changes from Preliminary Methodology*

Although the data is available to account for the difference between JP-5 consumed by the shipboard diesel engine and the helicopter turbine, the difference is insignificant. The preliminary methodology assumed that all of the JP-5 would be consumed by the helicopter. However, at this time, the preliminary methodology was excluded from the final methodology, and the JP-5 consumption is being consolidated with other hydrocarbon consumers into one section of the current methodology.

3.3.5 Cutter Boat Emissions

3.3.5.1 *Preliminary Methodology*

The preliminary methodology for calculating the carbon footprint of a small boat operating from a vessel is included in Appendix C. It was assumed that fuel consumption information attributed to the cutter small boats could be directly ascertained from either vessel log books or cutter fuel reports.

3.3.5.2 *Assumptions, Limitations, and Analysis of Data*

The 270-WMECs have both a diesel- and gasoline-powered rigid hull inflatable boat on board. The diesel cutter boats are refueled using the same fuel that is supplied to the main propulsion diesel engines and generator prime movers, with fuel taken directly from either a main engine or emergency generator service tank. It is important to note that cutters that use gasoline often do not consume the amount of gasoline procured. Depending on operations, the cutter is often unable to burn all of the gasoline in the required time; therefore, unused gasoline is often offloaded as waste oil at the end of a patrol. The amount of unused gasoline is not reliably documented. As a conservative estimate, it was assumed that all of the procured gasoline was burned aboard a vessel.

3.3.5.3 *Changes from Preliminary Methodology*

Due to the inability to reliably differentiate between fuel consumed by the cutter and fuel consumed by the small boat, the preliminary methodology of small boat fuel consumption is being consolidated with other hydrocarbon consumers under one section of the current methodology.

3.3.6 Refrigeration

3.3.6.1 *Preliminary Methodology*

The preliminary methodology for determining the GHG emissions attributed to refrigerant emissions is contained in Appendix C. The preliminary methodology recommended following an emission factor approach. The emission factor approach assumes no catastrophic system failures. A mass balance approach was also discussed but was not recommended. Regardless of the approach for determining the mass of refrigerant emitted, refrigerant fugitive emissions were multiplied by the global warming potential and converted into metric tons of CO₂-e.

3.3.6.2 *Assumptions, Limitations, and Analysis of Data*

There was essentially no information available beyond anecdotal reports regarding refrigeration consumption onboard the 270-WMECs. Over the past year, one vessel had multiple major refrigeration equipment casualties resulting in a much higher than normal R-134a emission. That vessel purchased approximately 300 pounds of R-134a, however half of that amount was used to replenish onboard spare



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bottles. A second WMEC used a much lower amount of refrigerant: only eight pounds of R-134A were utilized (emitted).

3.3.6.3 *Changes from Preliminary Methodology*

Using the emission factor approach, the predicted leakage of an average 270-WMEC is approximately 22 lbs per year. That equates to approximately 0.30 percent of the vessel's entire carbon footprint, an immaterial contribution. Using the emission factor approach would result in excluding refrigerant emissions from the current methodology. However, a catastrophic failure of the major refrigerant containing equipment onboard the WMEC may have a material effect on the overall carbon footprint of the vessel. In order to enable capture of these catastrophic failures, it is recommended that the USCG implement a mass balance approach to tracking refrigerant consumption.

3.3.7 Fire Suppression

3.3.7.1 *Preliminary Methodology*

The preliminary methodology for calculating the carbon footprint from the vessel's fire suppressing systems is presented in Appendix C. The preliminary methodology recommended an emission factor approach to keeping track the additions and consumption of fire suppressants. A mass balance approach was also discussed. As with refrigeration emissions, the mass of the fire suppressant was multiplied by the global warming potential and converted into metric tons of CO₂-e.

3.3.7.2 *Assumptions, Limitations, and Analysis of Data*

The fire suppressant capacity of equipment on the RB-S is significantly smaller, percentage wise, than the equipment capacity on the WMEC, so no further investigation was conducted in this area for the RB-S. The current list and location of fire suppressants were verified on several medium endurance cutters during the ship checks. RB-S crews do not keep a consolidated list of expended fire suppressants that were replaced, outside of individual invoices. Thus, it is not feasible to determine the actual amount of fire suppressant used by a vessel. Using the recommended leakage rates and planned preventative maintenance criteria, the carbon footprint of the mobile and fixed fire suppressants aboard the 270-WMEC is less than 0.002 percent of the vessel's total carbon footprint. Even if the entire system was released, the resulting emissions would still be immaterial.

It is important to note that CO₂ is the only greenhouse gas emitted by the fire suppressants aboard a 270-WMEC. Other USCG vessels use FM-200 as a fire suppressant. The active chemical in FM-200 is heptafluoropropane (HFC-227ea), which is 2,900 times more potent on the carbon footprint than CO₂. If FM-200 fire suppressants aboard those vessels were expended, the chance that fire suppressants could make up more than one percent of the carbon footprint is increased. Further research is required to verify this scenario.

3.3.7.3 *Changes from Preliminary Methodology*

The USCG currently does not keep sufficient records of fire suppressant usage on the WMEC, thus the usability of the mass balance or emission factor-based methodologies cannot be fully assessed. To create a baseline, the emission factor approach was used in the Methodology Assessment Workbook. Fire suppression remains in the final carbon footprint methodology due to the potential impact FM-200 systems



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have on the overall vessel carbon footprint. Until further notice, the fire suppression preliminary methodology remains intact in the final version.

3.3.8 Incinerator Emissions

The preliminary methodology for calculating the carbon footprint from using a vessel's incinerator is included in Appendix C. The WMEC and RB-S classes of vessels do not have incineration facilities, so the usability of this methodology could not be evaluated. This section of the methodology is being excluded from the current methodology. When assessing the usability of this section in the future, it is important to consider that the fuel used to operate the incinerators (on the WMSL class for example) is already captured by the fuel procurement data for the entire vessel. Including a separate methodology could result in double counting of this fuel.

3.3.9 Purchased Shore Power

3.3.9.1 *Preliminary Methodology*

Appendix C provides the preliminary methodology for calculating the carbon footprint from purchased shore power when the vessel is in port. In order to aid the user in making management decisions regarding the use of electricity aboard the vessel, the original design load analysis is used as the primary source of information regarding vessel electrical load. The design load was converted into kilowatt-hours (kWh). For the Scope 2 emissions associated with purchased shore power, an Emissions & Generation Resource Integrated Database (eGRID) subregion-based emission factors were applied to the expected amount of kWh consumed.

3.3.9.2 *Assumptions, Limitations, and Analysis of Data*

Measured shore tie consumption data for the 270-WMECs at the USCG Base Support Unit (BSU) in Portsmouth, Virginia, between the summer of 2009 and the summer of 2010 are used to assess the usability the design load analysis. BSU Portsmouth is the only known location for retrieving this type of data. This information indicates that the overall load is approximately 2.4 times less in the winter and 2.6 times lower in the summer than the design load analysis predicts (see Appendix E for calculations). The RB-S does not have an electrical shore tie

The inport electrical design load analysis has the same limitations as the underway electrical design load analysis. Furthermore, data collected from Portsmouth only represents the cutters which tied up in Portsmouth during that time frame, and may not be representative of the vessel class vessels for all of the ports of call. The loads were measured at shore tie terminals that served more than one ship, rather than on board each specific cutter. So, each set of readings was not necessarily associated with a specific vessel. Additional information would be required to associate an electrical load demand to a specific cutter. Additionally, the shore tie information has only been collected for one year. A greater data range would be required to increase confidence in the information collected. Finally, the climate of Portsmouth does not represent the range of temperatures (and consequently electrical loads) experienced by the WMEC class. In fact, Portsmouth is a rather temperate homeport when compared to the most northern or southern 270-WMEC homeports.



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3.3.9.3 *Changes from Preliminary Methodology*

The preliminary methodology was changed significantly due to the lack of electrical consumption data attributable to individual vessels. Though a correction factor was determined, the level of confidence in this correction factor is uncertain because it was derived based on data from unspecified vessels and from only one homeport. The preliminary methodology requires the collection of electrical consumption data from additional homeports and from specific vessels.

For reporting purposes, it is not feasible at this time to break out a vessel's electrical consumption data from a large base. It is recommended that the USCG develop the ability to separately measure electrical consumption from individual vessels that are tied should be included with the overall base/port electrical consumption. When it becomes possible to separate individual shore tie demands and track each individual demand to specific vessels, the more detailed methodology can be refined and utilized.

3.3.10 Towing Vehicle⁸

3.3.10.1 *Preliminary Methodology*

Appendix C provides the preliminary methodology for calculating the vehicle carbon footprint for boat towing operations. The intent of this investigation was to capture the operation of vehicles while towing a station small boat during operations. This would be a Scope 1 emission as a direct release of a GHG.

3.3.10.2 *Assumptions, Limitations, and Analysis of Data*

The Asset Logistics Management Information System (ALMIS) contains information relating to the operational towing of a station small boat by a small boat station vehicle. The departure and arrival locations are listed for each mission. The ability to extract this data from ALMIS is currently unknown. If the information becomes available, the related footprint associated with these events could be calculated and tied to the respective asset being towed.

In general, the USCG leases the towing vehicles from the General Services Administration. The FEMP portal requires agencies to utilize and export vehicle data from the FAST system. Thus, these towing vehicles will be rolled up and reported at the Agency level with the information flowing from the FAST system into the FEMP portal. There is no need to include these vehicles in the individual vessel methodology.

Another important consideration is the desire to maintain consistency with the rest of the vehicle fleet reporting process. Besides towing vehicles, cutters and small boat stations operate numerous other vehicles. Although these vehicles were deemed outside of the boundary at the beginning of this effort, the operation of these vehicles may be associated with the mission of the vessel. Therefore, it would be inconsistent to include boat towing emissions while excluding other vessel-related automobile emissions.

3.3.10.3 *Changes from Preliminary Methodology*

To avoid double **counting** and to maintain consistency with the FEMP vehicle reporting requirements, the final carbon footprint methodology for USCG vessels will not include a section on towing vehicles.

⁸ Before expending additional resources on investigating the impact of vehicles towing small boats for operational missions, it is recommended the reader review Table 3



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3.3.11 Employee Commute

The preliminary methodology for determining the carbon footprint from employee commute is shown in Appendix C. During the usability analysis, the team learned from the USCG Energy Manager that DHS is planning to conduct an agency-wide survey to capture the GHG emission impact of employee commute⁹. The inclusion of employee commuting in the vessel specific methodology, as well as in the DHS-wide survey, would create duplication of this portion of the total vessel's footprint. As a result, the employee commute section of the preliminary methodology was excluded from the current methodology.

3.3.12 Ashore Solid Waste Disposal

3.3.12.1 Preliminary Methodology

The preliminary methodology for calculating the carbon footprint attributable to the shoreside disposal of solid waste is shown in Appendix C. In order to determine the input for the carbon footprint attributed to solid waste, the design requirements from the USCG Appendix to the Naval Vessel Rules were utilized to specify the standard amount of solid waste produced by a vessel's crew per day.

3.3.12.2 Assumptions, Limitations, and Analysis of Data

Solid waste disposal is currently not monitored on an individual vessel basis within the USCG. When in port, the majority of vessels dispose of their waste into shoreside receptacles. That waste is then combined with the waste of several other units prior to disposal by the resident shoreside command.

FEMP requires reporting of solid waste as a weight within its portal. When inputting the same assumptions into the FEMP portal that were used in the assessment workbook, the predicted CO₂-e emissions from FEMP portal are less than emissions from the preliminary methodology. Discrepancies are likely due to differences in the assumed waste composition between the FEMP portal and the assessment workbook. Regardless, the anticipated carbon footprint from solid waste disposal is less than one percent of the total footprint using either method.

3.3.12.3 Changes from Preliminary Methodology

Solid waste emissions were excluded from the current methodology due to the immaterial contribution to the vessel's overall carbon footprint.

3.3.13 Ashore Liquid Waste Disposal

3.3.13.1 Preliminary Methodology

The preliminary methodology for calculating the carbon footprint attributable to the shoreside disposal of liquid waste is in Appendix C. In order to determine the amount of liquid waste generated by a vessel, the design requirements from the USCG Appendix to the Naval Vessel Rules were utilized to specify the standard amount of liquid waste produced by a vessel's crew per day.

⁹ Additionally, a default survey tool has been created by FEMP which allows federal employees to enter two different commuting options, each having up to two different commuting modes.



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3.3.13.2 Assumptions, Limitations, and Analysis of Data

Liquid waste (sewage and graywater) is typically disposed of via a shore tie into a main pier header. The quantity of waste disposed is not monitored on an individual vessel level. Additionally, complications exist for northern vessels that flow seawater through the shore tie during the colder months to prevent freezing of the shore tie.

FEMP requires reporting of liquid waste as a function of the number of people being serviced. FEMP uses factors that result in a slightly smaller predicted carbon footprint when compared results from the preliminary methodology. Regardless of calculation method, the carbon footprint generated by the vessel's crew will be less than one percent of the overall carbon footprint.

3.3.13.3 Changes from Preliminary Methodology

Liquid waste emissions were excluded from the current methodology due to their *de minimis* contribution to the vessel's overall carbon footprint.

4 CURRENT METHODOLOGY

The current methodology retained only four of the thirteen sections from the preliminary methodology. The paucity of data resulted in the combination of five sections (vessel propulsion, vessel electrical generation, boiler, helicopter, and cutter boat emissions) into one section (vessel hydrocarbon emissions). Four sections did not meet the *de minimis* criteria (solid waste shore disposal, liquid waste shore disposal, refrigerant, and fire suppressant emissions), although two, refrigerant and fire suppression, were retained. Finally, two sections had other methods put in place to account for GHG emissions (Towing Vehicle and Employee Commute) while one could not be evaluated due to the target vessels chosen (incinerator emissions).

Due to these changes, the current methodology and assessment workbook does not support management and technical decision making through assessment of the vessel's carbon footprint. This was readily apparent after conducting the usability analysis. However, the workbook allows the identification of the areas of operation that significantly contribute to the USCG vessel carbon footprint. In general, fuel consumption is ranked the highest in terms of the vessel's total carbon footprint. The emission sources included in the current methodology are listed in Table 2, and the details behind the current methodology are discussed in the sections that follow.

Table 2. Final carbon footprint methodology.

Emission Source	GHG Emission	Scope (1, 2, 3)
Vessel Hydrocarbon Emissions	CO ₂ , CH ₄ , N ₂ O	1
Purchased Shore Power Emissions	CO ₂ , CH ₄ , N ₂ O	2, 3
Refrigerant Emissions	HFC	1
Fire Suppressant Emissions	CO ₂ , HFC	1



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4.1 Vessel Hydrocarbon Emissions

An accurate accounting of the consumption of hydrocarbons is essential to the determination of a vessel's carbon footprint. Preferably, this information will be available in one central database containing sufficient information (e.g. type of fuel onboard, onload quantity, onload temperature, vessel, etc.) to allow proper calculation of the carbon footprint on an annual basis, per vessel. Currently, there is no such database in existence. At this time, it is recommended that the data available from the USCG procurement system be utilized.

Most vessels do not have an effective tank level indication system to keep an accurate enough track of the quantity of fuel onboard for the determination of the carbon footprint. Crews typically have to rely on soundings to determine the approximate tank levels of the vessel. Soundings are inherently unreliable due to such common shipboard occurrences as fluctuating tank levels (resulting from ship motions), inaccurate readings, et cetera. As a result, fuel data obtained from the cutter sources is not the best choice for the basis of calculating the carbon footprint of the fleet.

Once the amount of each type of fuel for a vessel during the fiscal year is determined, the calculation of the carbon footprint may proceed. For each fuel, applying its high heating value, corresponding emission factors for CO₂, CH₄, N₂O, and global warming potentials will result in the determination of the total CO₂-e due to hydrocarbon consumption. Figure 2 summarizes the revised Vessel Hydrocarbon Emission methodology. As the ability to differentiate between diesel fuel consumers becomes available in the future, the portion of the preliminary methodology that accounted for individual equipment consumption should be readdressed.

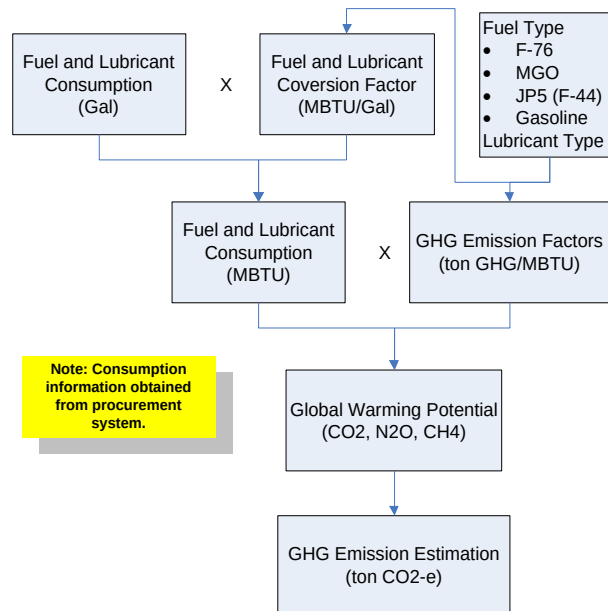


Figure 2. Final vessel hydrocarbon emission.



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4.2 Purchased Electricity Emissions

At this time, it is not possible to attribute inport electrical consumption to a single vessel throughout the entire USCG. The usability analysis, for the 270-WMEC, indicates that shore power consumption comprises a notable portion of the entire vessel's carbon footprint. This outcome warrants further investigation of inport electrical loads demanded by USCG vessels.

The best method to accomplish this would be to capture the in port electrical demand, either at the main switchboard or from within the machinery control system, the latter of which could be done on the WMSL Class at this time. This information could be captured on an annual basis. It would provide the benefit of attributing data to a specific vessel and would enable the capture of the data when the vessel is tied up to any pier, not just those with pier side meters.

Alternatively, the actual shore tie boxes could be instrumented with individual meters in all of the vessel homeports. In addition to reading the meters at the end of each vessel's time in port, the name of the vessel receiving the power, the number of shore ties used per vessel, and the days each vessel was connected to shore power could be recorded. To further complicate matters, USCG vessels dock at piers that are not controlled by the USCG directly. For example, the homeport of the TAHOMA is at Portsmouth Naval Shipyard in Kittery, Maine. The USCG rents pier space from the U.S. Navy and is given a bill. In Portsmouth, the U.S. Navy would have to approve such meters on its shore tie terminal boxes.

The methodology flow chart associated with the inport shore power is shown in Figure 3. This process can be used for the entire base or location where the vessel ties up.

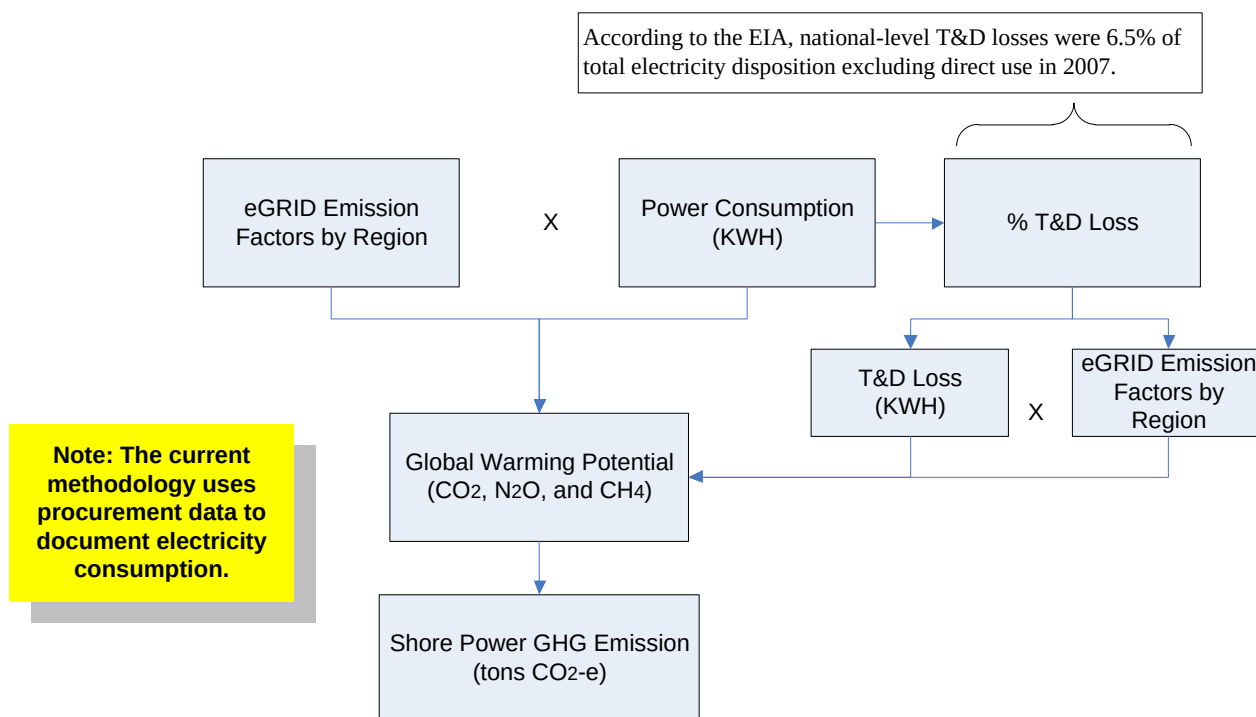


Figure 3. Inport electrical shore power emission flowchart.



4.3 Refrigerant Emissions

If the refrigeration systems are functioning properly, their impact on the vessel's overall carbon footprint will be significantly less than one percent. However, if there are significant system causalities, the impact of refrigeration on the vessel's carbon footprint could be material. The likely conclusion that ensues from this scenario is that the consumption of refrigerants should be monitored on all USCG vessels. Note that merely recording the amount of refrigerant bottles purchased is not enough. Ideally, the crew must record the amount of refrigerant expended in a fiscal year and track it to each particular piece of refrigeration equipment. Additionally, when using outside contractors to conduct maintenance, it is important to capture and account for the refrigerant used by that contractor.

The mass balance approach estimates emissions from assembly, operation, and disposal. If the installed equipment does not change from year to year, the annual refrigerant expended from inventory provides a reasonable estimate of actual leakage or emissions. If the equipment does change, it is important to take into account the addition (or deletion) of that equipment's capacity in order to not over (or under) estimate the amount of refrigerant released as a fugitive emission.

Equation (1). Mass balance for total consumption of a refrigerant.

$$\text{Fugitive Emissions} = (t_0 + \Delta t) - (I_0 + \Delta I) - (C_0 + \Delta C)$$

(metric tons HFC or PFC)

t_0	initial total mass	x_1	refrigerant inventory addition / deletion
I_0	initial mass of inventory	x_2	charged equipment (capacity addition)
C_0	initial equipment capacity (mass)	x_3	non – charged equipment capacity (filled from inventory)
Δt	change in mass of total system	y_1	charged equipment removal (capacity deletion)
ΔI	change in mass of inventory	y_2	non – charged equipment removal (recycled to inventory)
ΔC	change in equipment capacity (mass)	y_3	system recharge (as needed – inventory loss)

$$\Delta t = x_1 + x_2 - y_1$$

$$\Delta I = x_1 - x_3 + y_2 - y_3$$

$$\Delta C = x_2 + x_3 - y_1 - y_2$$

4.4 Fire Suppressant Emissions

Most USCG vessels will not need to monitor their fire suppressant consumption for the purpose of greenhouse gas reporting because the emissions are below the *de minimis* threshold. However, vessels using FM-200 fire suppression (e.g., 140 WTGB and 110 WPB) may need to monitor their consumption of FM-200. If analysis of these vessels suggests that the contribution of fire suppressants to the vessel's overall carbon footprint is more than one percent, these vessels will need to make note of their fire suppressant consumption. See Figure 4 for the fire suppressant portion of the current methodology.



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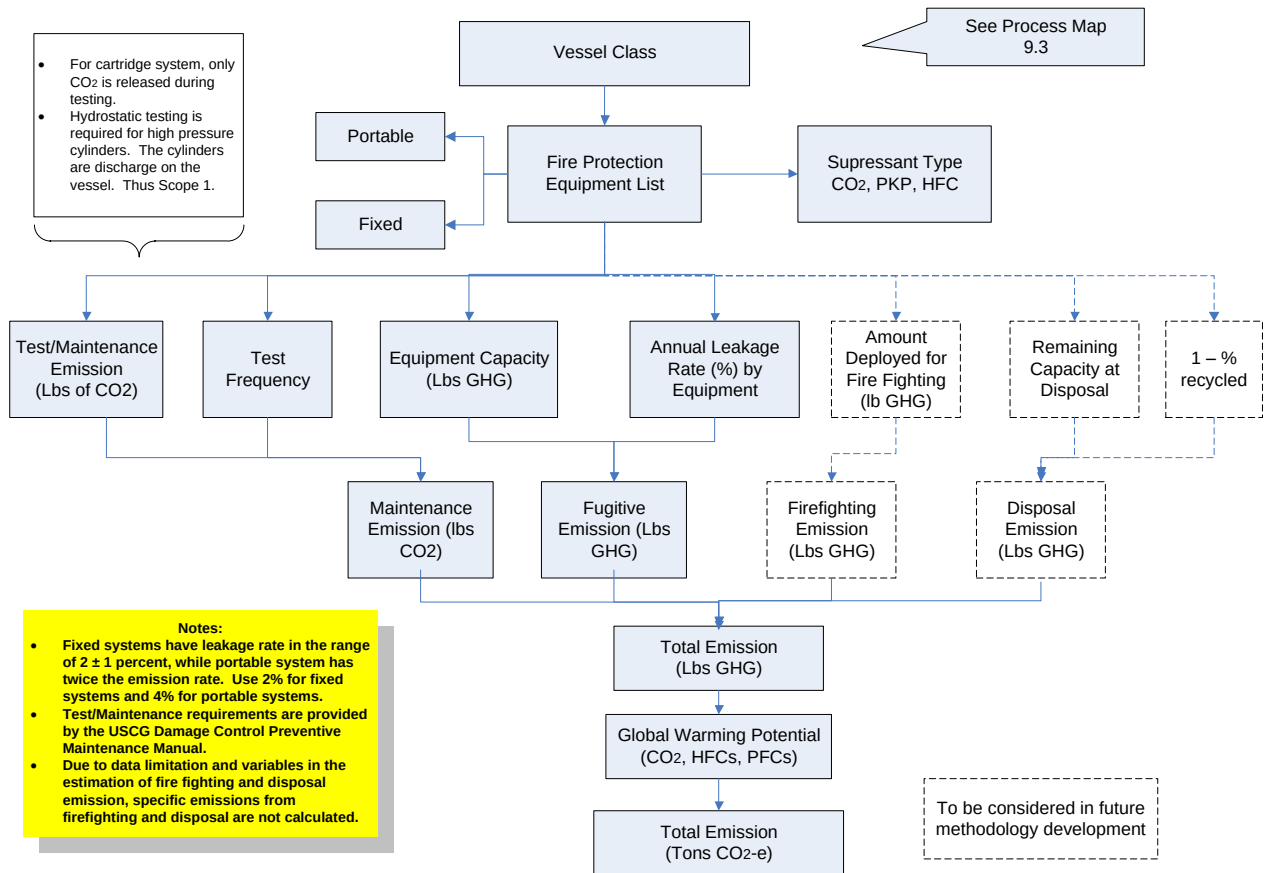


Figure 4. Shipboard fire suppressant emission estimation flowchart.

4.5 Carbon Footprint Comparisons

Utilizing the current methodology, a rough comparison of the annual carbon footprint of the RB-S, 270-WMEC, and 418-WMSL classes was made to a fleet of 345 pick-up trucks¹⁰ each traveling 20,000 miles a year¹¹. Table 3 shows this information. Class wide fuel budget data for fiscal year 2010 was used for this comparison. The RB-S does not use shore power; therefore the only contributor to the carbon footprint of the RB-S class is the fuel consumption value. Using the research from this study, it was assumed that the usage of shore power for the 270-WMEC and 418-WMSL is approximately 15 percent of the vessel's total footprint.¹² The fleet of pick-up trucks is included in the table to relate the carbon footprint of the USCG vessels to a more tangible statistic and to underscore the fact that vehicle emissions for towing small station boats would have a *de minimis* impact on the USCG's vessel carbon footprint.

¹⁰ A 2007 model year light-duty vehicle was used in the calculation. Fuel consumption information was from "Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2009" (EPA420-R-09-014) published by the EPA in November 2009. The carbon footprint of the truck is calculated is based on non-FEMP mobile asset.

¹¹ Chosen to equate total fuel usage (in gallons) between the pick-up truck fleet and one WMEC

¹² Additional research is required to verify that the ratio of fuel consumption to shore power for the 418-WMSL is similar to the 270-WMEC.



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Table 3. Carbon footprint comparison.

Vessel / Vehicle	No.	Fuel (Gallons)	Carbon Footprint (mt CO ₂ -e)	One 270-WMEC	One RB-S	One 418-WMSL	One Pick-up Truck
One 270-WMSL	1	390,000	4,700	1	111	0.19	473
270-WMEC Class	13	5,070,000	61,100	13	1,400	2.5	6,140
One RB-S	1	4,100	42.6	0.009	1	0.002	4.3
RB-S Class	505	2,100,000	41,500	4.6	505	0.88	2,160
One 418-WMSL	1	2,030,000	24,500	5.2	576	1	2,460
418-WMSL Class	8	16,200,000	196,000	42	4,600	8	19,700

5 CONCLUSIONS

The following conclusions were derived from the study:

- 1) Federal guidance currently does not provide a detailed methodology to calculate vessel-specific GHG emissions, vessel GHG estimates are currently based on the streamlined fuel consumption methodology, and the validity of the current approach has not been evaluated.. This study successfully developed a methodology to determine the annual carbon footprint of a USCG vessel while underway and in port. The fuel consumption methodology uses theoretical factors derived from the fuel's high heating value and respective chemical reactions. As research advances our understanding about fuel consumption and vessel operations, the assessment of the vessel carbon footprint may be further enhanced.
- 2) This study confirmed that fuel consumption is the primary contributor¹³ to the vessel carbon footprint (75-90 percent¹⁴ of the total CO₂ emission). Shore purchased power consumption is the second largest GHG contributor (10-15 percent¹⁵ of the total CO₂ emission). Uncertainty in this term is attributable to a temperature mediated change in fuel volume; the maximum error in a particular estimate could be as high as 2.5% of the fuel consumption, or 1.8% of the total vessel carbon footprint. The contributions of all other processes are on the order of one percent of the vessel's carbon footprint. It is important to note, however, that these estimates serve as a snapshot of the GHG contribution for the target vessels¹⁶ and are not necessarily representative of other classes of USCG vessels. Highly resource-intensive and complex analysis is required to track emissions for all vessels. Such analysis, which would require extensive data collection, is currently not cost effective on a large scale. Nevertheless, the assessment

¹³ All percentages are based on this first initial exercise through the preliminary methodology, using one target medium endurance cutter for one specific fiscal year. Additional refinement of the methodology and improved data collection are highly recommended to substantiate this information.

¹⁴ The percentage estimation is based on fiscal year 2009 budgeted fuel consumption for the 270-WMEC class.

¹⁵ The percentage estimation is based on 270-WMEC class vessels connecting to shore power at the Portsmouth (Virginia) Base Support Unit between the summer of 2009 and the summer of 2010. Further investigation is required to substantiate its class-wide application.

¹⁶ The current scope of the study includes two target vessels: 270-WMEC and RB-S.



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snapshot provides a general implication of the potential material contributors with respect to the vessel's total carbon footprint.

- 3) Study results indicated that fugitive emissions from refrigeration equipment¹⁷ and fire suppressants¹⁸ may be considered *de minimis*. As a result, technical and operational measures for reducing fugitive emissions in these two areas may not have a significant impact on the vessel's overall carbon footprint.
- 4) Major recurring maintenance is currently excluded largely because fuel consumption associated with maintenance activities has already been taken into account by the fuel procurement data. Furthermore, maintenance activities conducted off the vessel (within a repair facilities workshop for example) were defined as outside the vessel boundary. Moreover, there is uncertainty on how to properly plan or account for condition based maintenance that does not follow a time based schedule. Finally, consumables and supply chain emissions are currently excluded awaiting the release of Federal guidance and recommendations.
- 5) Vehicle emissions associated with the towing of small station boats are currently excluded. Towing vehicles are GSA-leased vehicles, and the emissions will be estimated using the FAST data through the FEMP portal. It will be a duplicative effort to develop a methodology to collect and calculate vehicle emissions separately.
- 6) Emissions from contracted waste disposal are considered *de minimis* and are currently excluded.
- 7) Emissions from employee commute are currently excluded awaiting results from the DHS agency-wide employee commute survey. The DHS survey is intended to capture the GHG emission impact of employee commute.
- 8) A detailed methodology to facilitate the making of management decisions (e.g. carbon footprint reduction measures, engineering change evaluations) is not feasible at this time. Data for the detailed calculation is not readily available within the present USCG vessel operating and maintenance documentation systems. In order to provide a detailed methodology to estimate the vessel emissions, data fidelity should be improved. This would require emission measurement and monitoring of vessel operations.
- 9) Although the carbon footprint estimate methodology is preliminary, it can be used as a framework for the assessment of pending energy reduction initiatives that are currently being considered by the USCG fleet. For example, the conversion to Light Emitting Diode (LED) lighting¹⁹ would have minimal impact on a major cutter's carbon footprint, because lighting represents a relatively insignificant portion of the vessel's total energy consumption. The large percentage of the carbon footprint attributable to fuel consumption clearly downplays the impact of other changes that do not directly contribute to fuel consumption. When competing for finite resources, it would be feasible to compare this LED lighting change to other efforts that may have a larger impact on fuel efficiency (and thus carbon footprint).

¹⁷ In case of catastrophic equipment failure, refrigerant emissions may exceed the *de minimis* threshold of one percent.

¹⁸ Vessels using FM-200 fire suppression (e.g., 140-WTGB and 110-WPB) may need to monitor their consumption of FM-200. Since FM-200 is 2,900 times more potent than CO₂, the chance that fire suppressants could become a material contributor is increased.

¹⁹ LED lighting was chosen for this example based on several pending engineering changes. The comparison is not meant to downplay the importance of the LED lighting initiatives, especially when considering the potential maintenance and supply chain savings. It is intended to demonstrate that lighting has a relatively small impact on energy consumption and vessel carbon footprint.



6 RECOMMENDATIONS

As the science behind GHG estimation is still evolving and with Federal GHG reporting guidance is expected to be continually revised, there are various opportunities to improve the vessel carbon footprint methodology. Below are recommendations for future USCG efforts to improve the carbon footprint investigation and to further refine the methodology:

- 1) Continue the current annual carbon footprint reporting methodology based on annual fuel usage and purchased shore power consumption. For *de minimis* emissions, the agency must explicitly detail and report its rationale for excluding the emission sources from the agency's GHG inventory. Sensitivity analysis is recommended to account for errors and uncertainties for the exclusion of *de minimis* emissions.
- 2) Invest in the continued refinement of the annual carbon footprint estimates for as many vessel classes as possible. This would provide a more accurate accounting of GHG inventory and a more objective basis for the future assessment of carbon reduction measures.
 - a) Although USCG vessels may be excluded from the agency's reduction target under the tactical operation exemption, Federal GHG reporting mandates and the impact of the vessel GHG emissions will continue to be the driver to motivate policy actions. Continued refinement of the current methodology is recommended in preparation for the anticipated eminent requirements for reducing the vessel carbon footprint.
 - b) Consider operational measures and emission control technologies to assess the fuel/CO₂-e savings potential. Assessing the amount and impact of emissions can help identify and more importantly prioritize technical and operational measures for reducing emissions.
 - c) Focus on the largest energy consumers (e.g. WMSL/WMEC fuel consumption) from the short-term perspective. Improved assessment of the carbon footprint for these vessels would yield the greatest effect on the overall USCG GHG inventory.
 - d) Improve the data collection process for shore-based power consumption through the implementation of vessel switchboard monitoring or shore-tie boxes monitoring. This improvement would provide more accurate data and enable monitoring and tracking of vessel electricity consumption. As mentioned previously, monitoring equipment installed onboard each vessel would enable a more exact and continuous tracking of the energy required by the asset.
 - e) Consider providing appropriate fuel meters and automated logging capabilities aboard a small sample of various USCG vessel classes. This would enable a better understanding of actual fuel usage and the respective vessel operational tasks. Having this data would further assist in the documentation and analysis of the potential impacts of alternative vessel operational strategies on the vessel's carbon footprint.
- 3) Coordinate with the USCG Logistics Information Management System (LIMS) acquisition team to ensure that data will be available in the future for detailed calculation of the vessel's annual carbon footprint. The long-term goal is to improve the data to enable life-cycle carbon footprint calculation. Coordination with LIMS ensures that the carbon footprint methodology is integrated and aligned with logistics lifecycle support functions of the system. Furthermore, the carbon footprint calculation tool (once refined) can be embedded in LIMS as standard practice for lifecycle management.



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- 4) Consider the integration of carbon footprint into the Major System Acquisition Manual (MSAM) processes. The consideration of annual and life-cycle carbon footprint shall be incorporated during new ship design and construction, in order to compare and monitor ship parameters (e.g. ship capacity, engine power and fuel consumption) with respect to GHG emissions. This would enable the assessment of energy efficiency of individual ship designs or integrate advanced technologies during its design phase.
- 5) The USCG shall continue to monitor and pursue opportunities to contribute to the development of Federal GHG reporting protocols. This would ensure that agency GHG implementing policies and strategies are meaningful, practical, and not cumbersome to the USCG naval engineering community.



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APPENDIX A. WORKSHOP PROCESS MAP

A.1 Determining System Boundaries

Two distinct approaches can be used to define the boundaries for GHG emissions: the equity share and the control approaches. Under the equity share approach, the organization accounts for GHG emissions from operations according to its share of equity in the operation. If the organization wholly owns all its operations, its organizational boundary will be the same regardless of approach used. Under the control approach, an organization accounts for 100 percent of the GHG emissions from operations over which it has control. It does not account for GHG emissions from operations in which it owns an interest but has no control. Control can be defined in either financial or operational control criteria. Given the nature of most government activities and organization structure, operational control would be the most generally relevant approach for GHG estimates. The following criteria determine the boundaries of the activities and processes considered:

- All processes from the operation of a Coast Guard vessel and deployed assets while underway or at pier.
- All processes from mobile assets.
- All processes from major recurring maintenance.
- Only processes that can be controlled or influenced by the vessel's operational or maintenance command will be considered.
- Only factors that make a material contribution will be considered. Material contribution indicates the level of significance for the emission and is defined as one percent of the total footprint.

A.2 Process/System Map Description

Headline processes, material sub processes, and the identified inputs/outputs form the basis for the GHG inventory. A high level illustration of processes contributing to the GHG inventory is provided in Figure A-1.

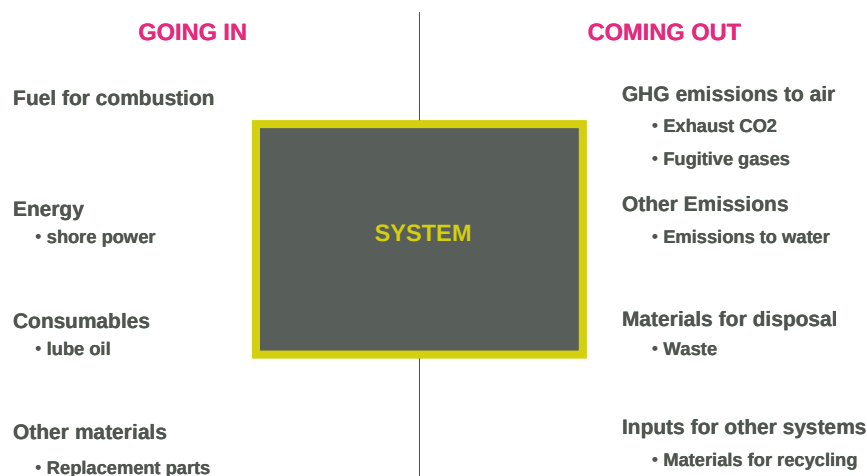


Figure A-1. Contributing GHG factors.



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The project team conducted a brainstorming session to help determine the key headline processes. Nine headline processes were identified during the brainstorming exercise that included experts in USCG operations, maintenance practices (including depot level maintenance and repair), shipboard environmental issues, maritime regulations and marine engineering. The nine headline processes identified for determining the carbon footprint of a USCG vessel are:

- Propulsion of the vessel/station keeping/stabilization.
- Generating and distributing electrical power.
- Cooling/heating the vessel (Boilers/AC/Reefer Plant/Galley).
- Operating deployed assets (Small Boat / Helicopter).
- Controlling pollution (incinerator/sewage).
- Operating electronics (C4I).
- Operating special equipment (chaff/gun/vessel of opportunity skimming system/science equipment/gas grills).
- Executing depot maintenance and repair (docksides & drydocks).
- Responding to emergencies (damage control pumps/fire suppression).

The second stage of the workshop involved producing a comprehensive list of sub-processes for each headline process. To facilitate this effort, three groups were created and each group took three headline processes for further breakdown. Assumptions and potential data gaps were identified and recorded. Following the break-out sessions, the groups reconvened to review and discuss the results of the sub-process identification effort.



Table A-1. Propulsion of the vessel/station keeping/stabilization.

Hdln	Headline Process	Lvl 1	Sub process 1	Lvl 2	Sub process 2	Lvl 3	Sub process 3	Lvl 4	Sub process 4	Input	Output	Consumables	Notes	
1	Propulsion of the vessel/station keeping/stabilization	1.1	Preparing to start engine	1.1.1	Keeping warm							Glycol		
				1.1.2	Venting gasoline fume (RB-M)					Electricity, Gasoline fumes	Gasoline fumes to atmosphere		Fumes are vented from the vessel interior to the atmosphere.	
				1.1.3	Prelubing					Engine oil		Filter		
		1.2	Starting engine	1.2.1	Producing compressed air							Lubricant, desiccants, filter		
				1.2.2	Blowing down cylinders					Compressed air				
		1.3	Running and operating engine	1.3.1	Burning fuel					Fuel	Exhaust gas			
				1.3.2	Burning oil					Oil				
				1.3.3	Purifying oil and fuel					Oil, Fuel	Sludge/waste oil			
				1.3.4	Operating reduction gear							Oil		
		1.4	Monitoring propulsion system							Electricity				
		1.5	Controlling propulsion system (Operating turbine control, engine control, CPP control, fin stabilization control and thruster control)							Electricity, air, hydraulic, cable	Oil leak	Filter	Potential oil leakage from CPP, fin stabilizer, and thruster CPP	
		1.6	Maintaining propulsion system	1.6.1	Conducting routine maintenance	1.6.1.1	Lube addition (engine, red gear, CPP, thrusters)						Oil and grease	
						1.6.1.2	Jacket Water addition						Glycol, NALCOOL	Research: What does the NSC MTU use?
				1.6.2	Conducting conditional maintenance					Compressed air, electricity		Filter, lubricant (oil and grease), spark plugs, belts		
		1.7	Conducting repairs										Use of consumables, parts replaced and repaired	
		1.8	Conducting housekeeping operations									Rags		

Table A-2. Generating and distributing electrical power.

2	Generating and distributing electrical power (transformers)											
	2.1	Generating power							Fuel	Exhaust gas		See Headline Process 1.0 for diesel engine operations
	2.2	Distributing power										No waste generated
	2.3	Converting power										
	2.4	Transforming power								Potential Fugitive Gases		Research: What is inside the transformers.
	2.5	Conditioning and protecting power									UPS, battery	
	2.6	Consuming power	2.6.1	Lighting the vessel					Electricity	Light		No emission created from consuming power.
					2.6.6.1	Providing normal lighting (interior and exterior)			Electricity	Light	Fluorescent, incandescent, halogen, sodium vapor, starters, CFL, LED	
					2.6.6.2	Providing emergency lighting			Electricity	Light	batteries, emergency ballast, bulbs listed in 2.6.6.1	
			2.6.2	Powering motors					Electricity			Drive water pumps, fans, compressors, bow & stern thrusters, hydraulic pumps
			2.6.3	Powering chain drives, cable drives					Electricity		Lubricant (oil and grease)	
			2.6.4	Powering heaters					Electricity			Duct, water, motor, and engine heaters.
			2.6.5	Powering reverse osmosis system					Electricity		Oil, filter, membrane, bromine	
	2.7	Maintaining electronics	2.7.1	Cleaning electronic equipment								
			2.7.2	Replacing batteries							Battery	
			2.7.3	Cleaning RO								
	2.8	Onloading shore power							Electricity			

Table A-3. Cooling/heating the vessel.

3	Cooling/heating the vessel (Boilers/AC/Reefer Plant/Galley)											
	3.1	Operating and maintaining boiler	3.1.1	Preparing light-off	3.1.1.1	Lining up system						
					3.1.1.2	Firing the boiler						
			3.1.2	Starting								
			3.1.3	Generating low-pressure system					Fuel	Ash, exhaust		
			3.1.4	Transferring heat								Steam to warm air.
			3.1.5	Collecting condensate								
			3.1.6	Distill Make-up water							Chemicals	
					3.1.6.1	Adding make-up water						
					3.1.6.2	Treating make-up water						
			3.1.7	Maintaining boiler						Chemicals	Rags, chemicals	
			3.1.8	Monitoring boiler								
	3.2	Operating and maintaining AC/Reefer	3.2.1	Lining up system								
			3.2.2	Starting the AC Unit					Electricity			
			3.2.3	Pumping chilled water (AC only)					Electricity	Cold Water	Chemicals	Research what is added to chill water.
			3.2.4	Operating the compressor					Electricity	Refrigerant fugitive emission	Oil	
			3.2.5	Filtering and drying refrigerant							Filter, dryer	
			3.2.6	Transferring heat between refrigerant and chilled water								
			3.2.7	Transferring heat between air in space and chilled water						Conditioned air	Filter	
			3.2.8	Salt water cooling						Zinc anodes	Zinc anodes	
			3.2.9	Maintaining AC/Reefer	3.2.9.1	Cleaning				Chemicals	Chemicals	
					3.2.9.2	Replacing refrigerant				Chemicals, fugitive emission	Chemicals	
					3.2.9.3	Storing replacement refrigerant gas						
	3.3	Operating and maintaining self contained refrigeration units							Fugitive emission	Refrigerant		
			3.3.1	Operating and maintaining ice makers								
			3.3.2	Operating and maintaining bubblers								
			3.3.3	Operating and maintaining reach-in refrigerators								
			3.3.4	Operating and maintaining ice cream makers								
			3.3.5	Operating and maintaining salad bar								
			3.3.6	Operating and maintaining mini-refrigerator								

Table A-4. Operating deployed assets (small boat/ HELO/ station trucks).

4	Operating deployed Assets (Small Boat / HELO / Station Trucks)										
		4.1	Operating small boats								
		4.1.1	Conducting daily boat check (engine running)					Fuel, gas, oil	Exhaust gas	Oil, gas	
		4.1.2	Launching the boat								
				4.1.2.1	Launching stern ramp						
				4.1.2.2	Launching, operating and maintaining hydraulic davit					Filter	
						4.1.2.2.1	Replacing the wire rope			Grease, Wire Rope	
						4.1.2.2.2	Replacing the hydraulic fluid	Hydraulic fluid	Waste hydraulic fluid		
				4.1.2.3	Launching, operating and maintaining nonhydraulic davit						
				4.1.2.4	Operating and maintaining gantry crane			Hydraulic fluid	Waste hydraulic fluid		
		4.1.3	Running the boat					Fuel, gas, oil	Exhaust gas	Flares	
		4.1.4	Recovering the boat								
				4.1.4.1	Driving the boat up the ramp						
				4.1.4.2	Winching boat into final position					Compressed air	
		4.1.5	Post mission boat check								
				4.1.5.1	Washing down the boat					Potable water	
				4.1.5.2	Refueling the boat			Fuel		Filter	
		4.1.6	Maintaining the boat IAW PMS system								
				4.1.6.1	Changing filters			Fuel		Lube oil	
				4.1.6.2	Checking battery						
				4.1.6.3	Lubricating fittings					Grease	
				4.1.6.4	Pumping bilge			Oil from leaks	Oily waste	Rags	
				4.7.6.5	Changing oil			Lube oil	Oily waste		
		4.1.7	Conducting major recurring maintenance								
		4.2	Operating HELO								
		4.2.1	Conducting pre-flight check								
		4.2.2	Starting the HELO								400 Hz converter in hanger
		4.2.3	Launching the HELO								
		4.2.4	Moving the HELO into the hangar					Electricity	fugitive gasses		Research the ASIST RSD for fugitive gasses. Electrical draw to telescope the hangar
		4.2.5	Maintaining HELO Fuel								
				4.2.5.1	Stripping fuel storage tanks			Fuel	Waste Fuel	Filters	
				4.2.5.2	Conducting clear and bright test, FSII test			Fuel	Waste Fuel	Test Pads	
				4.5.2.3	Recirculating the fuel			Fuel	Waste Fuel		
				4.5.2.4	Conducting Fuel analysis						
				4.5.2.5	Conducting quarterly lab tests						
		4.2.6	Flying the HELO					Fuel	Exhaust	Flares	
		4.2.7	Refueling the HELO					Fuel	Fumes		
		4.2.8	Conducting daily wash down						Potable water		
		4.2.9	Recovering the HELO								
		4.2.10	Operating A/C								
		4.2.11	Deploying small arms						Exhaust gas	Ammunition	
		4.2.12	Conducting HELO maintenance								
				4.2.12.1	Conducting engine water wash				Chemicals?	Chemicals?	Research!
				4.2.12.2	Changing tires (pressurize)				Nitrogen		
		4.3	Using boat station trucks for towing boat								
		4.3.1	Refueling the truck					Fuel	Fumes		
		4.3.2	Driving the truck					Fuel	Exhaust		
		4.3.3	Maintaining the truck								
		4.3.4	Connecting the truck to trailer								
		4.3.5	Trailer the boat								
		4.3.6	Launching the boat								
		4.3.7	Operating the truck A/C						Fugitive refrigerant		
		4.4	Operating and Maintaining UAVs								
		4.5	Conducting Boarding team activities off the vessel								Outside scope of boundary until USCG has a deployable UAV (not just a demonstrator) Outside scope of the boundary

Table A-5. Controlling pollution (incinerator/solid waste).

5	Controlling pollution (incinerator/sewage)									
	5.1	Managing solid waste								
		5.1.1	Burning solid waste					Fuel	Ash, GHG emission	
				5.1.1.1	Starting incinerator					
						5.1.1.1.1	Preheating incinerator			
						5.1.1.1.2	Cleaning and storing ash			
						5.1.1.1.3	Disposing ash ashore		Ash	
						5.1.1.1.4	Disposing ash overboard		Ash	
				5.1.1.2	Operating incinerator			Fuel	Ash, GHG emission	
				5.1.1.3	Maintaining incinerator					Cleaner? Research!
		5.1.2	Direct discharge overboard							
		5.1.3	Offloading to shore						Solid waste	
		5.1.4	Processing and storing aboard	5.1.4.1	Operating compactor					
				5.1.4.2	Maintaining compactor					
		5.1.5	Processing and discharging overboard							
				5.1.5.1	Operating pulper					
				5.1.5.2	Maintaining pulper					
	5.2	Managing sewage								
		5.2.1	Collecting and holding	5.2.1.1	Operating VCHT system				Methane (CH4)	Rags
				5.2.1.2	Maintaining VCHT system				Methane (CH4)	Rags
		5.2.2	Discharging overboard						Methane (CH4)	Rags
		5.2.3	Offloading to shore						Sewage	
	5.3	Managing graywater								
		5.3.1	Collecting and holding						Graywater	
		5.3.2	Discharging overboard						Graywater	
		5.3.3	Offloading to shore						Graywater	
	5.4	Managing oily water								
		5.4.1	Collecting & Transferring oily water							
		5.4.2	Processing oily water	5.4.2.1	Operating oily water separator (OWS)					
						5.4.2.1.1	Discharging <15pm		Effluent	
						5.4.2.1.2	Waste Oil to holding tank		Waste Oil	
						5.4.2.1.3	Burning sludge	Fuel, waste oil	Ash, exhaust gas	
						5.4.2.1.4	Transferring sludge ashore		Waste oil	
				5.4.2.2	Maintaining OWS					
						5.4.2.2.1	Changing filters		Filter	Filter, consumables
						5.4.2.2.2	Cleaning OWS			Rags

Table A-6. Operating electronics.

6	Operating electronics (C4I)											
	6.1	Operating electronic equipment	6.1.1	Operating electronic equipment					Electricity	Fugitive emission	Electricity, paper, ink	Depth, WMIS, computers, radar, sonar, fire control etc.
			6.1.2	Producing dry air							Desiccants	
	6.2	Maintaining electronics										
			6.2.1	Maintaining hardware					Gas		Replacement cards	Recharge N2
			6.2.2	Conducting system grooming					Unknown gases		Research	
	6.3	Replacing and repairing electronics									Printer cartridge, C.R.T monitors	Card replacement is done in ship level, lowest repair unit.
	6.4	Conducting technology refresh (hardware upgrade)										
			6.4.1	Replacing C.R.T monitors								Printer cartridge, C.R.T monitors
			6.4.2	Conducting logistics elements							Printer cartridge, paper	
6.5	Manufacturing, designing, testing hardware at hardware lab										Outside the boundary	

Table A-7. Operating special equipment.

7	Operating special equipment (chaff/gun/VOSS/science equipment/gas grills)											
		7.1	Discharging ordinance									
				7.4.1	Deploying medium caliber gun (57/76 mm)							
				7.1.2	Deploying 25mm gun					Propellant	Emission	
				7.1.3	Deploying small arms (portable)					Propellant	Emission	
				7.1.4	Deploying pyrotechnics					Propellant	Emission	
				7.1.5	Deploying chaff					Propellant	Emission	
				7.1.6	Maintaining ordinance							
				7.1.7	Disposing retrograde							Shells
				7.1.8	Disposing unused ammunition							Waste ammunition
		7.2	Operating the VOSS System- Diesel Engine, HPU							Fuel, hydraulic oil	Exhaust	Oil skimmed from the surface is outside the boundary
		7.3	Operating and maintaining science equipment								Fugitive emissions?	Research HEALY and POLAR Class equipment
		7.4	Operating and maintaining ice breaking equipment	7.4.1	Running the bubbler van					Fuel, Air, Oil,	Exhaust	140' ice breaker tug- Detroit Diesel Engine
		7.5	Activating type 5 Personal Flotation Device (PFD)								CO2	CO2 cartridge

Table A-8. Executing depot maintenance and repair.

8	Executing depot maintenance and repair (docksides & drydocks)										
	8.1	Conduct 100 Level SWBS Maintenance									
		8.1.1	Burning, Welding, Cutting Steel.. Operating welder, torch, etc..					Electricity, Steel, Argon, Oxygen, Acetylene, Welding Rods, flux	Finished Product		
		8.1.2	Cleaning Tanks (oil, fuel)					Water	waste oil		
	8.2	Conduct 200 Level SWBS Maintenance									
		8.2.1	Major overhaul of engines	8.2.1.1	Testing			Fuel	exhaust		
				8.2.1.2	overhaul					rag, oil	
		8.2.2	Major overhaul of main shafting	8.2.2.1	Fiberglass replacement			fiber, resin	fumes??		Any fugitive emissions?
		8.2.3	CPP System Overhaul	8.2.3.1	System Repair and flushing			Hydraulic oil	Waste Oil	filters, rags	
	8.3	Conduct 300 Level SWBS Maintenance									
		8.3.1	Power to equipment conducting work, Welders, Fans, Pumps, etc					Electricity			Is this going to be considered a Scope 3 emission for the vessel or Scope 2 emission for the drydock?
		8.3.2	Ship Service Fuel Engine Overhaul and Repair								See Fuel engines under 200 SWBS
		8.3.3	Repair/Replace Transformers						potential fugitive gasses from the transformer chemicals		Research!
	8.4	Conduct 400 Level SWBS Maintenance									
		8.4.1	Repair/Replace electronic equipment					Parts	direct emissions from maintenance?		Research!
	8.5	Conduct 500 Level SWBS Maintenance									
		8.5.1	Overhaul pollution control equipment- Overhaul oily water separators					water	Waste oil	Rags, Cleaners	
		8.5.2	Overhaul hydraulic equipment (davits, cranes, etc)					Hydraulic Oil, Parts	Waste oil	Filters	
		8.5.3	Overhaul refrigeration / air conditioning systems					Refrigerant	Fugitive emission		
	8.6	Conduct 600 Level SWBS Maintenance									
		8.6.1	Painting Surfaces	8.6.1.1	Prepare Surface for Painting	8.6.1.1.1	Sandblasting	electricity, grit, compressed air	paint chips, grit		
						8.6.1.1.2	Waterjetting	electricity, water, grit, compressed air	paint chips, grit, water, dirty filters	filters	
						8.6.1.1.3	Rust Inhibiting	chemicals			
						8.6.1.1.4	Washing surface				
				8.6.1.2	Painting the surface - Spraying			Propellant???, compressed air, paint	VOCs		
				8.6.1.3	Cleaning up the equipment			rag, water, chemicals?	rag, water, paint chips, chemicals?		
		8.6.2	Stocking spare parts					Spare Parts			Supply Chain issue.
	8.7	Conduct 800 Level SWBS Maintenance									
		8.7.1	Docking the vessel	8.7.1.1	Moving the vessel into position			tug boat, fuel	exhaust		
				8.7.1.2	Lifting the vessel out of the water			electricity, fuel	exhaust		
				8.7.1.3	Moving the vessel on a shiplift			tractor, fuel	exhaust		
		8.7.2	Provide temporary services					electricity, compressed air, HVAC, chilled water, refrigerated storage	exhaust, fugitive gasses (refrigeration)		
		8.7.3	Provide temporary berthing								Will be considered outside the scope of the boundary and part of the berthing facilities carbon footprint
		8.7.4	Provide temporary messing								Will be considered outside the scope of the boundary and part of the messing facilities carbon footprint
		8.7.5	Rigging equipment on and off the vessel					shore side crane, fuel, electricity	exhaust		
		8.7.6	Conducting an Inclining Experiment					tug boat, fuel	exhaust		

Table A-9. Responding to emergencies (damage control/fire suppression).

9	Responding to emergencies (damage control pumps/fire suppression)											
		9.1	Operating damage control pumps									
				9.1.1	Operating fuel powered pumps							
						9.1.1.1	Refueling pumps			Gasoline	Gas fumes	
						9.1.1.2	Replacing fuel			Gasoline	Gas fumes	
						9.1.1.3	Starting pump					
						9.1.1.4	Operating pump			Gasoline	Emission	
						9.1.1.5	Stopping pump					
						9.1.1.6	Flushing with freshwater					
		9.2	Maintaining damage control pumps									
		9.3	Conduct firefighting									
				9.3.1	Operating portable firefighting extinguishers (CO2)					CO2	CO2 direct emission	
				9.3.2	Operating portable firefighting extinguishers (PKP)					CO2, PKP	CO2 direct emission	
				9.3.3	Operating fixed CO2 extinguishing system					CO2	CO2 direct emission	
				9.3.4	Recharging CO2 extinguishers							
				9.3.5	Operating AFFF system					AFFF		
		9.4	Conducting atmospheric testing									Tubes
		9.5	Operating gas powered generator (portable)							Gas	Exhaust emission	

APPENDIX B. GHG LEGISLATION AND PROGRAM SUMMARY

B.1 GHG Legislation and Policy

The key GHG requirements are provided in Executive Order (E.O.) 13514. Although many energy legislation and policies, such as the Energy Policy Act (EPAct), Energy Independence and Security Act (EISA) and E.O. 13423, are not tied explicitly to GHG emissions, energy management and GHG are interrelated. As energy management is a crucial component for reducing GHG emissions, energy management regulatory requirements are also included in this summary. Table B-1 provides a comparison of sustainability goals and targets from E.O. 13514 and E.O. 13423, as well as other existing statutes.

E.O. 13514

On October 5, 2009, President Obama signed E.O. 13514 to require Federal agencies to measure, manage, and reduce GHG emissions. E.O. 13514 expands the energy reduction and environmental requirements of E.O. 13423 mandating GHG management. The E.O. requires agencies to set agency-wide reduction targets and provides a number of overall reduction goals for energy, water and waste. As defined by the E.O. scope 1 emissions are direct GHG emissions from sources that are owned or controlled by the Federal agency. Scope 2 includes direct GHG emissions resulting from the generation of electricity, heat, or steam purchased by a Federal agency. Scope 3 includes GHG emissions from sources not owned or directly controlled by a Federal agency but related to agency activities. Specific requirements from the E.O. are highlighted below:

- Designate agency Senior Sustainability Officer by 5 November 2009;
- Establish agency scope 1 and 2 reduction target by 4 January 2010;
- Establish agency scope 3 reduction target by 2 June 2010;
- Prepare Strategic Sustainability Performance Plan (Sustainability Plan or Plan) by 2 June 2010; and
- Report GHG inventory on 5 January 2011. Thereafter, annually at the end of January, for the preceding fiscal year.

Energy Independence and Security Act (EISA 2007)

Signed on December 19, 2007, EISA aims to increase U.S. energy security, develop renewable fuel production, and improve vehicle fuel economy. EISA requires federal agencies to reduce facility energy intensity by 30 percent by 2015 relative to 2005. Section 142 requires Federal agencies to achieve at least a 20 percent reduction in annual petroleum consumption and a 10 percent increase in annual alternative fuel consumption by 2015 from the 2005 baseline.

E.O. 13423

Signed on January 24, 2007, E.O. 13423²⁰ aims to improve agency energy efficiency and reduce greenhouse gas emissions. Additionally, E.O. 13514 ensures that the energy efficiency requirement of E.O. 13423 remain in effect. E.O. 13423 requires each agency to reduce energy intensity (energy consumption per square foot of building space) by 30 percent relative to 2003. The E.O. is the first legislation to require a

²⁰ E.O. 13423 was codified into law on February 17, 2009 by the 2009 Omnibus Appropriation Act.



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percentage of renewable energy to come from new sources. At least 50 percent of renewable energy consumed by the agency in a fiscal year comes from new renewable sources.

Energy Policy Act (EPAAct 2005)

Signed into law on August 8, 2005, EPAAct 2005²¹ requires federal agencies to reduce facility energy intensity by 20 percent by 2015, relative to 2003. The Act established government-wide renewable energy purchases in which by 2013, at least 7.5 percent of electricity consumption must be derived from renewable energy. Additionally, EPAAct 2005, which was effective upon enactment, mandated that dual-fuel vehicles shall be operated on alternative fuels unless a waiver is granted by the Department of Energy.

EPA Mandatory Reporting of Greenhouse Gases Rule

Effective December 29, 2009, EPA issued the Mandatory Reporting of Greenhouse Gases Rule in response to the FY2008 Consolidated Appropriations Act (H.R. 2764; Public Law 110–161). The rule requires reporting of GHG emissions from large sources and suppliers in the United States, including suppliers of fossil fuels or industrial greenhouse gases, manufacturers of vehicles and engines, and facilities that emit 25,000 metric tons or more per year of GHG emissions. EPA's phased-in approach will start in January 2011, when Clean Air Act permitting requirements for GHG will take effect for large facilities that are already obtaining Clean Air Act permits for other pollutants.

Corporate Average Fuel Economy (CAFE) standards

In 1975, Congress enacted the CAFE ratings under the Energy Policy and Conservation Act (EPCA). The purpose of CAFE is to reduce energy consumption and GHG emissions by increasing the fuel economy of cars and light trucks. The National Highway Traffic Safety Administration (NHTSA) and EPA are responsible for regulating CAFE. NHTSA sets fuel economy standards for cars and light trucks sold in the U.S.; EPA establishes the average fuel economy for each manufacturer.

In response to President Obama's call for a National Fuel Efficiency Policy²², NHTSA and EPA issued a joint final rule establishing a new National CAFE Program. The new standards cover model years (MY) 2012-2016 and require an average fuel economy standard of 35.5 mpg by MY 2016.

DHS Directive # 025-01

Entitled "Sustainable Practices for Environmental, Energy and Transportation Management (Sustainable Practices)", this management directive was issued in 2008. It requires DHS to develop and implement sustainable practices programs to ensure that all operations and necessary actions are carried out in an environmentally, economically, and fiscally sound manner and will meet the DHS goals, targets and objectives. As one of the key core programs, the energy management and GHG emissions reduction program requires annual report to be submitted to the Director of Occupational Safety and Environment Programs (OSEP).

²¹ EISA 2007, E.O. 13423, and EPAAct 2005 have been issued subsequent to the passage of EPAAct 1992. These authorities update and/or supersede many of its requirements.

²² On May 19, 2009, President Obama announced the National Fuel Efficiency Policy. The policy is aimed at both increasing fuel economy and reducing greenhouse gas pollution for all new cars and trucks sold in the U.S.



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Table B-1. List of existing GHG legislation.

Topics	E.O. 13514	E.O. 13423	Other Existing Statutes
GHG Reductions	- Establish agency GHG percentage reduction target for Scope 1, 2 and 3 emissions (FY2020 target, baseline 2008). - Government wide 28% reduction target for Scope 1 and 2.	3% annual reduction in building intensity through FY2015, or total 30% total reduction by FY2015 (baseline 2003).	[EISA]: 3% annual reduction in building intensity through FY2015, or total 30% total reduction by FY2015 (baseline 2003).
GHG Reporting	Establish comprehensive inventory for Scope 1, 2, and 3 emissions.		[EPA MGHGRR]: Facilities and suppliers of fossil fuels and industrial GHGs that emit more than 25,000 metric tons of CO ₂ -e per year must report their emission by March 31, 2011, for 2010 emission. Reports submitted annually thereafter.
Renewable Energy	Increase new of renewable energy.	Ensure that 50% of statutorily required renewables come from “new” sources.	[EPA 2005]: Increase renewables 3% in FY2007-2009. Increase to 5% in FY2010-2012. Increase to 7.5% in FY2013 and beyond. [EISA]: 30% of hot water demand in new Federal buildings and major renovations must be met with solar hot water if life-cycle cost is effective.
Fleet Petroleum Use	Reduce petroleum consumption by 2% per year through FY2020 (baseline FY2005).	- Reduce fleet petroleum consumption by 2% per year through FY2015 (baseline FY2005). - Increase 10% in non-petroleum fuel consumption annually (baseline FY2005).	[EISA]: Reduce vehicle petroleum reduction by 20% by FY2015 (baseline FY2005). Increase 10% in non-petroleum fuel consumption annually (baseline FY2005).



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Table B-1. List of existing GHG legislation (Continued).

Topics	E.O. 13514	E.O. 13423	Other Existing Statutes
Potable Water Consumption	Reduce water intensity by 2% annually (26% total reduction by FY2020) (baseline FY2007).	Reduce water intensity by 2% annually through 2015 (16% total reduction by FY2015) (baseline FY2007).	
Industrial, Landscaping, and Agricultural Water Consumption	Reduce water intensity by 2% annually (20% total reduction by FY2020) (baseline FY2010).	Reduce water intensity by 2% annually through 2015 (16% total reduction by FY2015) (baseline FY2007).	
Solid Waste	Achieve 50% or higher diversion rate for non-hazardous solid waste, construction and demolition materials and debris by FY2015.	Increase diversion of solid waste as appropriate.	
High Performance Sustainable Buildings	Ensure at least 15% of existing buildings and leases (>5,000 gross sq. ft.) meet the Guiding Principles by FY2015, with continued progress towards 100%.	Ensure 15% of existing buildings inventory incorporate the Guiding Principles by FY2015.	[EISA] As of December 19, 2010, federal agencies are prohibited from leasing buildings that have not earned the Energy Star label.
Sustainable Acquisition	Ensure 95% of all new contracts, including non-exempt contract modifications, require products and services that are energy-efficient, water-efficient, bio-based, environmentally preferable, non-ozone depleting, contain recycled-content, non-toxic or less-toxic alternatives.	Agency acquisition must ensure bio-based, environmental preferable, energy efficient, water efficient, recycled content.	



B.2 Overview of Current Greenhouse Gas Programs

This section summarizes key U.S., international, and regional GHG programs used as references to guide the development of the carbon footprint methodology for USCG vessels. Table B-2 provides a list of existing GHG programs from the literature research. The principal guidance documents include the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, which is one of the most widely used in international GHG accounting. Additionally, the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) developed the Greenhouse Gas Protocol Corporate Standard. Several programs and guidance documents are based on the Corporate Standard, including the EPA Climate Leaders and the Public Sector Standard. In response to E.O. 13514, various federal agencies are developing guidance and recommendations for GHG accounting and reporting. For example, the DOE is tasked to develop federal GHG reporting procedures, and GSA is responsible providing recommendations for tracking and reducing Scope 3 GHG emissions. As additional GHG guidance becomes available, new information shall be considered and incorporated for the continuous improvement of the USCG GHG methodology.

B.2.1 International

2006 IPCC Guidelines for National Greenhouse Gas Inventories

The 2006 Guidelines is built on the previous Revised 1996 IPCC Guidelines and the subsequent Good Practice reports. The guidelines are designed to assist countries in compiling national inventories of greenhouse gases. Default values for various parameters and emission factors are provided based on sectors. The IPCC also manages the IPCC Emission Factor Database (EFDB). The EFDB, a repository of emission factors and other relevant parameters, was launched in 2002 and is regularly updated. Country-specific emission factors and parameters are recommended, however, for more accurate emission estimates.

Corporate Standard

The Corporate Standard was developed by the WBCSD and WRI to help companies prepare a GHG inventory. To complement the standard and guidance, a number of cross-sector and sector-specific calculation tools are available. These tools provide step-by-step guidance and electronic worksheets to help users calculate GHG emissions from specific sources or industries. These tools are consistent with those proposed by the IPCC for compilation of emissions at the national level.

Climate Registry

The Climate Registry is a nonprofit collaboration among North American states, provinces, territories and Native Sovereign Nations that sets consistent and transparent standards to calculate, verify and publicly report GHG emissions into a single registry. The Climate Registry is based on the work of the California Registry. The General Reporting Protocol (GRP) v 1.1 was published in 2008, and additional updates and clarification have been released in 2010.

ICLEI – Local Governments for Sustainability

ICLEI is the first global network of cities and local governments to achieve sustainability at the local level. ICLEI developed the International Emissions Analysis Protocol (IEAP) and its U.S. government operations supplement, the Local Government Operations (LGO) Protocol. The IEAP provides a general framework for inventories around the world and draws on existing best practices from the IPCC and WRI. The LGO



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Protocol is the U.S. national standard guidebook on how to quantify and report local government greenhouse gas emissions.

International Organization for Standardization (ISO) Standards

ISO 14064-1 specifies the principles and requirements at the organization level for quantification and reporting GHG emissions and removals. It includes requirements for the design, development, management, reporting, and verification of an organization's GHG inventory.

ISO 14064-2 provides the principles, guidance, and requirements at the project level. It includes requirements for planning a GHG project, identifying and selecting GHG sources, sinks and reservoirs relevant to the project and baseline scenario.

ISO 14064-3 specifies principles and requirements and provides guidance for those conducting and managing validation and/or verification of GHG assertions. It can be applied to an organization or project for GHG quantification, monitoring, and reporting that are carried out in accordance with ISO 14064-1 and 2. This standard also specifies requirements for selecting GHG validators/verifiers, establishing the level of assurance, objectives, criteria, and scope.

While ISO 14064 provides requirements for organizations or persons to quantify and verify GHG emissions, ISO 14065 specifies accreditation requirements for organizations that validate or verify resulting GHG emission assertions or claims.

B.2.2 United States

Public Sector Standard

Also known as the Public Sector Protocol, the Public Sector Standard is developed by the WBCSD and WRI. It provides guidance for federal, state, and local agencies for accounting and reporting GHG emissions. Based on the Corporate Standard, the Public Sector Standard covers six GHG from the Kyoto Protocol. The Public Sector Standard applies the principles of financial accounting and reporting to ensure the accurate account of an agency's GHG emissions. These principles include relevance, completeness, consistency, transparency, and accuracy. They have been widely adopted by U.S. and international programs such as the Climate Registry and ICLEI (Local Governments for Sustainability).

EPA Climate Leaders Design Principles Guidance

Climate Leaders is an EPA industry-government partnership that works with companies to develop corporate-wide GHG reduction goal and emission inventory. The Design Principles Guidance includes overall guidance on defining inventory boundaries, identifying GHG emission sources, and defining and adjusting a base year. The Design Guidance also defines the minimum level of data and various optional emission and reduction sources that a corporate reports under Climate Leaders. Reported GHG include the six GHG from the Kyoto Protocol.

Inventory of Greenhouse Gas Emissions and Sinks

Prepared annually by the EPA, the national GHG inventory report presents estimates of U.S. GHG emissions and sinks. The current 2010 report provides data from 1990 through 2008. This report also discusses the methods and data used to calculate the emission estimates. The methodologies are consistent with the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories.



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B.2.3 Regional

California Climate Action Registry (California Registry)

The California Registry is a voluntary GHG program to protect and promote early actions to reduce GHG emissions by organizations. The California Registry has developed a number of protocols to assist members and verifiers in the process of calculating, reporting and verifying an emissions inventory. The General Reporting Protocol and Verification Protocol are currently used by members to complete their emissions inventories. The California Registry also offers industry-specific protocols to give further guidance to certain sectors. Currently, industry-specific protocols are available for the cement sector, power/utility sector, forest sector and local government operations. Additionally, the Climate Action Registry Reporting Online Tool (CARROT) is the California Registry's GHG calculation and reporting software.

Regional Greenhouse Gas Initiative (RGGI)

RGGI is the first mandatory, market-based CO₂ emissions reduction program in the U.S. RGGI is a cooperative effort by ten Northeast and Mid-Atlantic States to limit GHG emissions. The states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont are signatory states to the RGGI agreement. These ten states have capped CO₂ emissions from the power sector, and will require a 10 percent reduction in these emissions by 2018. RGGI is composed of individual CO₂ Budget Trading Programs in each of the ten participating states. These ten programs are implemented through state regulations, based on a RGGI Model Rule, and are linked through CO₂ allowance reciprocity.



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Table B-2. List of existing GHG programs.

Agency/ Organization	Program	Program Description	Focus	Calculation Tools/Data	Website	Program Status
U.S.						
World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI)	Public Sector Standards	An accounting guidance and management tool for government operations.	Government agencies	Various existing tools	http://www.ghgprotocol.org/the-public-sector-works-with-ghg-protocol-to-develop-a-new-standard	Provisional draft Oct 09. Final draft May 2010.
Climate Action Reserve	California Climate Action Registry	Sets consistent and transparent standards to calculate, verify and publicly report greenhouse gas emissions into a single registry.	Organization, Project	Climate Action Registry Reporting Online Tool (CARROT)	http://www.climateregistry.org/	General Reporting Protocol, v 3.1, 2009. General Reporting Protocol, 2008.
	The Climate Registry	A GHG registry serves all of North America. It is based upon the work of the California Registry.	Organization, Project	Reporting Online Tool (CARROT)	http://www.theclimateregistry.org/	General Reporting Protocol (GRP), v 1.1, 2008. GRP updates and clarification 2010.



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Table B-2. List of existing GHG programs (Continued).

Agency/ Organization	Program	Program Description	Focus	Calculation Tools/Data	Website	Program Status
U.S.						
EPA	2010 Inventory of Greenhouse Gas Emissions and Sinks	Prepared annually by EPA, the national greenhouse gas inventory report presents estimates of U.S. greenhouse gas emissions and sinks for the years 1990 through 2008. This report also discusses the methods and data used to calculate the emission estimates.	Nation-wide inventory	Publishes formulas and fuel factors	http://www.epa.gov/climatechange/emissions/	Prepared annually.
	National Emissions Inventory	The National Emissions Inventory (NEI) is EPA's compilation of estimates of air pollutants discharged on an annual basis and their sources. The Emissions Inventory System (EIS) is the new information system for storing all current and historical emissions inventory data.	National-wide inventory	EIS	http://www.epa.gov/ttn/chiefs/et/neip/index.html	Since 1996, compile data every three years. The most recent inventory is 2005 NEI, which was published in 2008.
	MOBILE6 Vehicle Emission Modeling Software	MOBILE6 is an emission factor model for predicting gram per mile emissions of Hydrocarbons (HC), Carbon Monoxide (CO), Nitrogen Oxides (NOx), <u>Carbon Dioxide (CO2)</u> , Particulate Matter (PM), and toxics from cars, trucks, and motorcycles under various conditions.	National, state, or county	MOBILE6	http://www.epa.gov/oms/m6.htm	Version 6.1 and 6.3, 2003.



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Table B-2. List of existing GHG programs (Continued).

Agency/ Organization	Program	Program Description	Focus	Calculation Tools/Data	Website	Program Status
U.S.						
	NONROAD Model (nonroad engines, equipment, and vehicles)	Calculates past, present, and future emission inventories (i.e., tons of pollutant) for all nonroad equipment categories except commercial marine, locomotives, and aircraft. The model estimates exhaust and evaporative hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), particulate matter (PM), sulfur dioxide (SO ₂), and <u>carbon dioxide (CO₂)</u> .	National, state, or county	NONROAD 2008	http://www.epa.gov/oms/nonrmdmdl.htm#docs	Latest model, NONROAD2008
	Office of Transportation and Air Quality (OTAQ)	Developed Motor Vehicle Emission Simulator (MOVES). This new emission modeling system is used to estimate emissions for mobile sources (cars, trucks and motorcycles) covering a broad range of pollutants and allow multiple scale analysis.	National, state, or county	MOVES2010	http://www.epa.gov/otaq/models/moves/movesback.htm	Replace MOBILE6.2 as the model states and local areas use to develop emission inventories for SIPs and conformity determinations.



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Table B-2. List of existing GHG programs (Continued).

Agency/ Organization	Program	Program Description	Focus	Calculation Tools/Data	Website	Program Status
U.S.						
	Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2009	This report provides data on the fuel economy, carbon dioxide (CO ₂) emissions, and technology trends of new light-duty vehicles (cars, minivans, sport utility vehicles, and pickup trucks) for model years 1975 through 2009 in the United States.	Vehicle	Fuel economy	http://www.epa.gov/OMS/fetr/ends.htm	2009
	eGRID	The latest two years of eGRID data are from 2005 and 2004. Contains sub-regional average emission factors.	Regional	eGRIDWeb	http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html	eGRIDWeb Version 1.0 launched in 2009
	Analysis of commercial marine vessels emissions and fuel consumption data	Development of fuel factors (g/kWh) based on Lloyds Register Engineering Services database and data from US Coastguard Headquarters Naval Engineering Division.	Ship	Fuel factor equation	http://www.epa.gov/oms/models/nonrdmdl/c-marine/r00002.pdf	2000



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Table B-2. List of existing GHG programs (Continued).

Agency/ Organization	Program	Program Description	Focus	Calculation Tools/Data	Website	Program Status
U.S.						
Energy Information Administration (EIA)/DOE	Voluntary Reporting of Greenhouse Gases Program	Fuel and Energy Source Codes and Emission Coefficients	Government agencies and organizations		http://www.eia.doe.gov/oiaf/1605/coefficient_s.html	Previous report released in 2005. Annual report planned starting in 2010.
California Air Resources Board (ARB)	Emissions Estimation Methodology for Ocean-Going Vessels	Developed a statewide emissions estimation methodology from ocean-going vessels (OGVs) operating in California coastal waters and California ports and inland waterways.	Ship	Uses Entec (2002) emission factors.	http://www.arb.ca.gov/regact/marine2005/appd.pdf	2005
GSA	Carbon Footprint and Green Procurement Tool	An online tool available for Federal agencies to use to complete their FY10 comprehensive GHG emissions inventory.	Government agencies		https://gsacarbontool.org/	June/July 2010 release
Regional Greenhouse Gas Initiative (RGGI)	RGGI	The Regional Greenhouse Gas Initiative (RGGI) is a cooperative effort by ten Northeast and Mid-Atlantic states to limit greenhouse gas emissions. RGGI is the first mandatory, market-based CO ₂ emissions reduction program in the United States.	States, Cap and Trade		http://www.rggi.org/about	



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Table B-2. List of existing GHG programs (Continued).

Agency/ Organization	Program	Program Description	Focus	Calculation Tools/Data	Website	Program Status
International						
Intergovernmental Panel on Climate Change (IPCC)	Emission Factor Database	An online database that contains IPCC default data presented in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. It also contains the data from CORINAIR94.	-	-	http://www.ipcc-nggip.iges.or.jp/EFDB/main.php	Launched in 2002. The database consists of data from IPCC guidelines version 1996 and 2006.
	2006 IPCC Guidelines for National Greenhouse Gas Inventories	Provide the best, widely applicable default methodologies and emission factors.	National level	Publishes formulas and fuel factors	http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html	2006
Royal Navy	UK Navy Surface Warships Engines Exhaust Emissions Study 1988- 2006	This paper highlights the emissions calculation methodology and the preliminary results which provide a first comparative outlook of the RN and RFA emissions burden in terms of CO ₂ , SO _x , NO _x and particulate matters (PM).	Ship (CO ₂ as the only GHG)	Provides formula	http://www.jne.web.com/entity/files/5/2623/jnepaperfilename/v44b2p13a.pdf	2008



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Table B-2. List of existing GHG programs (Continued).

Agency/ Organization	Program	Program Description	Focus	Calculation Tools/Data	Website	Program Status
International						
CONCAWE (The oil companies' European association for environment, health and safety in refining and distribution)	Impact on the EU of SO _x , NO _x and primary PM _{2.5} emissions from shipping in the Mediterranean Sea	Summary of the findings of the Euro Delta Project	Ship (SO _x , NO _x , and PM only)		http://www.concawe.be/Content/Default.asp?PageID=31	report no. 1/08, 2008.
Maritime and Coastguard Agency (MCA)	Interim Guidelines for Voluntary Ship CO ₂ Emission Indexing for Use in Trials	This is just a distribution channel for the IMO Guidelines.	Ship (CO ₂ only)	See EEOI. Provides C _f factors as g of CO ₂ /g of fuel consumed.	http://www.mca.gov.uk/c4mca/min_271.pdf	MIN 271 (M), 2007.
World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI)	Corporate Standards	Provides standards and guidance for companies and other organizations preparing a GHG emissions inventory. This protocol was developed jointly by The Climate Registry, the California Climate Action Registry, the California Air Resources Board and ICLEI - Local Governments for Sustainability.	Company	Provide links to various existing tools	http://www.ghgprotocol.org/standards/corporate-standard	The 1 st edition was published in 2001. The revised edition was released in 2004.



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Table B-2. List of existing GHG programs (Continued).

Agency/ Organization	Program	Program Description	Focus	Calculation Tools/Data	Website	Program Status
International						
	GHG Protocol for Project Accounting	Used to quantify the reductions associated with GHG mitigation projects for use as offsets or credits	Project		http://www.ghgprotocol.org/standards/project-protocol	Published in 2005.
IMO	Study of Greenhouse Gas Emissions from Ships	Examination of GHG emission reduction possibilities through different technical, operational and market-based approaches.	Ship	Provides emission factors from EMEP/CORINAIR, 1999	http://unfccc.int/files/methods_and_science/emissions_from_intl_transport/application/pdf/imoghmain.pdf	Published in 2000
	Energy Efficiency Operator Index (EEOI)	Guidelines for voluntary use of the Ship Energy Efficiency Operational Indicator (EEOI).	Ship (CO ₂ only)	Provides C _f factors as g of CO ₂ /g of fuel consumed. Based on ISO 8217 fuel standards.	http://www.imo.org/includes/blastDataOnly.asp/data_id%3D26403/684.pdf	2009
European Commission	Study conducted by Entec UK Limited	Quantification of emissions from ships associated with ship movements between ports in the European Community	Ship	Emission factors	http://ec.europa.eu/environment/air/pdf/chapter1_ship_emissions.pdf	2002



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Table B-2. List of existing GHG programs (Continued).

Agency/ Organization	Program	Program Description	Focus	Calculation Tools/Data	Website	Program Status
International						
European Environment Agency (EEA)	EMEP/EEA air pollutant emission inventory guidebook — 2009	The EEA and the Cooperative program for monitoring and evaluation of the long-range transmission of air pollutants in Europe (EMEP).	National emission inventory	Emission estimation methods used in air pollution studies in Europe and the UNECE geographical area.	http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009	2009
ISO	ISO 14064	Specifies principles and requirements at the organization level for quantification and reporting of greenhouse gas (GHG) emissions and removals. It includes requirements for the design, development, management, reporting and verification of an organization's GHG inventory.	Organization		http://www.iso.org/iso/catalogue_detail?csnumber=38381	2006
National Technical University of Athens	Ship Emission Study	Ship Emission Study and Model	Ship	Emission calculator (web tool)	http://www.martrans.org/emis/emis.htm	2008



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Table B-2. List of existing GHG programs (Continued).

Agency/ Organization	Program	Program Description	Focus	Calculation Tools/Data	Website	Program Status
International						
Swedish Environmental Protection Agency, Swedish Methodology for Environmental Data (SMED)	Methodology for calculating emissions from ships: 1. Update of emission factors	Derived emission factors for ships (> 100 Gross Register Tonnage) to be applied in Sweden's international reporting duties. The basis for this type of reporting is that only emissions derived from Swedish sold marine fuels are accounted for.	Ship	Fuel factors by engine and fuel type.	http://westcoastcollaborative.org/files/sector-marine/SMED%20Methodology%20for%20Calculating%20Emissions%20from%20Ships.pdf	2004
United Nations Economic Commission for Europe (UNECE)	Protocol on Pollutant Release and Transfer Registers	The Protocol is the first legally binding international instrument on pollutant release and transfer registers. PRTRs are inventories of pollution from industrial sites and other sources.	Industrial facility		http://www.unece.org/env/pp/prtr.htm	The Protocol became international law binding its Parties on 8 October 2009.
ICLEI	Bonn Center for Local Climate Action and Reporting (carbon)	ICLEI is the first global network of cities and local governments to achieve sustainability at the local level. Implemented many partnerships/climate programs including carbon.	City and local government	A number of software tools for inventorying GHG emissions for local governments	http://www.carbon.org/tools.php	Established carbon in 2009.
	Greenhouse Gas Accounting Protocols	Includes the International Emissions Analysis Protocol and Local Government Operations Protocol.	Local government		http://www.iclei.org/programs/climate/ghg-protocol	



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APPENDIX C. PRELIMINARY METHODOLOGY

C.1 Organization/Overview of Preliminary Methodology

The USCG vessel carbon footprint methodology is based on the process map generated during the workshop, and U.S. and international guidelines and protocols described in Appendix B.2. The GHG methodology is organized by emission sources shown in Table C-1

Each of the methodology sections include:

- A description of the emission source.
- Estimation method including equations for calculating tons of CO₂ or CO₂-e.
- Estimation Method Flow Chart.
- Data Item Definitions.
- Assumptions and Limitations of the Methodology.

It is important to point out that while the current methodology provides a solid foundation for the development of a comprehensive GHG inventory for vessel operation and maintenance, there are uncertainties associated with the emission estimates. Some of the current estimates, such as those for CO₂ emissions are considered to have relatively low uncertainties. For CH₄ and N₂O emissions, however, the lack of data or use of generalized consumptions may increase the uncertainty associated with the estimates. Acquiring a better understanding of the uncertainty associated with the GHG estimates is important in helping to prioritize future methodology development and improving the quality of the methodology. A qualitative discussion of uncertainty is presented for all vessel emission sources in the limitation section. Specific factors and data affecting the estimates are included in the discussion of each emission source.

Table C-1. Methodology overview.

Emission Source	GHG Emission	Scope (1, 2, 3)	Section #
Vessel Propulsion Emissions	CO ₂ , CH ₄ , N ₂ O	1	C.2
Vessel Electrical Generation Emissions	CO ₂ , CH ₄ , N ₂ O	1	C.3
Boiler Emissions	CO ₂ , CH ₄ , N ₂ O	1	C.4
Helicopter Emissions	CO ₂ , CH ₄ , N ₂ O	1	C.5
Cutter Boat Emissions	CO ₂ , CH ₄ , N ₂ O	1	C.6
Refrigerant Emissions	HFC	1	C.7
Fire Suppressant Emissions	CO ₂ , HFC	1	C.8
Incinerator Emissions	CO ₂ , CH ₄ , N ₂ O	1	C.9
Purchased Shore Power Emissions	CO ₂ , CH ₄ , N ₂ O	2	C.10
Towing Vehicle Emissions	CO ₂ , CH ₄ , N ₂ O	1 or 3*	C.11
Employee Commute Emissions	CO ₂ , CH ₄ , N ₂ O	3	C.12
Ashore Solid Waste Disposal Emissions	CH ₄ (Landfill)	3	C.13
Ashore Liquid Waste Disposal Emissions	CH ₄	3	C.14
* Scope 1 if the vehicle is under the operational control of the vessel. Scope 3 if the vessel is controlled and owned by the shore facility.			



C.2 Vessel Propulsion Emissions

The single largest source of GHG emissions for a USCG vessel is from the combustion of fossil fuels, primarily during the propulsion of the vessel. Fossil fuel combustion produces direct GHG emissions of CO₂, CH₄, and N₂O. Other emissions created during combustion that contribute to local and regional air pollution but are not contributors to GHG emissions, include carbon monoxide (CO), non-methane volatile organic compounds, sulfur dioxide (SO₂), particulate matter (PM), and nitrate oxides (NO_x). The current methodology is focused on GHG emissions, and does not address these environmental pollutants.

C.2.1 Emission Estimate Method

The fundamental methodology for estimating GHG emissions from vessel propulsion is tied to fuel consumption. Detailed ship movement data and technical information, such as engine type and efficiency, are utilized for estimating engine fuel consumption and emissions. CO₂ emission is calculated on the basis of the amount and type of fuel combusted and its carbon content. The carbon content coefficient based on energy units are less variable than carbon content coefficient per mass or volume units, because the heat content or energy value of a fuel is more closely related to the amount of carbon in the fuel than to the total physical quantity of fuel. As recommended by the Public Sector Standard, the fuel consumption is converted to British Thermal Unit (BTU) when calculating the GHG emissions. Also consistent with the IPCC guidelines, the emission factors assume full oxidation of the fuel. Finally, the CO₂ emission is estimated by applying the molecular weight conversion factor for carbon to carbon dioxide of (44/12). Figure C-1 provides the flow chart for estimating vessel propulsion engine emissions. Equation (C-1), Equation (C-2), and Equation (C-3) detail the CO₂, CH₄, and N₂O emission calculations, respectively.

Equation (C-1). Total CO₂ emission calculation from fuel consumption.

$$\begin{aligned} \text{Total Emissions} &= \text{Fuel Consumption} \cdot \text{Carbon Content Coefficient} \cdot \text{Fraction Oxidized} \cdot \frac{44}{12} \\ (\text{metric tons CO}_2) & \quad (\text{MBTU}) \\ &= \text{Fuel Consumption} \cdot \text{Emission Factor} \\ & \quad (\text{MBTU}) \quad (\text{metric tons CO}_2 / \text{MBTU}) \end{aligned}$$

Equation (C-2). Total CH₄ emission calculation.

$$\begin{aligned} \text{Total Emissions} &= \text{Fuel Consumption} \cdot \text{Emission Factor} \cdot \text{GWP} \\ (\text{metric tons CO}_2\text{-e}) & \quad (\text{MBTU}) \quad (\text{metric tons CH}_4 / \text{MBTU}) \end{aligned}$$

Equation (C-3). Total N₂O emission calculations.

$$\begin{aligned} \text{Total Emissions} &= \text{Fuel Consumption} \cdot \text{Emission Factor} \cdot \text{GWP} \\ (\text{metric tons CO}_2\text{-e}) & \quad (\text{MBTU}) \quad (\text{metric tons N}_2\text{O} / \text{MBTU}) \end{aligned}$$



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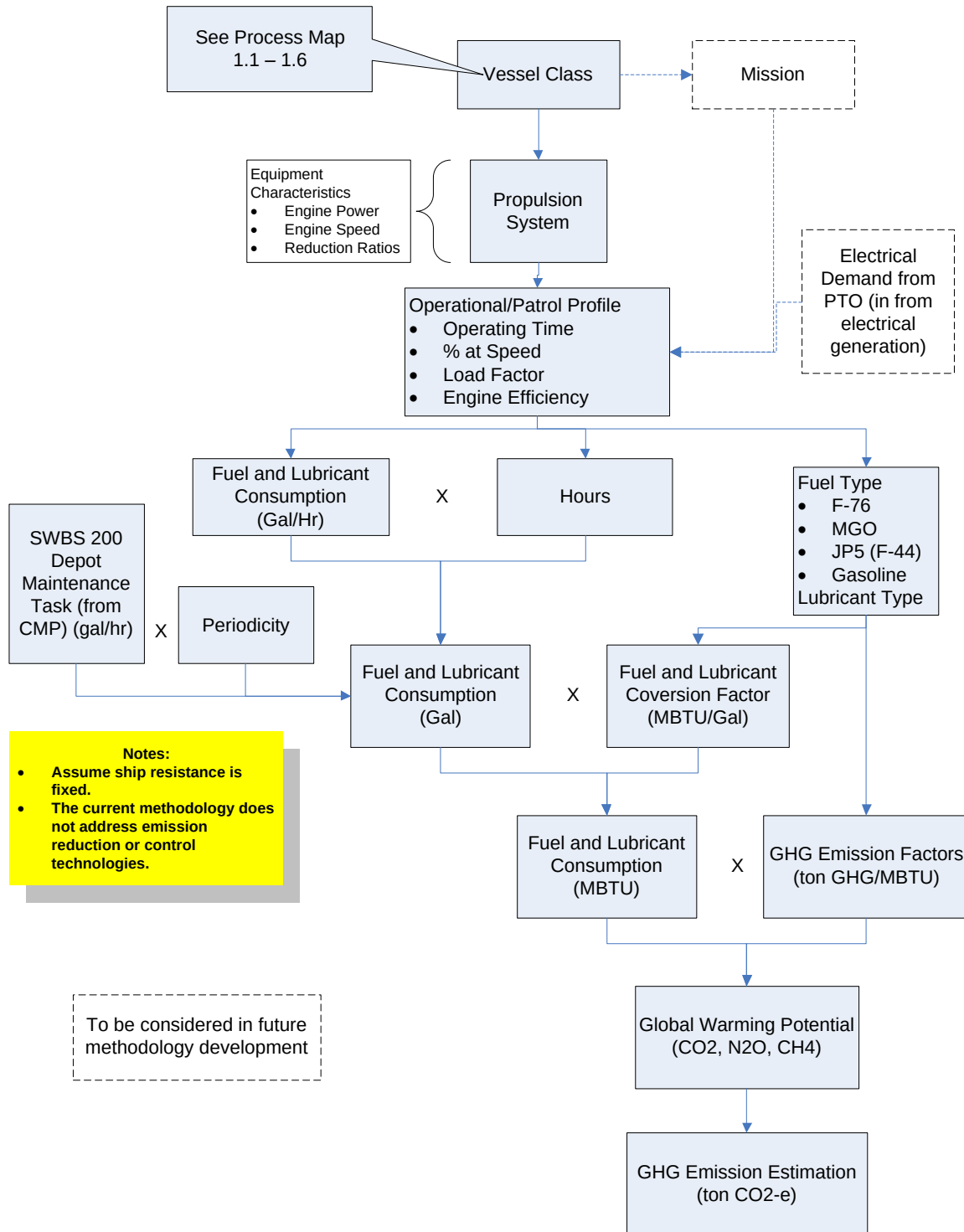


Figure C-1. Vessel propulsion emission estimation.



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C.2.2 Data Analysis

Vessel fuel consumption is dependent on vessel class, engine type, and the annual operational/patrol profile. This section summarizes the key data elements and identifies the potential data sources.

Vessel Class. A USCG publication²³ was used to categorize the GHG emission sources. USCG vessels longer than 65 feet in length are grouped by class (e.g., 378' SECRETARY-Class, 270' FAMOUS-Class), while boats, vessels ranging from 64 feet down to 12 feet, are grouped either as standard or nonstandard.

Propulsion System. The vessel class identifies the propulsion system (engines, reduction gear, shafting, propellers, etc.) applicable to the methodology. Speed/power relationships and power/fuel consumption relationships were used to estimate the fuel consumption based on the operational profile.

Operational/Patrol Profile. The annual operational/patrol profile defines the patrol speed/time distribution and percent of time the vessel spends in various ship states (days in homeport, days away from homeport, days in transit, etc.). The vessel Operational Requirements Document is used to construct the operational and patrol profile.

Fuel and Lubricant Type. The combustion of fuel and lubricants during engine operation contributes to GHG emissions. Fuel and lubricant types are identified by vessel class, and their use is applied based on the operational and patrol profile.

Fuel and Lubricant Conversion Factors. The thermal unit conversion factors for fuel and lubricant are provided by the Energy Information Administration (EIA). To be consistent with the Public Sector Standard, fuel and lubricant consumption is converted to BTU.

Emission Factors. CO₂ emission factors are primarily dependent on fuel type, while CH₄ and N₂O are dependent on engine type and combustion technology. Emission factors were derived from various sources including the 2006 IPCC Guidelines and the National Inventory of Greenhouse Gas Emissions and Sinks prepared by the EPA annually.

Ship Work Breakdown Structure (SWBS) 200 Depot Maintenance Tasks. Depot and organizational level maintenance is defined for each class of vessels in the respective Class Maintenance Plan. Any depot maintenance tasks that generate oil as a waste product or require engines to be operated during the course of the maintenance may contribute to the GHG emissions and carbon footprint of the vessel.

Global Warming Potential. GWP²⁴ is used to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to CO₂ as the reference gas. The GWP for different GHG is obtained from the IPCC Second Assessment Report (SAR). This study uses the SAR value²⁵ consistent with the U.S. national GHG inventory and the United Nations Framework Convention on Climate Change reporting guidelines.

²³ United States Coast Guard, "Aircraft, Boats, and Cutters, Information on USCG Resources", <http://www.uscg.mil/datasheet/> (accessed April 30, 2010)

²⁴ The GWP of a greenhouse gas is defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kilogram (kg) of a trace substance relative to that of 1 kg of a reference gas

²⁵ GWP values are also published in the IPCC Third Assessment Report and Fourth Assessment Report.



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According to National Inventory of Greenhouse Gas Emissions and Sinks, the GWP for 100-year time horizon is used in this study.

C.2.3 Assumptions and Limitations

This section describes the general assumptions and limitations associated with the engine GHG emission methodology. Additional assumptions related to specific elements and parameters are documented in the carbon footprint methodology assessment workbook.

- According to IPCC Guideline, the CO₂ emission factors for fuels are generally well determined as they are primarily dependent on the carbon content of the fuel. For example, the default uncertainty value for diesel fuel is about ± 1.5 percent and for residual fuel oil ± 3 percent. The uncertainty for non-CO₂ emissions, however, is much greater. The uncertainty of the CH₄ emission factor may range as high as 50 percent. The uncertainty of the N₂O emission factor may range from about 40 percent below to about 140 percent above the default value.
- Engine emission factors assume full oxidation of the fuel.
- The current methodology does not address emission control and reduction technologies.
- Assume ship resistance is fixed.
- Fuel experiences expansion and contraction with temperature changes. The current methodology does not consider fuel temperature variations when determining fuel consumption. The operation of the vessel during summer and winter months is assumed to off-set fuel temperature differentials that affect volume fluctuations.

C.3 Vessel Electricity Generation Emission

In large vessels, electricity is primarily generated by the auxiliary engines driving an attached generator. However, not all vessels in the USCG fleet utilize auxiliary engines alone to generate power. Some vessels utilize the main propulsion engines to generate electrical power through power takeoff (PTO) shafts connected to the main engine reduction gear, while others have an integrated electric propulsion plant. Smaller boats utilize a system similar to an automobile, where an alternator charges the battery and the battery provides the power to the electric and electronic equipment. Electrical power generation consumes fuel and generates GHG emissions as CO₂, CH₄, and N₂O.

C.3.1 Emission Estimate Method

The vessels annual operational patrol profile can be utilized to determine the duration of time the vessel spends underway producing power (or in various ports of call producing power). This information provides the annual number of operating hours the vessel is generating electricity. The vessels design powering analysis is then utilized to determine the specific power demands, and source of those demands and when coupled with the specific generator set characteristics (efficiencies, fuel consumption curves, etc.), a total annual fuel consumption can then be calculated. Once the amount of fuel consumption is determined, the remainder of the methodology is exactly the same as the methodology outlined for the propulsion engine.

GHG emissions are estimated by applying the emission factors to the amount of fuel consumed in MBTU. Figure C-2 provides the flow chart for estimating vessel electricity generation emissions. Equation (C-1),



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Equation (C-2), and Equation (C-3) in Section C.2.1 detail the CO₂, CH₄, N₂O emission calculations, respectively.

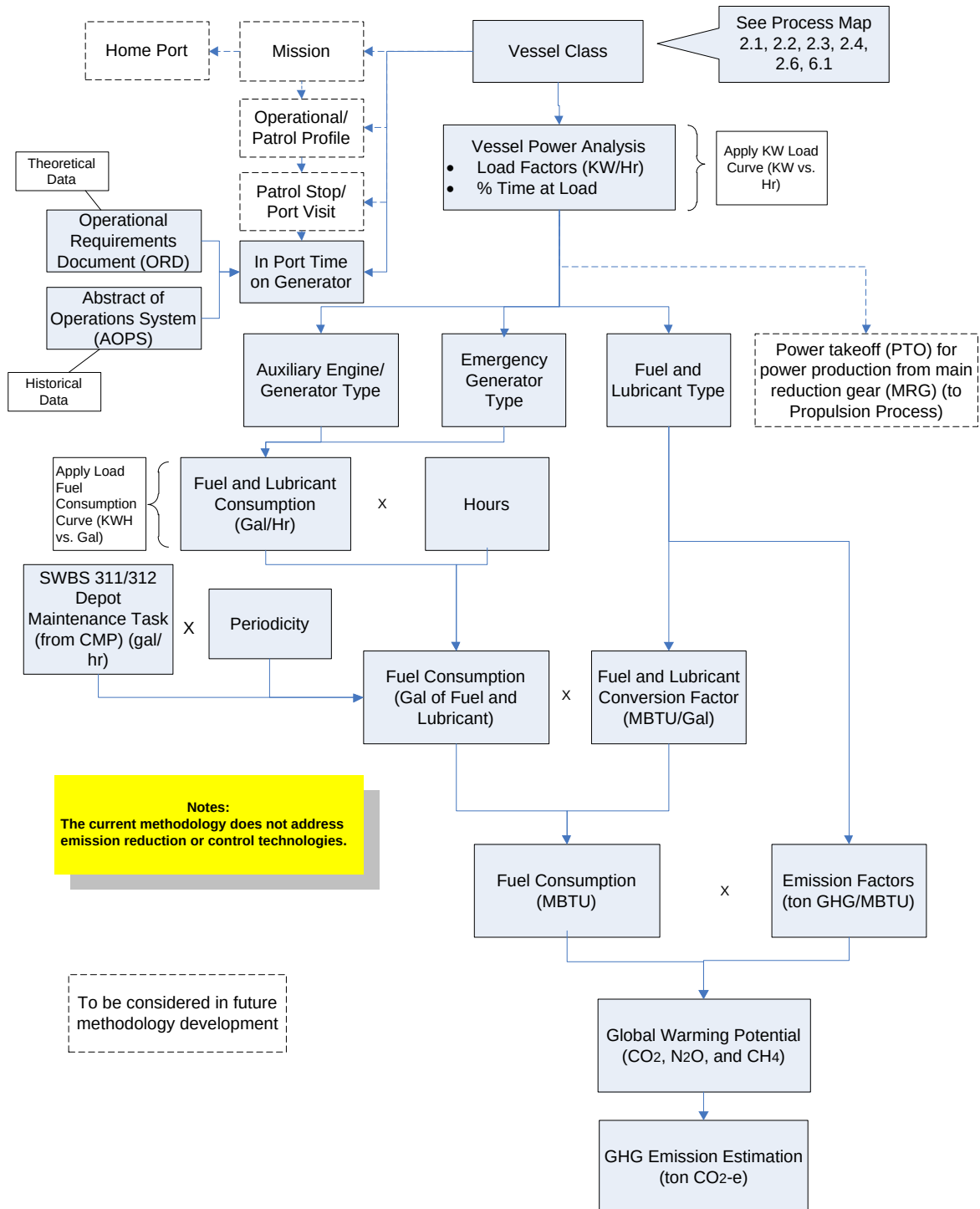


Figure C-2. Vessel electricity generation emission estimation.



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C.3.2 Data Analysis

Fuel consumption is dependent on vessel class, generator type, vessel design electrical load and operational/patrol profile. This section summarizes the key data elements and identifies the potential data sources. Since emissions from auxiliary engine are similar to the propulsion engine, many of the common parameters can be referred to in Section C.2.2 thus they are not repeated here.

Emergency Generator Type. An emergency power generator can be used to provide emergency services and to ensure uninterrupted supply of power for a vessel.

Vessel Power Analysis. The vessel power analysis will be utilized to apply the load factor and percentage of time at load to the generators in order to determine fuel consumption.

In Port Time on Generator. The vessel's service generators are sometimes used to generate power, while the vessel is in port, typically when shore power is not available.

Fuel and Lubricant Consumption Rate. The fuel consumption rate is calculated using the generator fuel consumption curve and vessel load analysis.

PTO for Power Production: Some vessels have a power takeoff shaft coming off the main reduction gear to produce electrical power (in the USCG this is primarily to generate power for vessel thrusters). This electrical demand is directly utilized for vessel positioning thus this demand is accounted for in the propulsion methodology section.

SWBS 311 and 312 Depot Maintenance Tasks. Depot and organizational level maintenance is defined for each class of vessels in the respective Class Maintenance Plan. Any depot maintenance tasks that generate oil as a waste product or require engine operation during the course of the maintenance may contribute to the GHG emissions and carbon footprint of the vessel.

C.3.3 Assumptions and Limitations

This section describes the general assumptions and limitations associated with the estimation methodology for vessel electricity generation emissions. Additional assumptions related to specific elements and parameters are documented in the carbon footprint methodology assessment workbook.

- The current methodology does not address emission control and reduction technologies.
- Engine emission factors assume full oxidation of the fuel.
- The default emission factors from the IPCC have higher uncertainty for CH₄ and N₂O. As a result, engine and technology specific emission factors should be developed and considered in future methodology development.

C.4 Boiler Emission

The major source of GHG emissions from a boiler system is CO₂ from the combustion of fossil fuels in the boiler. Other minor sources of GHG include CH₄ and N₂O as byproducts of combustion processes.



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C.4.1 Emission Estimate Method

GHG emissions are estimated by applying the emission factors and the amount of fuel consumed in MBTU. The emission estimation equations are detailed in . Equation (C-1), Equation (C-2), and Equation (C-3) in Section C.2.1 detail the CO₂, CH₄, N₂O emission calculations. Figure C-3 provides the flow chart for estimating boiler emissions.

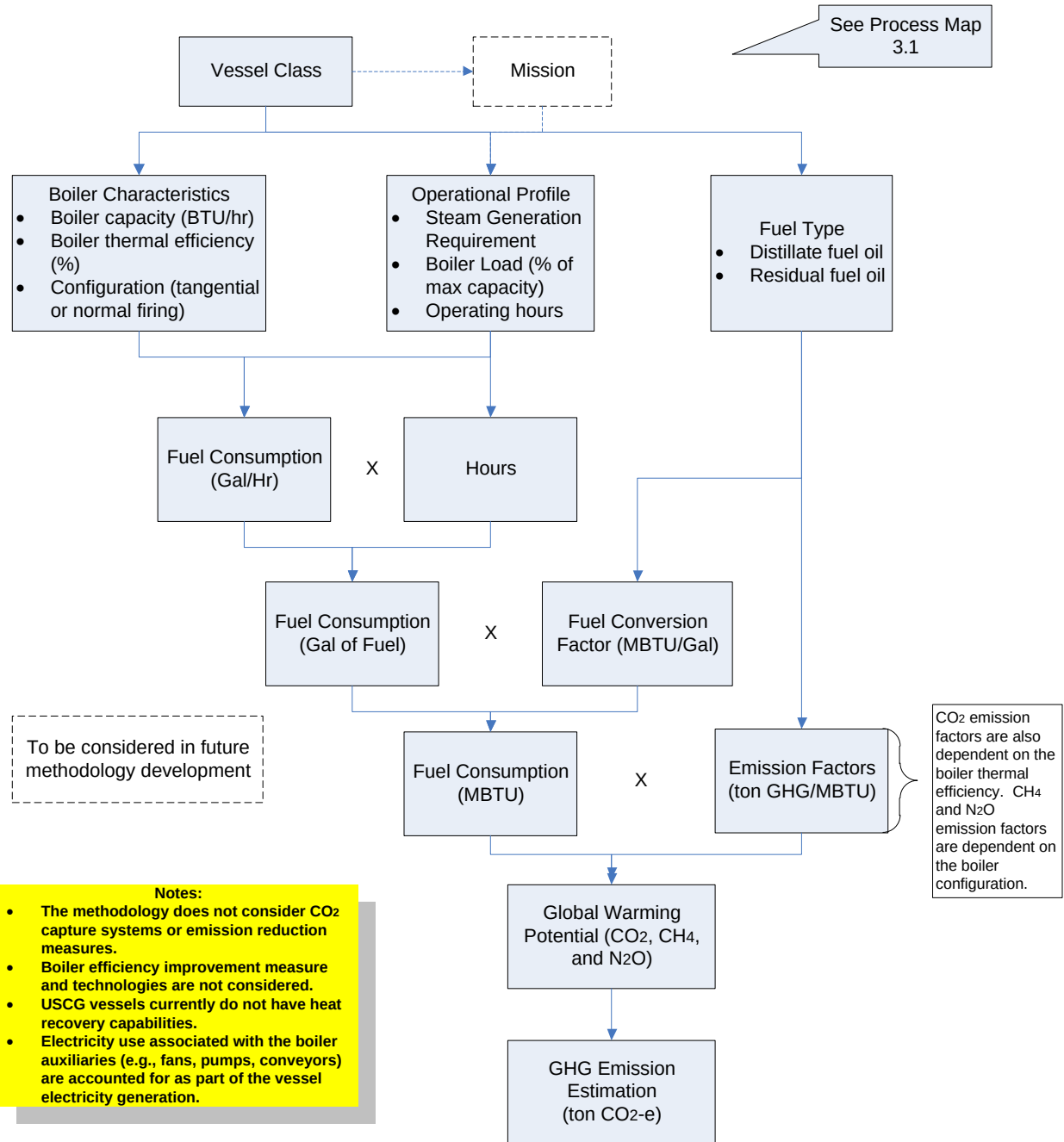


Figure C-3. Boiler emission estimation flowchart.



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The methodology requires data on the amount of fuel combusted and the emission factors. The CO₂ emission factors are determined based on fuel type and boiler thermal efficiency. The CH₄ and N₂O emission factors are based on fuel type and boiler configurations (e.g., tangential or normal firing). In reality, the emission estimation requires consideration of the combustion technology, operating conditions, control technology, quality of maintenance, and age of the equipment used to burn the fuel. The current methodology does not consider these other variables.

C.4.2 Data Analysis

Boiler fuel consumption is primarily dependent on vessel class, boiler characteristics, and operational profile. This section summarizes the key data elements and identifies the potential data sources.

Boiler Characteristics. Boiler characteristics, such as boiler capacity, thermal efficiency, and configurations are important factors in estimating emissions. The CO₂ emission factors are determined based on fuel type and boiler thermal efficiency. The CH₄ and N₂O emission factors are based on fuel type and boiler configurations²⁶. Boiler specifications and performance data can be obtained from the USCG Technical Information Management System.

Operational Profile. The vessel operational profile determines the boiler operational requirements such as the boiler load (percentage time at maximum capacity) and hours in operations. In other words, fuel consumption is dependent on operational profile. Operational profile can also be tied to mission, but will be considered in future methodology development.

Fuel Type. The emission factors are dependent on the type of fuel used. The type of fuels used on USCG vessels include F-76, marine gas oil, and JP-5 (F-44).

C.4.3 Assumptions and Limitations

This section describes the general assumptions and limitations associated with boiler emission estimation. Additional assumptions related to specific elements and parameters are documented in the carbon footprint methodology assessment workbook.

- The methodology considers only the current types of boilers in USCG inventory, and not any form of advanced (e.g., heat recovery) or supplementary technologies.
- The methodology does not consider CO₂ capture systems.
- Electricity use associated with the boiler auxiliaries (e.g., fans, pumps, conveyors) are accounted for as part of the vessel electricity generation.
- The boiler efficiency, boiler configuration, and fuel type are considered in determining the emission factors. The current methodology does not consider other technology variables such as the age and maintenance condition of the equipment.

²⁶ Emission factors are provided by the “*Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2009*,” April 2010. U.S. Environmental Protection Agency.



C.5 Deployed Helicopter Emission

A helicopter is considered a deployed asset of the vessel, and for this model it is considered as a component of the vessel's carbon footprint only while deployed with the cutter. In the future, should the USCG aviation community decide to develop a carbon footprint for each helicopter or decide to tie the helicopter's carbon footprint to the parent air station, this portion of the methodology can be easily removed from the cutter's calculation.

Helicopter flight operations involve a series of preparation activities and functions such as traversing, securing and unsecuring, fueling, firefighting standby, rescue boat preparation, helicopter maintenance and communication and control elements. The majority of these evolutions are part of a vessel's standard underway routine. This section of the methodology only considers the combustion of fuel from the helicopters while flying from the vessel in an operational or training capacity. This methodology currently does not include helicopter maintenance conducted onboard the vessel.

C.5.1 Emission Estimate Method

Emissions from aviation come from the combustion of jet kerosene and aviation gasoline. Emissions vary with the number and type of aircraft operations; the types and efficiency of the aircraft engines; the fuel used; the length of flight; the power setting; the time spent at each stage of flight; and, to a lesser degree, the altitude at which exhaust gases are emitted. The consideration of these factors requires sophisticated computer models to address fuel burnt and emissions throughout the full trajectory of each flight segment using aircraft and engine-specific aerodynamic performance information. The current methodology does not model the emissions using these factors, but relies on fuel consumption.

The methodology for estimating CO₂, CH₄ and N₂O emissions from a helicopter is primarily based on fuel consumption. The emission estimation in Equation (C-1), Equation (C-2), and Equation (C-3) in Section C.2.1 detail the CO₂, CH₄, N₂O emission calculations, respectively. Depending on the data availability and the significance of the helicopter emission, a more detailed method²⁷ can also be used to calculate emissions using the number of landing/take-off (LTO) cycles and fuel consumption. Due to data limitation²⁸ and given the current limited knowledge of CH₄ and N₂O emission factors, more detailed methods will not significantly reduce uncertainties for CH₄ and N₂O emissions. Therefore, the methodology based on fuel consumption is recommended for this study. Figure C-4 illustrates the process for estimating helicopter emissions.

²⁷ Total emission is the sum of LTO emission and cruise emission. LTO emissions can be estimated using the number of LTO and LTO emission factors. Cruise emission is product of cruise fuel consumption and cruise emission factors. Cruise fuel consumption is calculated using the total consumption and LTO fuel consumption. Additionally, LTO fuel consumption is dependent on fuel flow which is determined by the engine thrust setting,

²⁸ International Civil Aviation Organization established emissions measurement procedures and compliance standards for soot, unburned hydrocarbons, CO, and NO_x. CO₂ emission can be derived from fuel burn based on the correlation that 3.16 kg CO₂ is produced for each kg fuel used. Other emissions are not currently modeled in emissions databases because of insignificant quantity or the fact that little data exists.



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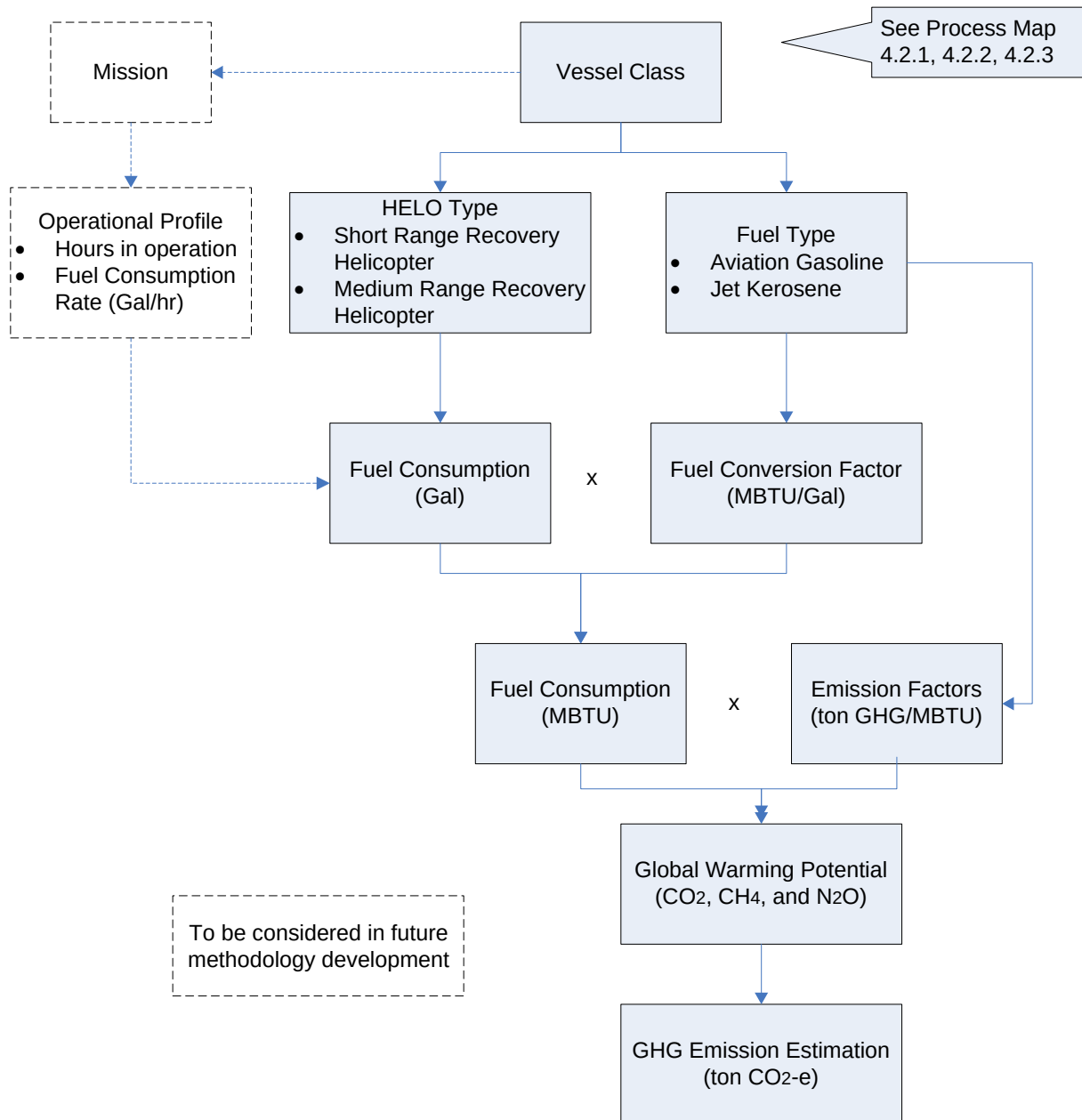


Figure C-4. Helicopter fuel emission estimation flowchart.

C.5.2 Data Analysis

The following section summarizes the key data elements for estimating helicopter emissions. Other common parameters that have been described previously will not be repeated here.

Fuel Consumption. Helicopter fuel consumption data can be obtained from the vessels JP-5 refueling log book or the vessels monthly fuel reports. The quality of the fuel consumption data strongly influences the accuracy of the emission estimation. For future methodology development, the total fuel consumption can



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be calculated based on mission and operational profile. Hours in operations and fuel consumption rates can be incorporated.

Fuel Type. USCG shipboard helicopters operate on JP-5 (F-44 NATO Symbol). GHG emission factors are dependent on fuel types: aviation gasoline and jet kerosene. As mentioned previously, if a more detailed methodology is used to incorporate LTO cycles. LTO emission rates are available for jet fuel.

C.5.3 Assumptions and Limitations

This section describes the general assumptions and limitations associated with helicopter carbon footprint estimation. Additional assumptions related to specific elements and parameters are documented in the carbon footprint methodology assessment workbook.

- The current methodology uses the default emission factors. The CO₂ emission factors should be within a range of ± 5 percent, as they are dependent only on the carbon content of the fuel and fraction oxidized.
- The CH₄ emissions are negligible and are assumed to be zero. The default CH₄ emission factors apply to LTO cycles only.
- Assume all aircraft have the same emission factors for CH₄ and N₂O based on the rate of fuel consumption. In reality, different types of aircraft/engine combinations have specific emission factors and these factors may also vary according to distance flown.
- The uncertainty of the CH₄ emission factor may range between -57 and +100 percent. The uncertainty of the N₂O emission factor may range between -70 and +150 percent.

C.6 Cutter Boat Emission

All vessels under 65 feet in length are classified as boats and usually operate near shore and on inland waterways. Craft include: motor lifeboats; motor surf boats; large utility boats; surf rescue boats; port security boats; aids to navigation boats; and a variety of smaller, non-standard boats including rigid inflatable boats. Non-standard boats are sized from 12-64 feet in length. Cutter boats are small boats that deploy from a larger USCG vessel and are attached to that specific parent vessel.

This section addresses small Cutter boats that are used as a deployed asset. Small Cutter boat emissions are considered an extension of the USCG vessel's carbon footprint. Station boats, which are categorized as a type of USCG vessel, are covered by this entire methodology less this section. A distinction is made between Cutter boats and station boats by the way fuel consumption is estimated. For Cutter boats, consumption data is derived from cutter log books and fuel consumption records. For station boats, the patrol and operational profiles are taken into consideration, in which the speed, engine efficiency and other factors are incorporated.

C.6.1 Emission Estimation Method

The methodology is focused on the direct emission of CO₂, CH₄, and N₂O resulted from fuel combustion. The emission estimation equations are detailed in Equation (C-1), Equation (C-2), and Equation (C-3) in Section C.2.1 which detail the CO₂, CH₄, N₂O emission calculations, respectively. Figure C-5 provides the flow chart for estimating small boat emissions.



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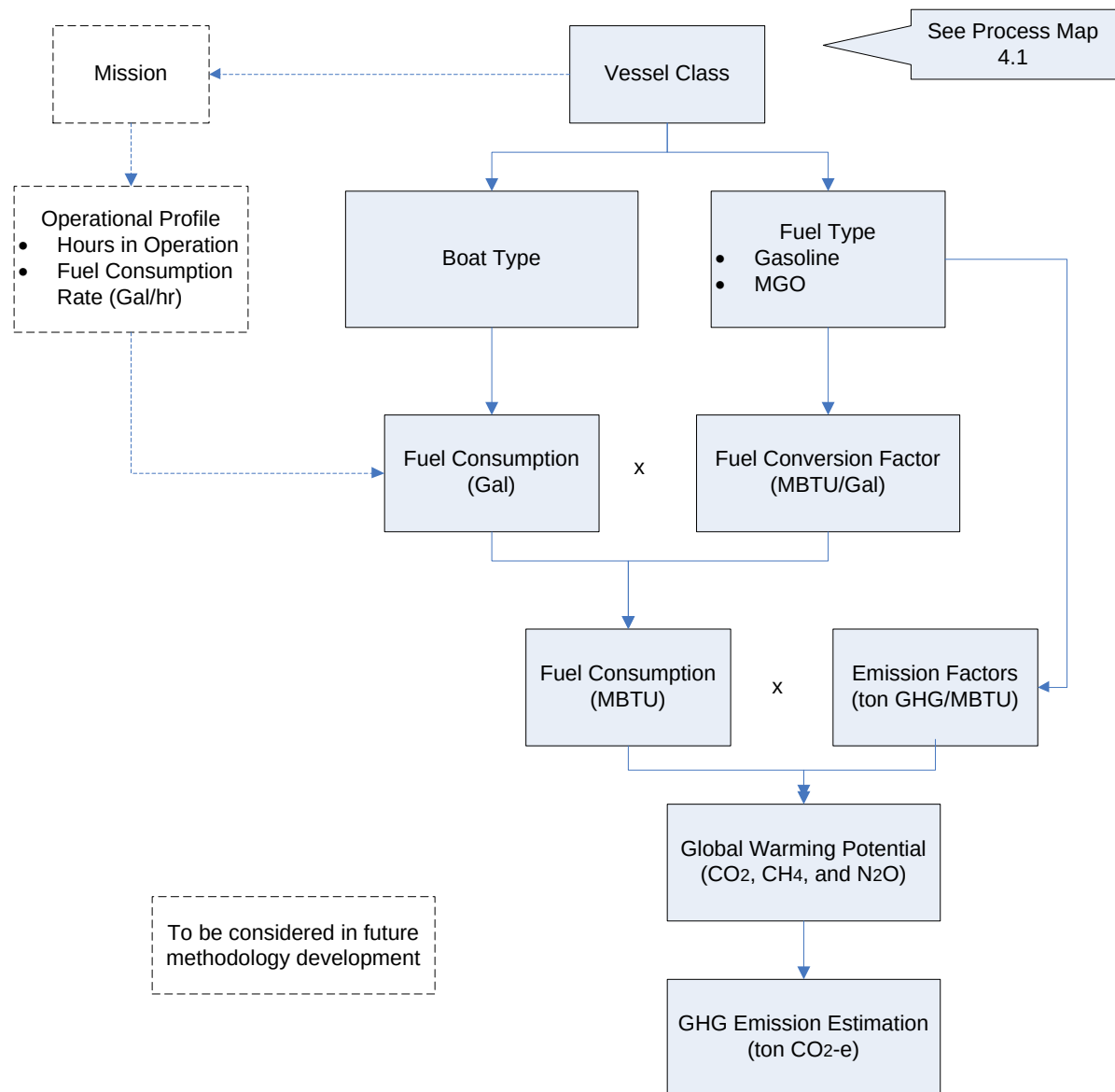


Figure C-5. Cutter boat fuel emission estimation flowchart.

C.6.2 Data Analysis

The following section summarizes the key data elements for estimating boat emissions. Other common parameters that have been described previously will not be repeated here.

Fuel Consumption. Fuel consumption data is obtained from vessel log books. The quality of the fuel consumption data strongly influences the accuracy of the emission estimation. For future methodology development, the total fuel consumption can be calculated based on mission and operational profile. Hours in operations and fuel consumption rates can also be incorporated.



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C.6.3 Assumptions and Limitations

This section describes the general assumptions and limitations associated with small boat emission estimation. Additional assumptions related to specific elements and parameters are documented in the carbon footprint methodology assessment workbook.

- The current methodology uses the default emission factors. The uncertainty of the CH₄ emission factor may range as high as 50 percent. The uncertainty of the N₂O emission factor may range from about 40 percent below to about 140 percent above the default value.
- CO₂ emission is major GHG emission category. The uncertain of the estimation is greatly dependent on the quality of the fuel consumption data. Currently, fuel use data is obtained from paper records and limited QA was conducted during initial data entry. Therefore, the fuel consumption records may have limited data confidence.

C.7 Shipboard Refrigerant Emission

Typical shipboard refrigerants include HFCs and PFCs which have high GWPs and, in the case of PFCs, long atmospheric residence times. HFCs and, to a limited extent, PFCs, are used as refrigerants and served as alternatives to ODS. HFCs can also be used in blends, such as the R-500 and HFC-23²⁹. When collecting data on HFCs in blends, one only needs to include GHG components and avoid including components, such as CFCs and HCFCs, which are not required to be reported. HFC-134a is currently used by most refrigeration and air conditioning equipment onboard USCG cutters. The USCG does not have an inventory of all the equipment which contains refrigerant onboard its vessels. The majority of the smaller refrigeration equipment on board the vessels, such as galley reach-in refrigerators, mess deck ice cream makers, coke machines, etc., is currently not centrally managed.

C.7.1 Emission Estimation Method

Two approaches can be used to estimate shipboard refrigerant emissions: the emission factor approach and the mass balance approach. The emission factor approach is based on calculating consumption data for individual pieces of equipment. This consumption data is calculated by applying generic equipment emission factors³⁰ and takes into account that fugitive emissions occur throughout the lifetime of the specific product. The mass-balance approach focuses on the annual refrigerant inventory and changes to that inventory. The difference between the starting and ending inventory, after taking into account capacity increases and decreases due to equipment changes and inventory procurement, is the GHG fugitive emission. Note, an important assumption is that all equipment is recharged to capacity at least once during the year.

²⁹ HFC-23 is a byproduct of hydrochlorofluorocarbon (HCFC) production.

³⁰ EPA, Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct HFC and PFC Emissions from Use of Refrigeration and Air Conditioning Equipment, 2008.



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The current methodology incorporates the emission factor approach, which uses the current inventory of equipment or products, and chemical acquisition data are to estimate the refrigerant emissions. In general, refrigerating equipment emits little or no refrigerant through leakage during its lifetime and most of its charge is released at disposal. Additionally, disposal may not entail significant emissions if the refrigerant and the blowing agent are both captured for recycling or destruction.

In order to estimate refrigerant emissions, it is necessary to estimate the net loss/leak of each HFC at a detailed product and equipment level. It is therefore also necessary to estimate the amount of refrigerant charged into the new equipment, the capacity of current equipment, and the capacity remaining at disposal for the retiring equipment. Emission factors are used to estimate precharge emission/assembly loss, operational fugitive emission, and disposal emission. The equations for the emission factor approach are as follows:

Equation (C-4). Total refrigerant emissions based on time-series/life cycle consideration.

$$\begin{aligned} \text{Total Emissions} = & \text{Precharge Emissions/Assembly Loss} + \\ & \text{Operational Fugitive Emissions} + \text{Disposal Emissions} \end{aligned}$$

(metric tons HFC or PFC)

Equation (C-5). Refrigerant precharge emissions/assembly loss.

$$\text{Total Emissions} = \text{Amount of Refrigerant Charged into the New Equipment} \cdot \text{Emission Factor}$$

(metric tons HFC or PFC)

Equation (C-6). Refrigerant operational fugitive emissions.

$$\text{Total Emissions} = \text{Refrigerant Capacity by Equipment} \cdot \text{Emission Factor/Leakage Rate}$$

(metric tons HFC or PFC)

Equation (C-7). Refrigerant disposal emissions.

$$\text{Total Emissions} = \text{Capacity Remaining at Disposal} \cdot \text{Emission Factor/Leakage Rate}$$

(metric tons HFC or PFC)

The mass balance approach also estimates emissions from assembly, operation, and disposal, but does not rely on emission factors. If the installed equipment does not change from year to year, the annual refrigerant expended from inventory provides a reasonable estimate of actual leakage or emissions. If the equipment does change, it is important to take into account the addition (or deletion) of that equipment's capacity in order to not over (or under) estimate the amount of refrigerant released as a fugitive emission.



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Equation (C-8). Mass balance for total consumption of a refrigerant.

t_0	initial total mass	x_1	refrigerant inventory addition / deletion
I_0	initial mass of inventory	x_2	charged equipment (capacity addition)
C_0	initial equipment capacity (mass)	x_3	non – charged equipment capacity (filled from inventory)
Δt	change in mass of total system	y_1	charged equipment removal (capacity deletion)
ΔI	change in mass of inventory	y_2	non – charged equipment removal (recycled to inventory)
ΔC	change in equipment capacity (mass)	y_3	system recharge (as needed – inventory loss)

$$\Delta t = x_1 + x_2 - y_1$$

$$\Delta I = x_1 - x_3 + y_2 - y_3$$

$$\Delta C = x_2 + x_3 - y_1 - y_2$$

$$\text{Fugitive Emissions} = (t_0 + \Delta t) - (I_0 + \Delta I) - (C_0 + \Delta C)$$

(metric tons HFC or PFC)

Figure C-6 provides the flow chart for estimating refrigerant emissions.



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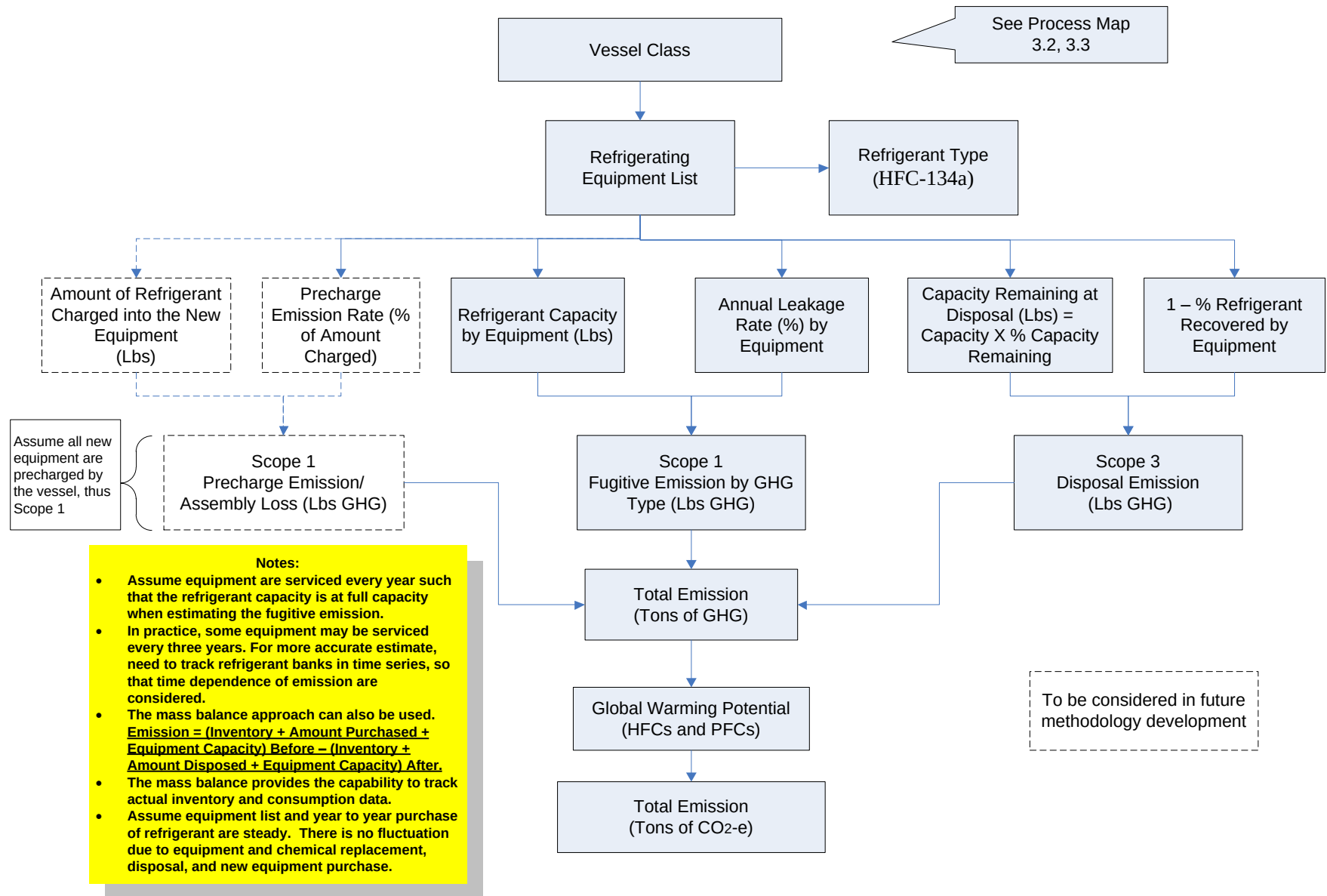


Figure C-6. Shipboard refrigerant emission estimation flowchart.



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C.7.2 Data Analysis

The following section summarizes the key data elements for estimating shipboard refrigerant emissions.

Refrigerating Equipment List. Refrigerating equipment include A/C, reefer, and self-contained refrigerating units such as ice maker, drinking fountains, mini-refrigerators, soda machine, ice-cream machine, etc. The methodology requires a detailed compilation and inventory of all refrigerating equipment aboard the vessel.

Refrigerant Type. Currently, no HFC blends are known to exist onboard USCG vessels. The primary air conditioning and refrigeration units onboard USCG vessels use only HFC-134a. Should a different blend be discovered during the compilation of the equipment inventory, that blend will be added to the methodology.

Amount of Refrigerant Charge into New Equipment. Identify any new equipment that is installed and charged on-site during the reporting period. If the new equipment is precharged by the manufacturer, the emission is considered Scope 3 and is not a direct emission from the USCG vessel.

Precharge Emission Rate. The precharge emission rate estimates assembly losses from precharging the new equipment. If done by the vessel, this is a Scope 1 emission. If the equipment is precharged by the manufactures, then it is considered Scope 3 emission.

Refrigerant Capacity by Equipment. The equipment inventory determines the number and types of equipment including the total charge capacity of each piece of equipment.

Annual Leakage Rate by Equipment. The annual leakage rate estimates losses from equipment leaks.

Capacity Remaining at Disposal. Identify any pieces of equipment that are disposed of during the reporting period. The capacity remaining at disposal is estimated by multiplying the equipment original capacity by an industry standard value for percentage of capacity at disposal.

Percent Refrigerant Recovered. The percentage recovery measures the recovery efficiency as a percentage of remaining capacity. The GHG emission is based on the amount disposed.

C.7.3 Assumptions and Limitations

This section describes the general assumptions and limitations associated with refrigeration emission estimation. Additional assumptions related to specific elements and parameters are documented in the carbon footprint methodology assessment workbook.

- The current methodology uses the default emission factors. There can be significant differences in emission factors over the lifetime of the equipment. Such differences can arise from climatic factors, construction methods, service and maintenance methods, as well as regulatory requirements.
- The current methodology assumes that all equipment is serviced annually, so that the fugitive emission is based on the full capacity of the equipment. In practice, some equipment is serviced every three years, and some equipment is serviced more frequently than one year.



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- For more accurate estimation, future methodology development can track refrigerant banks in time series, so that the time dependence of emission is considered.

C.8 Shipboard Fire Suppressant Emission

Chemical fire suppressants used onboard USCG vessels that contribute to the GHG inventory include HFCs (FM-200), PKP and CO₂.³¹ PKP, in itself, is not a contributor to the GHG emissions, however it is propelled by CO₂ and thus the extinguisher inventory should be included in the methodology. Contrary to refrigerating and air conditioning application where the chemical is part of a closed loop system, fire suppressants are meant to be emitted upon use.

In general, there are two types of fire protection equipment that involved GHG emissions: fixed and portable. Fire protection equipment must be designed, produced and maintained according to established fire protection codes and standards. All storage bottles are required to undergo periodic hydrostatic pressure testing. This involves removing the agent from the storage cylinder³². This agent can either be captured and recycled or expended prior to testing. Additionally, periodic system operational testing is required. This results in an actual expenditure of the firefighting agent, though normally not an expenditure of the entire system capacity. For cartridge style systems (PKP), only CO₂ is released during the testing. Cylinders that are discharged on the vessel contribute to Scope 1 emissions while cylinders that are tested and discharged at an offsite facility contribute to Scope 3 emissions.

C.8.1 Emission Estimation Method

Similar to refrigerant emission, there are two approaches that can be used to estimate fire suppressant emissions: the emission factor approach and the mass balance approach. The emission factor approach is based on consumption data and emission factors. The consumption data is calculated for each piece of equipment by applying generic equipment emission factors³³ and taking into account the fugitive emissions occurring throughout the lifetime of the equipment. The calculation for using the emission factor approach is shown as Figure C-7 and the mass balance approach is provided as follows:

Equation (C-9). Total fire suppressant emissions based on time-series/life cycle consideration.

$$\begin{aligned} \text{Total Emissions} = & \text{Maintenance Emissions} + \text{Fugitive Emissions} + \\ & \text{Fire Fighting Emissions} + \text{Disposal Emissions} \end{aligned}$$

(metric tons HFC or PFC)

Equation (C-10). Fire suppressant maintenance emissions.

$$\text{Total Emissions} = \text{Frequency of Tests} \cdot \text{Number of Cylinders Discharged} \cdot \text{Capacity}$$

(metric tons HFC or PFC)

³¹ Some vessels in the Coast Guard still have Halon fire protection systems. However, only chemical fire suppressants that contribute to the GHG inventory are captured under this methodology.

³² USCG vessels currently do not capture the fire suppressant agent during routine maintenance and testing.

³³ EPA, Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct HFC and PFC Emissions from Use of Refrigeration and Air Conditioning Equipment, 2008.



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Equation (C-11). Fire suppressant operational fugitive emissions.

$$\text{Total Emissions} = \text{Fire Suppressant Capacity by Equipment} \cdot \text{Leakage Rate}$$

(metric tons HFC or PFC)

Equation (C-12). Fire suppressant fire fighting emissions.

$$\text{Total Emissions} = \text{Amount Deployed for Fire Fighting}$$

(metric tons HFC or PFC)

Equation (C-13). Fire suppressant disposal emissions.

$$\text{Total Emissions} = \text{Capacity Remaining at Disposal} \cdot (1 - \% \text{ Recycled})$$

(metric tons HFC or PFC)

Equation (C-14). Mass balance for total consumption of a fire suppressant.

t_0	initial total mass	x_2	charged equipment (capacity addition)
C_0	initial equipment capacity (mass)	y_1	charged equipment removal (capacity deletion)
Δt	change in mass of total system	y_2	non – charged equipment removal
ΔC	change in equipment capacity (mass)	y_3	system recharge (as needed – inventory loss)

$$\Delta t = x_2 - y_1 + y_3$$

$$\Delta C = x_2 - y_1 - y_2$$

$$\text{Fugitive Emissions} = (t_0 + \Delta t) - (C_0 + \Delta C)$$

(metric tons HFC or PFC)

In general, fire suppressant equipment remains static unless there is an operational change that requires different fire protection capacity. Therefore, the annual chemical consumption based on the mass balance approach provides a reasonable estimate of actual leakage and operational emissions. If the equipment remains static, the accuracy of the emission factor approach improves and begins to approach the accuracy of the mass balance approach. Figure C-7 provides the flow chart for calculating shipboard fire suppressant emissions.



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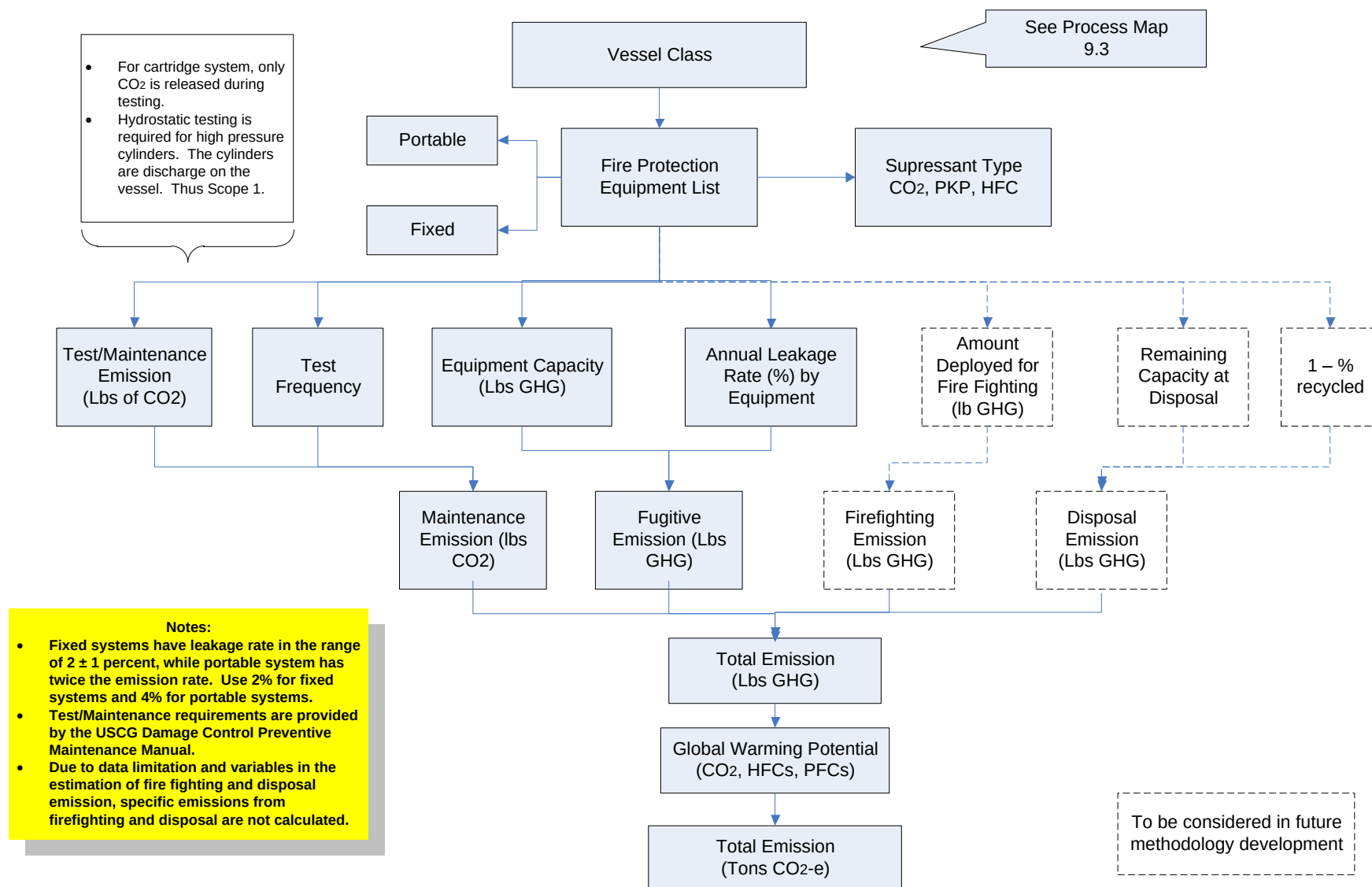


Figure C-7. Shipboard fire suppressant emission estimation flowchart.



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C.8.2 Data Analysis

The following section summarizes the key data elements for estimating shipboard fire suppressant emissions.

Fire Protection Equipment List. Fire suppressant equipment can be classified into two categories: portable and fixed. The methodology requires a detailed compilation and inventory of all fire protection equipment aboard the vessel.

Fire Suppressant Type. Currently, the types of chemical fire suppressant used on USCG vessels include CO₂, PKP and HFC.

Test/Maintenance Emission. Currently, fire protection equipment test and maintenance requirements are provided by the USCG Damage Control Preventive Maintenance Manual. During testing, CO₂ cartridges (for PKP) and cylinders (for fixed and portable CO₂ systems) are discharged. The amount discharged is estimated based on the requirements provided by the USCG maintenance manual.

Test Frequency. The test frequency is provided by the USCG maintenance manual. Different equipment have different maintenance schedules.

Equipment Capacity. The equipment inventory determines the number and types of fire protection equipment including the total charge capacity.

Annual Leakage Rate by Equipment. The annual leakage rate estimates losses from equipment leaks. According to the IPCC, fixed systems have leakage rate in the range of 2 ± 1 percent, while portable system rates are twice that amount. The current methodology applies 2% for fixed systems and 4% for portable systems.

Amount Deployed for Fire Fighting. Firefighting emission requires the estimation of the amount of chemical used per incident, which is also dependent on the severity of the fire. The amount of chemical used and number of fire incidents are currently not tracked. Due to data limitation and variables in the estimation of firefighting and disposal emission, specific emissions from firefighting and disposal are not calculated.

Capacity Remaining at Disposal. Identify any pieces of equipment that are disposed of during the reporting period.

Percent Recycled. The percentage recycled measures the recovery efficiency as a percentage of remaining capacity.

C.8.3 Assumptions and Limitations

This section describes the general assumptions and limitations associated with fire suppressant emission estimation. Additional assumptions related to specific elements and parameters are documented in the carbon footprint methodology assessment workbook.



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- The current methodology uses the default emission factors. There can be significant differences in emission factors over the lifetime of the equipment. Such differences can arise from climatic factors, service and maintenance methods, as well as regulatory requirements. The current methodology assumes that the annual equipment maintenance documents the capacity of the system so that the fugitive emission can be captured. During testing, the discharge of CO₂ from cartridges and fire suppressant from cylinders are not captured or recycled.

C.9 Shipboard Incinerator Emission

Incinerators can be used to treat solid and liquid waste aboard a USCG vessel. Solid waste that can be incinerated onboard a vessel is typically comprised of food, paper, wood, and cardboard. Liquid waste which can be incinerated onboard a vessel includes waste oil and sewage sludge. Medical waste and hazardous waste are usually segregated from other solid wastes and are not incinerated onboard the vessel. If the vessel is equipped with an incinerator, the incinerator ash may be discharged at sea³⁴. Currently, shipboard incinerators are regulated by MARPOL Annex VI, Prevention of Air Pollution from Ships. 46 CFR §63.25-9 requires incinerators to meet the requirements of IMO Resolution MEPC.76 (40) and obtain a USCG Certificate of Approval. Although other air pollutants from combustion such as NO_x, CO, and SO_x are regulated by U.S. laws and regulation, these pollutants are not considered GHG emission factors.

C.9.1 Emission Estimation Method

Waste incineration is a source of GHG emissions, which include CO₂, CH₄, and N₂O. In general, emissions of CO₂ from waste incineration are more significant than CH₄ and N₂O emissions. CH₄ and N₂O are dependent on technology and conditions during the incineration process. CO₂ emission is primarily dependent on the waste type.

Consistent with the IPCC guidelines, this methodology only considers CO₂ emissions resulting from oxidation of carbon in waste of fossil origin (e.g., plastics, certain textiles, rubber, liquid solvents, and waste oil). CO₂ emissions from combustion of biomass materials (e.g., paper, food, and wood waste) contained in the solid waste stream are biogenic emissions and are not considered due to their inclusion in the natural carbon cycle. Combustion of the biomass material itself is not considered a net contributor of carbon into the environment. IPCC does consider the incineration of biomass waste, if it is used for energy generation purposes, thus the fossil and biogenic CO₂ emissions would be included in the methodology. However, since the USCG vessels currently do not have energy or heat recovery capabilities from their installed incinerators, these components will be assigned a factor of zero at this time.

The methodology determines emissions based on incinerator type/operation and waste category. The methods for estimating CO₂, CH₄ and N₂O emissions from waste incineration vary because of the different factors that influence emission levels. The general approach to calculate GHG emissions from incineration is to obtain the dry weight of waste to be incinerated, its carbon content, the fossil carbon fraction, and the oxidation factor. Dry matter content is not applicable for waste oil and other liquid wastes. Additionally,

³⁴ Incinerator ash that exhibits a characteristic of hazardous waste as defined in 40 CFR Part 261 Subpart C must be disposed onshore in accordance with RCRA, which may include additionally applicable state law requirements specific to the jurisdiction where the ash is landed.



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biogenic liquid waste (e.g., waste oil from food processing) does not need to be reported, unless biogenic and fossil oil are mixed and a significant portion of their carbon content is of fossil origin. Incinerator emission consists of two components: the combustion of fuel oil used to power the incinerator and the combustion of waste. The combustion of fuel oil follows the methodology in section 3.2, where the amount of fuel is estimated based on the hours of incinerator operation and the appropriate emission factor. The following section provides the equations for estimating emissions from the combustion of waste.

Equation (C-15). CO₂ emission from shipboard solid waste incineration.

$$\begin{aligned} \text{Total Emissions} = & \text{Total Amount of Solid Waste Type Incinerated} \cdot \text{Dry Matter Content in the Waste} \cdot \\ & \text{Total Carbon Content} \cdot \text{Fraction of Fossil Carbon} \cdot \text{Oxidation Factor} \cdot \frac{44}{12} \\ & \text{(metric tons CO}_2\text{)} \end{aligned}$$

Equation (C-16). CO₂ emission from shipboard fossil liquid waste incineration.

$$\begin{aligned} \text{Total Emissions} = & \text{Total Amount of Fossil Liquid Waste Incinerated} \cdot \\ & \text{Carbon Content} \cdot \text{Oxidation Factor} \cdot \frac{44}{12} \\ & \text{(metric tons CO}_2\text{)} \end{aligned}$$

CH₄ emissions from waste incineration are a result of incomplete combustion. Important factors affecting CH₄ emissions include: the continuity of the incineration process, incineration technology, and management practices. CH₄ can also be generated in the waste bunker of incinerators if there are low oxygen levels and subsequent anaerobic processes in the waste bunker. This is only the case where wastes are wet, stored for long periods and not well agitated. The equation for calculating CH₄ emission is as follows:

Equation (C-17). CH₄ emission from shipboard waste incineration, continuous operation.

$$\begin{aligned} \text{Total Emissions} = & \text{Total Amount of Waste Incinerated} \cdot \text{Emission Factors} \\ & \text{(metric tons CH}_4\text{)} \qquad \qquad \qquad \text{(g CH}_4\text{ / MBTU)} \end{aligned}$$

Equation (C-18). CH₄ emission from shipboard waste incineration, non-continuous operation.

$$\begin{aligned} \text{Total Emissions} = & \text{Total Amount of Waste Incinerated} \cdot \text{Emission Factors} \\ & \text{(metric tons CH}_4\text{)} \qquad \qquad \qquad \text{(g CH}_4\text{ / g)} \end{aligned}$$

Nitrous oxide is emitted in combustion processes at relatively low combustion temperatures between 500 and 950 °C. Other important factors affecting the emissions are the type of air pollution control device, type and nitrogen content of the waste, and the fraction of excess air. N₂O emissions from the combustion of waste oil are considered negligible. The equation for calculating N₂O emission is as follows:

Equation (C-19). N₂O emission from shipboard waste incineration.

$$\begin{aligned} \text{Total Emissions} = & \text{Total Amount of Waste Incinerated} \cdot \text{Emission Factors} \\ & \text{(metric tons N}_2\text{O)} \qquad \qquad \qquad \text{(g N}_2\text{O / MBTU)} \end{aligned}$$

Figure C-8 outlines the process for estimating incinerator emissions.



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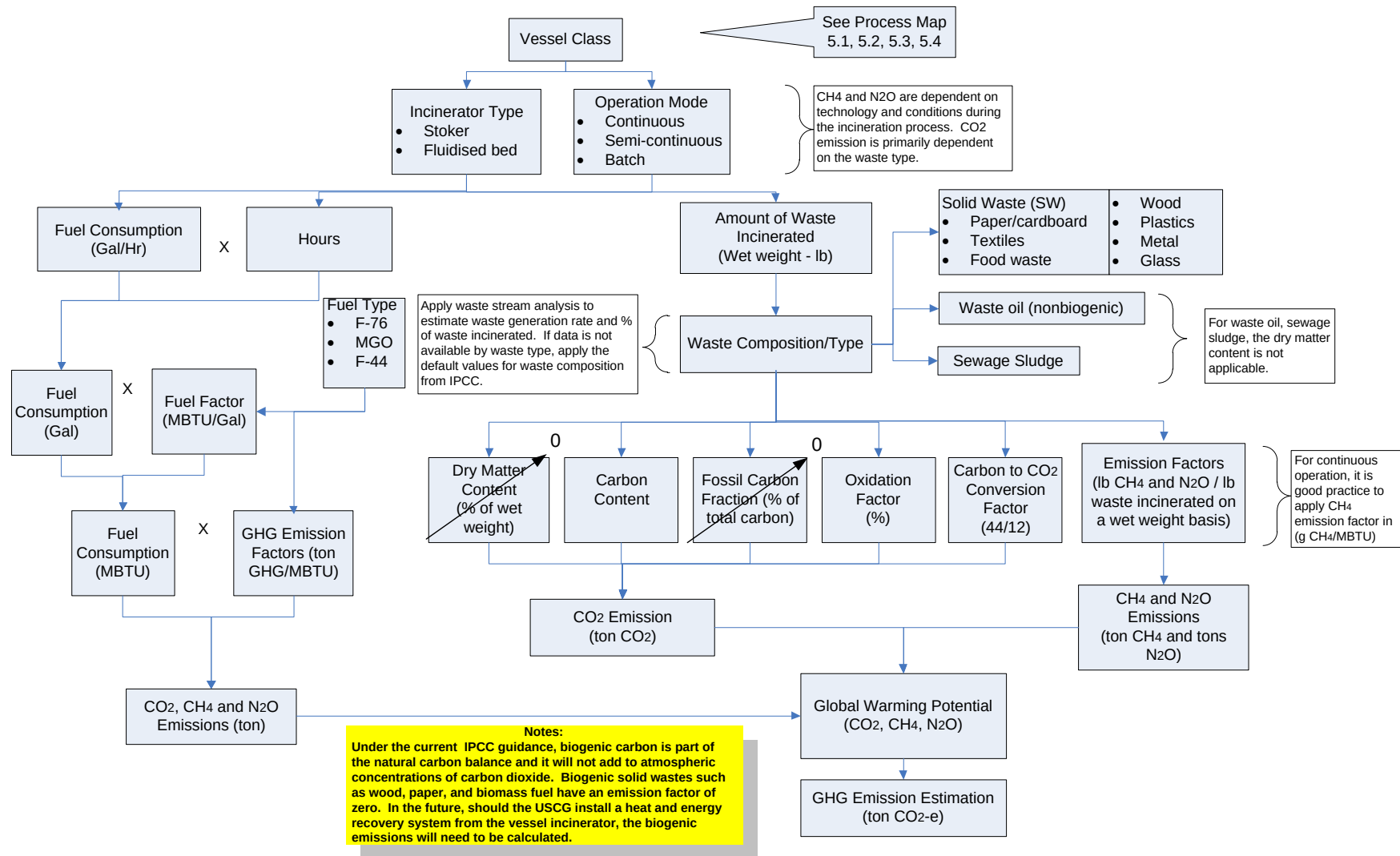


Figure C-8. Shipboard waste incineration emission estimation flowchart.



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C.9.2 Data Analysis

The following section summarizes the key data elements for estimating shipboard incinerator emissions.

Incinerator Type. Incinerator type includes: fixed bed, stoker, fluidized bed, and kiln. Currently, the CH₄ emission factors are provided for stoker and fluidized bed technologies.

Operation Mode. Continuous incineration includes incinerators without daily start-up and shutdown. Batch type and semi-continuous incineration mean that the incinerator is usually started-up and shutdown at least once a day. CH₄ and N₂O emission factors are based on the operation mode.

Amount of Waste Incinerated. Apply waste stream analysis to estimate waste generation rate and amount of waste incinerated.

Waste Composition/Type. The waste stream analysis determines the waste type. In general, wastes that can be incinerated include solid waste, waste oil, medical waste, and sewage sludge. If data is not available by waste type, apply the IPCC default values to estimate the waste composition.

Dry Matter Content. If waste data is available on a dry matter basis, which is preferable, the same equation can be applied without specifying the dry matter content and the wet weight separately.

Total Carbon Content. If data is available on the fraction of fossil carbon in the dry matter, the equation can combine the total carbon content and fossil carbon fraction into one component. These two terms do not need to be addressed separately.

Fossil Carbon Fraction. See Total Carbon Content description.

Oxidation Factor. In perfect combustion conditions, total carbon content of fuels would be converted to CO₂. Real combustion processes result in small amounts of unoxidized carbon that are left as ash or soot. The oxidation factor takes into account the unburnt fuel carbon. It is good practice to use the amount of ash (both bottom ash and fly ash) as well as the carbon content in the ash as a basis for determining the oxidation factor.

Carbon to CO₂ Conversion Factor. The ratio 44/12 considers the molecular weight ratio of CO₂ and C.

Emission Factors. While CO₂ is calculated based on waste type, fossil carbon content, and oxidation factor, CH₄ and N₂O emissions are calculated using emission factors. Emission factors are provided as the amount of GHG emitted/amount of waste incinerated. Emission factors are also based on the technology and the conditions during the incineration process. For continuous operation, it is good practice to apply CH₄ emission factor in thermal unit (e.g. g CH₄/MBTU).

C.9.3 Assumptions and Limitations

This section describes the general assumptions and limitations associated with shipboard incineration emission estimation. Additional assumptions related to specific elements and parameters are documented in the carbon footprint methodology assessment workbook.



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- The current methodology only considers waste incinerated aboard the vessel, which is accounted for as Scope 1 direct emissions. For ashore waste treatment provided by contractor services are considered as Scope 3 emissions.
- For waste incinerators, it is assumed that the combustion efficiencies are close to 100 percent. Thus the oxidation factor is 1. The same assumption is used for fuel combustion, as the amount of carbon remaining unoxidized should be low. To demonstrate, the amount of carbon oxidized for coal is 98 percent, oil is 99 percent, and gas is 99.5 percent.

C.10 Purchased Shore Power Emission

Purchased electricity contributes to indirect emissions. The generation of the electricity creates GHG emissions from sources that are not owned or controlled by the USCG vessel. When a USCG vessel is in port, both in home port or during a logistics stop, the vessel often switches to a “cold iron” status. This entails using shore-side supplied electrical power. Shore power, which is purchased from an electricity utility company, is tracked as Scope 2 emissions. Additionally, utility companies often purchase electricity from independent power generators or the grid and resell it to end-consumers through a transmission and distribution (T&D) system. A portion of the electricity purchased by a utility company is consumed (T&D loss) during its transmission and distribution to end-consumers. As an end-consumer, USCG vessels may include indirect emissions associated with T&D losses as Scope 3 emissions.

C.10.1 Emission Estimation Method

The methodology uses the annual output emission rates from the EPA Emissions & Generation Resource Integrated Database (eGRID) as the default factors for estimating GHG emissions. eGRID is a comprehensive source of air emission and electricity generation data for U.S. power plants. Since eGRID is limited to U.S. regions, the current methodology applies eGRID factors for ports in the U.S. For overseas shore power use, the emission factors are derived from the Energy Information Administration.³⁵

The total GHG emission for purchased electricity include CO₂, CH₄, and N₂O emissions. Equation (C-20) contains the calculation for purchase power emissions and is based on electricity consumption (e.g. kWh) and emission factors (e.g. lb GHG/kWh). Figure C-9 illustrates the process for estimating emissions from purchased shore power.

The vessels annual operational patrol profile is utilized primarily to determine the duration of time the vessel spends in the various ports of call. The vessels design powering analysis is then utilized to determine the specific power demand and source of that demand over the time spent in port.

Equation (C-20). Total GHG emissions from purchased shore power.

$$\text{Total Emissions} = \text{Electricity Consumption} \cdot \text{Emission Factor} \cdot \text{GWP}$$

(metric tons CO₂-e) (kWh) (lb GHG / kWh)

³⁵ U.S. Energy Information Agency's *Voluntary Reporting of Greenhouse Gases* Appendix F (2007)



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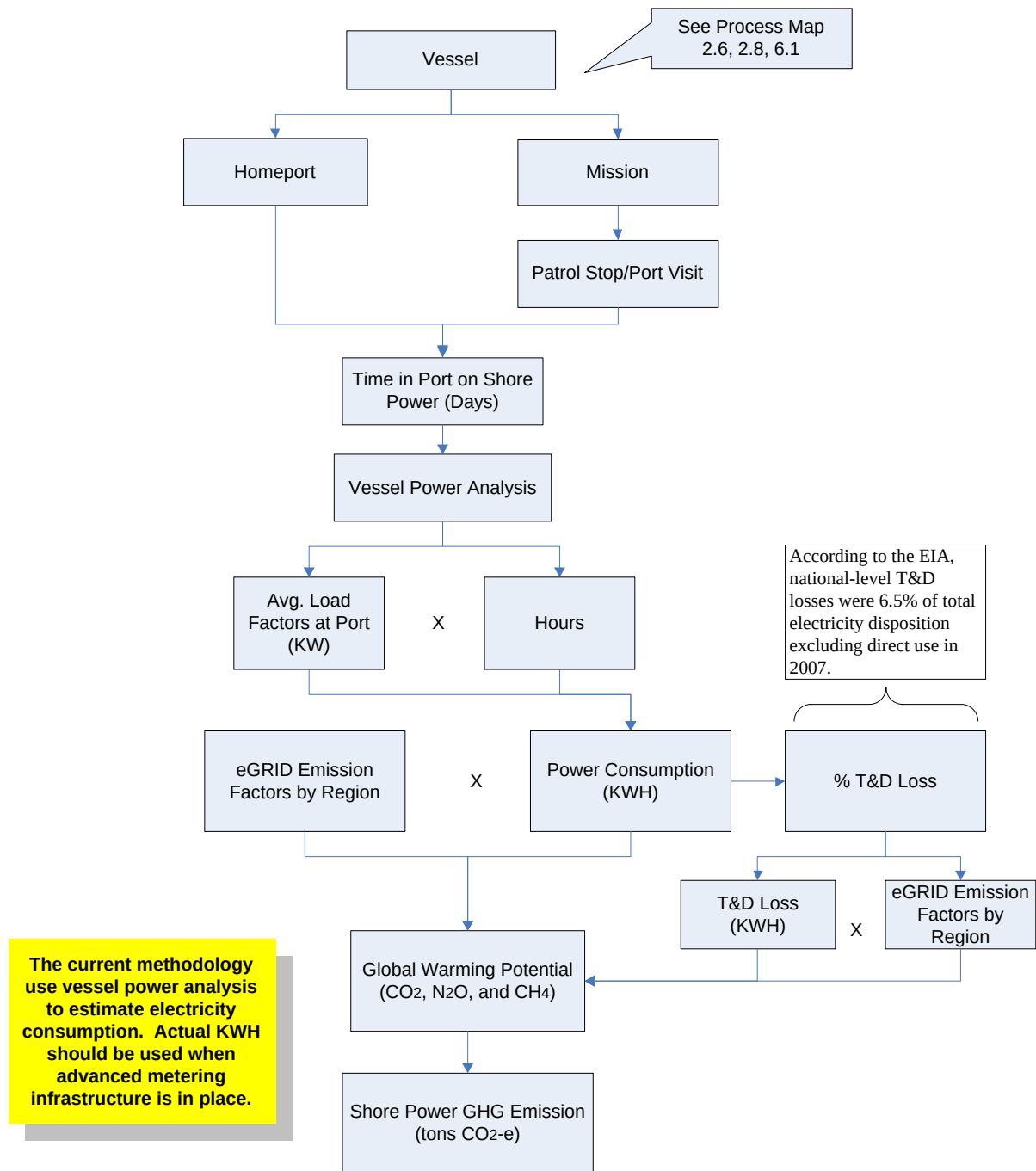


Figure C-9. Purchased shore power emission estimation flowchart.

C.10.2 Data Analysis

The following section summarizes the key data elements for estimating purchased shore power emissions.

Homeport. The vessel inventory analysis identifies the homeport for each USCG vessel. The homeport location determines the eGRID subregion for which the emission factors are based on.



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Mission. The type of mission determines the patrol stop and port visit for the USCG vessel. During port visit, the vessel may or may not use shore power depending on the port infrastructure and duration of the visit.

Time in Port on Shore Power. It is important to draw a distinction between percentage time at port and percentage of time in port on shore power because when a vessel docks at a port, shore power may or may not be used. In order to accurately account for shore power consumption, the actual number of days the vessel uses shore power should be applied to the methodology.

Vessel Power Analysis. Vessel power analysis shall be utilized, which provides the load factor and designed power consumption rates.

Emission Factors. CO₂, CH₄, and N₂O emission factors are provided for each eGRID subregion. When estimating carbon footprint, the eGRID annual non-baseload output emission rates should not be used.

T&D Loss. T&D loss is considered Scope 3 emission. It can be estimated based on the national average T&D loss and electricity disposition data. According to the EIA³⁶, the national-level losses were 6.5 percent of total electricity disposition excluding direct use³⁷.

C.10.3 Assumptions and Limitations

This section describes the general assumptions and limitations associated with purchased shore power emission estimation. Additional assumptions related to specific elements and parameters are documented in the carbon footprint methodology assessment workbook.

- During cold iron, the vessel only consumes shore-side electricity. There is no requirement for purchased steam or hot water. Therefore, the methodology only considers emission from purchased electricity use.

C.11 Station Towing Vehicle Emission

To improve operational flexibility and decrease response time, smaller station boats³⁸ are often towed by vehicles to alternate launch locations. The USCG has desired this towing evolution to be incorporated into the carbon footprint of the respective station boat and not be tied to the small boat station or the motor pool from which the vehicle may have been checked out from, or the agency from which the vehicle may have been leased.

³⁶ EIA, State Electricity Profile, 2008.

³⁷ Direct Use electricity is electricity that is generated at facilities that is not put onto the electricity transmission and distribution grid, and therefore does not contribute to T&D losses.

³⁸ Small station boats typically include Law Enforcement boats such as the 25-foot Defender Class and the 33-foot Special Purpose Craft.



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duration. The cold start emission factors should therefore be applied only for this initial fraction of a vehicle's journey and then the running emission factors should be applied.

Figure C-10 summarizes the process for estimating the vehicle emissions from towing operations.

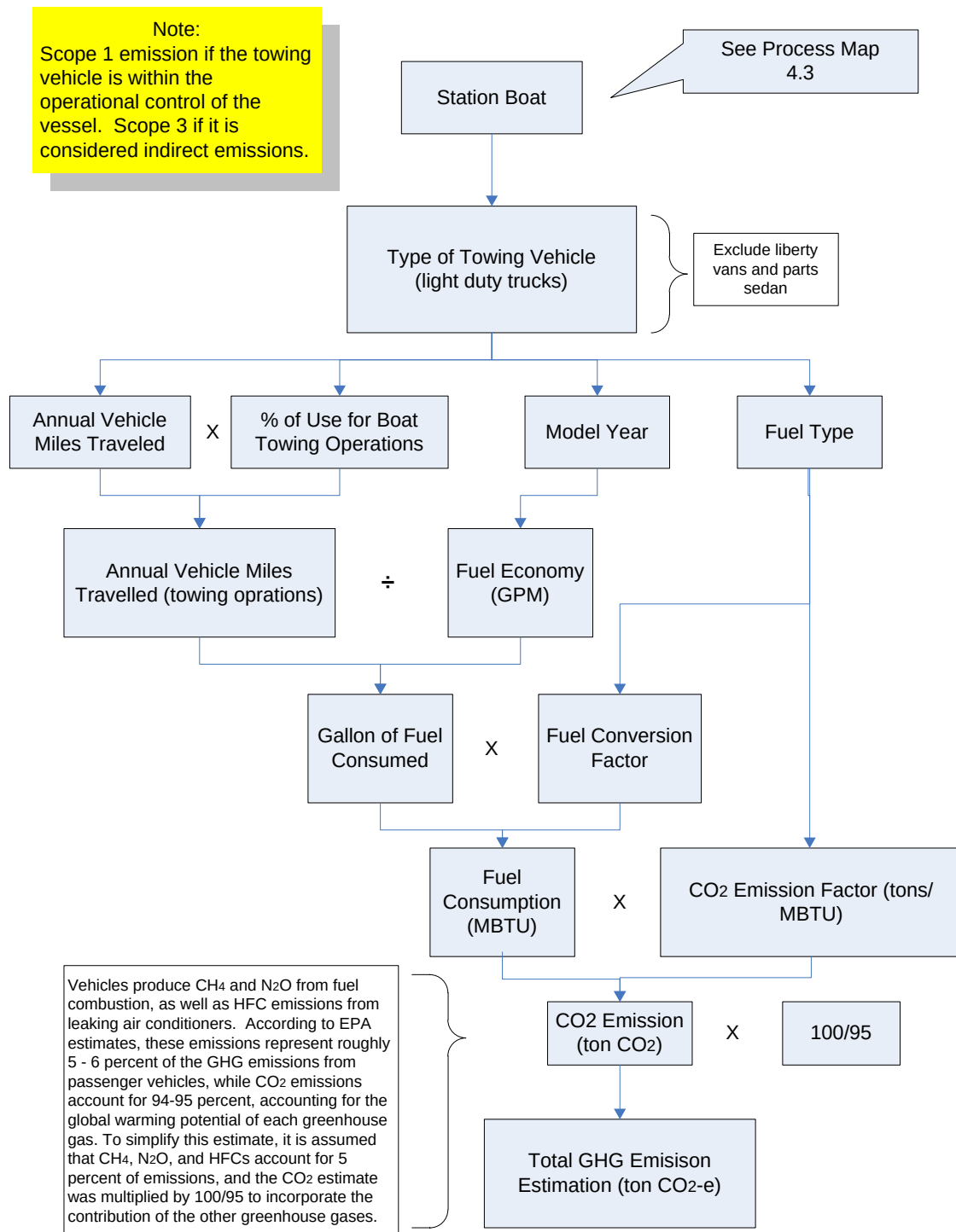


Figure C-10. Towing vehicle emission estimation flowchart.



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C.11.2 Data Analysis

The following section summarizes the key data elements for estimating vehicle emissions.

Type of Towing Vehicle. In general, light duty trucks are used to tow small boats. Liberty vans and other government vehicles utilized by the vessels and stations are excluded from the vessel carbon footprint. Liberty vans and part sedans are part of the “motor pool” emissions. These vehicles are typically leased assets from GSA and are not owned by the vessel. Moreover, the operation of the liberty vans and part sedans remain the same for all vessels. Thus, the current methodology do not consider “motor pool” emissions.

Annual Vehicle Miles Traveled. The methodology requires vehicle miles traveled data by vehicle type and fuel type.

Percent Use for Boat Towing Operation. Since the vehicles are not exclusively used for towing small boats, it is important to estimate the amount of use for boat towing. The percentage adjustment is used to estimate annual vehicle miles for towing. This percentage can be derived from the station vehicle and trailer logs

Model Year. In addition to vehicle type, vehicle age is used to determine the fuel economy.

Fuel Type. Fuel type, which includes diesel, gasoline, natural gas, liquefied petroleum gas, is used to determine the CO₂ emission factors.

Fuel Economy. The methodology uses either the adjusted EPA "real-world" miles per gallon (MPG) values or unadjusted EPA laboratory (LAB) values⁴⁰.

C.11.3 Assumptions and Limitations

This section describes the general assumptions and limitations associated with station towing vehicle emission estimation. Additional assumptions related to specific elements and parameters are documented in the carbon footprint methodology assessment workbook.

- The current methodology does not consider the use of biofuels.
- Emission control technology is not considered. Assume non-catalyst equipped vehicles.
- Vehicles produce CH₄ and N₂O from fuel combustion, as well as HFC emissions from leaking air conditioners. To simplify this estimate, it is assumed that CH₄, N₂O, and HFCs account for 5 percent of emissions, and the CO₂ estimate was multiplied by 100/95 to incorporate the contribution of the other greenhouse gases⁴¹.

⁴⁰ In 2006, EPA revised the methodology by which EPA estimates adjusted fuel economy to better reflect changes in driving habits and other factors that affect fuel economy such as higher highway speeds, more aggressive driving, and greater use of air conditioning.

⁴¹ According to EPA estimates, these emissions represent roughly 5 – 6% of the GHG emissions from passenger vehicles, while CO₂ emissions account for 94-95 percent, accounting for the global warming potential of each greenhouse gas.



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- Assume 100 percent oxidation of fuel carbon⁴².
- The current methodology does not consider different phases of engine operation (e.g., hot and cold start).
- According to IPCC, the uncertainty in the CO₂ emission factor is typically less than 2 percent. The use of fuel blends or uncertainty in fuel composition may increase the uncertainty in emission factors.
- The accuracy of the emission estimate hinges on the quality of the vehicle data, such as distance traveled by vehicle type and fuel type, vehicle fleet inventory data (e.g., age and vehicle characteristics).

C.12 Employee Commute

Travel by crew members to and from their USCG vessel is considered a Scope 3 emission source. Although emission from employee commuting is not owned or controlled by the vessel, it is related to the vessel operation and considered as optional Scope 3 emissions. Major forms of crew transportation include vehicle travel, rail service and bus commutes. The vessel's homeport will often determine the percentage of crew using these major forms of transportation primarily due to its proximity to government provided housing, as well as the expense of the local housing market. It is important to note that GHG emissions associated with employee commute are from ground transportation sources, no air transportation is considered. Other travels conducted during non-homeport visits are considered employee business travel.

C.12.1 Emission Estimation Method

Crew commuting generates CO₂, CH₄, and N₂O emissions through the combustion of fossil fuels in different types of mobile equipment. As a result, GHG emissions are primarily based on fuel consumption and emission factors. As described in Section 3.11, emissions of CO₂ are calculated on the basis of the amount and type of fuel combusted and its carbon content. Emissions of CH₄ and N₂O are more difficult to estimate accurately than those for CO₂ because emission factors depend on mode of transport, vehicle technology, fuel, and operating characteristics. Emissions of these gases also vary with the efficiency and vintage of the combustion technology, as well as maintenance and operation practices.

Due to data limitation and the extensive data requirements for modeling vehicle emissions, the estimation of emission from employee commute does not follow the same method in Section 3.11. The CO₂, CH₄, and N₂O emissions are estimated primarily based on travel distance. If a more detailed methodology is required, the USCG shall develop an inventory to collect employee vehicle data such as model year, vehicle type, and fuel type. Since these data are highly variable, therefore, the use of emission factors based on travel distance is recommended in order to simplify the data collection requirements. Passenger vehicle (e.g., cars, trucks, etc.) GHG emissions can be estimated using the annual vehicle miles travel, percent use for employee commute, and greenhouse gas emission factor (grams of GHG/vehicle miles).

Equation (C-23) is used to estimate passenger vehicle emissions.

⁴² EPA research on carbon mass balances for U.S. light-duty gasoline cars and trucks indicates that “the fraction of solid (unoxidized) carbon is negligible.”



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Equation (C-23). Passenger vehicle emissions.

$$\text{Passenger Vehicle Emissions} = \text{Vehicle Miles Traveled} \cdot \text{Emission Factor} \cdot \text{GWP} \cdot \text{Conversion Factor}$$

(metric tons CO₂-e) (miles) (kg CO₂, CH₄, N₂O / vehicle-mile) (metric ton / kg)

GHG emissions attributable to USCG crews who commute on public bus or rail systems can be estimated from annual passenger miles traveled and greenhouse gas emission factor (grams of GHG / passenger mile). Different GHG emission factors are applied depending on the type of rail systems used, while the emission factor for bus travel is based on diesel buses. Equation (C-24) and Equation (C-25) are used to estimate passenger vehicle emissions.

Equation (C-24). Rail commute emissions.

$$\text{Rail Vehicle Emissions} = \text{Passenger Miles Traveled} \cdot \text{Emission Factor} \cdot \text{GWP} \cdot \text{Conversion Factor}$$

(metric tons CO₂-e) (miles) (kg CO₂, CH₄, N₂O / vehicle-mile) (metric ton / kg)

Equation (C-25). Bus commute emissions.

$$\text{Bus Vehicle Emissions} = \text{Passenger Miles Traveled} \cdot \text{Emission Factor} \cdot \text{GWP} \cdot \text{Conversion Factor}$$

(metric tons CO₂-e) (miles) (kg CO₂, CH₄, N₂O / vehicle-mile) (metric ton / kg)

Figure C-11 summarizes the process for estimating the GHG emissions from employee commutes.



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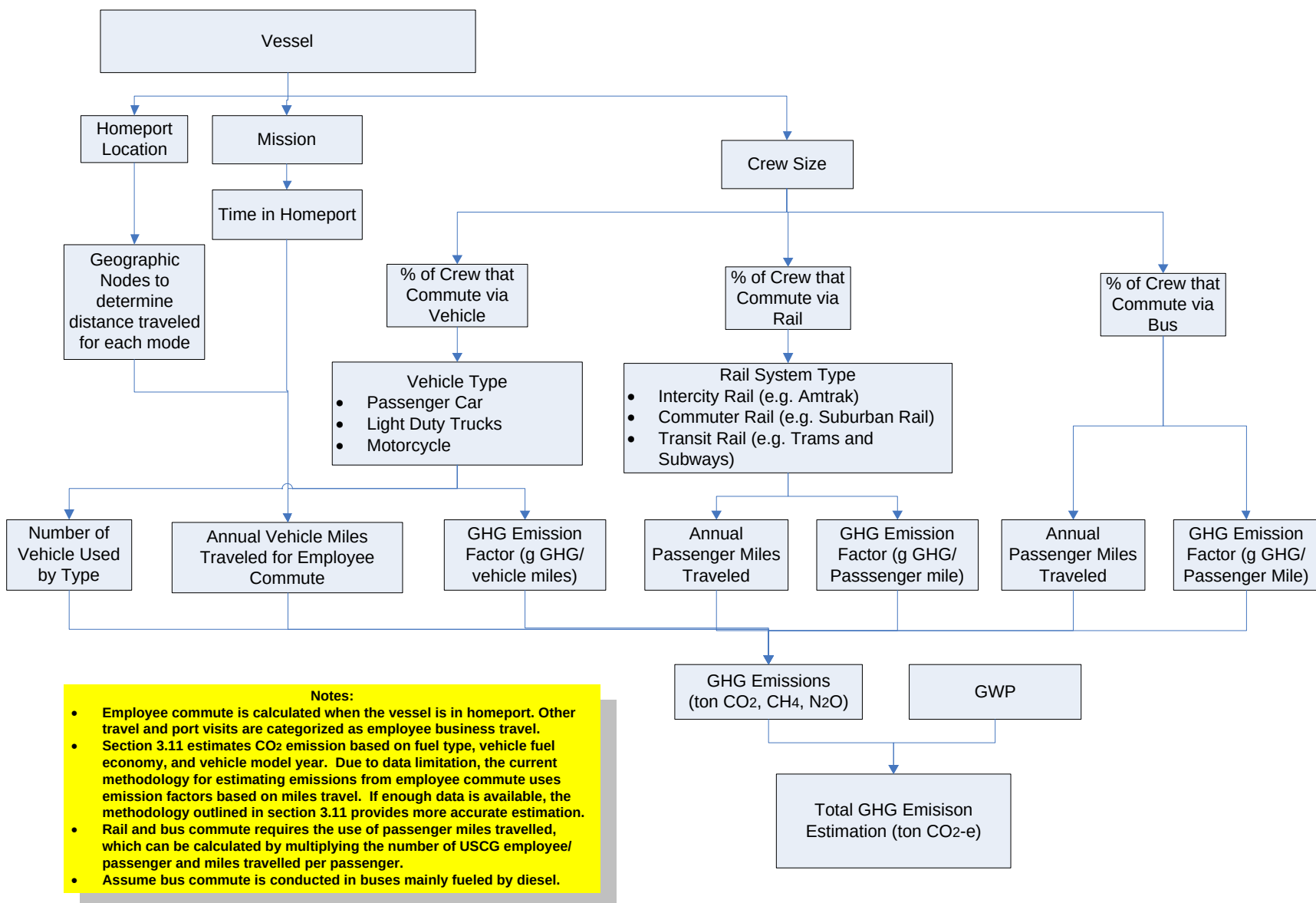


Figure C-11. Employee commute emission estimation flow chart.



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C.12.2 Data Analysis

The following section summarizes the key data elements for estimating GHG emissions associated with employee commuting.

Time in Homeport: The number of days the vessel is in homeport is determined by the annual mission profile which sets the number of times an employee has to commute. Each employee is assumed to commute to and from their home each day the vessel is in port minus 30 days of vacation and five Federal holidays. It is assumed the remainder of the federal holidays are spent underway. Time in port is then multiplied by 5/7 to account for weekend days.

Geographic Nodes: For each homeport region, different geographic locals determine where the standard commuting distances will be calculated. These locations are based primarily on rail and bus hubs or government housing locations. The geographic node profiles link employee housing to homeport locations. If employee housing is located closer to homeport, travel distances and GHG emissions will be reduced. The consideration of geographic nodes allows USCG to develop strategic actions and policies regarding employee housing or homeport locations.

Percent of Crew that Commute via Vehicle/Rail/Bus: The personnel allowance list contains the official listing of the crew makeup and size for the USCG cutters. For a station boat, the normal boat crew size will be utilized for commuting purposes and all members will be assumed to travel by car. The percentage of crew that commute via different transportation modes may vary depending on the homeport location. Although the availability of public transportation has a direct impact on employee commute, the current methodology applies the assumption that all homeport locations have the same public transportation infrastructure. This assumption is necessary in order to estimate the percentage of use for vehicle, rail, and bus independent of the homeport location.

Vehicle Type and Emission Factor: Vehicle types include cars, light duty trucks, and motorcycles. The current methodology uses the vehicle emission factors compiled by the EPA Climate Leaders GHG Inventory Protocol. The emission factors are derived from passenger vehicle travel statistics⁴³.

Rail System Type and Emission Factor: Rail systems are comprised of transit rail (e.g., subway, tram), commuter rail (e.g. suburban rail), and intercity rail (e.g., Amtrak). The current methodology uses the rail emission factors compiled by the EPA Climate Leaders GHG Inventory Protocol. The emission factors are derived from statistical information⁴⁴ of railway services.

Bus Emission Factor: Bus travel is assumed to be conducted in diesel-fueled buses. The current methodology uses the bus emission factors compiled by the EPA Climate Leaders GHG Inventory Protocol. The emission factors are derived from statistical information⁴⁵ on passenger-mile.

⁴³ Table VM-1 of the Federal Highway Administration Highway Statistics 2005 and U.S. Greenhouse Gas Emissions and Sinks: 1990–2005. Table 2-17, Table A-108.

⁴⁴ Tables 9.10 to 9.12 and Tables A.13 to A.15 of the Center for Transportation Analysis, Transportation Energy Data Book: Edition 26.

⁴⁵ Table VM-1 of the Federal Highway Administration's Highway Statistics 2005, Emissions data from Table 2-17 from the U.S. Greenhouse Gas Emissions and Sinks: 1990–2005.



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C.12.3 Assumptions and Limitations

This section describes the general assumptions and limitations associated with employee commute emission estimation. Additional assumptions related to specific elements and parameters are documented in the carbon footprint methodology assessment workbook.

- The current methodology does not consider fuel type, vehicle or emission control technology. If employee travel is a significant emission source for a USCG vessel, the methodology outlined in Section 3.11 is preferred. However, the current methodology employs emission factors that are derived from well-established statistical information and are provided by the EPA Climate Leaders.
- Currently, the GHG emissions from bus commute are primarily due to diesel fueled buses. Compressed natural gas is used to a less extent. If there is a significant change in the type of fuel used, the methodology should be revised to consider fuel type and consumption.

C.13 Land Disposal of Solid Waste

Onshore solid waste (SW) disposal is conducted by contractor services and is considered a Scope 3 emission. Solid waste can be generated when the vessel is underway or at port. While underway, solid waste can be discharged overboard if the effluent is treated to meet the U.S. and international standards⁴⁶, with the exception that no plastic can be discharged at sea. Additionally, no solid waste can be discharged when the vessel is within 3 nm of land. The current vessel carbon footprint methodology only considers the amount of solid waste that requires ashore disposal on land. Solid waste can be disposed in landfills, where bacteria decompose the organic material. A product of the bacterial decomposition is landfill gas, which is composed of CH₄ and CO₂ in approximately equal concentrations. If not collected and combusted, this landfill gas is released to the atmosphere over time. It is important to note that CO₂ emissions from a landfill are considered biogenic emission and is excluded from reporting. However, CH₄ emissions from a landfill are considered anthropogenic and contribute to GHG emissions. Landfill gas recovery can reduce the CH₄ emission by burning the gas through flaring or burning the gas for energy or heat production.

Section C.9 may be used to estimate emissions if the solid waste is disposed of via incineration. It is important to note that emissions from the vessel's incinerator are considered Scope 1, while emissions from contracted ashore incineration are considered Scope 3.

C.13.1 Emission Estimation Method

Waste in landfills decays slowly over a period of a few decades, during which CH₄ and CO₂ are formed. If conditions are constant, the rate of CH₄ production is dependent on the amount of degradable organic compound (DOC) remaining in the waste. CH₄ emission from landfill waste is highest during the first few years after deposition, then gradually declines as the degradable carbon in the waste is consumed by the bacteria responsible for the decay. The transformation of degradable material in the landfill to CH₄ and CO₂ occurs through a chain of reactions and parallel reactions. A full model is likely to be very complex and

⁴⁶U.S. solid waste disposal requirements are provided by the Act to Prevent Pollution from Ships (APPS) and its implementing regulations (33 CFR 151), MARPOL Annex V, Prevention of Pollution by Garbage from Ships is the current international standard for solid waste.



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vary with the conditions in the landfill, however, laboratory and field observations on CH₄ generation data suggest that the overall decomposition process can be approximated by first order decay (FOD), which has been adopted by the IPCC⁴⁷.

Various data, such as the current and previous years accumulative decomposable DOC at landfill, waste reaction constant, half-life time, and delay time, are required to model the first order decay. In order to simplify the data collection requirement, the current methodology does not consider FOD while recognizing that the use of CH₄ generation potential may overestimate the CH₄ emission.

Equation (C-26) through Equation (C-29) can be used to calculate the CH₄ emission.

Equation (C-26). Mass of decomposable DOC.

$$\text{Mass of Decomposable DOC (metric tons)} = \text{Mass of Solid Waste (metric tons)} \cdot \% \text{ DOC} \cdot \% \text{ Decomposable DOC} \cdot \text{Methane Conversion Factor (\%)}$$

Equation (C-27). CH₄ generating potential.

$$\frac{\text{CH}_4 \text{ Generating Potential}}{(\text{metric tons of CH}_4)} = \frac{\text{Mass of Decomposable DOC}}{(\text{metric tons})} \cdot \frac{\text{Fraction of CH}_4 \text{ in Generated Landfill Gas}}{(\%)}$$

$$\frac{\text{Molecular Weight Ratio CH}_4/\text{C}}{(16/12)}$$

Equation (C-28). Net CH₄ generating potential.

$$\text{Net } CH_4 \text{ Generating Potential} = \underset{\substack{\text{(metric tons of } CH_4\text{)}}}{CH_4 \text{ Generating Potential}} - \underset{\substack{\text{(metric tons)}}}{CH_4 \text{ Recovery}} \cdot \underset{\substack{\text{(metric tons of } CH_4\text{)}}}{\left(1 - \underset{\substack{\text{(\%)}}}{\text{Oxidation Factor}}\right)}$$

Equation (C-29). CH₄ emissions.

$$CH_4 \text{ Emissions} = \text{Net } CH_4 \text{ Generating Potential} \cdot GWP$$

(metric tons of CO₂-e) (metric tons of CH₄)

Figure C-12 summarizes the process for estimating the GHG emissions from solid waste disposal.

⁴⁷ The IPCC developed a FOD model, which is available for download at <http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html>.

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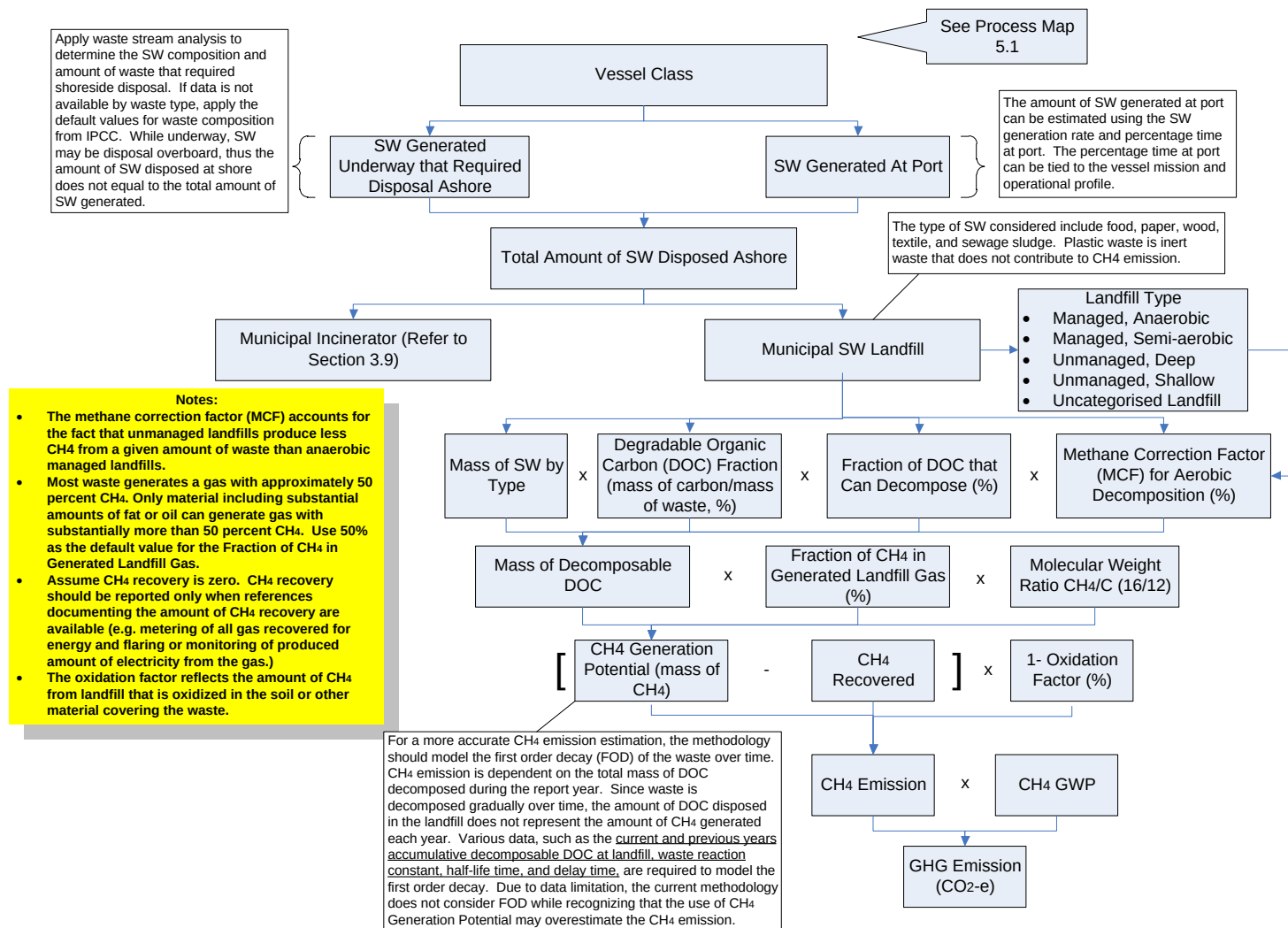


Figure C-12. Ashore solid waste disposal emission estimation flow chart.



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C.13.2 Data Analysis

The following section summarizes the key data elements for estimating GHG emissions associated with solid waste landfill disposal.

SW Generated Underway that Required Disposal Ashore: The amount of SW disposed ashore depends upon the operational profile and applicable environmental regulations.

SW Generated At Port: The amount of SW generated at port can be estimated using the USCG solid waste generation rate and the number of crew onboard the vessel in port.

Total Amount of SW Disposed Ashore: The amount of waste generated and waste composition can be determined from waste stream analyses. In the absence of vessel specific solid waste data, the IPCC provides national waste composition statistics that can be used to estimate the waste composition. Landfill solid waste can be categorized as food, paper and cardboard, wood, textiles, and others. The current methodology requires the estimation of the amount of solid waste by these categories. Glass and plastic wastes can be recycled and if disposed by landfill, they do not contribute to CH₄ emissions because glass and plastic wastes are inert and do not decompose.

DOC Fraction (%): DOC is the organic carbon in waste susceptible to biochemical decomposition, and should be expressed as mass of carbon per mass of waste. The DOC in bulk waste is estimated based on the composition of waste and can be calculated from a weighted average of the degradable carbon content of various components of the waste stream.

Fraction of DOC that can Decompose (%): Some DOC does not degrade or degrades very slowly under anaerobic conditions in the landfills. The fraction of DOC that can decompose is an estimate of the fraction of carbon that is ultimately degraded and released from landfill. the value is dependent on many factors like temperature, moisture, pH, composition of waste, etc. The recommended default value is 0.5.

Methane Correction Factor (MCF) (%): Waste disposal practices vary in the control, placement of waste and management of the site. The MCF accounts for the fact that unmanaged landfills produce less CH₄ from a given amount of waste than anaerobic managed landfills. In unmanaged landfills, a larger fraction of waste decomposes aerobically in the top layer. In unmanaged landfills with deep disposal and/or with high water table, the fraction of waste that degrades aerobically should be smaller than in shallow landfills. The MCF in relation to solid waste management is specific to that area and should be interpreted as the waste management correction factor for aerobic decomposition.

Landfill Type: Landfills are categorized by type in order to determine the default value for MCF.

Fraction of CH₄ in Generated Landfill Gas (%): Most waste in landfills generates gas with approximately 50 percent CH₄. Only material with substantial amounts of fat or oil can generate gas with more than 50 percent CH₄. The use of the IPCC default value for the fraction of CH₄ in landfill gas is 0.5.

Oxidation Factor: The oxidation factor reflects the amount of CH₄ from landfills that is oxidized in the



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soil or other material covering the waste⁴⁸. The default value for oxidation factor is zero. The oxidation factor of 0.1 can be used for covered, well-managed landfills to estimate both diffusion through the cap and escape by cracks/fissures. The use of an oxidation value higher than 0.1, should be clearly documented, referenced, and supported by data relevant to circumstances.

CH₄ Recovered: It is important to note that any CH₄ that is recovered must be subtracted from the amount generated before applying the oxidation factor. CH₄ recovery includes combustion by flaring or combustion used for energy.

C.13.3 Assumptions and Limitations

This section describes the general assumptions and limitations associated with solid waste landfill disposal emissions. Additional assumptions related to specific elements and parameters are documented in the carbon footprint methodology assessment workbook.

- The current CH₄ emissions are estimated based on the generation potential, which may overestimate the emission. Since waste is decomposed gradually over time, a more accurate approach would require the modeling of the first order decay (FOD) of the waste over time. The FOD model can provide a more accurate estimation of the total mass of DOC decomposed during the report year, however, the FOD model requires extensive input data. Various data, such as the current and previous years accumulative decomposable DOC at the landfill, waste reaction constant, half-life time, and delay time, are required to model the FOD. In order to simplify the data collection requirements, the CH₄ generating potential is used to estimate the GHG emissions.
- Assume CH₄ recovery is zero. CH₄ recovery should be reported only when references documenting the amount of CH₄ recovery are available (e.g. metering of all gas recovered for energy and flaring or monitoring of produced amount of electricity from the gas.)
- The current methodology does not consider the delay time⁴⁹ between deposition of the waste and full production of CH₄. If FOD model is required, the IPCC recommends a default value of six months for the time delay.
- The quality of CH₄ emission estimates is directly related to the quality and availability of the waste generation, composition and management data used to derive these estimates. The uncertainty in waste disposal data depends on how the data is obtained. Uncertainty can be reduced when the actual amounts of waste disposed are weighted and reported by the vessel.

⁴⁸ CH₄ oxidation is by methanotrophic micro-organisms in cover soils and can range from negligible to 100 percent of internally produced CH₄. The thickness, physical properties and moisture content of cover soils directly affect CH₄ oxidation. Studies show that sanitary, well-managed landfills tend to have higher oxidation rates than unmanaged dump sites. The oxidation factor at sites covered with thick and well-aerated material may differ significantly from sites with no cover or where large amounts of CH₄ can escape through cracks/fissures in the cover.

⁴⁹ In most solid waste landfill sites, waste is deposited continuously throughout the year, usually on a daily basis. However, there is evidence that production of CH₄ does not begin immediately after deposition of the waste. At first, decomposition is aerobic, which may last for some weeks, until all readily available oxygen has been used up. This is followed by the acidification stage, with production of hydrogen. The acidification stage is often said to last for several months. After which there is a transition period from acidic to neutral conditions, when CH₄ production starts. The period between deposition of the waste and full production of CH₄ is chemically complex and involves successive microbial reactions. Time estimates for the delay time are uncertain, and will probably vary with waste composition and climatic conditions. Estimates of up to one year have been given in the literature.



C.14 Land Disposal of Wastewater

Ashore wastewater disposal is conducted by contractor services and it is considered as Scope 3 emissions. Wastewater includes sewage and graywater, as well as oily water (e.g., bilge water) resulting from the normal operations of a vessel. Sewage, often referred to as backwater, is exclusively human waste from toilets and other receptacles intended to receive or retain body wastes. Graywater discharge includes wastes from showers, sinks, deck drains, laundries, and galleys. In general, direct discharge of sewage and graywater is permitted when the vessel is beyond 3 nm from shore. Some vessels are not equipped with sewage and graywater treatment systems and thus are limited in where they can discharge compared to vessels with treatment systems onboard. Typical treatment methods on ships include a marine sanitation device (MSD) that performs solids screening, maceration or biological treatment and chemical/chlorine disinfection. Oily/bilge water is usually stored in a holding tank for shore disposal or treated with an Oil Water Separator (OWS) before being discharged overboard. Vessels equipped with an OWS also have an Oil Content Monitor (OCM) that measures the concentration of oil in water and either allow overboard discharge if less than the prescribed limit of 15-ppm or redirect it back to the OWS system for further processing. Wastewater is retained for pierside disposal when the vessel is at port. The current vessel carbon footprint methodology only considers the amount of wastewater that requires ashore disposal.

In general, oily water is processed ashore to reclaim the oil. Used oil can be recycled and used as a boiler fuel supplement or burned in approved industrial furnaces. If oily water is disposed via incineration, Section C.9 can be used to estimate the incinerator emissions. Sewage and graywater, which is treated by the public water treatment plant, is a source of CH₄ and N₂O emissions. CO₂ emissions from wastewater are not considered because these are of biogenic origin and should not be included.

C.14.1 Emission Estimation Method

This section is focused on estimating sewage and graywater emissions from public wastewater treatment plants. The incineration of oily waste can use the same methodology as outlined in Section C.9. Wastewater and sludge can generate CH₄ emission when degraded anaerobically. The extent of CH₄ production depends primarily on the quantity of degradable organic material in the wastewater, temperature, and the type of treatment system. With increases in temperature, the rate of CH₄ production increases. Common parameters used to measure the organic component of the wastewater are the Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). Under the same conditions, wastewater with higher COD or BOD concentrations will generally yield more CH₄ than wastewater with lower COD or BOD concentrations. The BOD concentration indicates only the amount of carbon that is aerobically biodegradable. The COD measures the total material available for chemical oxidation (both biodegradable and non-biodegradable). Usually, BOD is more frequently reported for domestic wastewater, while COD is predominantly used for industrial wastewater. Both the type of wastewater and the type of bacteria present in the wastewater influence the BOD concentration of the wastewater. The equations below can be used to calculate the CH₄ emission.



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Equation (C-30). Total organics in wastewater.

Total Organics in Wastewater (TOW) (kg BOD/yr) = Avg Effluent BOD (mg/L) x Amount of Sewage and Graywater Disposed at Public Treatment System (Gal/Yr) * Unit Conversion

Equation (C-31). CH₄ emission (tons of CH₄).

CH₄ Emission (metric tons of CH₄) = TOW x Maximum CH₄ Producing Capacity (Bo) (kg CH₄/kg BOD) x Methane Correction Factor (MCF) (%) - CH₄ recovery (tons of CH₄)

Equation (C-32). CH₄ emission (tons of CO₂-e).

CH₄ Emission (metric tons of CO₂-e) = CH₄ emission (tons of CH₄) * GWP

N₂O is associated with the degradation of nitrogen components in the wastewater, e.g., urea, nitrate and protein. Public wastewater treatment systems may include a variety of processes, ranging from lagooning to advanced tertiary treatment technology for removing nitrogen compounds. Nitrification and denitrification processes⁵⁰ used by the treatment plant contribute to direct emissions. After the wastewater is processed, treated effluent is typically discharged to a receiving water environment (e.g., river, lake, estuary, etc.). The disposal of treated effluent into waterways contributes to indirect emission. The current methodology does not consider N₂O emissions because effluent emission is considered indirect emission for the treatment plant and direct emission from the treatment plant is not a significant source. Figure C-13 summarizes the process for estimating the GHG emissions from ashore wastewater disposal.

⁵⁰ Nitrification is an aerobic process converting ammonia and other nitrogen compounds into nitrate (NO₃), while denitrification occurs under anoxic conditions (without free oxygen), and involves the biological conversion of nitrate into nitrogen gas (N₂). Nitrous oxide can be an intermediate product of both processes, but is more often associated with denitrification.



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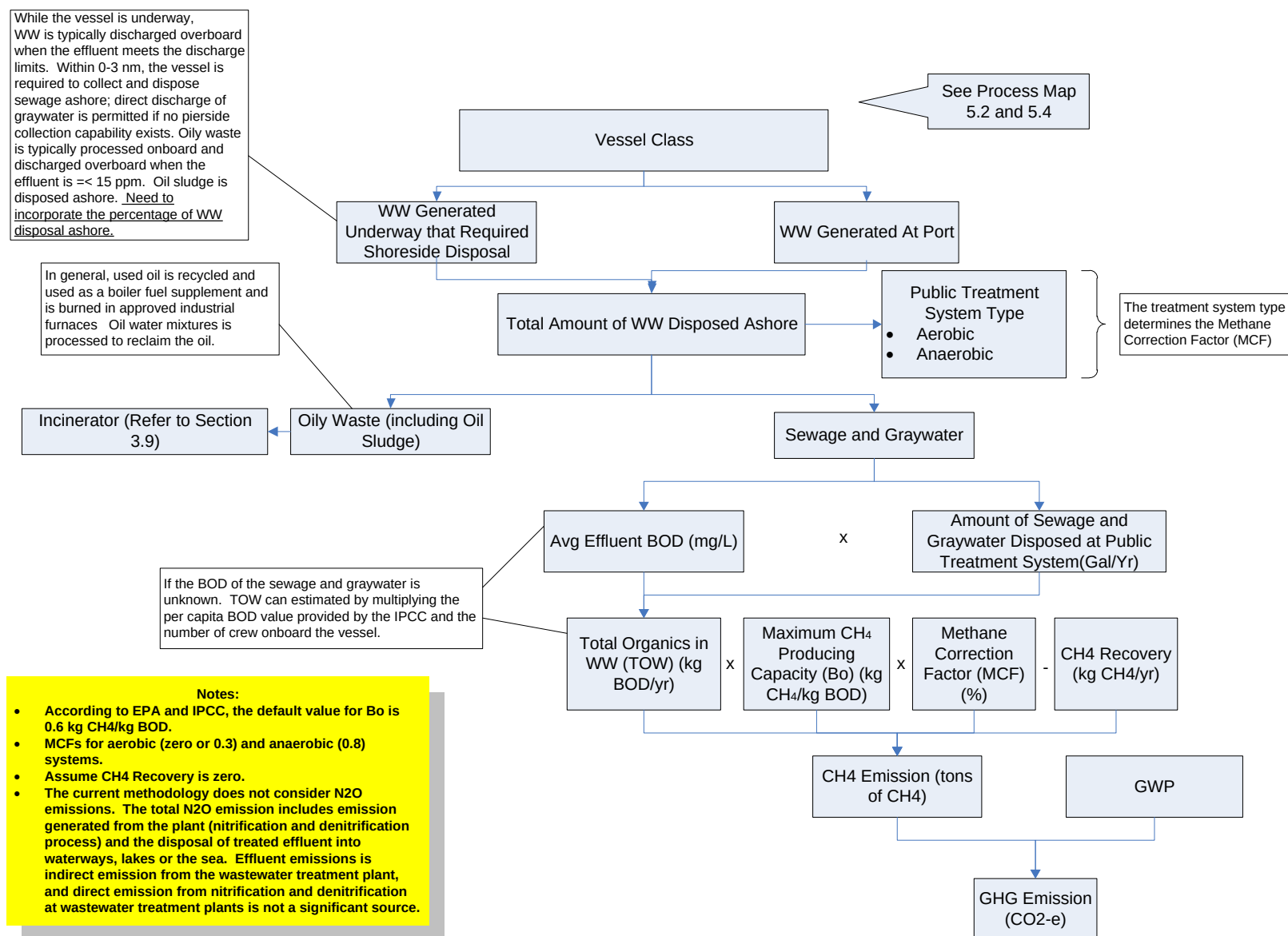


Figure C-13. Ashore wastewater disposal emission estimation flowchart.



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C.14.2 Data Analysis

The following section summarizes the key data elements for estimating GHG emissions associated with ashore wastewater treatment.

Wastewater Generated Underway that Required Disposal Ashore: The amount of wastewater disposed ashore does not necessarily equal to the total amount of wastewater generated by the vessel because while the vessel is underway, sewage and graywater can be disposed overboard when the conditions are met. The amount of wastewater disposed ashore requires the analysis of regulatory standards, and the mission and operational profile to determine the percentage time the vessel is operating within 3 nm.

Water Generated At Port: The amount of wastewater generated at port can be estimated using the Navy or USCG sewage and graywater generation rate and the number of crews onboard the vessel while at port.

Total Amount of Wastewater Disposed Ashore: The total amount of wastewater disposed ashore is the sum of underway and at port wastewater disposal volume. Wastewater generation and disposal rate can be tied to mission, time in port, and percentage time within 3 nm, as well as crew size.

Average Effluent BOD: The average effluent BOD can be determine from waste stream analyses. However, in the absent of vessel specific data, the per capita BOD (g/person/day) provided by the IPCC can be used. Note that the IPCC value is based on population and is independent of the actual amount of wastewater disposed ashore.

Total Organics in Wastewater (TOW): The total organics in wastewater is estimated as kg of BOD per year. It can be calculated by multiplying the average effluent BOD and the volume of wastewater disposed. If BOD data is not available, TOW can be estimated by multiplying the per capita BOD and the number of crew.

Maximum CH₄ Producing Capacity (Bo): Bo is the maximum CH₄ producing potential of wastewater. The default value is 0.6 kg CH₄/kg BOD or 0.25 kg CH₄/kg COD.

Methane Correction Factor (MCF): Treatment systems or discharge pathways that provide anaerobic environments will generally produce CH₄ whereas systems that provide aerobic environments will normally produce little or no CH₄. The MCF indicates the degree to which the system is anaerobic. The MCF ranges from zero to one, where zero is used for untreated systems such as open sewer, while one can be used for anaerobic treatment systems.

CH₄ Recovery: CH₄ recovery is obtained through flaring or for energy generation. The default for CH₄ recovery is zero. CH₄ recovery should be included only if there are sufficient facility-specific data. The quantity of recovered CH₄ should be subtracted from the total CH₄ produced.

C.14.3 Assumptions and Limitations

This section describes the general assumptions and limitations associated with ashore wastewater disposal emissions. Additional assumptions related to specific elements and parameters are documented in the carbon footprint methodology assessment workbook.



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- Due to limited plant specific CH₄ recovery data, the current methodology assumes zero CH₄ recovery for the public wastewater treatment plants. If emissions from flaring and energy generation are required, they shall be included in separation categories as stationary combustion. In general, emissions from flaring are not significant, as the CO₂ emissions are of biogenic origin, and the CH₄ and N₂O emissions are very small.
- Emissions from wastewater and sludge should be estimated together. The current methodology assume zero sludge removal. CH₄ emissions from sludge sent to landfills, incinerated or used in agriculture are not included in the wastewater treatment and discharge category.
- According to the IPCC, TOW can be calculated as a function of human population and BOD generation per person. This method is used when there is insufficient vessel specific data on effluent BOD and wastewater disposal volume.
- The current methodology uses the MCF to characterize the treatment of wastewater according aerobic and anaerobic systems. Since treatment systems can vary for urban and suburban areas, and can also vary from port to port, it is difficult to derive the MCF based on port location. The methodology applies a national average MCF by taking into consideration of the fraction of wastewater treated anaerobically.
- N₂O emissions include the direct emissions from the treatment plants and indirect emissions from disposal of effluent into waterways, lakes or the sea. The current methodology does not consider N₂O emissions.



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APPENDIX D. METHODOLOGY ASSESSMENT WORKBOOK

The purpose of the workbook is to exercise the preliminary methodologies by testing their usability. The results of the usability assessment were used to create the current recommended methodologies. The vessel classes used in this exercise are the USCG 270' Medium Endurance Cutter (270-WMEC) and the USCG Response Boat Small (RB-S). The Methodology Assessment Workbook has been developed using Microsoft Excel. It calculates the carbon footprint on an annual basis, in accordance with CEQ guidance.

The user navigates through the workbook by clicking the buttons at the top of each screen. The 000-series sheets contain primary information. Sheet 001 is a general welcome and explanation of the workbook. A brief summary of the philosophy of carbon footprint calculation is included in Sheet 002. Sheet 003 (Figure D-1) includes all primary selections the user must make, such as vessel type, vessel class, vessel, data source, homeport, fuel type, crew work hours, operational profile, speed profile, and fiscal year. The actual carbon footprint calculations are completed in Sheet 004. Finally, Sheet 005 (Figure D-2) contains a summary of the calculated carbon footprint of the selected vessel. The 100-series sheets contain specific information that allows the user to further modify the analysis. The user can modify information pertaining to the propulsion fuel consumption, electrical use, helicopter use, cutter boat use, refrigerant consumption, fire suppressant consumption, liquid and solid waste generation and processing, and cutter boat towing. All other sheets contain information that is merely present for reference purposes. The 300-series contains class-specific information. The 400-series houses the carbon footprint factors. The 500-series contains miscellaneous information. See Figure D-3 for a flow chart of the entire workbook.

The preliminary carbon footprint methodologies were developed with the intent of using the subsequently designed workbook as a means to make management decisions considering the changes to the vessel's carbon footprint and to determine which contributors to the carbon footprint are significant. At this time, the USCG simply does not collect enough information consistently throughout the fleet to allow this workbook to be used to make management decisions. However, this workbook was able to successfully establish which portions of the vessel's carbon footprint are worthy of investing in refined accounting. Based on the information from the WMECs, the primary carbon footprint generator is hydrocarbon consumption. The other significant contributor is the electricity consumed via shore connection. The emission of refrigerants will likely only be significant if there is a major system failure. For most vessels in the fleet, the emissions from the fire suppression systems will be insignificant, but further research is needed to assure that the emission of FM-220 aboard the 140 WTGB and 110 WPB classes will not affect the carbon footprint significantly.

In order to create a Methodology Assessment Workbook that could allow the user to make meaningful management decisions, further development is needed. A few suggestions are listed below:

1. General need for more data points.
2. Collect handle position data to correlate speed to engine operating hours.
3. Outfit main machinery with flow meters to track the fuel consumption.
4. Switch to a web-based application to accommodate additional classes and a more-robust workbook.
5. Track shore power consumption from the switchboards on all vessels.
6. Track the consumption of refrigerants.



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- Investigate the consumption of fire suppressants (FM-200) on the 140 WTGB and 110 WPB classes.

Worksheet 003: High Level Input

INSTRUCTIONS: Enter basic information about the vessel in which you would like to investigate.

001 002 004 NEXT 005

OUTPUT SNAPSHOT:

Scope 1 Total	Scope 2 Total	Scope 3 Total	Total Calculated Carbon Footprint
3719 mt	505 mt	43 mt	4317 mt

INPUT:

- Are you looking to determine the carbon footprint of a cutter or boat? ☒ Cutter ☐ Boat
- Use historical data where available or only use operational capabilities? ☐ Historical Data ☒ Operational Capabilities
- Use the vessels current homeport or specify a new homeport? ☒ Current ☐ User Defined
- Fuel and Oil Utilized on the vessel?
- Tropical Hours or Regular Work Hours? ☒ Regular Hours ☐ Tropical Work Hours
- Operational Profile, Pre-Defined or User Defined? ☒ Pre-Defined ☐ User Defined

Choose Class	Choose Vessel (or entire class)
270' Medium Endurance Cutter (WMEC)	CGC FORWARD (000516)

Homeport used for Calculation		User Input Homeport	
Portsmouth			
Prop. Fuel	Lube Oil	Cutter Boat Fuel	Vehicle Fuel
Diesel	Diesel	Gasoline	Gasoline

Op Profile Used for Calculations	User Annual Input Value	Op Profile Used for Calculations	User Annual Input Value
Days Away From Homeport	Days Inport, Away from Homeport		
186	123	36	24
Total Underway Days	Days in Homeport		
150	99	179	242
Total Underway Hours	Total Transit Hours		
3592	2376	389	250

- Speed Profile, Pre-Defined or User Defined? ☐ Pre-Defined ☒ User Defined

Fiscal Year Data for Validation FY 2009

Name	Speed (kts)	% Time	Speed (kts)	% Time
Idle	0	3%	0	3%
Tow	5	40%	3	65%
Patrol	10	45%	7	25%
Transit	12	10%	10	5%
Intercept	18	2%	15	2%
Total		100%	Total	100%

Figure D-1. Sheet 003 of methodology assessment workbook.



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Worksheet 005: Output



Vessel Class
270' Medium Endurance Cutter (WMEC)

Subject Vessel
CGC FORWARD (000516)

mt CO2e		
Scope 1 Total	=	3,719
Scope 2 Total	=	505
Scope 3 Total	=	43.0
Total Calculated Carbon Footprint	=	4,317

SUMMARY OUTPUT:

Scope	Sheet	Source	Include in Calculation	Annual Input		SUM (mt CO2e)	% of Total Footprint	UW Power Validation Factor is...
1	101	Vessel Propulsion	☒ Yes ☐ No	235,654 Gallons of Fuel	=	2413	55.90%	ON
				1,761 Gallons of Lube Oil	=	18.0	0.42%	
1	102	Electrical Generation	☒ Yes ☐ No	100,469 Gallons of Fuel	=	1029	23.83%	
				577 Gallons of Lube Oil	=	5.9	0.14%	
1	103	Boiler	☐ Yes ☒ No		=			
1	104	Deployed Helicopter Operations	☒ Yes ☐ No	13,433 Gallons of JP-5	=	184.8	4.28%	ON
1	105	Deployed Cutter Boat Operations	☒ Yes ☐ No	8,980 Gallons of Fuel	=	79.1	1.83%	
1	106	Vessel Refrigerant Emissions	☒ Yes ☐ No	21.9 lbs of Refrigerant	=	12.9	0.30%	
1	107	Vessel Fire Suppressant Emissions	☒ Yes ☐ No	181.1 lbs of CO2	=	0.1	0.002%	
1	107	Vessel Fire Suppressant Emissions (FM-200)	☐ Yes ☒ No		=			
1	108	Vessel Incinerator Operations	☐ Yes ☒ No		=			Shore Power Validation Factor is...
2	102	Shore Power Consumption	☒ Yes ☐ No	976,049 kW hr	=	505.4	11.71%	ON
3	102	Shore Power T&D Losses	☒ Yes ☐ No	64,293 kW hr	=	33.3	0.77%	
3	108	Ashore Solid Waste Disposal Emissions	☒ Yes ☐ No	10,352 lbs of Food Waste	=	4.9	0.11%	
				14,202 lbs of Paper/Cardboard	=	18.1	0.42%	
3	108	Ashore Liquid Waste Disposal Emissions	☒ Yes ☐ No	25,667 Gallons of Blackwater	=	4.7	0.11%	
				427,781 Gallons of Graywater	=	2.9	0.07%	
				17,111 Gallons of Grinder Effluent	=	4.7	0.11%	
3	109	Towing Vehicle Operations	☐ Yes ☒ No		=			

Figure D-2. Sheet 005 of methodology assessment workbook.



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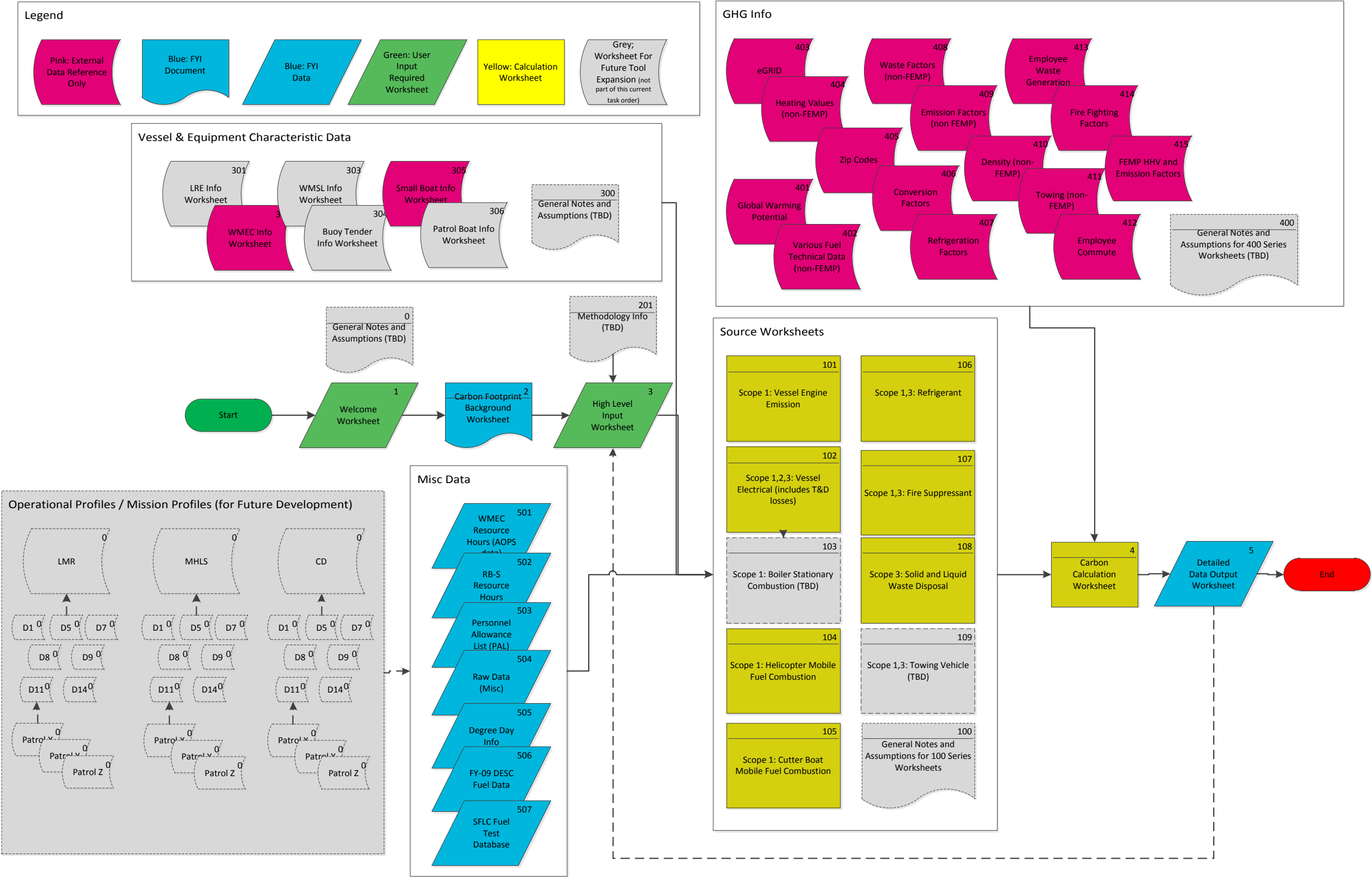


Figure D-3. Methodology assessment workbook flowchart.

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APPENDIX E. LIMITATIONS, ASSUMPTIONS, AND FACTORS



Report on the Recommended Method to Measure the Carbon Footprint of a USCG Vessel

	TITLE	
	Higher Heating Value Discrepancy Calculation	
	PROJECT USCG Carbon Footprint Methodology Development	JOB NUMBER 2853-011

Problem:
The U.S. Department of Energy's Federal Energy Management Program's *Annual GHG and Sustainability Data Report* Reference (A) provides federal agencies the tool in which they are required to report their greenhouse gas emissions. The primary way in which the user must enter emission from mobile resource forces the user to classify each individual fuel as one of nine basic fuels. Assuming an inaccurate high heating value for a particular fuel could result in an inaccurate carbon footprint.

References:
a) United States. Dept. of Energy. Federal Energy Management Program's Annual GHG and Sustainability Data Report, Version 1.3. 9 November 2010.
b) Katikaneni, S., C. Yuh, S. Abens, and M. Farooque. "The Direct carbonate Fuel Cell Technology: Advances in Multi-fuel Processing and Internal Reforming." *Catalysis Today* 77 (2002) 99–106.
c) Tosh, J.D., D.S. Moulton, and C.A. Moses. "Navy Fuel Specification Standardization, Interim Report BFLRF No. 225." April 1992.
d) United States. Dept. of Defense. Detail Specification: Turbine Fuel, Aviation, Grades JP-4 and JP-5. MIL-DTL-5624U. 5 January 2004.
e) Bowden, J.N., S.R. Westbrook, M.E. LePera. "A Survey of JP-8 and JP-5 Properties, Interim Report BFLRF No. 253." September 1988.

Background:
The purpose of Executive Order 13514 is to establish an integrated strategy for sustainability throughout the Federal Government and to make reduction of greenhouse gas emissions a priority for Federal agencies. Reference (A) is a technical support document that accompanies the Federal Greenhouse Gas Accounting and Reporting Guidance and provides detailed information on the inventory reporting process and accepted calculation methodologies. It is supposed to be used as the "go-to" guide for government agencies to calculate their carbon footprint.

Calculations:
Using the widely-used fuels F-76 and JP-5 as examples. There is no specific mention of F-76 in Reference (A); therefore, F-76 must be classified as "Diesel" and JP-5 must be considered "jet fuel" to ensure the use of proper emission factors. According to this reference, the higher heating value for diesel is 138,000 Btu/gallon and for jet fuel is 135,000 Btu/gallon. Compare these higher heating value to the higher heating values found in References (B), (C), (D), and (E) which give explicit heating values.

SUMMARY TABLE		Higher Heating Value (Btu/gal)	How Different from Ref. a (%)
F-76	Ref. (B)	130,235	5.63
	Ref. (C)	129,291	6.31
JP-5	Ref. (D)	124,797	7.56
	Ref. (E)	125,964	6.69

Results:
By using the higher heating values in Reference (A), the indicated amount of actual energy expended during combustion is significantly higher (5.6 - 7.6%) than it would be if more precise higher heating values (as found in References (B), (C), (D), and (E)) were used. In order for USCG vessels to be compared with vessels from other subagencies within federal government, it is important to follow Reference (A). The usability tool therefore uses the values from Reference (A) and not the actual values for the specific fuels burned by the USCG.

PREPARED BY SEW	DATE 12-Nov-10	CHECKED BY MSO	DATE 19-Nov-10	SHEET 1 OF 1
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Report on the Recommended Method to Measure the Carbon Footprint of a USCG Vessel

	TITLE	
	Underway Electrical Load Analysis Validation	
	PROJECT USCG Carbon Footprint Methodology Development	JOB NUMBER 2853-011

Problem:
Actual inport and underway power consumption data does not correlate with the original electrical load analysis predicted power consumption.

Background:
The design electrical load analysis was utilized as a basis for determining the amount of carbon footprint attributed to power consumption while both inport and underway. Electrical load analyses are known to over estimate the amount of power required by a vessel, primarily due to inaccuracies in the predicted duty cycle. In order to utilize the load analysis as a basis for the carbon footprint tool, a correction factor needs to be applied. Additionally, the operation of the generators in parallel is primarily dictated by the need for redundancy due to the vessel's ongoing operations (flight operations, small boat operations, etc) and not by the engineering need to manage the electrical load. Thus a correction factor and percentage of time operating in parallel is going to be determined based on actual data received

References:
a) USCGC ESCANABA Engineering Round Sheets 01 Sept 2010 to 30 Sept 2010

1) Underway Correction Factor:
Reference (a) provided electrical power data from USCGC ESCANABA. This data was captured by the engineering watchstander every two hours throughout the day for the time ESCANABA spent underway during the month of September. This manually collected data was entered by the Engineer of the Watch into MS Excel.

Underway Predicted Average Electrical Load from Load Analysis (kW) 571

Summary of Electrical Power Data from the Engineering Round Sheets

Power Average when Singled up on NR1 SSDG (kW)	Power Average when Singled up on NR2 SSDG (kW)	average) when Singled up on One SSDG (kW) ^{Note 1}	Underway Correction Factor (when Singled up)
296.2	286.3	291.3	1.96

NR1 SSDG Power Average when Paralleled (kW)	NR2 SSDG Power Average when Paralleled (kW)	Generator Load (on average) when Paralleled on Two SSDGs (kW) ^{Note 2}	Underway Correction Factor (in Parallel)
185.1	175.4	180.2	3.17

Total Possible Running Hours (per SSDG) over Data Collection Period	Total Hours Paralleled	% of Available Time Paralleled ^{Note 3}	% of Available Time Singled up on One SSDG ^{Note 4}
718.0	423.3	59%	41%

	#1 SSDG Hours	#2 SSDG Hours	Total Hours
Total SSDG Operating Hours for Data Collection Period	517.1	622.5	1139.6
% of Available Time Singled Up on Specific Generator	13.1%	27.7%	
% of Available Time Online (in Parallel or Singled up)	72.0%	86.7%	

Note 1: This will be utilized to calculate the correction factor for the underway power load applied from the electrical load analysis when the SSDGs are singled up.

Note 2: This will be utilized to calculate a correction factor to the underway power load applied from the electrical load analysis when the

Note 3: This will be applied to the cutter resource hours for determination of the number of cutter resource hours spent operating with SSDGs

Note 4: This will be applied to the cutter resource hours for determination of the number of cutter resource hours spent operating on one

PREPARED BY MSO	DATE 01-Nov-10	CHECKED BY SEW	DATE 17-Nov-10	SHEET 1 OF 1
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Report on the Recommended Method to Measure the Carbon Footprint of a USCG Vessel

	TITLE		
	Inport Electrical Power Calculations		
	PROJECT	USCG Carbon Footprint Methodology Development	JOB NUMBER 2853-011

Problem:
Actual inport and underway power consumption data does not correlate with the original electrical load analysis predicted power consumption.

References:
a) Shore.Tie.Energy.Data.xls, email from Emily Ansell, 10/6/2010.

Background:
The design electrical load analysis was utilized as a basis for determining the amount of carbon footprint attributed to power consumption while both inport and underway. Electrical load analyses are known to over estimate the amount of power required by a vessel, primarily due to inaccuracies in the predicted duty cycle. In order to utilize the load analysis as a basis for the carbon footprint tool, a correction factor needs to be applied.

Calculations:
Determine the shoretie consumption factors based on the design load analysis and Reference a.

Design Load for Continuous Cruising:
 Summer = 450 kW = 10800 kWh/day
 Winter = 490 kW = 11760 kWh/day

Portsmouth Loads:

	Month	Load per Shoretie (kWh/day)	Average Load per Shoretie (kWh/day)	Load Per Ship (kWh/day)
Winter	Oct. '09	2,131	2,308	4,616
	Nov. '09	2,340		
	Dec. '09	2,422		
	Jan. '10	2,684		
	Feb. '10	2,004		
Summer	Mar. '10	2,269	2,224	4,449
	Apr. '10	2,357		
	May '10	2,349		
	June '10	2,145		
	July '10	1,877		
	Aug. '09	2,317		
	Sept. '09	2,301		

Factors:
Summer Factor = Summer Design Load / Summer Portsmouth Ship Load
2.43
Winter Factor = Winter Design Load / Winter Portsmouth Ship Load
2.55

Results:
 The inport summer electrical factor is 2.43, and the winter inport electrical factor is 2.55.

PREPARED BY SEW	DATE 11/18/2010	CHECKED BY MSO	DATE 11/19/2010	SHEET 1	OF 1
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Report on the Recommended Method to Measure the Carbon Footprint of a USCG Vessel

 BMT Designers & Planners	TITLE	
	Lube Oil Consumption Calculation	
	PROJECT USCG Carbon Footprint Methodology Development	JOB NUMBER 2853-011

Problem:
The lube oil consumption of the main engines and generator sets aboard the WMEC-270s is unknown.

References:
 a) USCGC CAMPBELL, Operating Logs, acquired 16 October 2010
 b) USCGC TAHOMA, Engine Hours, acquired 28 October 2010
 c) USCGC ESCANABA, "Escanaba Equipment Hours Main Prop (2).xls", acquired 26 October 2010

Background:
 Various logs from the USCG cutters CAMPBELL, TAHOMA, and ESCANABA (References (A), (B), and (C), respectively) show the number of hours an engine or generator set has been running during a year. In addition, these logs record the amount of lube oil added to each piece of equipment.

Calculations:
 Determine the average lube oil consumption for the propulsion engines and generator sets.

Propulsion Engines

	CAMPBELL				ESCANABA ('07,'08)/TAHOMA ('09)				Avg. consump.
	Engine 1		Engine 2		Engine 1		Engine 2		
YEAR	Hr	LO(gal)	Hr	LO(gal)	Hr	LO(gal)	Hr	LO(gal)	
2006	3155	1029	2998	1420					0.400
2007	2794	1107	2560	1421	2725	582	2782	698	0.354
2008	2678	1895	2277	1166	3167	422	3101	394	0.370
2009	2138	1667	2076	808	1205	268	1273	170.5	0.381
AVERAGE									0.376 gal/hr

Generator Sets

	CAMPBELL				ESCANABA ('07,'08)/TAHOMA ('09)				Avg. consump.
	Gen Set 1		Gen Set 2		Gen Set 1		Gen Set 2		
YEAR	Hr	LO(gal)	Hr	LO(gal)	Hr	LO(gal)	Hr	LO(gal)	
2006	2870	401	2345	343					0.143
2007	2798	376	2830	426	2699	334	3100	181	0.117
2008	3660	403	3219	374	3419	203	3204	200	0.087
2009	2631	55	2383	256	1571	80	1051	59	0.059
AVERAGE									0.101 gal/hr

Results:
 The average lube oil consumption of a main propulsion engine is 0.376 gal/hr. The average lube oil consumption of a generator set is 0.101 gal/hr.

PREPARED BY SEW	DATE 01-Nov-10	CHECKED BY MSO	DATE 19-Nov-10
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Report on the Recommended Method to Measure the Carbon Footprint of a USCG Vessel

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