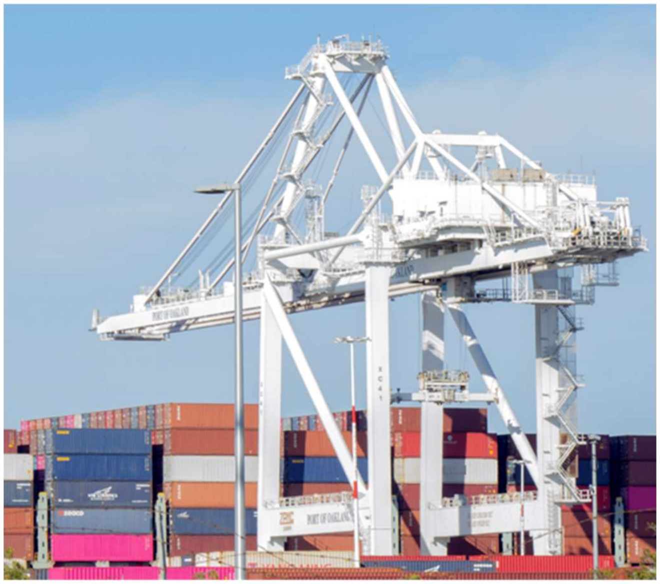
2022 Cargo Handling Equipment Emissions Inventory



December 2022

CALIFORNIA
AIR RESOURCES BOARD

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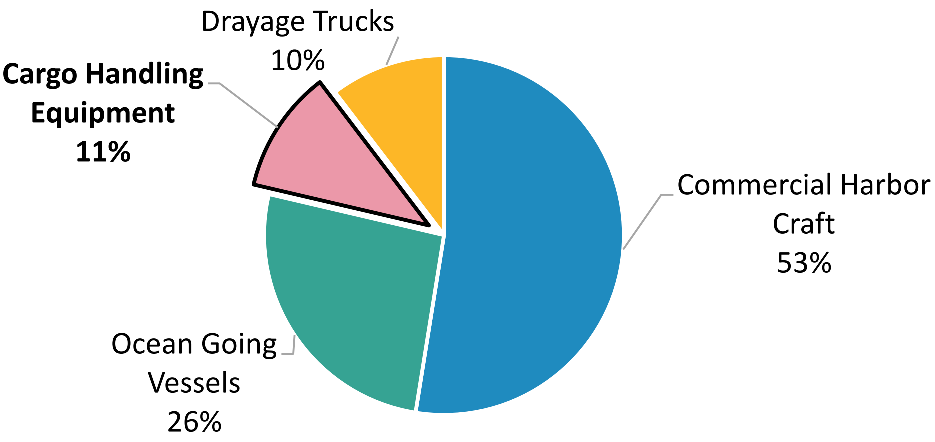
1 Summary

Cargo handling equipment (CHE) includes a wide range of equipment used at ports and intermodal rail yards, such as yard trucks, container handling equipment, cranes, forklifts, skid-steer loaders, rubber-tired gantry (RTG) cranes, and more. The California Air Resources Board's (CARB) 2022 CHE emission inventory covers all mobile self-propelled off-road diesel equipment that operates at California ports and intermodal rail yards, which is used to transfer containers between locomotives, trucks, or ocean-going vessels. This analysis updates CARB's previous 2011 CHE inventory.

The current CARB regulation for CHE took effect on January 1, 2007, and phased in compliance through December 31, 2017. Broadly, the regulation required in-use yard trucks to meet the 2007 or later model year certified on-road engine standards, or meet the certified Tier 4 offroad standards, or apply emission controls equivalent to those options, by December 31, 2017. The regulation required other equipment (including top handlers, side handlers, and forklifts, dozers, loaders, excavators, and sweepers, and RTG cranes) to meet 2007 or later model year on-road engine standards, Tier 4 off-road engine standards, or Tier 1 off-road standards with a level 3 VDECS by December 31, 2015.

The majority of CHE have diesel engines, which are significant emitters of particulate matter (PM) and oxides of nitrogen (NOx). Diesel particulate matter emissions have a significant negative health impact and are responsible for 70 percent of cancer risk from airborne toxics in California[1]. CHE emissions are projected to be a significant source of fine particulate matter (PM2.5) emissions from port-related equipment in 2031, as shown in Figure 1. The emissions from CHE are particularly important because they are concentrated around seaports and intermodal rail yards, and combined with other freight-related sources, pose significant health risks to nearby communities.

Figure 1: Statewide Port Mobile Source PM2.5 (tons per day, tpd) Emissions Contributions in 2031[2]



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[1] https://ww2.arb.ca.gov/resources/overview-diesel-exhaust-and-health

[2] Based on CARB CEPAM 2019 v1.03: https://ww2.arb.ca.gov/applications/cepam2019v103-standard-emission-tool

The CHE emissions inventory was last updated in 2011. In December 2020, CARB staff updated the CHE inventory as summarized below, and is described in greater detail throughout the report:

1. Population, model year, horsepower and activity data are based on data from CARB's CHE reporting database, and data received from the Port of Los Angeles, Port of Long Beach (Ports of LA/LB)[3] and Port of Oakland[4](POak). Data from all of these sources represents data as of the end of the 2019 calendar year or statistics summarizing the duration of the 2019 calendar year.
2. Growth factors are based on forecasting reports from Mercator for the Ports of LA/LB, the Tioga Report[5] for the Port of Oakland, and the Freight Analysis Framework (FAF)[6] for the remainder of the State.
3. Engine load factors are based on the 2011 CARB CHE Emission Inventory[7] and are compared against the load factors from the Ports of LA/LB emission inventories.
4. Emission factors (EFs) were updated using CARB's 2017 updates to the diesel emission factors[8], and the 2016 updates to propane and gasoline off-road emission factors[9]. EMFAC2017 (CARB's inventory for on-road trucks) emission rates were used for on-road yard trucks[10].

Overall, the largest changes included more complete population data sources from the ports, and updated emission factors for all fuel types. These changes result in higher emissions in early 2020 due to increased population, but the emissions drop faster than previously estimated due to the updates in emission factors.

Figure 2 and Figure 3 below show the NOx and PM emission results, respectively. Both Figure 2 and Figure 3 present emissions from 2019 to 2050 in stacked area plots, separating different diesel tiers and fuel types. The black line represents the 2011 CARB CHE Emission Inventory. Emissions are projected to decline over time as older equipment from Tiers 1, 2, 3 and 4 Interim turn over to Tier 4 Final by 2035.

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[3] https://www.portoflosangeles.org/environment/air-quality/air-emissions-inventory

[4] https://www.portofoakland.com/community/environmental-stewardship/seaport-air-emissions-inventory-2005/

[5] https://www.bcdc.ca.gov/seaport/2019-2050-Bay-Area-Seaport-Forecast-Draft.pdf

[6] https://faf.ornl.gov/faf5/

[7] https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2011/cargo11/cargoappb.pdf

[8] https://ww3.arb.ca.gov/msei/ordiesel/ordas_ef_fcf_2017.pdf

[9] https://ww2.arb.ca.gov/sites/default/files/2020-09/SORE2020_Technical_Documentation_2020_09_09_Final_Cleaned_ADA.pdf

[10] https://ww3.arb.ca.gov/msei/downloads/emfac2017-volume-iii-technical-documentation.pdf

Figure 2: Statewide NOx emissions from Cargo Handling Equipment

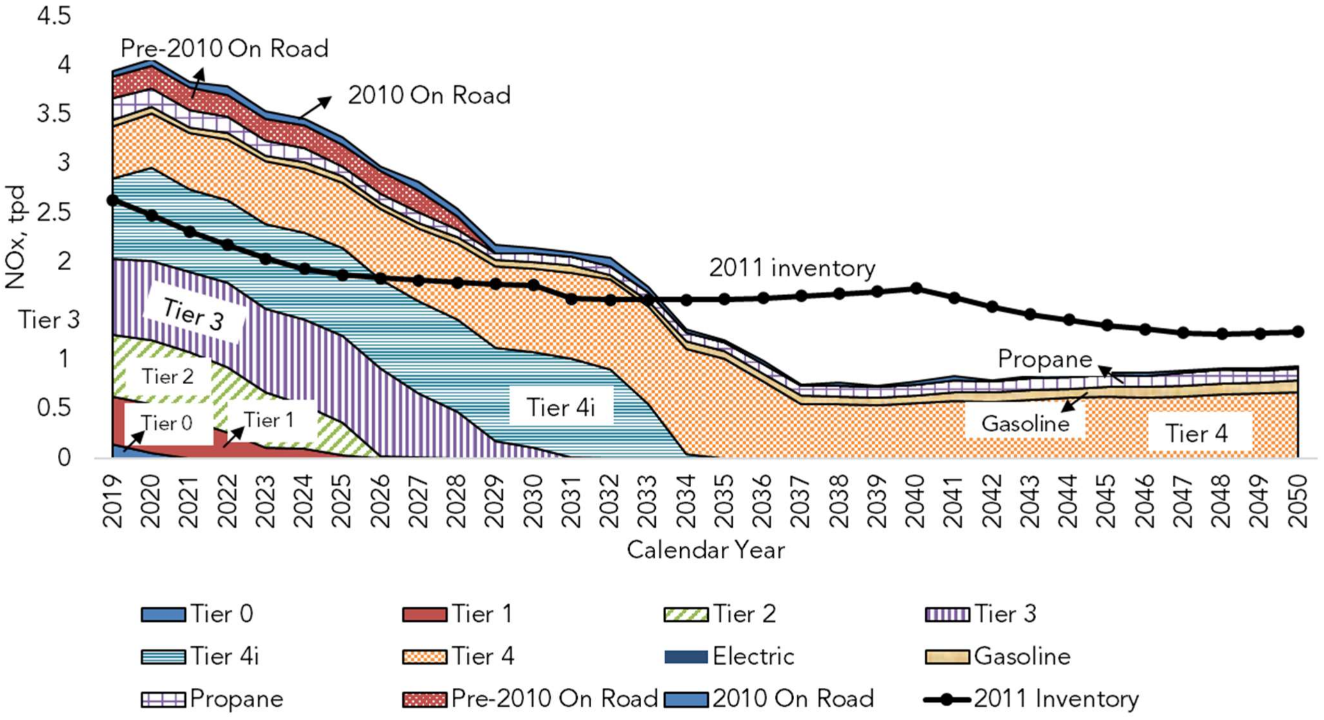
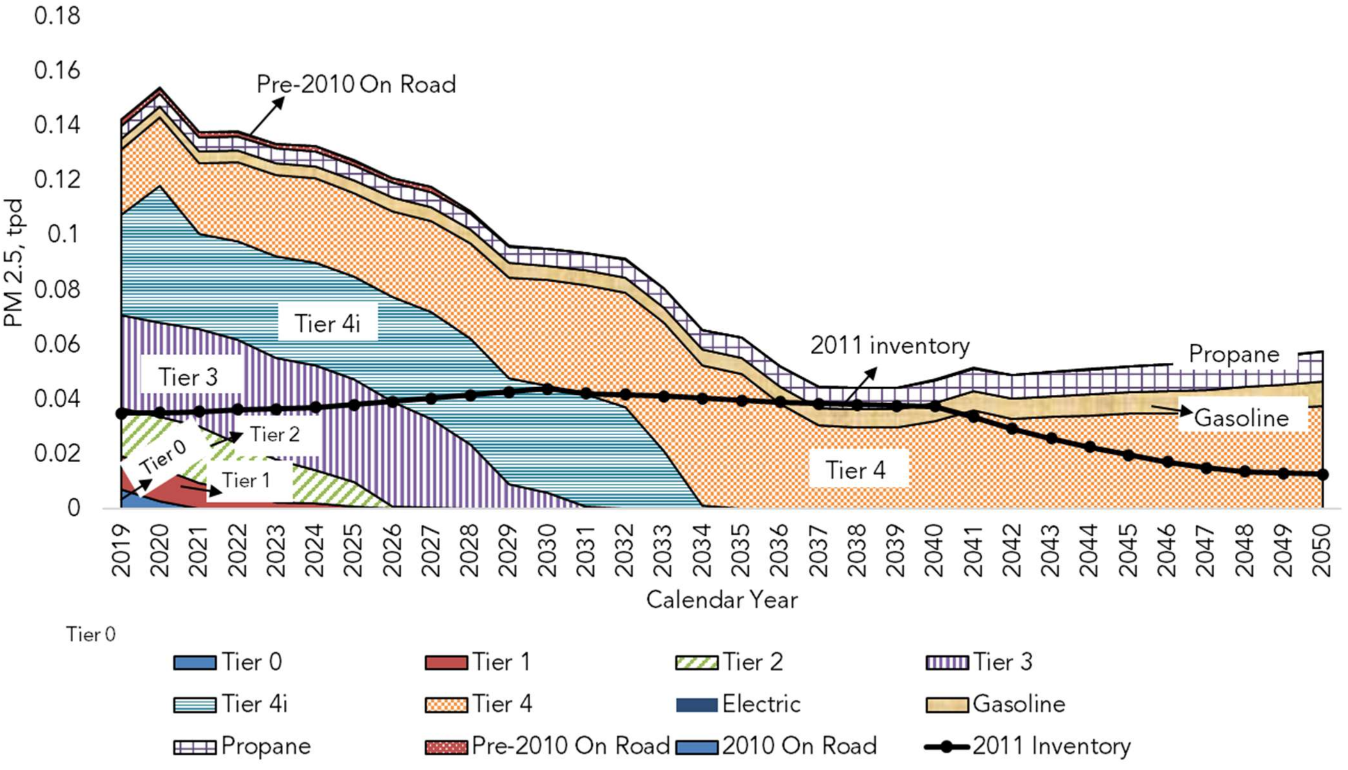


Figure 3: Statewide PM Emissions from Cargo Handling Equipment



2 Background

The emission inventory uses the best available data, methods, and research to determine current emissions from the CHE sector and forecasts emissions to 2050. This work informs regulatory planning, State Implementation Plans (SIPs), incentive programs, and more. The following sections will cover the data sources and methodology used to calculate the emissions inventory.

This inventory includes all fuel types, both off-road and on-road equipment. On-road equipment is limited to yard trucks used exclusively at the ports or intermodal rail yards, and does not include on-road equipment that operates outside the port such as regional delivery trucks or similar.

2.1 Emission Inventory Calculation

CARB staff calculates emissions using the equation shown below.

Emissions = Population * Activity * Horsepower * Load Factor * Emission Factor

Emissions: CHE emissions for each calendar year

Population: Engine population

Activity: Average number of hours the engine is running per year

Horsepower: average rated brake-horsepower (bhp)

Load factor: average fraction of engine maximum brake horsepower used while running (unit-less)

Emission factor: emission of pollutant in units of grams per brake-horsepower-hour (grams/bhp-hr) including fuel correction for diesel engines, and deterioration rates

3 CHE Population Sources

3.1 Port of LA/LB and Port of Oakland Emissions Inventories

The three largest California ports by freight volume, the Ports of LA/LB and Port of Oakland, maintain emissions inventories for their ports and update the information annually by working directly with equipment owners and operators. CARB’s 2022 CHE statewide inventory utilizes 2019 equipment populations provided by the Port of Los Angeles[11], Port of Long Beach[12], and Port of Oakland[13]. The

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[11] Port of Los Angeles Emissions Inventories, https://kentico.portoflosangeles.org/getmedia/4696ff1a-a441-4ee8-95ad-abe1d4cddf5e/2019_Air_Emissions_Inventory

[12] Port of Long Beach Emissions Inventories; https://polb.com/environment/air/#emissions-inventory

[13] Port of Oakland Emission Inventory; https://www.portofoakland.com/files/PDF/Port_Oakland_2017_Emissions_Inventory.pdf

port emission inventories included gasoline, natural gas, propane, electric, and diesel fuel types. The inventories also specified if the vehicles had on-road or off-road engines.

For equipment population at these three largest ports, CARB staff used port-specific data supplied by the ports instead of the CARB reporting data described below. CARB staff's comparison of the port emissions inventories and the CARB reporting data showed that the port inventories included significantly more equipment than is reported to CARB, which his discussed further below in Section 3.2

The Port of Los Angeles inventory included 2,038 pieces of equipment compared to the 1,253 pieces of equipment in CARB reporting data, while the Port of Long Beach inventory contained 1,478 pieces of equipment compared to the 843 pieces of equipment in the CARB reporting data, and Port of Oakland inventory contained 472 pieces of equipment compared to 275 pieces of equipment in the CARB reporting data.

The Port of Los Angeles emissions inventory included 1,359 pieces of diesel equipment compared to the 1,250 in the reporting data. The Port of long Beach emissions inventory included 984 pieces of diesel equipment compared to the 843 in the reporting data. The Port of Oakland reported 275 pieces of diesel equipment to CARB, while their emissions inventory included 369 pieces of diesel equipment.

3.2 CARB Reporting Data for All Other Ports and Intermodal Rail Yards

CARB's CHE regulation required owners of diesel CHE to report annually by January 31, 2007 through January 31, 2016. Thereafter, the CHE regulation no longer required annual reporting, but some terminal operators voluntarily reported information to CARB. Because the CHE regulation applies statewide, CARB reporting data includes equipment from ports across the State, including the large Ports of LA/LB and Port of Oakland and "Small Ports", defined below. CARB staff reviewed the 3,139 pieces of equipment reported to CARB as of the end of 2019. CARB reporting data indicated 778 pieces of diesel equipment were in operation at the smaller ports, which are defined as all ports other than LA, LB, and Oakland. Table 1 summarizes the population data from each port facility..

The Ports in the CARB reporting data include Bay Area Bulk Terminal, Concord Naval Weapons Station, LA Berth 240, Port of Hueneme, Port of Redwood City, Port of Richmond, Port of Sacramento, Port of San Diego, Port of San Francisco, and Port of Stockton, collectively referred to as "Small Ports".

The intermodal rail yards in the reporting data are owned by the two Class I linehaul companies that operate in California: Union Pacific Railroad (UPPR) and BNSF Railway (BNSF). The specific rail yard locations represented in the reporting data are UPRR City of Industry, UPRR Commerce, UPRR Intermodal Container Transfer Facility (ICTF), UPRR Los Angeles Transportation Center (LATC), UPRR Lathrop, UPRR Oakland, BNSF Commerce, BNSF Los Angeles (Hobart), BNSF North Bay Intermodal Yard, BNSF Oakland, BNSF San Bernardino, and BNSF Stockton.

There are no requirements to report propane, gasoline, and electric equipment used at the ports or intermodal rail yards. Thus, CARB's emission inventory does not reflect non-diesel equipment for the Small Ports. This is an area for future improvement and would require CARB to resume reporting requirements and expand the equipment required to be reported.

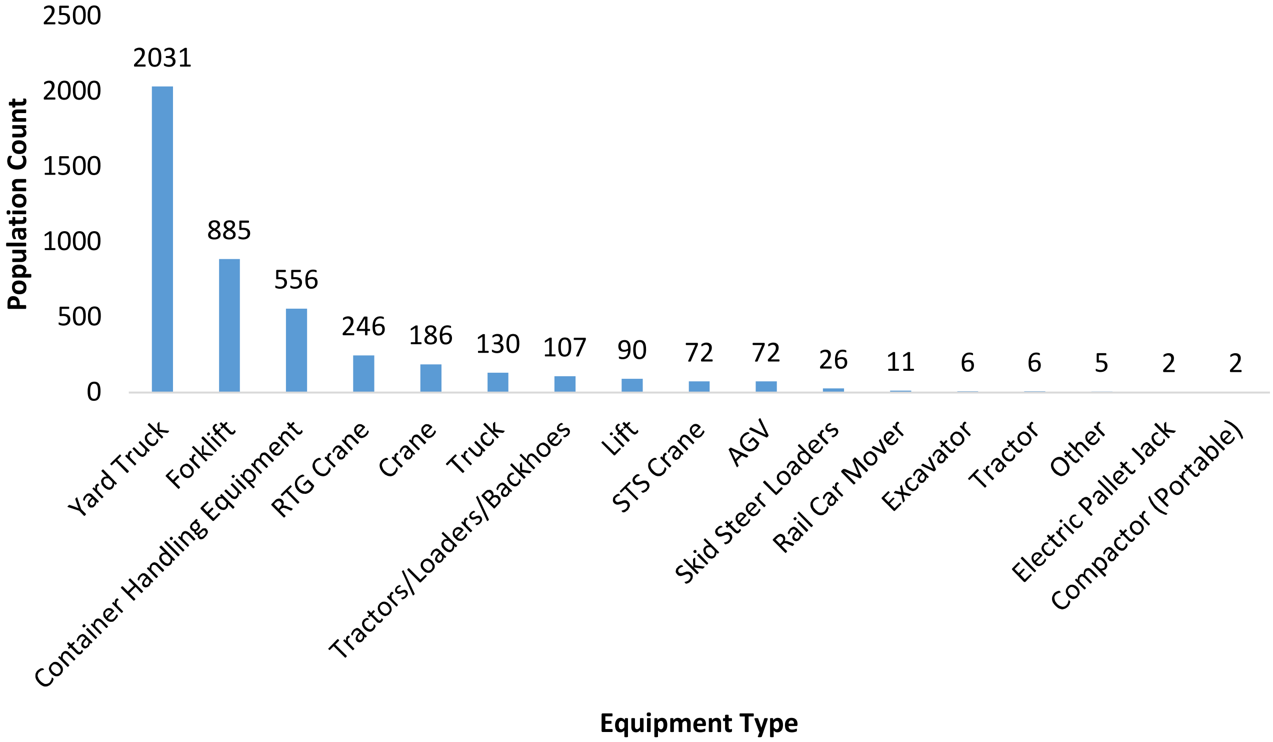
Table 1: Port Equipment Counts from CARB Reporting Data and Port Emission Inventories

Port Name	CARB Reporting Data	Port Emission Inventories
Port of Los Angeles	1,253	2,038
Port of Long Beach	843	1,478
Port of Oakland	275	472
Port of Stockton	76	
Port of Los Angeles; Long Beach	46	
Port of San Diego	32	
Port of Hueneme	30	
Port of Richmond	28	
Port of San Francisco	22	
Port of Redwood City	18	
Port of Los Angeles, Port of Long Beach	15	
Port of Richmond (Levin Richmond Terminal)	13	
Stockton	11	
Port of Long Beach and Los Angeles	9	
Pier 80 (closed 2016) & 94 Port of San Francisco; Redwood City	9	
Port of Long Beach; Los Angeles	7	
Port of Sacramento	6	
Port of Richmond; Port of Redwood Port of Sacramento	5	
Bay Area Bulk Terminal	4	
Port of LA	3	
Port of Long Beach; Port of San Diego	3	
Port of Long Beach/Los Angeles	2	
LA Berth 240	1	
Concord Naval Weapons Station	1	
Port of Long Beach, Port of Los Angeles	1	
POLA	1	
Port of Oakland -old army base	1	

3.3 Combined Population

The combined population from the port inventories and the CARB reporting data is shown below in Figure 4, grouped into 17 equipment types.

Figure 4: Statewide CHE Population by Equipment Type



4 Annual Activity

Activity in this emission inventory refers to the total number of hours equipment is used during one calendar year. This inventory reflects equipment-specific activity for over 90 percent of the equipment and uses activity averages when equipment-specific activity was unavailable. Including equipment-specific activity levels for most of the pieces of equipment is possible because in both the port emission inventories and the CARB reporting data, equipment owners report the activity for each piece of equipment.

In cases where CARB reporting data contained blanks for annual engine activity hours, average annual activity from the reporting data was used to fill missing activity information. Table 2 lists the annual average activity by equipment type for Small Ports and intermodal rail yards. As defined in Section 3, Small Ports include all ports except the Ports of LA/LB and the Port of Oakland.

These values reflect the average activity within the reporting data as well as the values used to fill in blanks. For example, the average reported activity for forklifts was 879 hours per year. Where an owner reported activity values for a forklift, that value was maintained in the inventory (the average was not used). Where owners did not report the activity and the value was blank, CARB staff used the average forklift activity of 879 hours per year.

In some cases, the reporting data did not include any activity values for a specific type of equipment. For those cases (noted in the table with an asterisk*), CARB staff used the average activity for that equipment type from the Ports of LA/LB and Oakland.

Table 2: Annual Activity from CARB Reporting (Small Ports and Intermodal Rail Yards)

Equipment Type	Average Activity (hours per year)
Compactor (Portable)	3,527
Container Handling Equipment	3,066
Crane*	1,561
Excavator	260
Forklift	879
Lift	100
Other*	779
Rail Car Mover*	484
Railcar Mover	1,500
RTG Crane*	2,479
Skid-steer Loaders	4,562
Tractors/Loaders/Backhoes	1,029
Truck	7,434
Yard Truck	2,559

For the Ports of Los Angeles, Long Beach, and Oakland, the port emission inventory also lists activity for individual pieces of equipment. Similar to the reporting data, CARB staff maintained these specific values in the inventory. Table 3 lists the annual average activity for the POLA, POLB, and POAK for reference. Note that, like the CARB reporting data, the emission inventory uses the equipment-specific activity and not the averages.

Unlike the reporting data, the information for these three large ports did not include any missing entries for activity.

Table 3: Annual Activity Averages from Port of LA/LB and Oakland

Port Equipment Type for LA/LB and Oakland	Average Activity (hours per year)
AGV (electric)	2,285
Container Handling Equipment	2,006
Crane	1,561
Electric Pallet Jack	141
Excavator	7
Forklift	505
Lift	203
Other	779
Rail Car Mover	484
RTG Crane	2,479
STS Crane (electric)	1,832
Tractor	821
Tractors/Loaders/Backhoes	974
Truck	806
Yard Truck	1,679

5 Horsepower

Horsepower in the inventory refers to the maximum brake horsepower of the engine, which is the maximum power the engine can produce continuously according to the manufacturer. Horsepower reflects not only the power of the engine but determines the emission standards the engine is certified to, discussed in the following section.

Similar to activity, CARB staff maintained equipment-specific horsepower values in the inventory wherever it was reported in the CARB reporting data or the port emission inventories. Where it was not reported, CARB staff used average for that equipment type and fuel type. Table 4 below shows the average horsepower by equipment type across all fuel types. Electric-only categories such as pallet jacks are not shown here, as information and reporting for their power or power consumption is not currently available.

Table 4: Average Horsepower from CARB Reporting Data

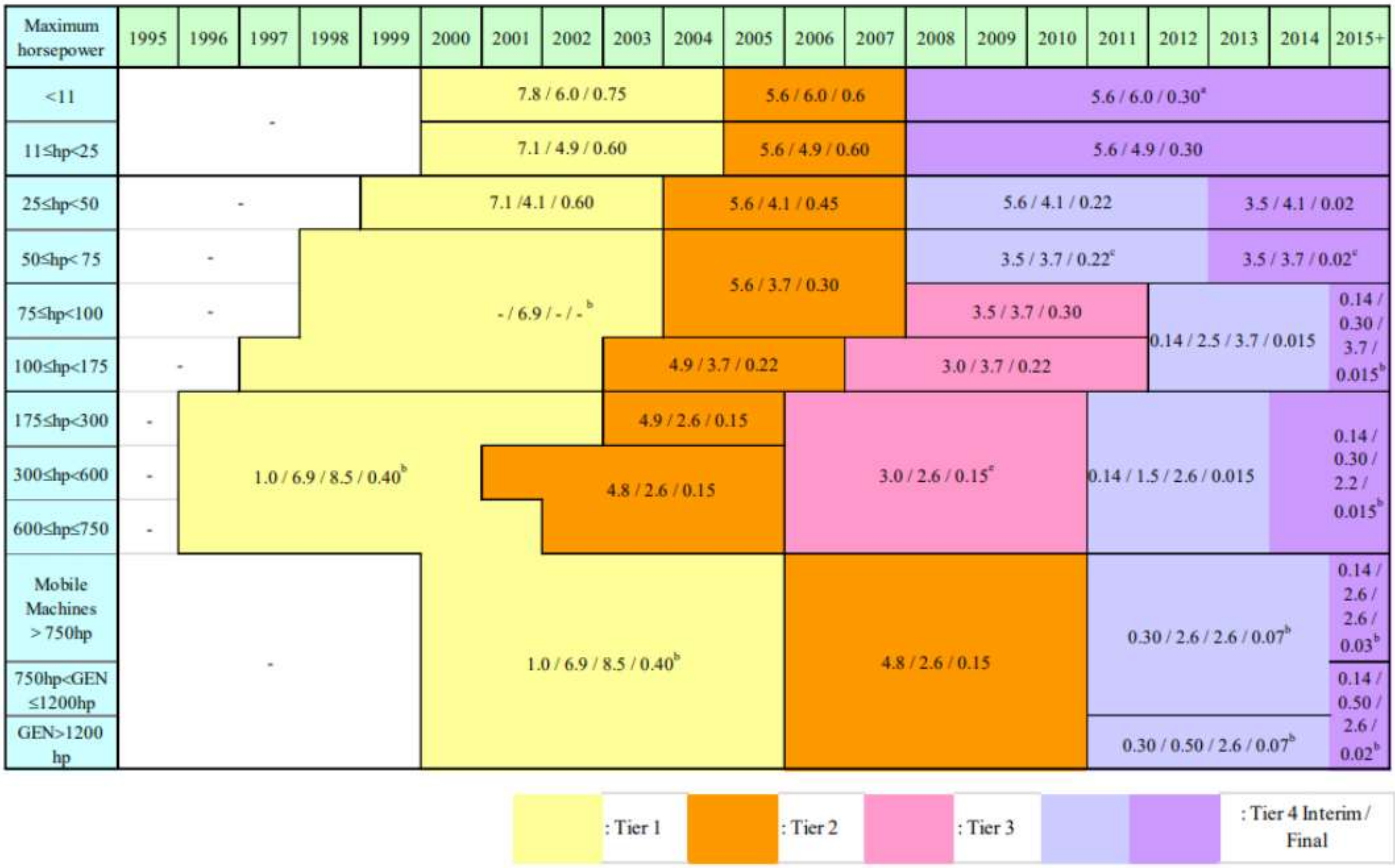
Equipment Type	Average Horsepower
RTG Crane	496
Container Handling Equipment	337
Compactor (Portable)	324
Tractors/Loaders/Backhoes	278
Excavator	261
Yard Truck	225
Rail Car Mover	218
Truck	172
Forklift	106
Skid Steer Loaders	104
Tractor	94
Other	80
Lift	74
Crane	19

6 Model Year and Engine Tier Distribution

CARB and U.S. Environmental Protection Agency (U.S. EPA) require off-road engine manufacturers to meet emission standards for each engine they produce and sell. These standards vary depending on horsepower bins, but generally become stricter over time in a series of step functions. These step functions create model-year groups of engines subject to the same standards, which are defined as engine tiers. The first engine standards began in 1996 for select horsepower groups and are defined as Tier 1.

The most recent standards are Tier 4 Final, which took effect in 2014 or 2015 for most horsepower groups. Engines produced before standards took effect are referred to as Tier 0, or sometimes “Pre-Tier”. These standards apply to newly sold engines, and do not impact engines already in use. Figure 5 shows the off-road engine tiers by horsepower bin and model year. The lowest, or cleanest, engine standard as of the release of this inventory is Tier 4 Final (or Tier 4F).

Figure 5: Diesel Engine Standards



Maximum horsepower	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015+
<11	-					7.8 / 6.0 / 0.75					5.6 / 6.0 / 0.6			5.6 / 6.0 / 0.30[a]							
11≤hp<25						7.1 / 4.9 / 0.60					5.6 / 4.9 / 0.60			5.6 / 4.9 / 0.30							
25≤hp<50	-				7.1 /4.1 / 0.60					5.6 / 4.1 / 0.45				5.6 / 4.1 / 0.22					3.5 / 4.1 / 0.02		
50≤hp< 75	-			- / 6.9 / - / -[b]						5.6 / 3.7 / 0.30				3.5 / 3.7 / 0.22[c]					3.5 / 3.7 / 0.02[c]		
75≤hp<100	-													3.5 / 3.7 / 0.30				0.14 / 2.5 / 3.7 / 0.015			0.14 / 0.30 / 3.7 / 0.015[b]
100≤hp<175	-								4.9 / 3.7 / 0.22				3.0 / 3.7 / 0.22								
175≤hp<300	-	1.0 / 6.9 / 8.5 / 0.40[b]							4.9 / 2.6 / 0.15			3.0 / 2.6 / 0.15[c]					0.14 / 1.5 / 2.6 / 0.015			0.14 / 0.30 / 2.2 / 0.015[b]	
300≤hp<600	-						4.8 / 2.6 / 0.15														
600≤hp≤750	-																				
Mobile Machines > 750hp	-					1.0 / 6.9 / 8.5 / 0.40[b]						4.8 / 2.6 / 0.15					0.30 / 2.6 / 2.6 / 0.07[b]				0.14 / 2.6 / 2.6 / 0.03[b]
750hp<GEN ≤1200hp																					0.14 / 0.50 / 2.6 / 0.02[b]
GEN>1200 hp																	0.30 / 0.50 / 2.6 / 0.07[b]				

🟨 : Tier 1
🟧 : Tier 2
🟥 : Tier 3
🟦 🟪 : Tier 4 Interim / Final

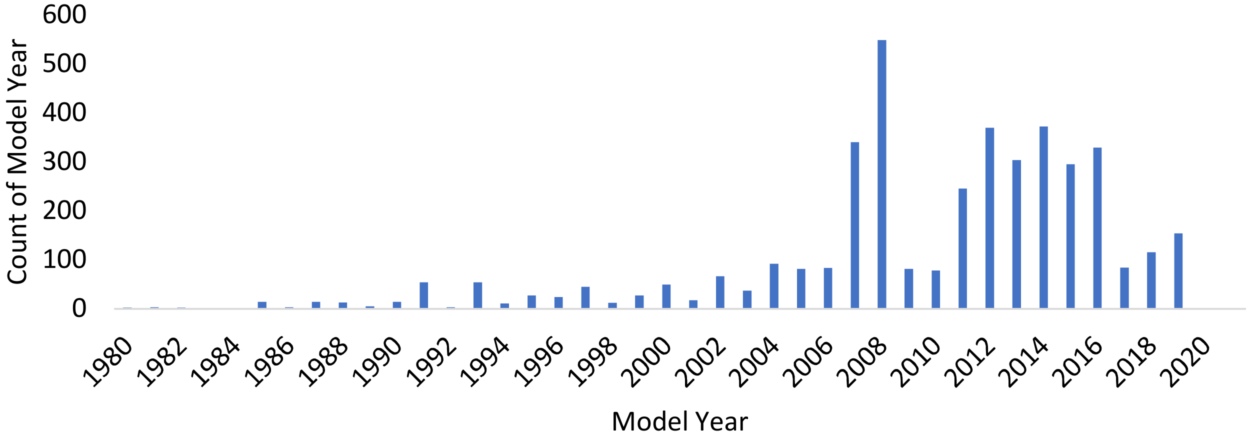
Standards given are NMHC/NO$_x$/CO/PM in g/bhp-hr.

As shown in Figure 5, equipment model year is important because it determines which emission standard the engine must meet. The equipment model year field was reported for 90 percent of the equipment for Ports of LA/LB, 100 percent of the equipment for the Port of Oakland, and 78 percent of the equipment in the CARB reporting data.

Discussions with port staff suggested that equipment missing model year information was likely older, missing engine labels due to age and use. However, both port staff and equipment owners from the major ports related that a small portion of Tier 0 equipment was operating, based on their first-hand experience. Using this information, CARB staff assumed that the majority of equipment missing model year information meet either Tier 1 or Tier 2 emission standards, representing equipment with model year from 1996 to 2007. Following discussion and consensus with port staff, CARB staff assigned this equipment model years from 1996 to 2007 using a population-weighted function, where model years with greater population received a proportionally larger percent of the equipment.

Figure 6 shows the model year distribution of all equipment in the inventory after this adjustment.

Figure 6: Statewide CHE Model Year Distribution



The model year distribution represented in Figure 6 shows a large increase in purchases in 2007 and 2008, which is in part responsible for the increase in emissions compared to the 2011 emission inventory.

Table 5 below shows the average age of CHE by equipment type in the base year, not including electric equipment. Electric are excluded simply because model year has no impact on emissions.

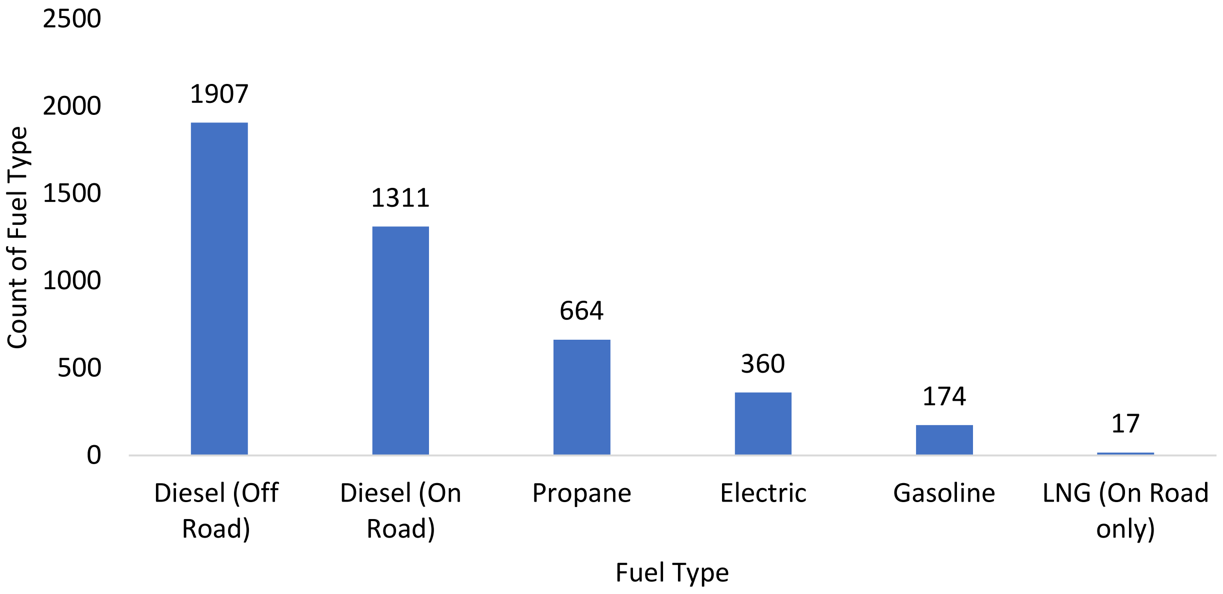
Table 5: CHE Average Age by Equipment Type (Non-Electric)

Equipment Type	**Average Age**
Container Handling Equipment	10.4
Crane	6.9
Excavator	12.3
Forklift	8.5
Lift	11.5
Other	13.0
Rail Car Mover	10.2
RTG Crane	10.9
Skid Steer Loaders	9.5
Tractor	2.8
Tractors/Loaders/Backhoes	10.9
Truck	10.3
Yard Truck	10.2
All Equipment	**9.9**

7 Fuel Type Comparison

The three largest ports supplied inventories of all CHE, including equipment powered by diesel, propane, gasoline, and electric powertrains. Therefore, for the three largest ports, equipment of all fuel types are included in this inventory. Because CARB reporting data is limited to diesel equipment, and CARB staff did not have any other data than CARB reporting data for all other port and intermodal rail yards, only diesel equipment is included for every other facility. CARB staff did not have sufficient data to expand and include non-diesel equipment at facilities other than the three largest ports. Figure 7 shows CHE by fuel type, with the majority diesel, however, the other fuels add roughly another 1,000 pieces of equipment to the inventory. It is important to note that the inventory includes non-diesel fuels only from the Ports of LA/LB and Port of Oakland as this non-diesel data is only available for the three large ports.

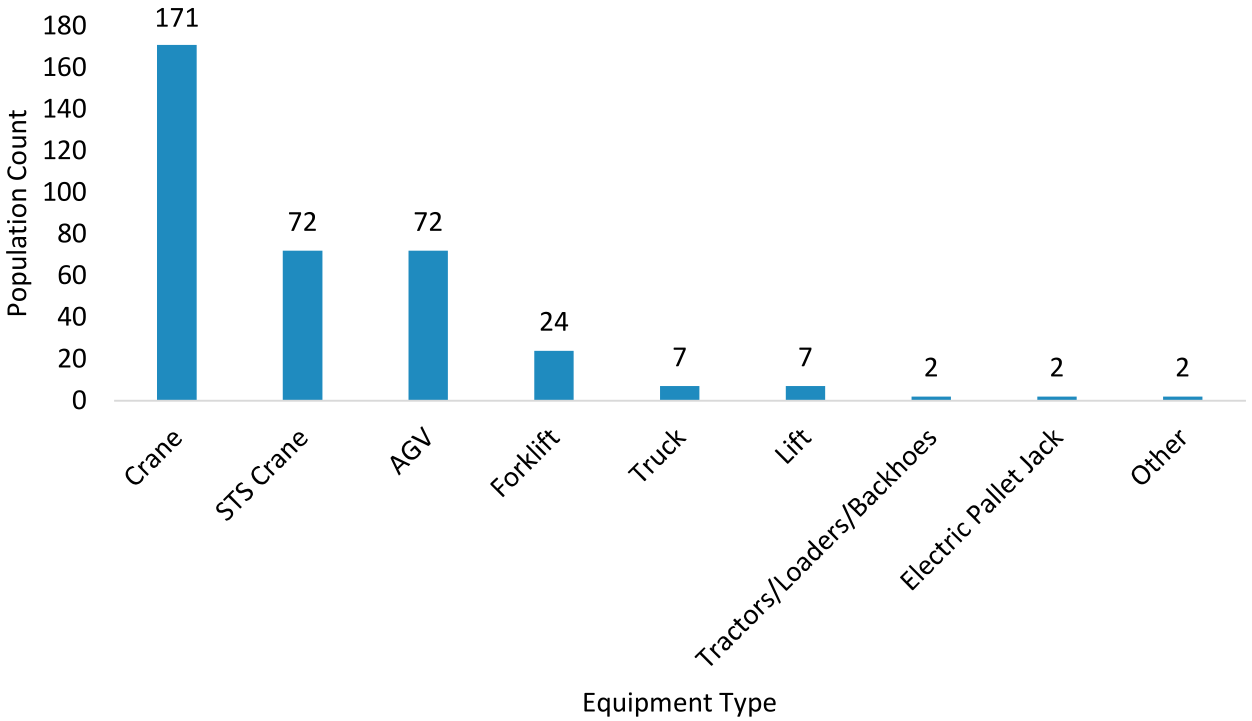
Figure 7: Statewide CHE population by Fuel Type



7.1.1 Electric Equipment at California’s Large Ports

Figure 8 shows the electric equipment in the statewide CHE inventory. The majority of electric equipment is cranes and automated guided vehicles. After discussion with the Port of Oakland, CARB staff determined that not all electric equipment are reflected in their port inventory. Approximately 10 to 20 electric RTG cranes were not reported. The missing equipment does not change emission results, and CARB staff plans to continue collecting data and refining the emission inventory to include all types of equipment, including those that are electric or otherwise zero-emission at the source.

Figure 8: Statewide Electric Equipment by Type



8 Load Factors

An engine load factor represents the percent of maximum horsepower an engine uses on average. For example, a load factor of 0.5 would represent an engine being used at half of maximum power **on average**, even if some of the time the engine is idling at very low load or being used at full power at other times.

The new 2022 CHE inventory uses the same load factors as the 2011 inventory and is consistent with San Pedro Bay Ports emissions inventories. Load factors were based on the 2006 and 2009 studies by Starcrest[14]. Table 6 presents the load factors by equipment type that were carried forward and used in this inventory update.

The load factors analysis could be improved in future emission inventories if equipment owners reported both equipment activity and fuel use, either to CARB or the larger port inventories. Load can be derived if both fuel and activity are reported, using the relationship of fuel consumption, engine horsepower, and annual activity. Fuel use was not required to be reported to CARB and was not in the POLA/LB or POAK emission inventories hence staff did not have a data source to re-calculate load factors.

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[14] https://www.portoflosangeles.org/environment/air-quality/air-emissions-inventory

Table 6: Load Factor by Equipment Type

Equipment Type	Load Factor
Compactor (Portable)	0.51
Container Handling Equipment	0.59
Crane	0.43
Electric Pallet Jack	0.50
Excavator	0.55
Forklift	0.30
Lift	0.51
Other	0.51
Rail Car Mover	0.51
RTG Crane	0.20
Skid-steer Loaders	0.55
STS Crane	0.43
Tractor	0.55
Tractors/Loaders/Backhoes	0.55
Truck	0.51
Yard Truck	0.39

9 Forecasting and Growth

9.1 Equipment Turnover

All of the input data described so far in this report forms the base-year emission inventory, providing population, activity, and load for calendar year 2019.

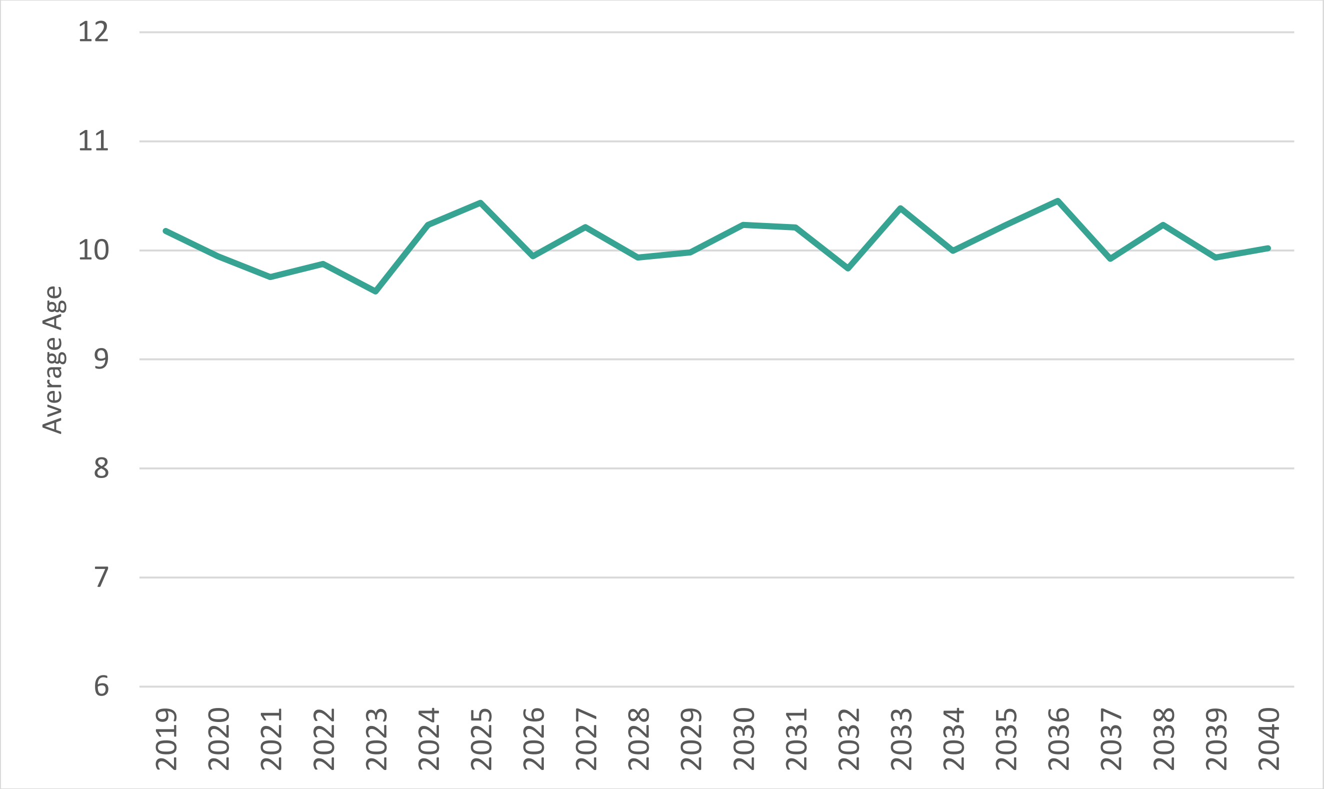
CARB staff forecast this CHE emission inventory by projecting the age distribution from the base calendar year 2019 out to 2050. The age distribution in future years was forecast by replacing the oldest CHE equipment with new equipment, at a rate set by maintaining the average age for each equipment type at each location.

For example, assume in 2022 a port has 100 yard trucks, and the average age of these yard trucks is 10.5 years old. As the emission inventory is forecast from 2022 to 2023, each yard truck becomes one year older, and the average age of yard trucks is now 11.5 years old. To maintain the average age, the inventory forecasts that the port will retire the oldest trucks until the average age of all yard trucks is once again 10.5 years old. The exact number retired each year can vary as one very old yard truck would have more impact on average age than two yard trucks that were only moderately older than the average age. On average, the inventory would need to turn over 4.8 yard trucks per year to maintain the average age of 10.5, for this example.

Annually, the inventory model replaces between 4 and 7 percent of total equipment population for each equipment type and location in order to maintain its average age. Because the existing CHE rule prevents replacement with older tiers, this inventory forecasts that all purchases will be new Tier 4 Final equipment.

Average age by location and equipment type contains confidential information and cannot be shown directly, however Figure 9 shows the average age by equipment type across the State from 2019 to 2040. There are minor variations in average age from year to year, as older equipment is turned over to maintain the overall average age by location and equipment type.

Figure 9: Statewide CHE Average Age Forecast from 2019 to 2040



9.2 Large Ports Growth Sources

9.2.1 Tioga Report for Port of Oakland

The 2020 Tioga report[15] was a location-specific growth study conducted for the Bay Conservation and Development Commission. CARB's CHE emission inventory uses this data specifically for the Port of Oakland and projects an annual growth rate of 2.2 percent beginning in 2020 and lasting through 2050.

9.2.2 Mercator Report

The Mercator Report[16] for the Ports of LA/LB forecasts container and non-container cargo volumes to 2045, represented by the blue line in Figure 11. To forecast beyond 2045 , the emission inventory used

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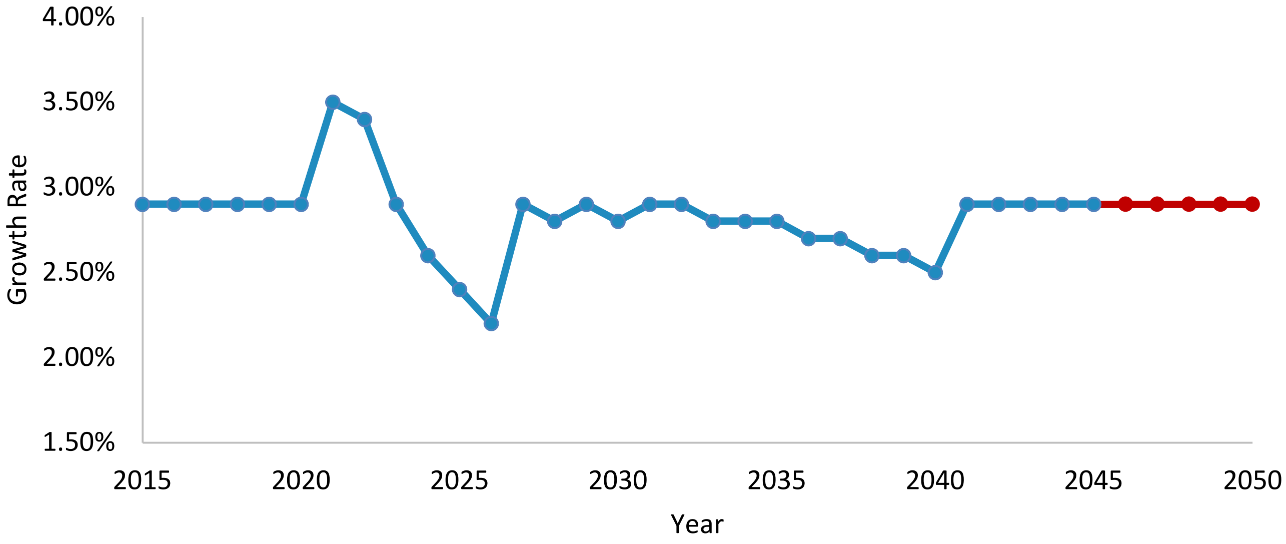
[15] https://www.bcdc.ca.gov/seaport/2019-2050-Bay-Area-Seaport-Forecast-Draft.pdf

[16] https://mercatorintl.com/long-term-forecast-southern-california-port-authority/

the 2040 to 2045 growth rates, represented by the red line in Figure 11 below, as a surrogate for the 2045 to 2050 growth rates. The growth scenario in the report fluctuates from approximately 2.1 to 3.5 percent annually. The red portion of the graph below was extrapolated from the 2040 to 2045 period.

Figure 10: Mercator Growth Rates for Ports of LA/LB



9.3 Small Ports and Intermodal Rail Yard Growth Sources

Annual growth rates were applied to the base year inventory by calendar year and region, using sources outlined in the following sections. CARB staff used port-specific studies of growth when available instead of a statewide source, as these studies were able to consider factors specific to a location, such as port capacity, channel depth for ocean going vessels, local traffic patterns, and more. In most cases, the growth sources forecast freight growth to 2045, while the inventory forecasts to 2050. To forecast beyond 2045, the emission inventory used the 2040 to 2045 growth rates for each data source as a surrogate for the 2045 to 2050 growth rates. Growth rates were applied to the inventory population.

Growth of freight activity in 2021 and 2022 has already shown that the growth rates used in this emission inventory likely underestimated short term freight growth at the ports. If these trends of rapid near-term growth continue through the next couple of years, CARB staff anticipates adjusting forecasts in future updates to this emission inventory. Currently, CARB staff has estimated the potential impacts of the recent trends of higher freight totals in a summary covering both the port congestion and freight movement increases[17].

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[17] https://ww2.arb.ca.gov/our-work/programs/mobile-source-emissions-inventory/msei-documentation-port-congestion-impacts

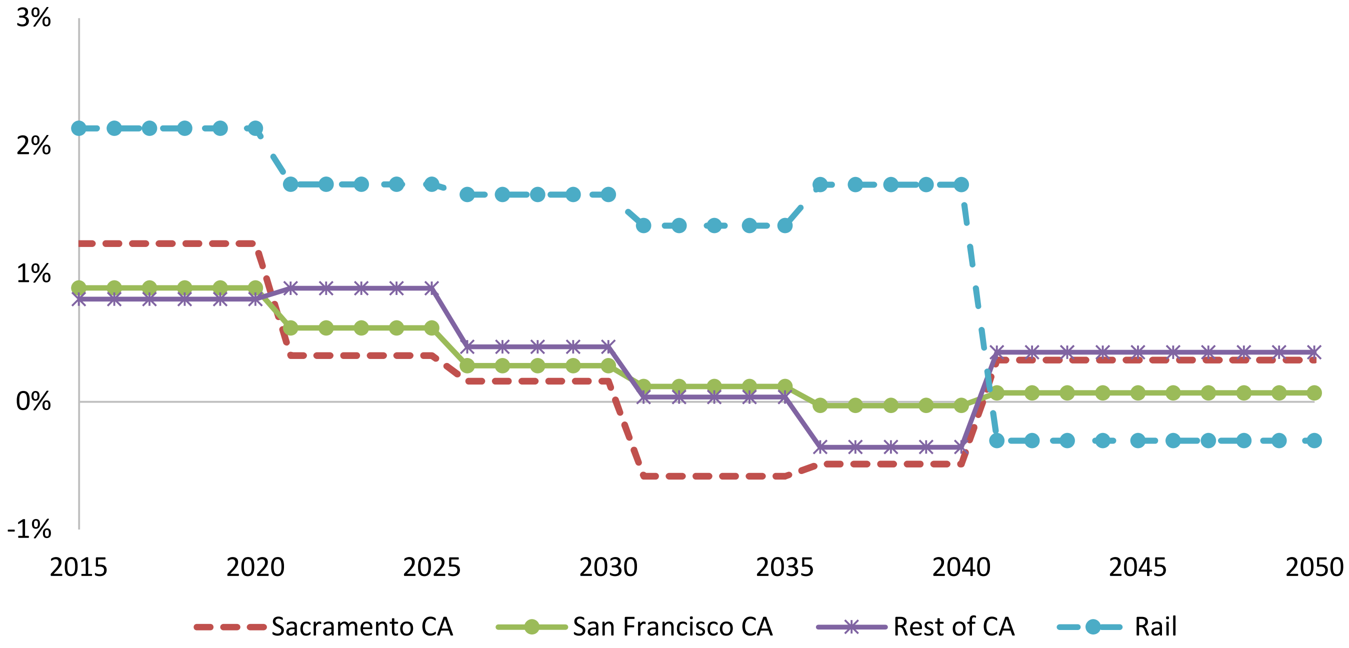
9.3.1 Freight Analysis Framework

For all locations except the Ports of LA/LB and Port of Oakland, the emission inventory growth forecast relies on the Freight Analysis Framework (FAF). FAF is a comprehensive model of national freight movements developed through the partnership of the Bureau of Transportation Statistics (BTS) and the Federal Highway Administration (FHWA). The FAF model estimates commodity flows by region, forecasted out to 2045 by freight mode, tonnage, and commodity type based on several data sources including the Commodity Flow Survey (CFS), international trade data from the Census Bureau, and sector specific data from agriculture, extraction, utility, construction, among others.

FAF forecasts freight tonnage and TEU movements, and CARB staff assumed for this inventory that CHE population and activity will increase proportionally to the increase in freight volumes.

FAF growth rates are shown below in Figure 10. The graph shows growth rates for Sacramento, San Francisco, the Rest of California and Rail. The Rest of California is defined as anywhere in the state that falls out of the regions of Sacramento, San Francisco, Oakland, and Los Angeles and Long Beach. Sacramento, San Francisco, and the rest of California is projected to increase by about 0.5 percent until 2030. By 2035 Sacramento and the rest of California are projected to see a decline in freight movements.

Figure 11: FAF Growth Rates for Small Ports and Rail yards



10 Emissions Results

10.1 Statewide Emissions

Figure 12 presents population projections from the 2022 CHE inventory according to diesel engine tier, non-diesel fuel type, and on- or off-road engine standards. Note that the 2022 CHE emission inventory does not reflect the Heavy-Duty Vehicle and Engine Omnibus Regulation adopted in December 2021 for on-road equipment[18]. Furthermore, it does not forecast Tier 5 standards for off-road equipment that are under development by CARB[19]. These standards will be reflected in future inventories.

Figure 12 shows the changes in statewide CHE population from 2019 to 2050 due to natural turnover. By 2034, most off-road equipment will meet the Tier 4 Final standard. Additionally, pre-2010 on-road vehicles will be phased out by 2029. The inventory does not forecast any direct replacement of diesel equipment with other fuel types. Instead, the inventory increases population and total activity of all fuel types at the growth rate for the port or intermodal rail yard described earlier in the report.

Figure 12: Statewide CHE Population Projection by Diesel Tier Group and Fuel Type

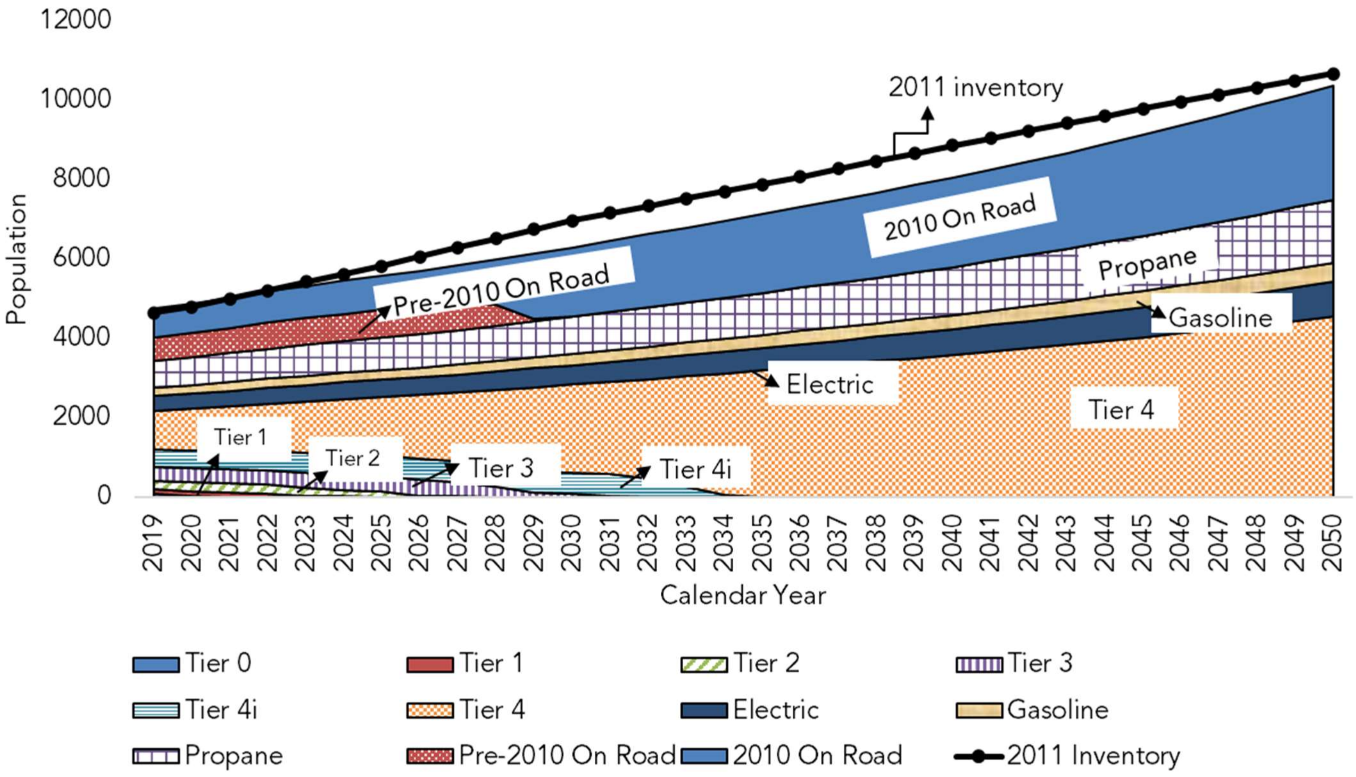


Figure 13 show baseline statewide CHE emissions for NOx by diesel tier standard group, fuel type, and on-road standards. By 2035 diesel equipment will meet Tier 4 Final standards resulting in lower NOx emissions. Additionally, as a result of the equipment turnover method discussed in Section 9.1, pre-2010 on-road equipment phase out completely by 2029, resulting in lower on-road NOx emissions from CHE operating at the ports and intermodal rail yards.

Note that in the previous inventory, the drop in emissions in 2040 is due to the retirement of a large number of forklifts. The previous inventory assumed that very few forklifts retired before 33 years of use, leading to a large number of Tier 2 to 3 forklifts operating until 2040. The updated inventory

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[18] https://ww2.arb.ca.gov/rulemaking/2020/hdomnibuslownox

[19] https://ww2.arb.ca.gov/our-work/programs/tier5

reflects a lower and more realistic survival rate for forklifts, which have an average age of 8.5 years based on the latest data.

Figure 13: Statewide CHE NOx Emission Projection by Diesel Tier Group and Fuel Type

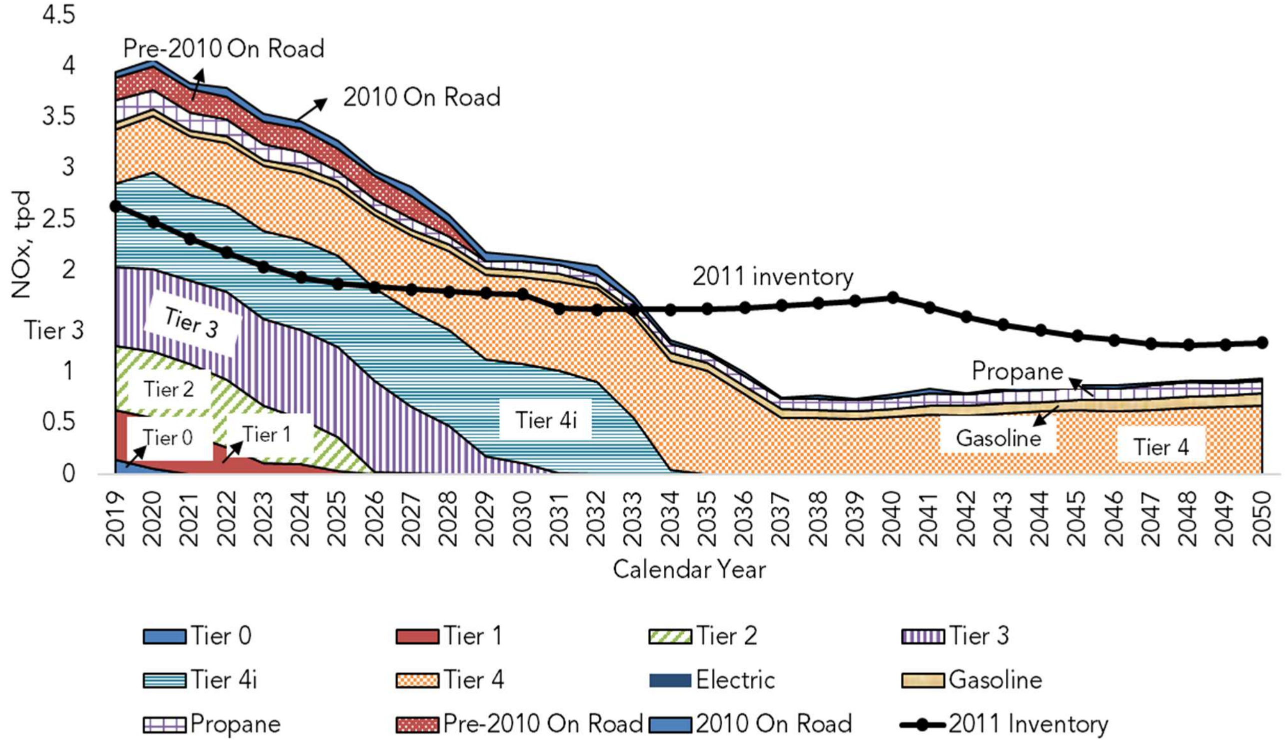

Figure 14 show baseline statewide CHE emissions for PM2.5 by diesel tier standard group, fuel type, and on-road standards. Total emissions are higher in this update as compared to the CARB 2011 CHE Inventory because in the base year 2019, there are significantly more Tier 0 to Tier 3 engines in the inventory than the previous emission inventory forecast. This is due in part to more complete data sources for population (with the major ports collecting data directly on facility and providing that to CARB) and also to the assumption of high natural turnover in the previous emission inventory. Additionally, the emission factors for 2015 to 2019 engines are significantly over the Tier 4 Final PM standard as manufacturers used flexibility provisions in the Tier 4 language such as Averaging, Banking and Trading (ABT) to delay meeting PM standards[20].

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[20] https://ww3.arb.ca.gov/msei/ordiesel/ordas_ef_fcf_2017.pdf

Figure 14: Statewide CHE PM 2.5 Emission Projection by Diesel Tier Group and Fuel Type

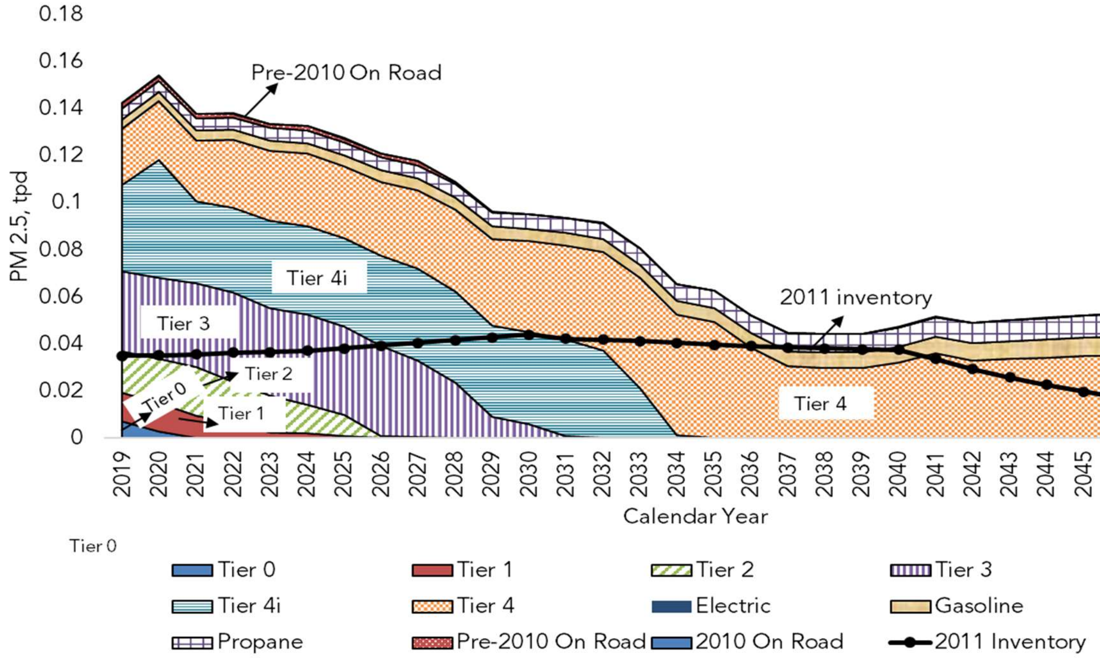


Figure 15 shows the NOx emissions for the Port of LA/LB by diesel tier standard, fuel type, and on-road standards. As California's largest port, Port of LA/LB emits roughly half of the total CHE emissions in the State.

Figure 15: Port of LA/LB CHE NOx Emission Projection by Diesel Tier Group and Fuel Type

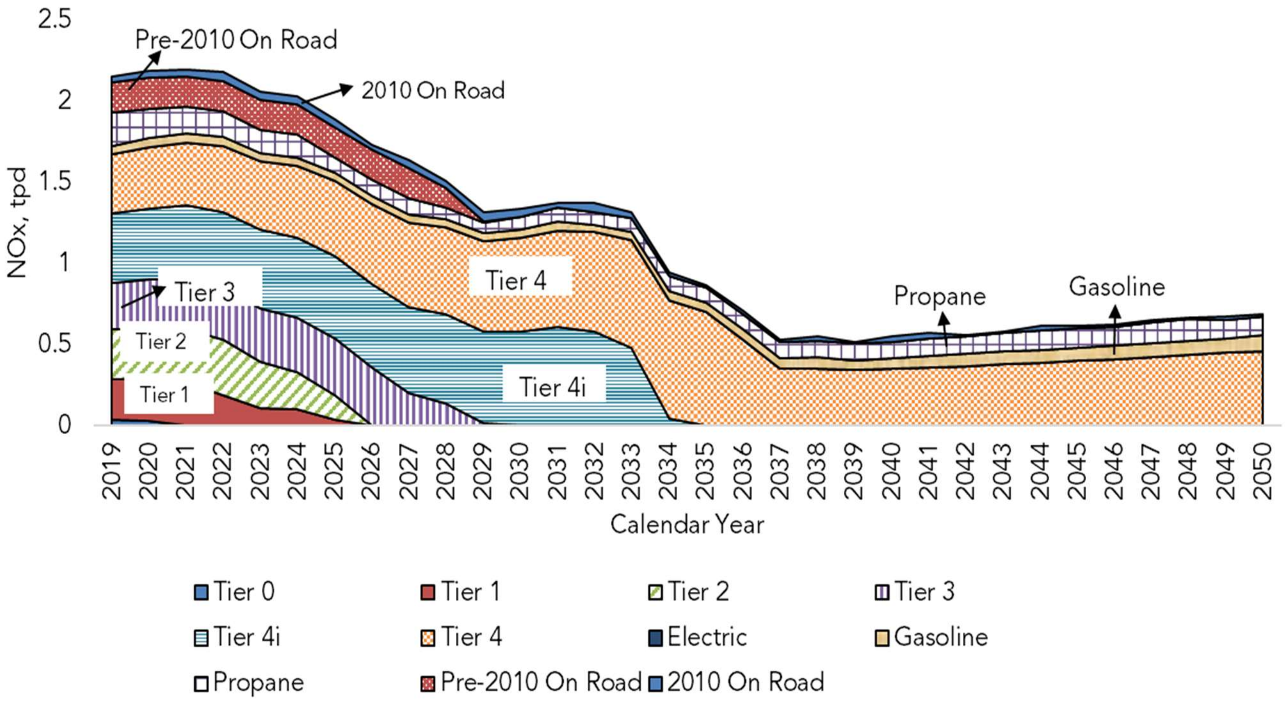


Figure 16 shows the PM 2.5 emissions for the Port of LA/LB by diesel tier standard, fuel type, and on-road standards. As California's largest port, Port of LA/LB emits half of the total CHE emissions in the State.

Figure 16: Port of LA/LB CHE PM2.5 Emission Projection by Diesel Tier Group and Fuel Type

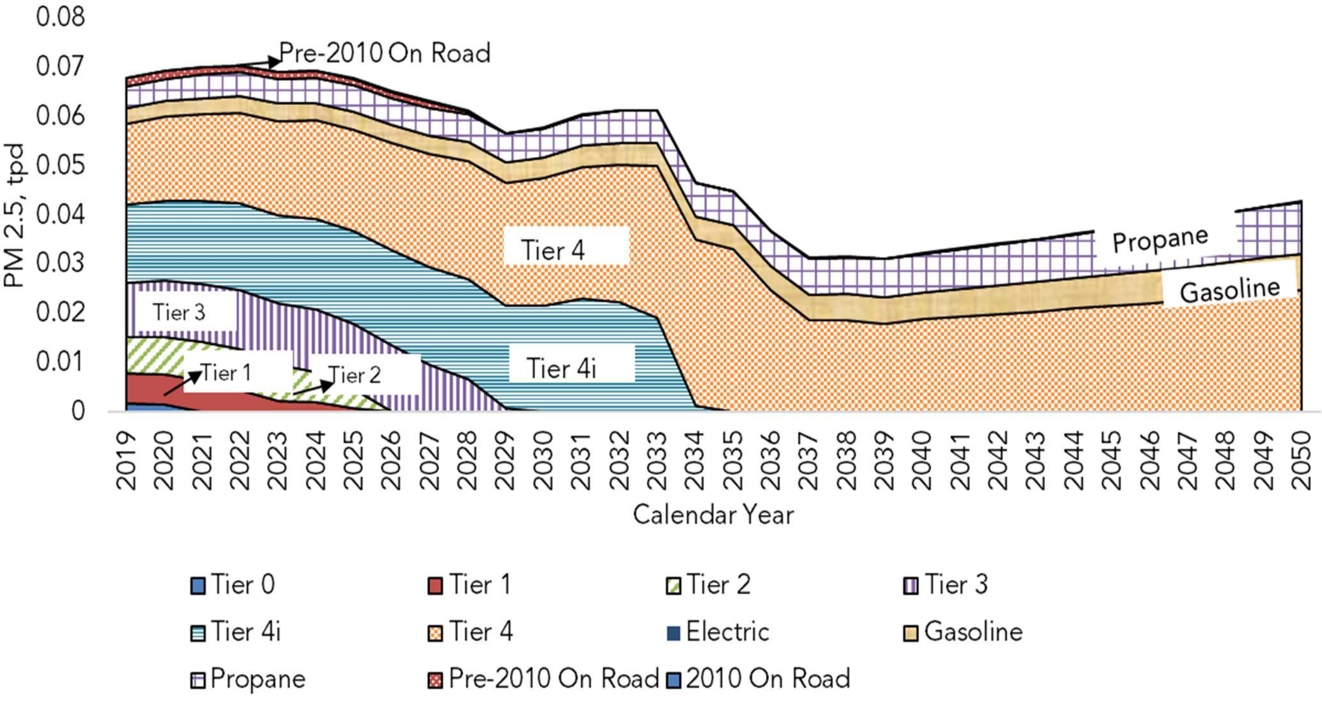


Figure 17 and Figure 18 shows the NOx and PM2.5 emissions, respectively, for the Port of Oakland by diesel tier standard, fuel type, and on-road standards. On-road equipment was not included in these figures because only one piece of equipment was reported as on-road in the Port of Oakland emissions inventory.

Figure 17: Port of Oakland CHE NOx Emission Projection by Diesel Tier Group and Fuel Type

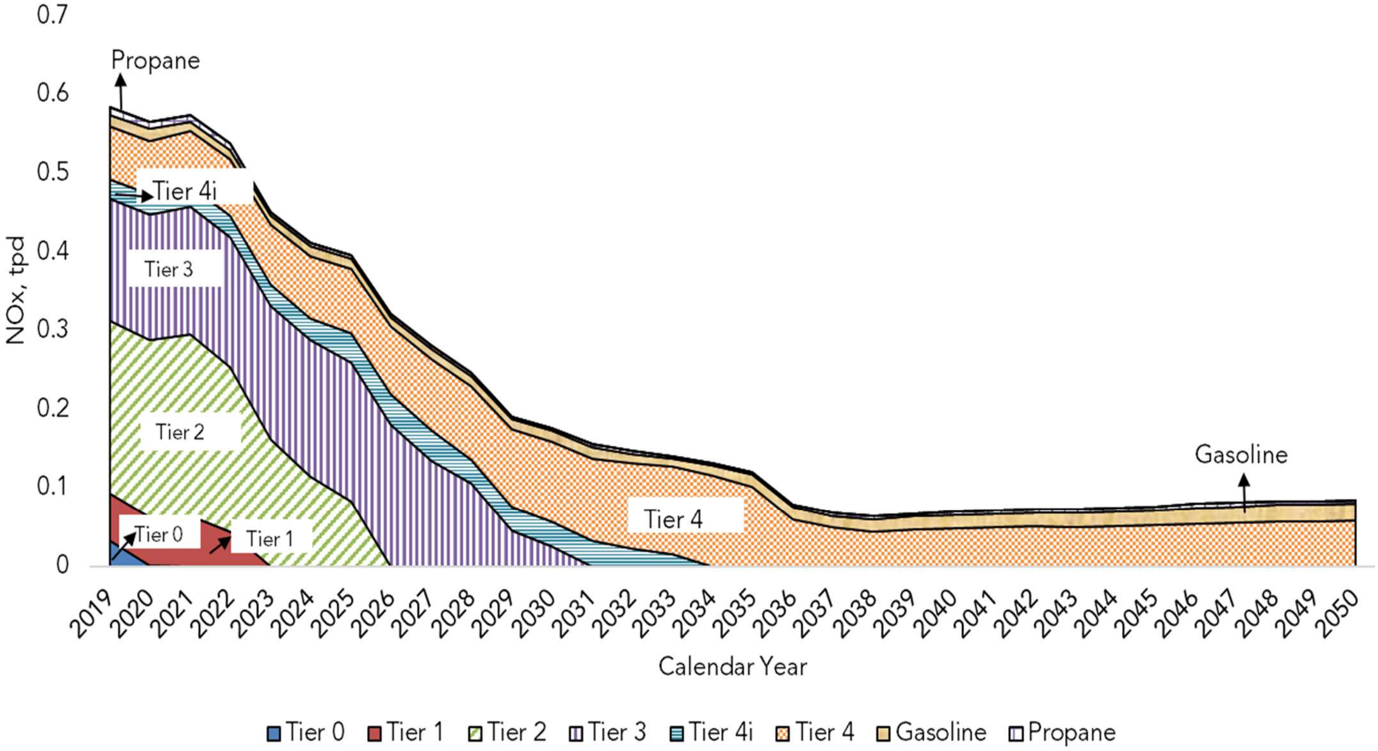
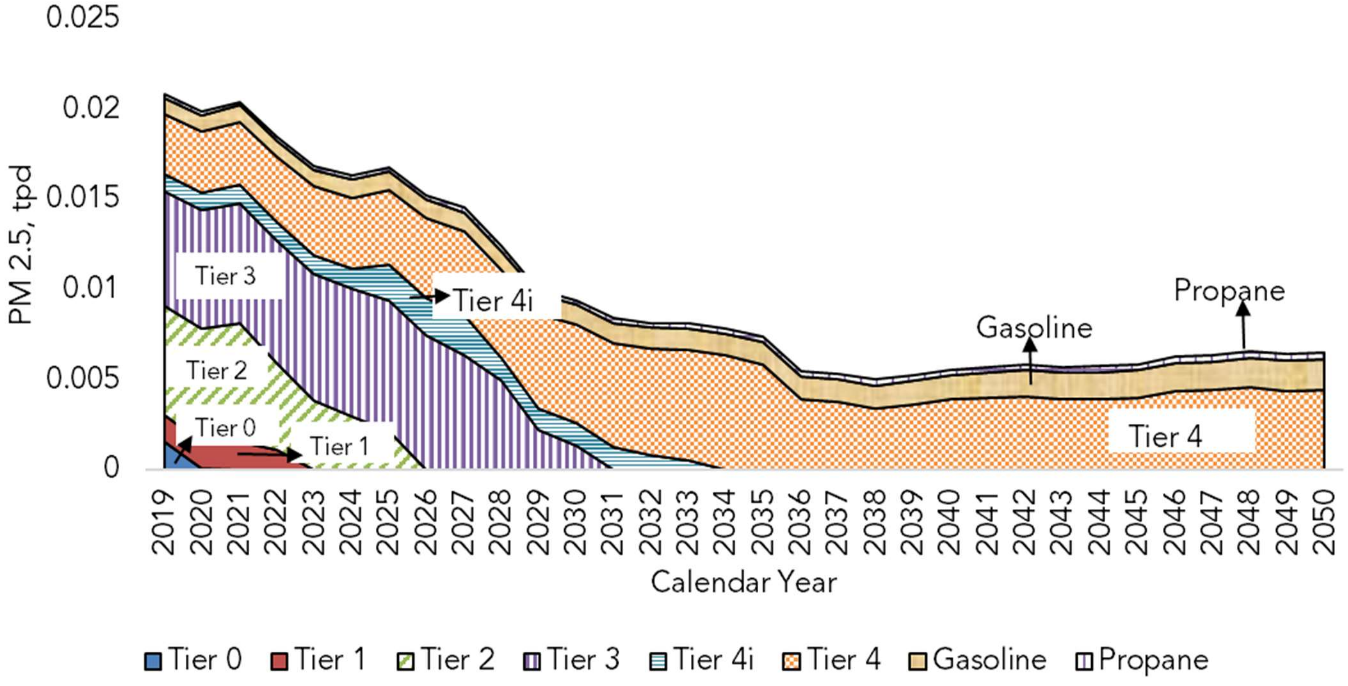


Figure 18: Port of Oakland CHE PM2.5 Emission Projection by Diesel Tier Group and Fuel Type



11 Appendix A: Electrification Programs and Trends

Multiple state agencies, as well as the Port of Los Angeles, Port of Long Beach, and the Port of Oakland have a variety of grants and programs to demonstrate and implement zero-emission technologies.

These programs have ambitious goals, not all of which are reflected in the emission inventory. The success of these programs could shift the emission inventories toward additional electric vehicles and fewer combustion vehicles. CARB staff plan to monitor the progression of programs and demonstration projects and will update the inventory accordingly.

Table 7 lists these grants and programs for reference.

Table 7: Grants and Programs from California Ports

Program Name	Description
Clean Air Action Plan (CAAP)[21]	The San Pedro Bay Port's joint plan to transition to zero-emissions technologies by deploying over 100,000 zero-emission and near-zero-emission freight vehicles powered by renewable energy by 2030.
Sustainable Terminals Accelerating Regional Transformation Project (START)[22]	The California Air Resources Board awarded a $50 million grant for demonstrations of a near-zero and zero-emissions supply chain. The START project includes the ports of Oakland, Long Beach and Stockton and more than 100 pieces of zero-emission terminal equipment.
Zero-Emissions Terminal Equipment Transition[23]	$9.7 million grant from the California Energy Commission to demonstrate and deploy 12 battery-electric yard trucks, 9 electric rubber-tired gantry cranes, and four plug-in hybrid electric drayage trucks.
C-Port Zero-Emissions Demonstration[24]	The Port will demonstrate three electric top handlers and a comparison of a hydrogen fuel truck and a battery-electric yard truck. The California Air Resources Board awarded a $5.3 million grant to fund the demonstration.
Technology Advancement Program (TAP)[25]	The San Pedro Bay Port's program goal is to accelerate the verification or commercial

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[21] https://cleanairactionplan.org/2017-clean-air-action-plan-update/

[22] https://ww2.arb.ca.gov/sites/default/files/movingca/pdfs/start.pdf

[23] https://polb.com/environment/our-zero-emissions-future/#program-details

[24] https://polb.com/environment/our-zero-emissions-future/#program-details

[25] https://cleanairactionplan.org/technology-advancement-program/

	availability of clean technologies through demonstrations and evaluations.
Advanced Yard Tractor Deployment[26]	Funded in partnership with the California Energy Commission, the goal of the program is to enhance market acceptance of advanced yard trucks to reduce greenhouse gas emissions at the Port of Los Angeles.
Everport Advanced Cargo Handling Demonstration Project[27]	Demonstrates zero-emissions pathway for loading and unloading cargo at the marine container terminal at the Port of Los Angeles.
Zero Emission Freight Vehicle Advanced Infrastructure Demonstration (AID) Project[28]	Focuses on the implementation of a zero-emissions cargo pathway throughout the marine container terminal with a focus on the infrastructure needed to support zero-emissions equipment at the Port of Los Angeles.
Port Infrastructure Development Program (PIDP)[29]	The plan to guide the Port of Oakland in its transition from fossil-fuels to clean energy.
Seaport Air Quality 2020 and Beyond Plan: The Pathway to Zero Emissions[30]	Plan to minimize diesel particulate matter and greenhouse gas emissions at the Port of Oakland.

11.1.1 International Ports

California Ports are not the only ports looking toward a more sustainable future. Some of the world's largest ports have implemented sustainability plans to reduce emissions. In particular, Shanghai's Yangshan Deep-Water Port is aiming for zero emissions and a decrease of energy consumption by 70 percent[31]. The Port of Kaohsiung in Taiwan is following the Integrated Planning and Development Project for International Commercial Ports in Taiwan which includes implementing electric RTG and RMG cranes[32]. The Port of Rotterdam in the Netherlands is implementing a three-step plan to teach its energy transition goals. Step 1 is increasing the efficiency of already existing infrastructure, step 2 is transitioning to electricity, hydrogen, and green hydrogen and step 3 is replacing fossil fuels with sustainable alternatives[33]. The Port of Singapore is working on reducing 50% of total GHG emissions by 2030 and

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[26] https://kentico.portoflosangeles.org/getmedia/5f3562b1-68ba-488f-9b22-4b4c00d4c287/fact_sheet_cec_2015

[27] https://kentico.portoflosangeles.org/getmedia/a374b9ef-59bf-4862-ab66-9b8f69c62315/fact_sheet_cec_2017

[28] https://kentico.portoflosangeles.org/getmedia/ffe04622-f7bc-47b4-afbd-5d385531a4d3/fact_sheet_aid_cec_wave

[29] https://www.portofoakland.com/pidp/

[30] https://safety4sea.com/wp-content/uploads/2019/06/Port-of-Oakland-Seaport-Air-Quality-2020-and-Beyond-Plan-2019_06.pdf

[31] https://www.greenport.com/news101/asia/asia-switches-its-focus-to-green-initiatives

[32] https://www.sciencedirect.com/science/article/pii/S2210539513000333

[33] https://www.portofrotterdam.com/en/port-future/energy-transition

achieving net zero by 2050. To achieve these targets the port plans to double solar power production as well as convert diesel-powered port equipment to electric equipment[34].

11.1.2 Electrification Trends

CARB staff evaluated changes in electric equipment at the Port of Los Angeles and the Port of Long Beach. Figure 19 shows the changes in fuel type proportion across all equipment types based on the available air emissions inventories[35] data from 2005-2019 from the Port of Los Angeles. There is a slight increase in propane, LNG and electric equipment over time.

Figure 19: Comparison of CHE fuel types from the Port of Los Angeles

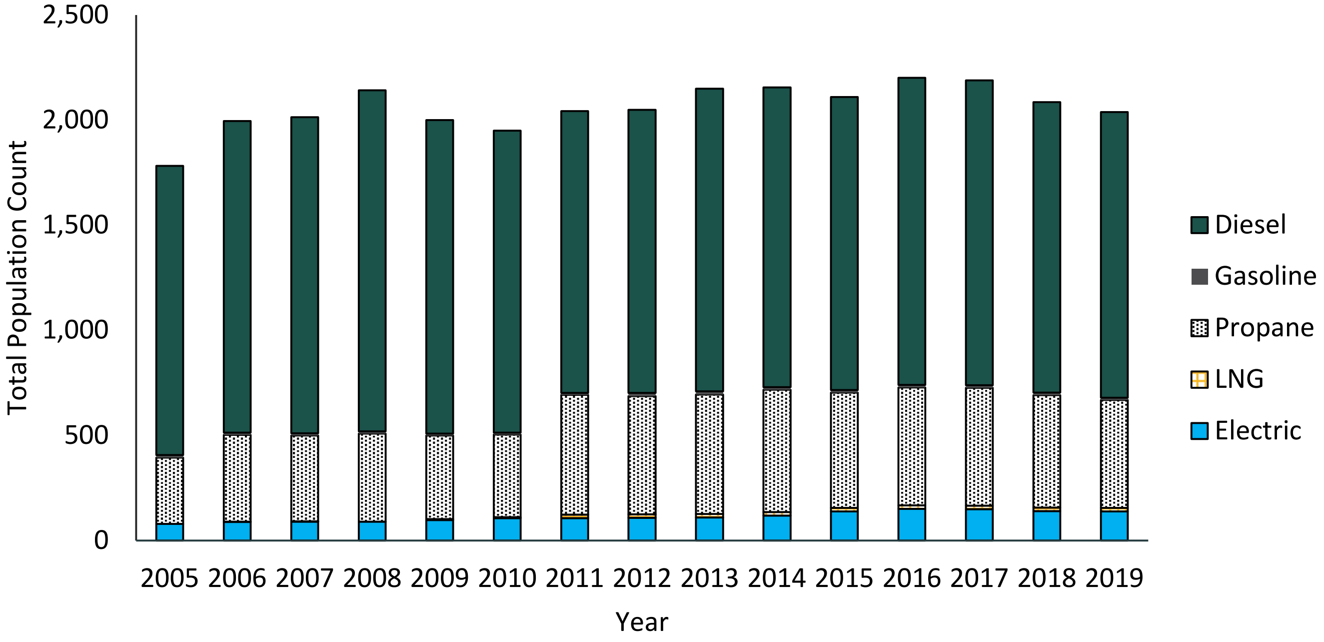

Figure 20 shows the change of electric CHE population over time in the Port of Los Angeles. From 2005 to 2016 there is an increase in electric equipment, that starts to slightly diminish from 2017 to 2019.

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[34] https://www.singaporepsa.com/our-commitment/Sustainability

[35] https://www.portoflosangeles.org/environment/air-quality/air-emissions-inventory

Figure 20: Count of Electric CHE at the Port of Los Angeles

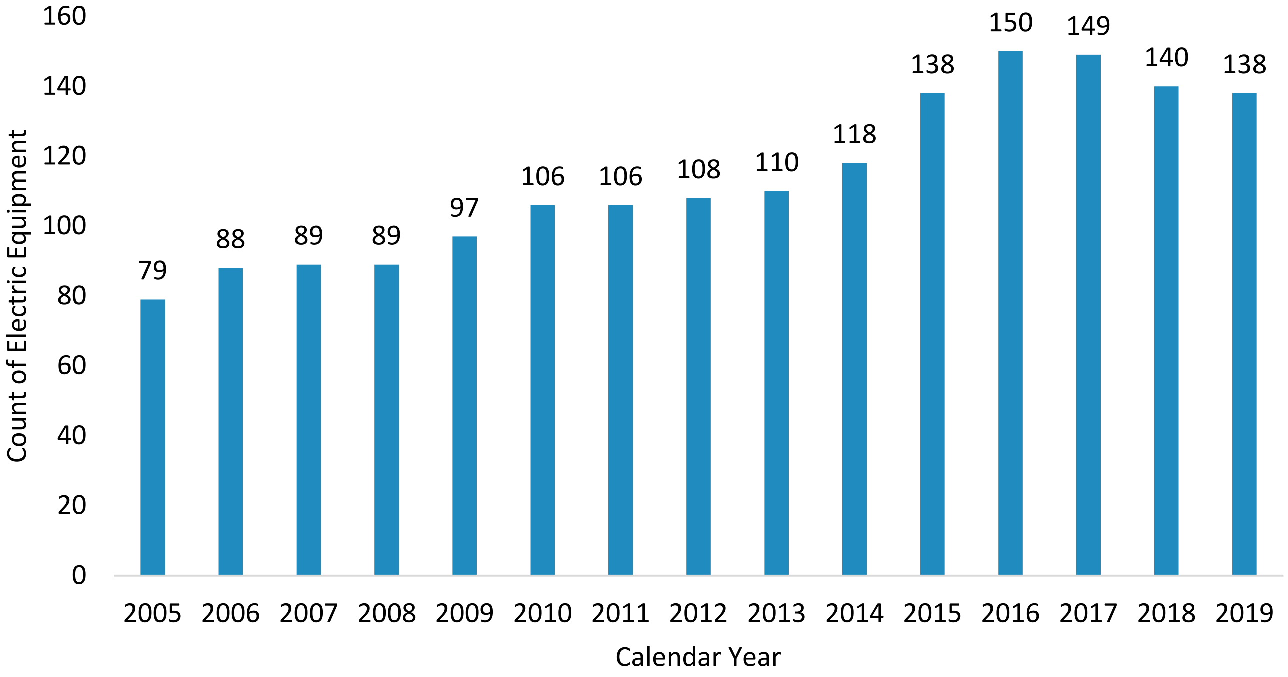

Figure 21 shows the change in fuel type proportion across all equipment types from the available air emissions inventories[36] from 2007-2019 for the Port of Long Beach. There is a slight increase electric equipment starting in 2009, with a large increase from 2016-2019. There was also an increase in gasoline equipment starting in 2011 that continues to slightly increase through 2019.

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[36] https://polb.com/environment/air/#emissions-inventory

Figure 21: Comparison of CHE fuel types from the Port of Long Beach