# PhilaPort
# 2023 Emissions Inventory

PhilaPort
THE PORT OF PHILADELPHIA

Cargo Handling Equipment and Heavy-Duty Trucks



*Prepared by:*

STARCREST CONSULTING GROUP, LLC
*ENVIRONMENTAL MANAGEMENT • AIR QUALITY • CLIMATE • SUSTAINABILITY*


*December 2024*

# PhilaPort 2023 Emissions Inventory
# Cargo Handling Equipment and Heavy-duty Trucks

Prepared for:

December 2024

Prepared by:

**Starcrest Consulting Group, LLC**

Established 1997

## TABLE OF CONTENTS

## LIST OF FIGURES



## LIST OF TABLES

## ACKNOWLEDGEMENTS

*Project Leadership and Management*
Valerie Piper, PhilaPort Grant Compliance Administrator
Jeff Theobald, PhilaPort Executive Director/CEO

| | |
|---|---|
| Authors: | Archana Agrawal, Principal, Starcrest<br>Guiselle Aldrete, Consultant for Starcrest<br>Eric Bayani, Consultant for Starcrest<br>Graciela Lubertino, Consultant for Starcrest |
| Contributors: | Steve Ettinger, Principal, Starcrest<br>Russelle Hansen, Consultant for Starcrest<br>Nohemi Taguite, Consultant for Starcrest |
| Cover: | Melissa Silva, Principal, Starcrest |
| Document Preparation: | Denise Anderson, Consultant for Starcrest |
| Photos: | Provided by PhilaPort |

## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| CHE | cargo handling equipment |
| $CH_4$ | methane |
| CO | carbon monoxide |
| $CO_2$ | carbon dioxide |
| $CO_2e$ | carbon dioxide equivalent |
| E | emissions |
| EF | emission factor |
| EPA | U.S. Environmental Protection Agency |
| g/bhp-hr | grams per brake horsepower-hour |
| g/hr | grams per hour |
| g/kW-hr | grams per kilowatt-hour |
| g/mi | grams per mile |
| GHG | greenhouse gas |
| GWP | global warming potential |
| hp | horsepower |
| kW | kilowatt |
| kW-hr | kilowatt hour |
| LF | load factor |
| mph | miles per hour |
| MOVES | Motor Vehicle Emissions Simulator, EPA model |
| $N_2O$ | nitrous oxide |
| $NO_x$ | oxides of nitrogen |
| OGV | ocean-going vessel |
| PM | particulate matter |
| $PM_{10}$ | particulate matter less than 10 microns in diameter |
| $PM_{2.5}$ | particulate matter less than 2.5 microns in diameter |
| SCC | source classification code |
| $SO_2$ | Sulfur dioxide |
| tons | Short tons |
| tonnes | metric tons |
| tpy | tons per year |
| ULSD | ultra-low sulfur diesel |
| VOC | volatile organic compound |

# SECTION 1 INTRODUCTION

PhilaPort developed the 2023 Emissions Inventory of cargo handling equipment and heavy-duty trucks operating at and/or calling to the facilities of the Port of Philadelphia (the Port). This inventory, based on 2023 calendar year activity, is the first time for the Port to develop an activity-based emissions inventory that provides detailed emissions information for the cargo handling equipment and on-terminal heavy-duty truck operations.

## 1.1 Port Overview

PhilaPort, centrally located on the U.S. East Coast, handled 7.6 million tons of varied cargo in 2023, including agricultural, dry and reefer containers, industrial machinery, vehicles, breakbulk and liquid bulk. The PhilaPort facilities/terminals included in this study are:

- ✓ Container terminals
  - Packer Avenue Marine Terminal
  - Tioga Marine Terminal
- ✓ Roll-on/Roll-off (RoRo) facilities
  - Pier 98 Annex
  - Southport Marine Terminal
  - Pier 122
- ✓ Breakbulk facilities
  - Piers 96, 98, 100 (not operational in 2023, no equipment or trucks)
  - Pier 84
  - Pier 82
  - Piers 74, 78, 80
- ✓ Liquid Bulk facilities
  - Pier 124
  - Tioga Liquid Bulk Terminal
- ✓ Other facilities
  - PhilaPort Distribution Center
  - Philadelphia Wholesale Produce Market

The geographical domain is within the facility boundaries for the cargo handling equipment (CHE) located at the facilities, and trucks that call the PhilaPort facilities.

The following figures show the various PhilaPort facilities. Figure 1.1 shows Packer Avenue Marine Terminal, the largest container terminal for PhilaPort. Figure 1.2 shows Tioga Marine Terminal which is a container and general cargo terminal.

**Figure 1.1: Packer Avenue Marine Terminal**


**Figure 1.2: Tioga Marine Terminal**

PhilaPort has several facilities that are warehouses for the varied cargo received that includes perishables and forest products. These facilities, shown in Figures 1.3 and 1.4, mainly use electric equipment such as electric forklifts and electric pallet jacks inside the warehouses, along with some propane forklifts. Electric equipment is optimum inside the warehouses due to the commodities being handled, but also from a safety perspective for the workers and visitors to the warehouses. The Philadelphia Wholesale Produce Market is open to the public and is the largest refrigerated building in the world, housing 700,000 square feet of the world's freshest produce.

**Figure 1.3: Various Breakbulk Facilities**

**Figure 1.4: Philadelphia Wholesale Produce Market**

Figure 1.5 shows the RoRo berth, adjacent to Packer Avenue Facility, where the vehicles are driven out of the vessel and driven to the Southport Marine Terminal. Some vehicles go to the Auto Processing Facility. Cargo handling equipment is not used to unload the RoRo vessels as they are driven out of the vessel to be parked for processing or to be taken to their next destination by land.

**Figure 1.5: RoRo Facilities**

## 1.2 Scope of Study

The scope of the study is described in terms of the pollutants estimated, the source categories included, and the geographical domain. The activity year for this study is 2023 calendar year. The geographical domain for the on-terminal cargo handling equipment and heavy-duty trucks are within the PhilaPort facilities as shown in the map below in green.

**Figure 1.6: PhilaPort Facilities**


Exhaust emissions of the following pollutants are estimated:

- Criteria pollutants, surrogates, and precursors:
  - Oxides of nitrogen ($NO_x$)
  - Particulate matter (PM) (10-micron, 2.5-micron)
  - Volatile organic compounds (VOC)
  - Carbon monoxide (CO)
  - Sulfur dioxide ($SO_2$)
- Diesel particulate matter (DPM)
- Fuel combustion-related greenhouse gas (GHG) emissions expressed as $CO_2$ equivalents[1] ($CO_2e$) are comprised of the following:
  - Carbon dioxide ($CO_2$)
  - Nitrous oxide ($N_2O$)
  - Methane ($CH_4$)

[1] *www.epa.gov/ us-ghg-inventory-2024-annex-6-additional-information.pdf*, November 2024

The GHG emission are multiplied by their respective Global Warming Potential[2] values of 1 for $CO_2$, 265 for $N_2O$ and 28 for $CH_4$ and summed to calculate carbon dioxide equivalent ($CO_2e$) emissions that are presented in metric tons (tonnes) throughout the report.

Table 1.1 provides a description of the pollutants and greenhouse gases.

**Table 1.1: Pollutant and Greenhouse Gases Description**

| Pollutant | Sources | Health & Environmental Effects |
|---|---|---|
| **Oxides of nitrogen ($NO_x$)** is the generic term for a group of highly reactive gases; all of which contain nitrogen and oxygen in varying amounts. Most $NO_x$ is colorless and odorless. | $NO_x$ forms when fuel is burned at high temperatures, as in a combustion process. The primary manmade sources of $NO_x$ are motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels. | $NO_x$ can react with other compounds in the air to form tiny particles adding to PM concentrations. $NO_x$ is an ozone precursor and is also associated with respiratory health effects. |
| **Particulate matter (PM)** refers to tiny, discrete solid or aerosol particles in the air. Dust, dirt, soot, and smoke are considered particulate matter. Two types of PM are included in this emissions inventory: **$PM_{10}$**, which consists of particles measuring up to 10 micrometers in diameter; and **$PM_{2.5}$**, which consists of fine particles measuring 2.5 micrometers in diameter or smaller. | Vehicle exhaust (cars, trucks, buses, among others) are the predominant sources of fine particles in urban areas. In rural areas, land-clearing burning and backyard burning of yard waste contribute to particulate matter levels. | Fine particles are a concern because their very tiny size allows them travel more deeply into lungs, increasing the potential for health risks. Exposure to $PM_{2.5}$ is linked with respiratory disease, decreased lung function, asthma attacks, heart attacks and premature death. |
| **Volatile organic compounds (VOC)** are included in the emissions inventory because they are an ozone ingredient. | VOCs come from the transportation sector: cars and light trucks, marine vessels, and heavy-duty diesel vehicles. | In addition to contributing to the formation of ozone, some VOCs are air toxics, which can contribute to a wide range of adverse health effects. |

[2] *https://www.epa.gov/ghgemissions/understanding-global-warming-potentials*

**Table 1.1: Pollutant and Greenhouse Gases Description (cont'd)**

| Pollutant | Sources | Health & Environmental Effects |
|---|---|---|
| **Carbon monoxide (CO)** is a colorless, odorless, toxic gas commonly formed when carbon-containing fuel is not burned completely. | CO forms during incomplete combustion of fuels. The majority of CO comes from on and off-road vehicle engine exhaust. | CO combines with hemoglobin in red blood cells and decreases the oxygen-carrying capacity of the blood. CO weakens heart contractions, reducing the amount of blood pumped through the body. It can affect brain and lung function. |
| **Sulfur dioxide ($SO_2$)** is a colorless, corrosive gas produced by burning fuel containing sulfur, such as coal and oil, and by industrial processes such as smelters, paper mills, power plants and steel manufacturing plants. | $SO_2$ emissions are primarily a result of combustion fuels in cars, trucks, vessels, locomotives and equipment. Over the past decade, levels of sulfur in diesel and gasoline fuels have decreased dramatically due to federal regulations set by the EPA, which resulted in decreasing $SO_2$ emissions. | $SO_2$ is associated with a variety of respiratory diseases. Inhalation of $SO_2$ can cause increased airway resistance by constricting lung passages. Some of the $SO_2$ become sulfate particles in the atmosphere adding to measured PM levels. |
| **Greenhouse gases (GHG)** included in this emissions inventory are carbon dioxide, methane, and nitrous oxide. Other gases that are not significantly emitted by maritime-related sources or included in this inventory also contribute to climate change. | Both natural processes and human activities are a source of GHG. Increases of human made GHG are most responsible for disrupting the balance of the atmosphere. Transportation and electricity generation are a major source of GHG. | Climate change, also referred to as global warming, occurs when excessive amounts of GHG accumulate in our atmosphere. These gases trap heat and are thought to cause the temperature of the earth to rise. |

## SECTION 2 SUMMARY RESULTS

PhilaPort 2023 Air Emissions Inventory is an overview of emissions from port-related cargo handling equipment and heavy-duty truck operations within the facilities.

Table 2.1 summarizes the cargo throughput for 2023. The cargo includes containers, steel, forest products, cocoa beans, breakbulk, autos, liquid bulk and miscellaneous cargo.

**Table 2.1: 2023 TEU and Cargo Throughput**

| Year | TEU | Autos Cargo | Tonnage Metric Tons | Tonnage Short Tons |
|---|---|---|---|---|
| 2023 | 743,335 | 259,048 | 6,890,644 | 7,595,626 |

Table 2.2 summarizes the cargo handling equipment (equipment or CHE) and on facility/terminal heavy-duty truck (truck) emissions for calendar year 2023.

**Table 2.2: 2023 CHE and Heavy-Duty Truck Emissions**

| Category | $NO_x$ tons | $PM_{10}$ tons | $PM_{2.5}$ tons | VOC tons | CO tons | $SO_2$ tons | $CO_2e$ tonnes |
|---|---|---|---|---|---|---|---|
| Equipment | 270 | 17 | 16 | 40 | 624 | 0 | 41,942 |
| Trucks | 57 | 3 | 2 | 4 | 23 | 0 | 7,485 |
| **Total** | **327** | **19** | **19** | **45** | **647** | **0** | **49,427** |

## SECTION 3 CARGO HANDLING EQUIPMENT

This section includes emission estimates for cargo handling equipment, a term used for equipment that moves cargo, products, and supplies; material handling equipment; and other equipment that is essential to port facility operations. All of the cargo handling equipment are equipped with nonroad engines.

### 3.1 Source Description

The equipment data was provided by the tenants at the Port. Figure 3.1 shows a forklift which is the most prevalent equipment type at PhilaPort. Out of the 856 pieces of equipment inventoried, half are forklifts with diesel or propane engines and electric. Figure 3.2 shows the distribution of cargo handling equipment by engine or power source. A large percentage of the equipment at PhilaPort is electric (38%), followed by diesel (34%) and propane (28%). The reason for the high electric count is the fact these electric forklifts and pallet jacks are used inside warehouses that move perishable cargo. The use of electric equipment lowers contamination of food and is best for the workers' health to not have diesel exhaust inside the warehouse.

**Figure 3.1: Forklifts**

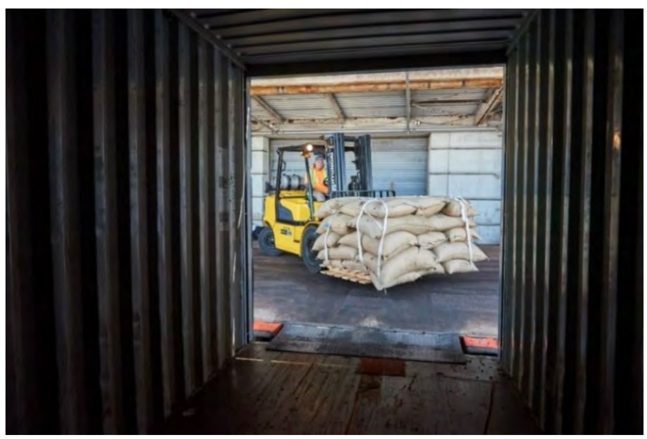


**Figure 3.2: Equipment Distribution by Engine Type**

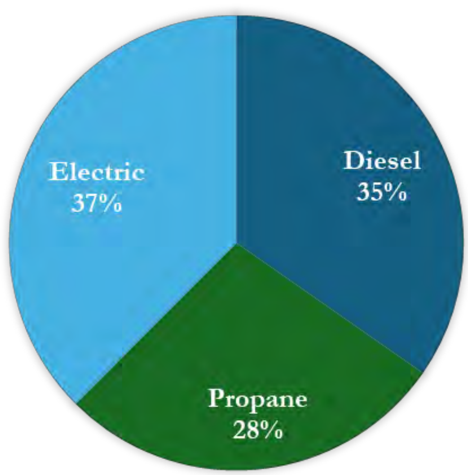


Table 3.1 summarizes the engine characteristics and operating hours for the 856 pieces of equipment operating at the Port in 2023. Averages of the model year, horsepower, or operating hours are used as default values when equipment specific data is not available. The "na" in the tables means that data was not available or applicable. The electric equipment has zero exhaust emissions. Electric equipment is included for equipment count purposes only. Only tailpipe emissions from the fossil fueled equipment are included in the emissions tables.

During emissions calculations, the average model year, horsepower and hours by equipment and fuel type are used as defaults in order to estimate the emissions for each piece of fossil fueled equipment.

**Table 3.1: CHE Count and Characteristics**

| Equipment Type | Count | Model Year Average | Horsepower Average | Hours Average |
|---|---|---|---|---|
| **Diesel** | | | | |
| Yard tractor | 117 | 2007 | 212 | 2,038 |
| Forklift | 104 | 2002 | 165 | 1,472 |
| Manlift | 5 | 2009 | 66 | 343 |
| Light Tower | 10 | 2011 | 18 | 500 |
| RTG crane | 1 | 2001 | 250 | 500 |
| Top handler | 12 | 2001 | 354 | 2,000 |
| Loader | 6 | 2001 | 173 | 387 |
| Reach Stacker | 37 | 2015 | 350 | 4,432 |
| Crane | 4 | 1998 | 570 | 750 |
| Tractor | 1 | 2014 | 38 | 780 |
| **Diesel Count Total** | **297** | | | |
| **Propane** | | | | |
| Forklift | 236 | 2005 | 206 | 1,128 |
| Sweeper | 1 | 2005 | 135 | 750 |
| Manlift | 1 | 1996 | 74 | 2,100 |
| **Propane Total** | **238** | | | |
| **Electric** | | | | |
| Forklift | 84 | na | na | na |
| Electric Pallet Jack | 232 | na | na | na |
| Ship to Shore Crane | 5 | na | na | na |
| **Electric Count Total** | **321** | na | na | na |
| **Total** | **856** | | | |

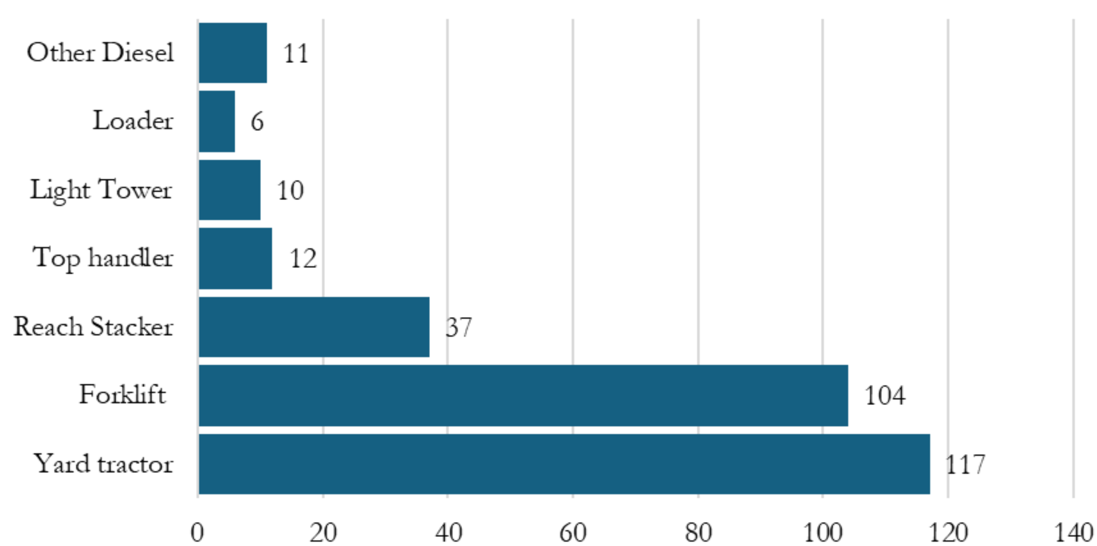
Table 3.2 lists the nonroad diesel engine Tiers by equipment type for 2023. It shows the majority of the diesel equipment has newer and cleaner engines with 30% having a Tier 3 or Tier 4 engine. The unknown engine Tiers is 34% of the total diesel count due to unknown engine model year and horsepower at the time of data collection. The number of unknowns may be reduced in future inventories with better data collection.

**Table 3.2: Nonroad CHE Diesel Engine Tiers**

| Equipment Type | Tier 0 | Tier 1 | Tier 2 | Tier 3 | Tier 4i | Tier 4f | Unknown | Total |
|---|---|---|---|---|---|---|---|---|
| Crane | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| Forklift | 21 | 2 | 0 | 0 | 4 | 2 | 75 | 104 |
| Light Tower | 0 | 0 | 1 | 0 | 0 | 5 | 4 | 10 |
| Loader | 0 | 3 | 1 | 0 | 0 | 0 | 2 | 6 |
| Manlift | 0 | 0 | 3 | 0 | 1 | 0 | 1 | 5 |
| Reach Stacker | 0 | 0 | 0 | 8 | 4 | 24 | 1 | 37 |
| Rub-trd Gantry Crane | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Top handler | 1 | 1 | 6 | 0 | 0 | 0 | 4 | 12 |
| Tractor | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Yard tractor | 13 | 16 | 38 | 0 | 0 | 38 | 12 | 117 |
| **Total** | **35** | **23** | **49** | **8** | **9** | **70** | **103** | **297** |
| **Percent** | **12%** | **8%** | **16%** | **3%** | **3%** | **24%** | **35%** | |

Figure 3.3 shows the diesel equipment counts, excluding electric equipment and propane equipment. Diesel equipment, yard tractors, forklifts and reach stackers are the equipment types with not only the most count, but also used the most based on average hours per equipment type (Table 3.1).

**Figure 3.3: Diesel Equipment Counts**



## 3.2 Emissions Estimation Methodology

Emissions were estimated using the MOVES4 emission estimating model.[3] The model was designed to accommodate a wide range of nonroad equipment types and recognize a defined list of equipment designations. The pieces of terminal equipment were matched with equipment types recognized by the model. The equipment collected was categorized into the most closely corresponding MOVES4/NONROAD equipment classified by Source Classification Code (SCC), load factor, and category common name. Table 3.3 summarizes the SCC by equipment type.

**Table 3.3: MOVES4 Engine Source Categories**

| Equipment Type | Engine Type | SCC | Load Factor | NONROAD Category |
|---|---|---|---|---|
| Light Tower | Diesel | 2270002027 | 0.43 | Signal board / light plant |
| Crane | Diesel | 2270002045 | 0.43 | Crane |
| Loader | Diesel | 2270002060 | 0.59 | Front end loader |
| Manlift | Diesel | 2270003010 | 0.21 | Aerial lift |
| Manlift | Propane | 2267003010 | 0.21 | Aerial lift |
| Forklift | Diesel | 2270003020 | 0.59 | Forklift |
| Forklift | Propane | 2267003020 | 0.30 | Forklift |
| Sweeper | Propane | 2267003030 | 0.43 | Sweeper / scrubber |
| Top handler | Diesel | 2270003040 | 0.43 | Other industrial equipment |
| Reach stacker | Diesel | 2270003040 | 0.43 | Other industrial equipment |
| RTG crane | Diesel | 2270003050 | 0.21 | Other material handling equipment |
| Yard tractor, tractor | Diesel | 2270003070 | 0.39 | Terminal tractor |

The general form of the equation used for estimating CHE emissions is:

Equation 1

$$\boldsymbol{E = Power \times Activity \times LF \times EF}$$

Where:

E = emissions, grams or tons or tonnes/year
Power = rated power of the engine, hp or kW
Activity = equipment's engine operating time, hr/year
LF = load factor (ratio of average load used during normal operations as compared to full load at maximum rated horsepower; it is an estimate of the average percentage of an engine's rated power output that is required to perform its operating tasks), dimensionless
EF = emission factor by equipment type obtained by running the NONROAD module of MOVES4, grams of pollutant per unit of work, g/hp-hr or g/kW-hr

[3] *www.epa.gov/otaq/models/moves/*

For each calendar year, MOVES4/NONROAD can be run by state/county to output emissions factors in grams/hp-hr by fuel type, equipment types, by horsepower groups and model year. These emission factors represent the average emissions in grams/hp-hr that take into account the characteristic of the non-road fuel available in that year and the change in engine emission (in general increase in emissions) as the engine parts get older and less efficient. The horsepower groups are aligned with U.S. Environmental Protection Agency's (EPA) non-road equipment emissions standards.

Per equation 1 above, CHE emissions in tons per year from each piece of equipment were calculated using model year, horsepower rating, annual hours of operation information collected for port operation, equipment-specific load factor assumptions described above and MOVES4/NONROAD emission factors output. MOVES4/NONROAD was run for Philadelphia County with default conditions to obtain emission factors in grams/hp-hr by model year and horsepower group.

### 3.3 Emission Estimates

Table 3.4 presents the estimated equipment emissions by equipment type and engine type. The engine types are diesel and propane. Emissions by equipment are sorted and presented from highest to lowest $NO_x$ emissions.

**Table 3.4: CHE Emissions by Equipment and Engine Type, tons and tonnes**

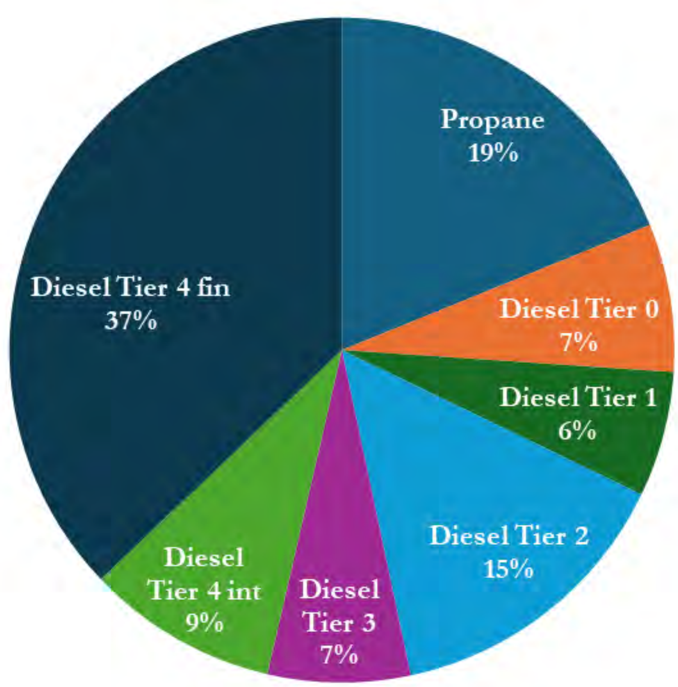
| Equipment | Engine Type | Count | $NO_x$ tons | $PM_{10}$ tons | $PM_{2.5}$ tons | VOC tons | CO tons | $SO_2$ tons | $CO_2e$ tonnes |
|---|---|---|---|---|---|---|---|---|---|
| Forklift | Propane | 235 | 78.84 | 0.97 | 0.97 | 18.51 | 561.50 | 0.04 | 8,408 |
| Forklift | ULSD | 104 | 75.58 | 7.29 | 7.07 | 9.49 | 13.81 | 0.03 | 7,966 |
| Yard tractor | ULSD | 117 | 62.57 | 6.03 | 5.85 | 8.87 | 25.85 | 0.04 | 9,817 |
| Reach Stacker | ULSD | 37 | 23.64 | 1.22 | 1.19 | 1.57 | 7.41 | 0.04 | 13,194 |
| Top handler | ULSD | 12 | 22.30 | 0.88 | 0.85 | 1.22 | 5.80 | 0.01 | 1,950 |
| Crane | ULSD | 4 | 5.00 | 0.17 | 0.16 | 0.19 | 1.17 | 0.00 | 393 |
| Manlift | Propane | 1 | 0.97 | 0.01 | 0.01 | 0.23 | 4.35 | 0.00 | 50 |
| Loader | ULSD | 6 | 0.61 | 0.06 | 0.06 | 0.08 | 0.23 | 0.00 | 56 |
| Sweeper | Propane | 1 | 0.29 | 0.01 | 0.01 | 0.07 | 3.83 | 0.00 | 39 |
| RTG crane | ULSD | 1 | 0.18 | 0.01 | 0.01 | 0.02 | 0.06 | 0.00 | 17 |
| Light Tower | ULSD | 10 | 0.16 | 0.01 | 0.01 | 0.02 | 0.08 | 0.00 | 23 |
| Manlift | ULSD | 5 | 0.12 | 0.01 | 0.01 | 0.02 | 0.11 | 0.00 | 18 |
| Tractor | ULSD | 1 | 0.07 | 0.00 | 0.00 | 0.00 | 0.01 | - | 9 |
| Forklift | Gasoline | 1 | 0.01 | 0.00 | 0.00 | 0.00 | 0.13 | - | 2 |
| Electric Pallet Jack | Electric | 232 | | | | | | | |
| Forklift | Electric | 84 | | | | | | | |
| STS Crane | Electric | 5 | | | | | | | |
| **Total** | | **856** | **270.33** | **16.66** | **16.19** | **40.30** | **624.34** | **0.16** | **41,942** |

Table 3.5 and Figure 3.4 summarize the equipment energy consumption (kWh) by engine Tier for fossil fueled equipment, including propane and diesel. The one gasoline forklift is included with the propane category. It shows that the newer diesel equipment (Tier 3-4) consumed 53% of the total energy, followed by 19% propane, meaning less emissions due to the use of cleaner equipment to move the cargo. Only 28% of the energy consumed is with older diesel equipment (Tier 0-2).

**Table 3.5: CHE Energy Consumption by Engine Tier**

| Engine Type and Tier | Energy Consumption kWh | Percent Total 2023 |
|---|---|---|
| Propane | 10,651,209 | 19% |
| Diesel Tier 0 | 4,069,328 | 7% |
| Diesel Tier 1 | 3,438,765 | 6% |
| Diesel Tier 2 | 8,211,195 | 15% |
| Diesel Tier 3 | 3,911,351 | 7% |
| Diesel Tier 4 int | 5,255,325 | 9% |
| Diesel Tier 4 fin | 20,958,808 | 37% |
| **Total** | **56,495,981** | **100%** |

**Figure 3.4: Energy Consumption Distribution for Fossil Fueled CHE**



# SECTION 4 HEAVY-DUTY TRUCKS

This section includes emission estimates for heavy-duty trucks which include class 7 and 8 trucks operated within the Port facilities. On road driving emissions outside of the Port's facility are not estimated for this report.

## 4.1 Source Description

Heavy-duty trucks move cargo to and from the terminals and facilities that serve as the bridge between land and sea transportation. They are primarily driven on the public roads near the port and on highways within the inventory domain as they arrive from or depart to locations within and outside the domain. The vehicles are usually not under the direct control of the ports, the terminals, or the shippers who use the terminals, but are usually either owner-operated or are components of a carrier fleet. The most common configuration of heavy-duty trucks in maritime freight service is the articulated tractor-trailer (truck and semi-trailer) having five axles, including the trailer axles.

## 4.2 Emission Estimation Methodology

In general, emissions from heavy-duty trucks are estimated using the general equation.

Equation 1

$$\boldsymbol{E} = \boldsymbol{EF} \times \boldsymbol{A}$$

Where:

E = mass of emissions per defined period (such as a year), short tons or metric tons
EF = emission factor (mass per unit of distance or time), g/mile or g/hour
A = activity (distance driven, or time at idle, during the defined period), miles or hours

Emissions are estimated by multiplying the emission factor by the distance driven or the amount of idling time. The units of distance in this inventory are miles, the idling units are hours, and the emission factors are expressed as grams of emissions per mile of travel (g/mile) or grams of emissions per hour of idling (g/hr). Annual emissions are expressed in short tons for the criteria pollutants and metric tons (tonnes) for greenhouse gases.

The emission factors have been developed using the EPA model MOVES4, which estimates emissions and emission factors for on-road vehicles of all types, including heavy-duty trucks.

The MOVES4 model is EPA's latest iteration in a series of on-road vehicle emission estimating models. The model can be run in such a way as to produce emission estimates for different vehicle types in a given county, and the estimated total number of miles driven in the county. These model outputs are used to calculate g/mile and g/hr emission factors that are used to estimate driving and idling emissions from a particular fleet such as the trucks serving the Port terminals.

The MOVES4 model was run for Philadelphia County using the model's own data related to average road speeds and distribution of truck model years for Class 7 and Class 8 trucks (combination short-haul trucks). Table 4.1 lists the emission factors used to estimate emissions.

**Table 4.1: Emission Factors for HDVs, grams/mile and grams/hour**

| Vehicle Type | Speed (mph) | Units | $NO_x$ | $PM_{10}$ | $PM_{2.5}$ | VOC | CO | $SO_2$ | $CO_2$ | $N_2O$ | $CH_4$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Combination | Idling (0) | g/hr | 68.21 | 3.25 | 2.99 | 6.83 | 22.27 | 0.03 | 7,679 | 0.65 | 0.28 |
| Combination | 5 | g/mi | 138.83 | 5.22 | 4.80 | 3.44 | 61.64 | 0.08 | 24,474 | 1.80 | 0.25 |
| Combination | 10 | g/mi | 69.41 | 2.61 | 2.40 | 1.72 | 30.82 | 0.04 | 12,237 | 0.90 | 0.12 |
| Combination | 12 | g/mi | 47.42 | 1.83 | 1.68 | 1.36 | 20.85 | 0.03 | 8,284 | 0.61 | 0.09 |
| Combination | 15 | g/mi | 14.44 | 0.66 | 0.61 | 0.81 | 5.89 | 0.01 | 2,354 | 0.19 | 0.04 |
| Single unit | Idling (0) | g/hr | 31.90 | 2.24 | 2.06 | 7.13 | 32.86 | 0.02 | 5,881 | 0.43 | 1.42 |
| Single unit | 5 | g/mi | 60.88 | 2.65 | 2.43 | 5.67 | 112.32 | 0.06 | 14,815 | 0.84 | 1.20 |
| Single unit | 10 | g/mi | 30.44 | 1.32 | 1.22 | 2.87 | 56.16 | 0.03 | 7,408 | 0.42 | 0.60 |
| Single unit | 12 | g/mi | 20.68 | 0.92 | 0.85 | 2.13 | 37.50 | 0.02 | 4,985 | 0.28 | 0.45 |
| Single unit | 15 | g/mi | 6.04 | 0.32 | 0.29 | 1.02 | 9.51 | 0.01 | 1,351 | 0.08 | 0.22 |

## 4.3 Heavy-duty Vehicles Emission Estimates

The total gate moves, idling time, and vehicle miles traveled for the facilities in this study are summarized in Table 4.2. The facilities provided the gate moves, and the estimated average time spent idling within the facility and at the in and out gates. The vehicle miles traveled are the total miles traveled within the facilities based on the average distance a truck travels within a facility multiplied by the gate moves. The estimated facility operation (driving and idling) truck emissions are presented in Table 4.3.

**Table 4.2: Gate Moves and On Terminal Activity Data**

| Source | Gate Moves | Idling Time (Hours) | Vehicle Miles Traveled (VMT) |
|---|---|---|---|
| On-Terminal Trucks | 609,379 | 3.8 | 1,681,784 |

**Table 4.3: Estimated Emissions from Heavy-duty Trucks, tons and tonnes**

| Mode | $NO_x$ tons | $PM_{10}$ tons | $PM_{2.5}$ tons | VOC tons | CO tons | $SO_2$ tons | $CO_2e$ tonnes |
|---|---|---|---|---|---|---|---|
| Driving | 30 | 1.3 | 1.2 | 1.6 | 13.7 | 0.02 | 4,572 |
| Idling | 28 | 1.3 | 1.2 | 2.8 | 9.3 | 0.01 | 2,913 |
| **On-Terminal Trucks** | **57** | **2.6** | **2.4** | **4.4** | **23.0** | **0.03** | **7,485** |

## SECTION 5 KEY FINDINGS

PhilaPort's focus on electric equipment helps reduce emissions, especially in enclosed spaces like warehouses. Emissions from diesel and propane equipment may be lowered in future years with newer equipment with cleaner engines (Tier 3-4 for diesel). To help mitigate emissions, diesel equipment with Tier 4 engines will provide the lowest $NO_x$ and PM emissions as Tier 4 is the cleanest diesel engine currently available.

Heavy-duty trucks contribute notable emissions, but detailed data from truck activities (including idling and time at terminal) allows for targeted emission reduction strategies. Similar to equipment, transitioning to newer trucks with cleaner diesel engines will help to mitigate the emissions.