

CLEAN TRUCK TECHNOLOGY COMPARATIVE REPORT 1 Baseline Conditions

METRO GOODS MOVEMENT PLANNING



Metro

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Nomenclature

ACF	Advanced Clean Fleets
ACT	Advanced Clean Trucks
CAIRP	California Registered International Registration Plan
CARB	California Air Resources Board
CCA	Clean Air Act
CERP	Community Emissions Reduction Plan
DPM	Diesel Particulate Matter
EMFAC	EMission FACTor
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
HD I&M	Heavy-Duty Inspection and Maintenance
MATES V	Multiple Air Toxics Exposure Study
NAAQS	National Air Ambient Air Quality Standards
NOx	Nitrogen Oxides
NREL	National Renewable Energy Laboratory
PPB	Parts per Billion
PPM	Parts per Million
SCAB	South Coast Air Basin
SCAQMD	South Coast Air Quality Management District
SIP	State Implementation Plan
VMТ	Vehicle Miles Traveled
VOC	Volatile Organic Compounds

1 Background and Overview

The purpose of this report is to provide an overview of Class 8 heavy-duty truck operations, emissions and environmental impacts in Los Angeles (LA) County considering business-as-usual conditions. This report leverages tools and studies by the state's public air quality agencies, such as California Air Resources Board (CARB) and South Coast Air Quality Management District (SCAQMD) to develop baseline conditions of truck operations in this region. This report utilizes CARB's Emission FACtor, EMFAC2021 model, fleet database, as well as California's official State Implementation Plan (SIP) emissions inventories to extract vehicle population, vehicle miles traveled (VMT), criteria pollutant, toxic air contaminants, greenhouse gas (GHG) emissions and fleet distribution metrics. The EMFAC2021 model also reflects the latest heavy-duty regulations adopted by CARB and U.S. Environmental Protection Agency (EPA), such as Heavy-Duty Low Nitrogen oxides (NOx) standards, Advanced Clean Trucks and Advanced Clean Fleets regulations and national/California heavy-duty GHG standards.

This report begins with a synopsis of air quality in Southern California over the past decades and how compliance to progressively tighter emissions standards have shaped present air quality. Among the sources contributing to air quality issues in the region, heavy-duty trucks are a major source of pollution. Heavy-duty trucks are essential to goods movement but are major sources of toxic diesel particulate matter (DPM) within disadvantaged communities¹. Over the years, several policies, regulations and incentive programs have been implemented in response to the disproportionate impact of heavy-duty trucks on air quality and public health in disadvantaged communities. Those include various engine emission standards, fleet modernization programs such as the in-use diesel fleet rules (e.g., Statewide drayage truck regulation, and Truck and Bus rule), as well as zero-emission mandates such as the Advanced Clean Trucks and the upcoming Advanced Clean Fleets regulations. In September 2020, Governor Newsom signed Executive Order N-79-20, a call for all drayage trucks operating in California to be zero-emission by 2035 and all other heavy-duty trucks to be zero-emission by 2045, an ambitious goal that sets California as the first state in the nation to establish an all-zero-emission fleet requirement for its heavy-duty fleets. A summary of the regulations described in this section is presented in Table 1 as reference. Following the establishment of past and current air quality standards in LA County, the report sets the lay of the land for Class 8 Truck activity in the region to estimate projected air quality improvements and associated public health outcomes.

¹ Disadvantaged communities are designated by CalEPA for the purpose of Senate Bill 535. These investments are aimed at improving public health, quality of life and economic opportunity in California's most burdened communities, and at the same time, reducing pollution that causes climate change.

Table 1 - Summary of Heavy-Duty Truck and Emissions Regulations

Name	Description	Effective Date
Truck and Bus Rule	The Truck and Bus regulation has been in effect since December 2008 and we are now in the last replacement phase of the regulation with a final deadline of January 1, 2023, to upgrade to 2010 or newer model year engines. As heavy-duty on-road vehicles are such a significant source of pollutants, the Truck and Bus Regulation is one of the most far-reaching and important tools to reduce smog-forming and toxic emissions and protect public health in disadvantaged communities. It is a key element in CARB's Diesel Risk reduction plan and the State Implementation Plan, both of which are designed to provide clean air for Californians by helping to meet state and federal health-protective standards.	Dec 12, 2008
Statewide Drayage Truck Regulation	Starting January 1, 2023, drayage trucks are subject to the provisions of title 13, California Code of Regulations, section 2025, the Regulation to Reduce “Emissions of Diesel Particulate Matter, Oxides of Nitrogen and Other Criteria Pollutants from In-Use Heavy-duty Diesel-Fueled Vehicles (Truck and Bus Regulation)”, which requires that all not otherwise exempt in-use on-road diesel vehicles, including drayage trucks, have a 2010 model year emissions equivalent engine by January 1, 2023.	Dec 24, 2008
National/CA HD GHG Standards	In 2011, the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Transportation’s National Highway Traffic Safety Administration (NHTSA) jointly adopted the first federal GHG emission standards and fuel economy standards for heavy-duty engines and vehicles, referred to as the federal Heavy-duty GHG Phase 1 regulation (Phase 1). In 2013, the CARB approved for adoption California Phase 1 GHG regulations that were substantially identical to the federal Phase 1 regulations. This provided California the authority to certify new California certified engines and vehicles to the Phase 1 standards, as well as enforce them.	Oct 23, 2013

Name	Description	Effective Date
Executive Order N-79-20	By setting a course to end sales of internal combustion passenger vehicles by 2035, the Governor's Executive Order establishes a target for the transportation sector that helps put the state on a path to carbon neutrality by 2045. It is important to note that the Executive Order focuses on new vehicle sales for automakers, and therefore does not require Californians to give up the existing cars and trucks they already own.	Sep 23, 2020
Advanced Clean Trucks Regulation	Per the Executive Order N-79-20, California Air Resources Board enacted this rule to provide guidance and time for automakers to scale up and market new zero-emission vehicles (ZEVs), as well as further impetus for the providers of charging and refueling infrastructure, electric utilities and others to plan for and support the increasing consumer demand for these vehicles. Clear policies such as the Governor's Executive Order help provide market signals to investors and can mobilize private capital.	Mar 15, 2021
Heavy-Duty Inspection and Maintenance (HD I/M) Program	Senate Bill (SB) 210 (Leyva; Chapter 298, Statutes of 2019) was signed into law by Governor Newsom on September 20, 2019. SB 210 directs CARB to develop an HD I/M program, in consultation with the Department of Motor Vehicles and the Bureau of Automotive Repair, and to adopt and implement the HD I/M program within two years of completing a pilot program. CARB's existing programs, the Heavy-Duty Vehicle Inspection Program (HDVIP) and the Periodic Smoke Inspection Program (PSIP), are intended to ensure vehicle emissions control systems are properly operating throughout the life of the vehicle. However, these programs do not adequately ensure that NOx emissions are controlled for the life of the vehicle. CARB research, testing and modeling indicates substantial levels of in-use emissions beyond that expected from heavy-duty trucks based on current engine and vehicle standards.	Dec 9, 2021

Name	Description	Effective Date
HD Low NOx Omnibus	CARB staff has proposed the heavy-duty omnibus regulation, which would establish oxides of nitrogen (NOx) engine emission standards 90 percent lower than that of today's standards. This regulation would implement a key measure in the 2016 Mobile Source Strategy, which is critical for attaining federal health-based air quality standards for ozone in 2031 in the South Coast and San Joaquin Valley air basins, and fine particulate matter (PM2.5) standards in the next decade.	Dec 22, 2021
Advanced Clean Fleets Regulation	CARB is developing a medium and heavy-duty zero-emission fleet regulation with the goal of achieving a zero-emission truck and bus California fleet by 2045 everywhere feasible and significantly earlier for certain market segments such as last mile delivery and drayage applications. The initial focus would be on high-priority fleets with vehicles that are suitable for early electrification, their subhauleders and entities that hire them. The goal of this effort is to accelerate the number of medium and heavy-duty zero-emission vehicle purchases to achieve a full transition to zero-emission vehicles in California as soon as possible.	Jan 1, 2024

The current and projected Class 8 truck populations are compiled for the years 2020 through 2035 to generate narratives and use graphic aids to describe Class 8 trucks within LA County, including their diverse operational characteristics and duty cycles. Additionally, this report will quantify the impact of Class 8 diesel and natural gas trucks on overall GHG emissions, regional air quality issues (ozone and PM) and public health impacts, especially those that acutely burden disadvantaged communities. The report relies on the available health impact analysis conducted by SCAQMD through their Multiple Air Toxics Exposure Study V (MATES V), as well as the most recent AB 617 Community Emissions Reduction Plans (CERP) for AB 617 communities in LA County. These analyses and datasets offer a comprehensive overview of the public health, air quality and climate impacts of Class 8 truck operations in LA County and the immediate need for reducing emissions from these trucks to meet near- and long-term air quality, public health and climate goals.

This report consolidates several distinct evaluations to provide the necessary knowledge base for the remainder of the Clean Truck Technology Comparative Report into the following sections:

- **Air Quality Challenges in South Coast Air Basin:** In this section, past- and current-state air quality conditions are reviewed to understand the unique challenges SCAQMD faces when implementing emissions standards and regulations. The South Coast Air Basin, for example, has federal air quality attainment goals and public health equity targets that it is working towards achieving within the next 15 years. Meeting these goals is a top priority for SCAQMD. This section also highlights why it is crucial to reduce the harmful air pollutants in disadvantaged communities; this report provides the necessary context and guidance for LA County Metropolitan Transportation Authority's (Metro) role in reducing emissions from goods movement activities.
- **Categorization of Class 8 Trucks by Operational Characteristics and Duty Cycles:** Following an overview of air quality challenges and public health disparity in the South Coast Air Basin, this section sets the lay of the land for Class 8 trucks operating within the region. The types of trucks, operational characteristics and typical duty cycles are described to provide perspective on the goods movement activities. Other operational characteristics, such as typical range requirements to perform work tasks are also reviewed.
- **Current and Projected Class 8 Truck Populations in Los Angeles:** This section leverages the EMFAC2021 model to provide the most recent vehicle population counts for all Class 8 trucks identified previously. Additionally, a forecast of the change in vehicle populations between 2020 and 2035 is provided to facilitate a discussion around the environmental impacts of Class 8 trucks in the present and future.
- **Current and Projected Environmental and Public Health Impacts of Class 8 Trucks by Technology:** This section builds upon established air quality challenges and Class 8 trucks in the South Coast Air Basin by assessing present and future air quality degradation due to harmful air pollutants, most notably DPM and NOx, as well as GHG emissions.

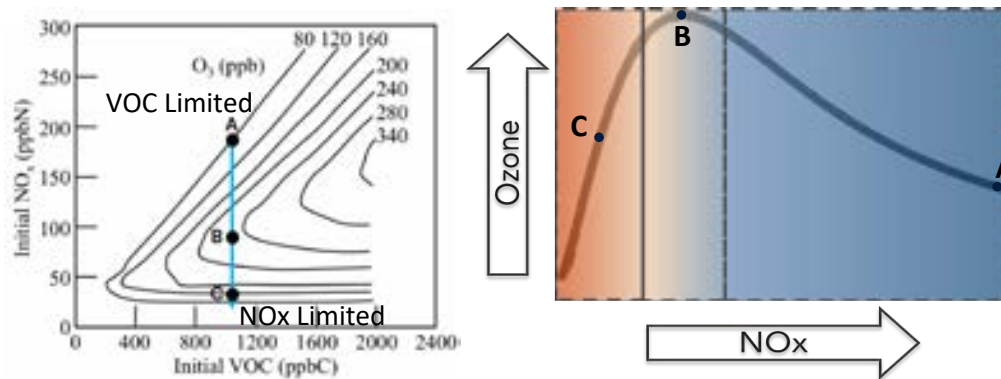
The contents of this report aim to facilitate better understanding and insights on current conditions of Class 8 trucks operating in LA County. The narrative developed in this report is intended to enable policymakers and Metro staff to take immediate, tangible steps towards meeting the agency's own technology, public health and climate goals.

2 Air Quality and Public Health in Los Angeles

LA County is the most populous county in the United States with more than 10 million inhabitants as of 2020. Over time, the number of vehicles and industrial facilities in the region has significantly increased, diminishing the ability to improve the air quality of the county. The major known air quality issue in LA County is the photochemical smog, which is a type of air pollution containing ground level ozone and other chemicals that is formed through a series of complex reactions of Nitrogen Oxides (NO_x) and Volatile Organic Compounds (VOCs) in the presence of sunlight. Ozone in the air we breathe can harm our health, especially on hot sunny days. People with asthma, children, older adults and people who are active outdoors are at most risk from breathing air containing ozone. Health problems from ozone exposure includes coughing, sore throat, difficulty breathing, aggravated lung diseases such as asthma and chronic bronchitis.

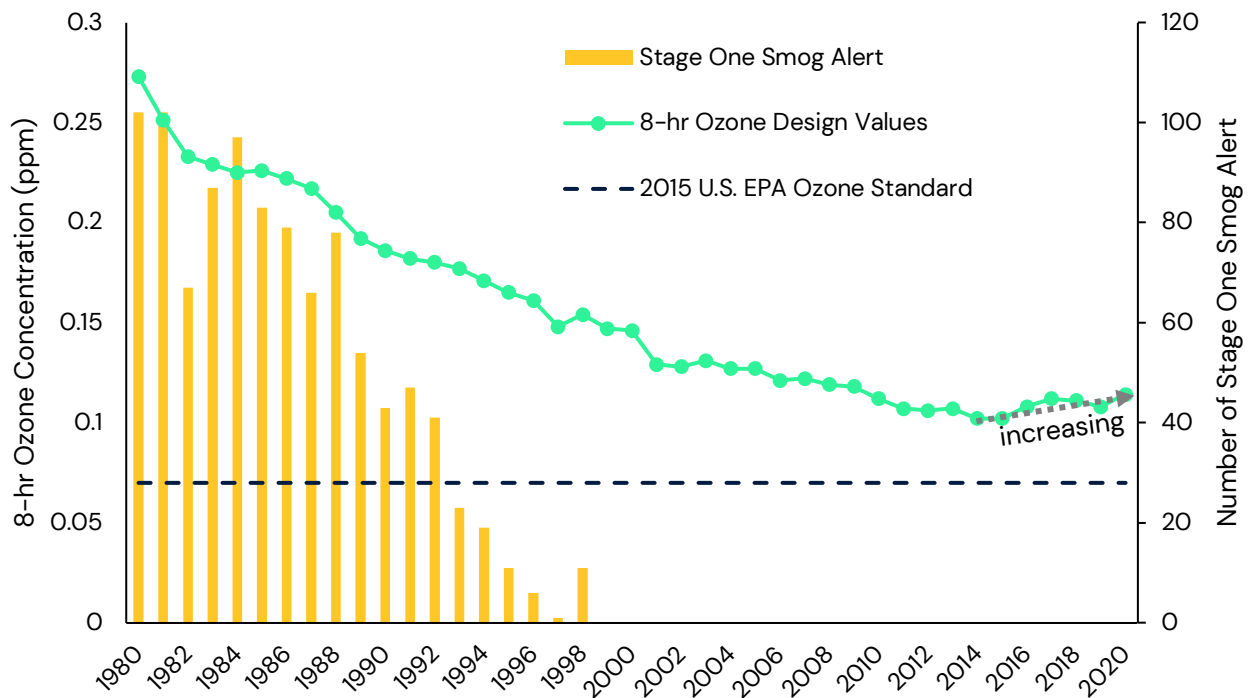
The complexity of ozone chemistry means that ozone levels will respond differently to changes in NO_x emissions depending on the amount of NO_x in the atmosphere. Figure 1 illustrates an example of this complexity. The chart on the left, also known as the *Ozone Isopleth*, shows the relationship of NO_x, VOC and ozone concentrations. When NO_x concentrations are high enough and VOC concentrations are low (point A), reducing NO_x emissions by moving from point A to point B can lead to an increase in ozone. This region is also known as a “VOC Limited” region. As NO_x emissions are reduced further, we pass a point where ozone remains constant as NO_x emissions are reduced (Point B). However, with further NO_x reductions we will move into a region where ozone will begin to decrease as a response to NO_x reductions (Point C). Point C is also referred to as a “NO_x Limited” region. The relationship of ozone concentrations and NO_x emissions are more clearly demonstrated in the right figure. In the blue-shaded region, reducing NO_x (from A to B) will lead to increased ozone concentrations, whereas in the red-shaded region ozone concentrations will start decreasing with reduced NO_x emissions. An isopleth plot provides valuable information on the future ozone sensitivity for different levels of NO_x and VOC emissions in a region with ozone air quality issues such as LA County. According to CARB’s analysis of air quality data in the South Coast Air Basin, currently many regions are within the NO_x limited region, however, there still exists regions that are within the VOC limited region (i.e., ozone concentrations will increase with reduced NO_x emissions). However, the agency’s extensive modeling analysis has demonstrated that the ultimate pathway to improve ozone air quality in the South Coast Air Basin is through reducing NO_x emissions, as VOC emission reductions alone would not allow LA County to reach air quality levels that are at or below National Ambient Air Quality Standards (NAAQS).

Figure 1. 8-hour ozone isopleth and ozone vs. NO_x relationship²



Despite significant population and economic growth, air quality in LA County has improved significantly over the years. As shown in Figure 2, the 8-hr average ozone design value in South Coast Air Basin has been continuously decreasing from 0.273 parts per million (ppm) in 1980 to approximately 0.114 ppm in 2020. Notably, the number of Stage One smog alerts went down from more than 100 event in 1980 to almost no events since 1999. Much of this progress is due to technology improvements implemented to help meet stringent emissions standards established by the U.S. EPA, CARB and SCAQMD.

Figure 2. 8-hr ozone design values in South Coast Air Basin and Number of Stage One Smog Alerts



² The chart on the left is only for illustration purposes and the chart on the right is extracted from CARB's Board Presentation on February 24, 2022

Even with substantial progress, however, many communities in LA County continue to suffer from exposure to high levels of ozone air pollution. Despite significant reductions in NOx and VOC emissions, ozone concentrations in the South Coast Air Basin have not been reduced in recent years. Adverse meteorology that is conducive for pollution buildup and high temperatures that produce more VOC emissions from evaporation and emissions from trees and vegetation have contributed to poor air quality. Complex ozone chemistry and VOC limited chemical conditions led to higher ozone levels despite on-going NOx emission reductions. The county is speculated to be undergoing a transition from VOC Limited (Point A in Figure 1) to NOx limited (Point B in Figure 1) where ozone remains constant despite NOx emissions reductions. This effect also emphasizes the importance of reducing NOx emissions at a much more rapid pace, especially since VOC emission reductions would not significantly impact ozone. To see meaningful decreases in ozone, LA County needs to work towards entering the NOx Limited region (Point C in Figure 1), which can only be achieved with dramatic NOx emissions reductions.

According to the latest Ozone NAAQS established by U.S. EPA in 2015³, the South Coast Air Basin where LA County is located is one of the only two areas in the country that is designated as an “extreme” ozone nonattainment area. As an “extreme” ozone nonattainment area, SCAQMD has until August 3, 2038 to attain the 2015 Ozone NAAQS for the Basin (dotted line in Figure 2), which is 20 years from the designation as an “extreme” nonattainment area. Aside from the 2015 Ozone NAAQS, the South Coast Air Basin is still in non-attainment with both 1997 and 2008 Ozone NAAQS of 80 and 75 ppb, respectively. The attainment date for the 1997 80 ppb Ozone NAAQS is June 15, 2024, and for the 2008 75 ppb Ozone NAAQS is July 20, 2032. Table 2 shows the ozone non-attainment classification for the South Coast Air Basin and their respective attainment deadline.

Table 2. Ozone Nonattainment Classification for South Coast Air Basin (from Draft 2022 Air Quality Management Plan⁴)

Standard	Level	South Coast Classification	Attainment Date
2015 8-hour Ozone	70 ppb	Extreme	August 3, 2038
2008 8-hour Ozone	75 ppb	Extreme	July 20, 2032
1997 8-hour Ozone	80 ppb	Extreme	June 15, 2024
1979 1-hour Ozone	120 ppb	Extreme	December 31, 2022

Failure to meet these NAAQS would not only have negative public health impacts but could also trigger various federal sanctions, including withholding of federal highway funds, which will impose adverse

³ In 2015, the U.S. EPA established a new ozone standard of 70 ppb. The design value of an air basin for the 2015 8-hour ozone standard is determined by the highest ozone value of all stations, based on a 3-year average.

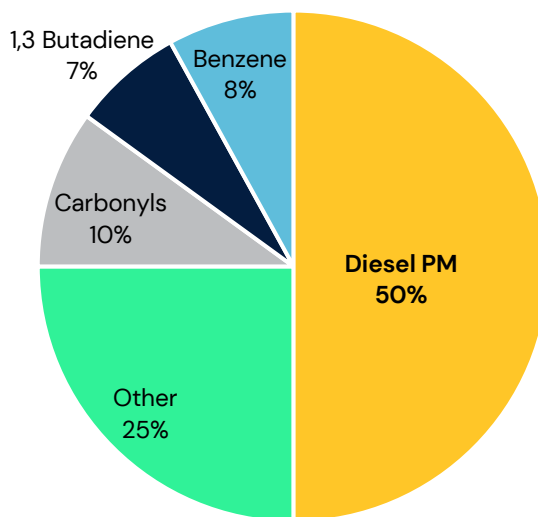
⁴ <http://www.aqmd.gov/home/air-quality/clean-air-plans/air-quality-mgt-plan>

economic impacts on the region. According to the Clean Air Act (CAA), where a region fails to attain the NAAQS or does not make necessary revisions to its state implementation plan (SIP), no transportation project or grant can be approved other than for safety, mass transit or transportation improvement projects related to air quality improvement or maintenance. Such federal sanctions will impede LA County's ability to continue moving goods to serve the regional and national demand and would result in adverse economic impacts on the region.

Aside from the regional air quality issues (e.g., non-attainment with NAAQS), there are many communities in LA County, often disadvantaged communities neighboring major freight facilities, which are suffering from concentrated exposure to air contaminants and high levels of local air pollution. For example, communities adjacent to ports, rail yards and warehouses are exposed to higher levels of DPM, a carcinogen in California⁵ that is associated with emissions from diesel ships, locomotives and trucks. Scientific studies have linked elevated long-term air concentrations of DPM to health effects for communities surrounding the Ports. These health effects include exacerbation of asthma, increased hospitalizations, premature birth and premature deaths from heart and/or lung diseases⁶.

In August 2021, SCAQMD released the MATES V final report, a monitoring and evaluation study that provides a detailed assessment of air toxics trends across communities in the South Coast Air Basin. According to this study, DPM is responsible for 50 percent of air toxics cancer risk⁷ in the South Coast Air Basin (Figure 3). As shown in Figure 4, the study also revealed that the highest levels of air toxics cancer risk are still around major ports, rail yards and transportation corridors, where many of the disadvantaged communities are located. MATES V also illustrated that almost 90 percent of the air toxics risks in the South Coast Air Basin are associated with emissions from mobile sources.

Figure 3. Cumulative Air toxics cancer risk, based on MATES V modeled data



⁵ Note that while diesel PM is considered as a carcinogen in California, U.S. EPA does not identify it as a carcinogen

⁶ Pope et al. 1995, 2002; Jerrett et al. 2005, Krewski et al, 2001

⁷ Note that MATES V estimates cancer risks by taking into account multiple exposure pathways, which includes inhalation and non-inhalation pathways

Figure 4. Modeled multi-pathway air toxics cancer risk from MATES V⁸ (2018 Base year)

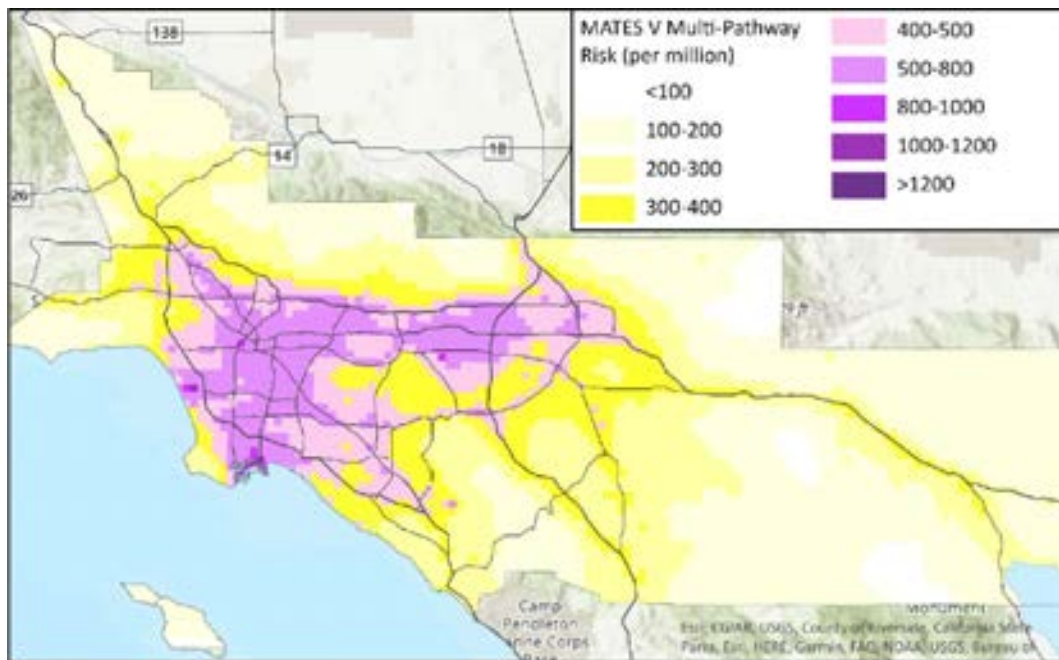
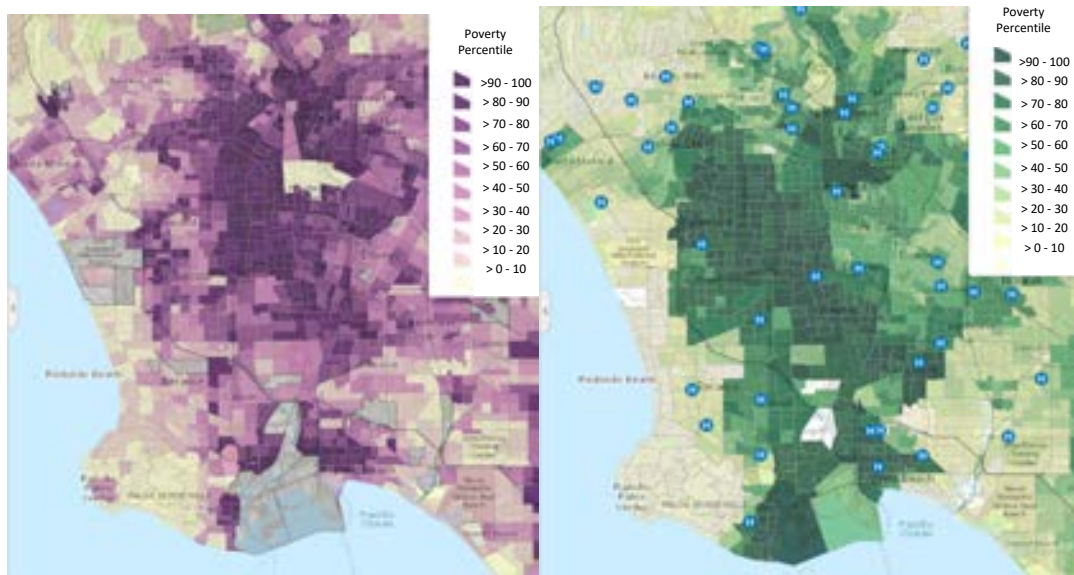


Figure 4 illustrates that the impact of air toxics emissions from mobile sources are not equitably distributed throughout LA County. As further demonstrated in Figure 5, a side-by-side comparison of asthma cases in LA County to poverty levels shows a strong correlation between regions with higher levels of poverty and high levels of asthma, and in fact those are the same regions with high levels of air toxics risk from mobile sources in LA County.

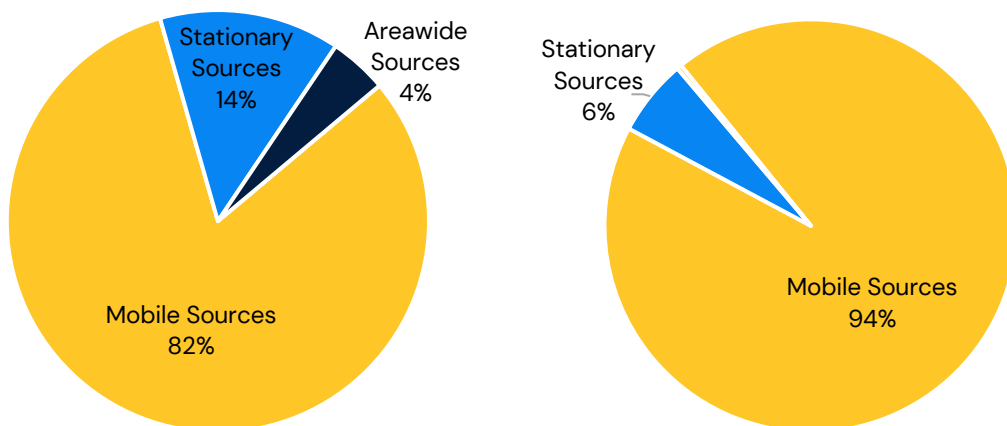
⁸ <http://www.aqmd.gov/docs/default-source/planning/mates-v/mates-v-final-report-9-24-21.pdf?sfvrsn=6>

Figure 5. Poverty (left) and asthma cases (right) in LA County⁹



To further illustrate the role of mobile sources on local and regional air quality issues in LA County, Figure 6 shows the estimated NOx and DPM contributions of mobile sources in 2022¹⁰. As shown, currently 82 percent of NOx emissions and 94 percent of DPM emissions in LA County are associated with mobile sources. Considering that LA County is home to the largest seaport complex in the nation, and over a third of all cargo imported to the nation comes through the Ports of Los Angeles and Long Beach, it is no surprise that goods movement activities in the region are responsible for the majority of air quality issues that the region has been experiencing over the past decades.

Figure 6. NOx (left) and Diesel PM (right) Emissions in LA County (calendar year 2022)



To better understand the impact of goods movement activities on emissions, Figure 7 shows the distribution of mobile source emissions among vehicle classes and equipment types. As shown, marine

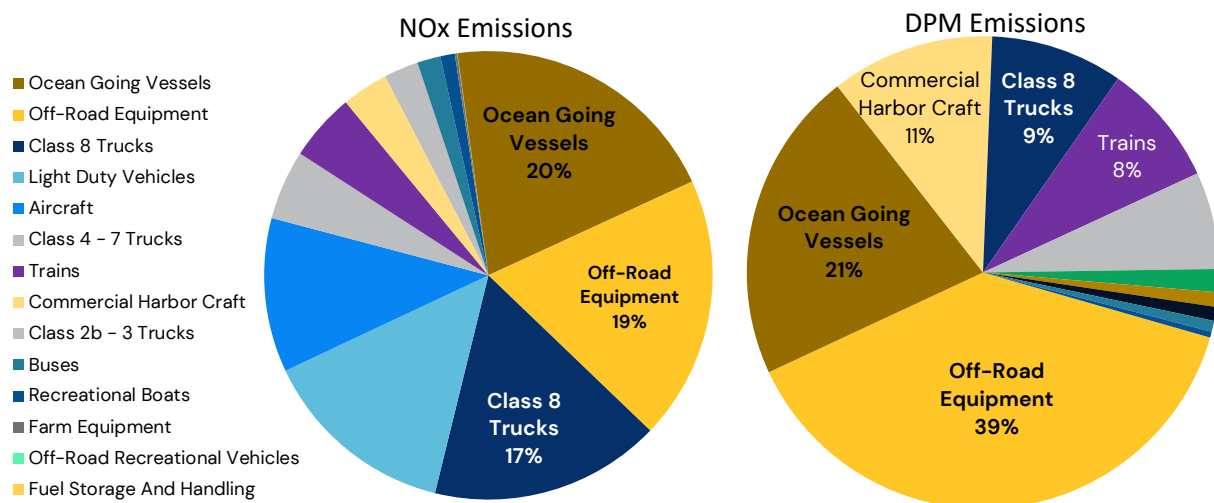
⁹ Based on CalEnviroScreen 4.0. <https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40>

¹⁰ California Emissions Projection Analysis Model, CEPAM2019v1.03, Link: <https://ww2.arb.ca.gov/applications/cepam2019v103-standard-emission-tool>

vessels such as ocean-going vessels and commercial harbor craft, off-road equipment (e.g., transport refrigeration units, cargo handling equipment, forklifts, etc.) and Class 8 trucks are among the top contributors of NOx and DPM emissions in LA County, all of which are major components of the goods movement industry in LA County. Of significant importance are the Class 8 heavy-duty trucks that operate in close proximity to schools and residential areas as they travel through communities. As shown, currently it is estimated that Class 8 trucks contribute to almost 17 percent of NOx and almost nine percent of DPM emissions within LA County.

Of all sources highlighted in this chart, heavy-duty trucks, especially Class 8 trucks, offer the greatest opportunity for emission reductions due to: a) recent technological advancements leading to the development and commercialization of near-zero¹¹ (i.e., low NOx natural gas) and zero emission technologies for this sector; and b) the State’s broad legal authority in controlling emissions from this sector. For this reason, we will focus on Class 8 trucks, and provide a detailed assessment of their operation and emissions impact within LA County. This is not to say that regulatory and planning agencies should ignore other sectors, but that the emissions reduction opportunities within Class 8 trucks and California’s authority to regulate make this sector an ideal target for air quality improvement programs.

Figure 7. NOx and DPM emissions by mobile source categories – LA County, 2022¹²



Aside from the air quality and public health impacts of Class 8 trucks, they are also responsible for a significant fraction of GHG emissions in California. As it will be further illustrated in the following sections, despite these trucks comprising less than 1 percent of vehicles on the road, they are responsible for more than 10 percent of GHG emissions from on-road vehicles in LA County. Currently, California has ambitious climate change goals to reduce its GHG emissions by 40 percent below 1990 levels by 2030, and reach

¹¹ While CARB’s Advanced Clean Truck (ACT) regulation defines near-zero emission vehicles (NZEV) as an on-road hybrid electric vehicle that has the capability to charge the battery from an off-vehicle conductive or inductive electric source and achieves all-electric range, in this report near-zero emission vehicles mainly refer to low NOx natural gas trucks certified to 0.02 g/bhp-hr NOx standard.

¹² California Emissions Projection Analysis Model, CEPAM2019v1.03, Link: <https://ww2.arb.ca.gov/applications/cepam2019v103-standard-emission-tool>

carbon neutrality no later than 2045. With the transportation sector and their fuels contributing to almost 50 percent of GHG emissions in California, it is no surprise to see that reducing GHG emissions from this sector is one of the top priorities of local and state agencies in California.

3 Categorization of Class 8 Trucks by Operational Characteristics and Duty Cycles

In the transportation sector, there are broad classes of vehicles that perform different kinds of jobs. Cars are used for commuting and personal travel, ships and other marine vessels transport large cargo by sea to ports, and heavy-duty trucks receive and deliver payloads nearly anywhere. These vehicles, despite having different engines and fuel inputs, are all mobile sources of air pollution. Over time, U.S. EPA and CARB have set emissions standards on mobile sources to regulate the criteria pollutants, toxic air pollutants and GHG emissions generated by their operation. Mobile sources are often further distinguished by other vehicle metrics, such as weight and purpose.

This report focuses on the impact mobile sources have on air quality in LA County and takes special interest in the proportion of air pollution that comes from heavy-duty Class 8 trucks. The significant impact heavy-duty Class 8 trucks have on air quality merits a deeper understanding of the different types of heavy-duty Class 8 trucks, as well as their operational duty cycles. Doing so enables a more comprehensive assessment of what types of trucks operating in LA County are contributing to deteriorating air quality. In the following section, the most recent vehicle data is leveraged to form baseline or business-as-usual conditions to develop projections of environmental impacts. The goal of this assessment is to provide potential environmental impacts of this sector and provide supporting evidence of the need to transition certain truck populations towards cleaner technologies.

3.1 Types of Trucks Operating in Southern California

The EMFAC2021 model is used to obtain the most recent vehicle information on light-duty through Class 8 vehicles in LA County. The emphasis of this work is placed on heavy-duty Class 8 trucks, which are distinct from other mobile sources by weight, having a gross vehicle weight rating greater than 33,000 lbs. Additionally, heavy-duty Class 8 trucks can be further categorized by use or purpose, and whether the vehicle is registered in- or outside the state of California.

In general, most Class 8 trucks are either single-body or tractor-trailer combinations. Single-body trucks do not have detachable trailers and can be fitted to have moving equipment, such as a waste compactor or "bucket" (a sky lift for people to reach high working heights). Tractors are a class of trucks meant to pull trailers. The next section continues the heavy-duty truck overview by describing the typical duty cycles for trucks in LA County. The following list is intended to summarize the different types of heavy-duty Class 8 trucks most recently in LA County:

- **Out of State**

- Out of State trucks refer to trucks that are not registered to the state of California. This category would include trucks from neighboring and non-neighboring states that are deployed to move goods through California.
- **California Registered Intrastate**
 - California Registered Intrastate trucks refer to tractor-trailer combination trucks that move heavy loads, livestock, and refrigerated trailers and only operate within California boundaries.
- **California Registered Interstate**
 - California Registered Interstate trucks travel within and outside California. Trucks in this category can be identified through the International Registration Plan¹³ (IRP) for the latest population and operations information. These are commonly tractor-trailer combination trucks that can move heavy loads and goods across states.
- **Drayage**
 - Trucks that pick up and deliver shipping containers from Ports or intermodal railyards to other facilities. In EMFAC2021 model, drayage trucks are defined as California registered Class 8 trucks that on average visit the ports two times a week.
- **Single Unit**
 - Single Unit trucks are often single-body trucks that are more purpose oriented. The following list describes different examples of Single Unit trucks found in Southern California:
 - Concrete: Trucks that slowly rotate cement-rock mixes into concrete.
 - Dump: Trucks with hydraulically actuated open-box beds to store materials for transport and deposition.
 - Solid-Waste Collection: Trucks that collect waste receptacles and compact trash for transport to a waste facility.
 - Utility: Trucks used by private- or public utilities, such as Pacific Gas & Electric (PG&E) and Southern California Edison (SCE), to carry equipment and line men to job sites.
 - Delivery: Single body trucks with broad transport purposes that can be found on highway and non-highway roads. Examples include parcel delivery, beverage delivery, and local refrigerator trucks.

3.2 Heavy-Duty Class 8 Truck Operation

3.2.1 Typical Operating Conditions and Duty Cycles

In May 2017, CARB released its final report titled Collection of Activity Data from On-Road Heavy-Duty Diesel Vehicles¹⁴, which documents observed vehicle activity patterns to develop its regional emissions inventory of on-road mobile sources. This study provides vehicle and engine activity data for 90 heavy-duty vehicles by activity type across California, including those identified by the EMFAC2021 and EMFAC2011 models. A separate data repository from National Renewable Energy Laboratory (NREL)

¹³ The International Registration Plan is a registration reciprocity agreement between the contiguous United States and Canadian provinces, which provides apportioned payments of registration fees, based on the total distance operated in participating jurisdictions, to them

¹⁴ <https://ww2.arb.ca.gov/sites/default/files/classic/research/apr/past/13-301.pdf>

called Fleet DNA¹⁵ also provides duty cycles of commercial vehicle operations, such as tractor trucks and delivery trucks, and is used to support CARB vehicle activity pattern descriptions. A duty cycle is a series of data points that describe the relationship between the speed of a vehicle over time, meant to represent that vehicle's "typical" driving pattern. Duty cycles are instrumental to vehicle performance and emissions testing when performed on chassis dynamometers, since other data, such as energy consumption or temperature, can be recorded to garner insight on how the vehicles will perform in real-world settings. Duty cycles are also immensely useful in vehicle simulations, they can be used as model inputs to predict performance of engines, electric drive systems, batteries, hydrogen fuel cells, and other systems without a dynamometer or other equipment. In general, duty cycles are developed by research institutes or transportation agencies, so that they are standardized.

The duty cycle development is a statistically intricate process, meaning that although the final product is instantaneous speed versus time in seconds, duty cycles can be constructed from GPS-velocity data, probabilistic joint speed-acceleration calculations, and even averaging different snippets of duty cycles (snippets can come from the raw data of the duty cycle in development or other raw data from other vehicles performing the duty cycle). How particular duty cycles are developed is outside the scope of work. Instead, ICF leverages CARB's 90 heavy-duty vehicle study, which developed Class 8 truck duty cycles in Southern California and can be characterized by four groups as discussed below:

1. **Line- and Long-Haul Trucks - Highway Cruising¹⁶:** A duty cycle for California Registered Interstate and Out of State trucks (sometimes referred to as long-haul trucks) is shown in Figure 8. Trucks with highway cruising duty cycles can spend between 53 percent through 68 percent of the time traveling at highway speeds. A small portion of the typical duty cycle is at lower speeds on non-freeway roads, where trucks travel between a freeway and an origin or destination. According to the 90 heavy-duty vehicle study, California Registered Intrastate trucks (sometimes referred to as line-haul trucks) have more engine starts and idle for significant portions of an operation day as compared to Interstate trucks, which have much fewer engine starts and spend few hours idling. This difference is emphasized in Figure 9, which shows shorter freeway-speed travel sections over the same time. This suggests that Intrastate trucks make more frequent stops than Interstate or Out of State trucks, but the exact reason why is not explicitly qualified in the 90 heavy-duty vehicle study.

¹⁵ [Fleet DNA: Commercial Fleet Vehicle Operating Data | Transportation and Mobility Research | NREL](#)

¹⁶ The average daily mileage and average trip distance reflect daily operations statistics and are not meant to summarize the statistics of the duty cycle. In example, the long haul duty cycle describes a trip of 21 miles that occurred in 26 minutes. On average, however, a long haul truck will travel at least 200 miles per day with a trip average distance of 67 miles per day.

Figure 8 - Long-Haul Duty Cycle for Interstate and Out of State Trucks

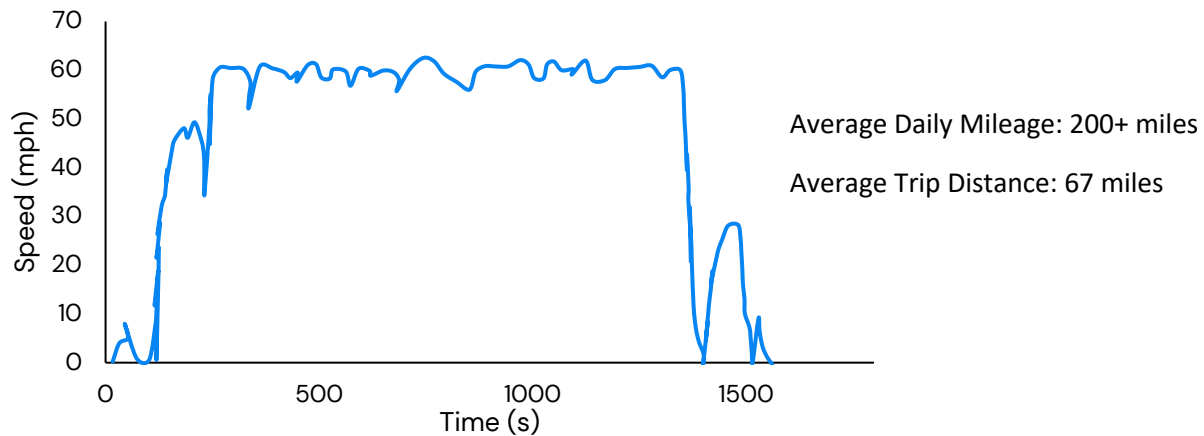
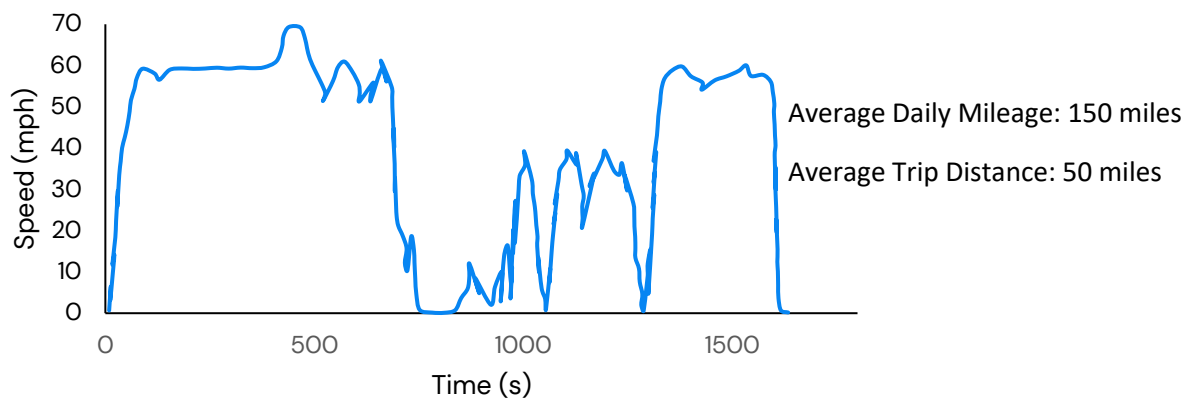
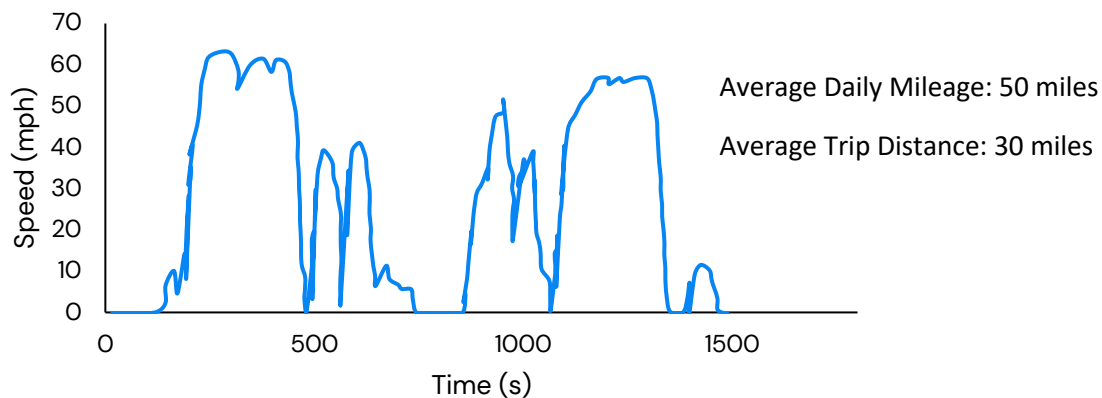


Figure 9 - Line-Haul Duty Cycle for Intrastate California Registered Trucks



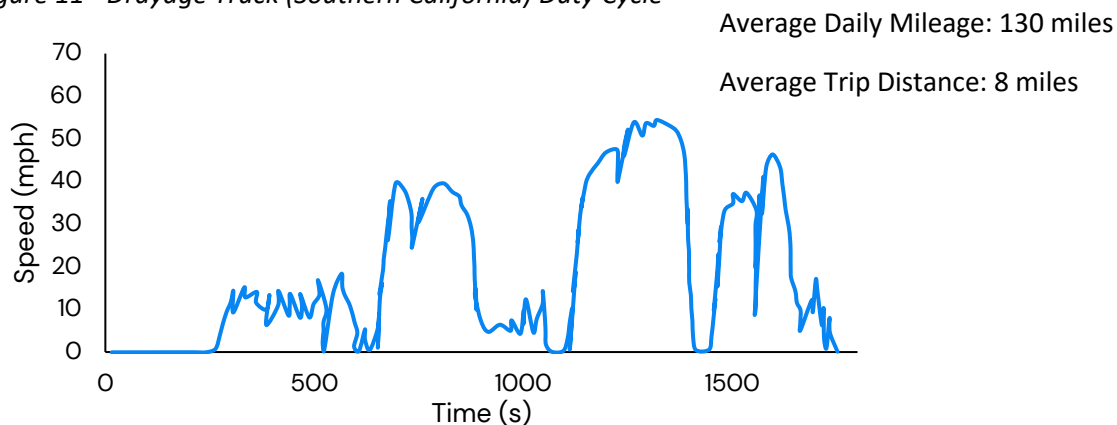
2. **Single Unit Trucks - Mixed Driving:** A duty cycle for Single Unit trucks is shown in Figure 10. Trucks with Mixed Driving duty cycles perform freeway and non-freeway driving in urban areas. Freeway driving makes up of one or more short segments (representing a situation where the vehicle gets on a freeway, cruises over a short distance, and then gets off the freeway). There are larger portions of non-freeway driving as compared to line- and long-haul trucks with highway cruising duty cycles, since there are shorter trips between locations without having to drive on the freeway. Other vocations whose duty cycle falls within Mixed Driving are delivery trucks, which have broad goods movement purposes in localized areas. Delivery trucks often travel through stretches of highway and non-highway roads to transport construction materials, food, and heavy goods movement applications.

Figure 10 - Single Unit Truck Duty Cycle



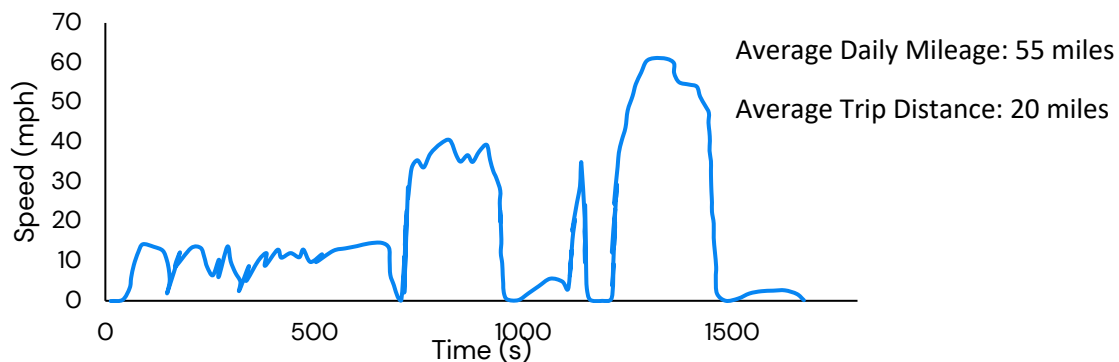
3. **Drayage Trucks - Mostly Transient:** Drayage trucks are characterized by mostly transient duty cycles as shown in Figure 11. The duty cycle of these trucks is a combination of highway as well as local arterial driving – when these trucks pass through the communities or local roads. There are often significant portions of idle time and “stop and go” operations in and around the ports and intermodal railyards as well as when the truck is picking up or dropping off freight.

Figure 11 - Drayage Truck (Southern California) Duty Cycle



4. **Utility Trucks - Mostly Creeping:** A duty cycle for Utility Trucks is shown Figure 12. Trucks with a mostly creeping duty cycle spend most of the time at low speeds or idling while the vehicles are performing their job. It is possible for trucks with this duty cycle to come up to highway speeds briefly as they travel to and from job site. Other trucks with a similar duty cycle are sweeping and refuse trucks.

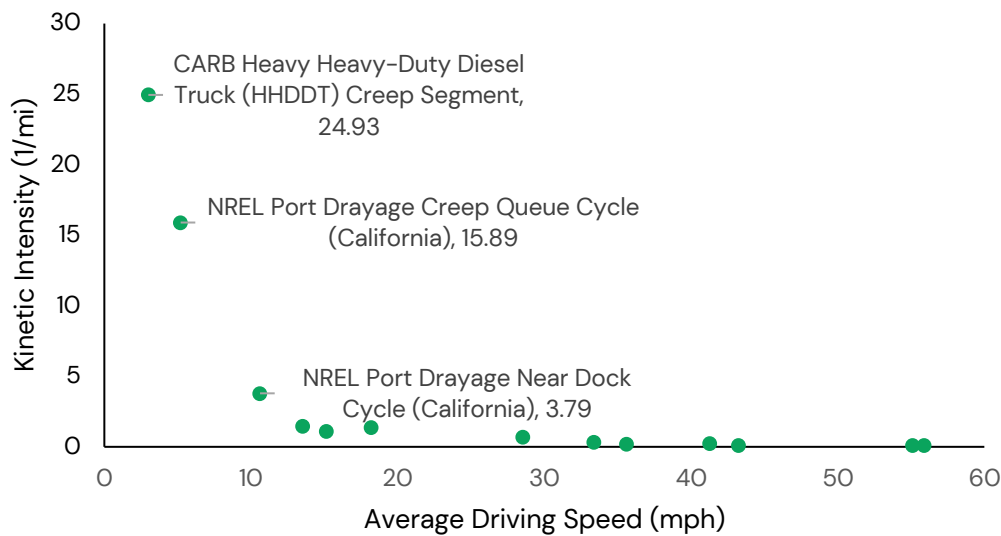
Figure 12 - Utility Truck Duty Cycle



The assessment of duty cycles performed by diesel-powered heavy-duty trucks merits an outlook on what alternative vehicle technologies are available to perform the same duty cycles more efficiently (i.e., perform the duty cycle with less energy demand). In other words, it is important to determine what zero- or near-zero (i.e., low NO_x natural gas) emission technologies are available and may be suitable replacements for the eventual technology transition. One way to garner insight on this subject is to look at a duty cycle metric called kinetic intensity. Kinetic intensity is a quantitative property that describes how much “stop-and go traffic” exists in a duty cycle. Quantitatively, the kinetic intensity is just the ratio of aerodynamic speed to acceleration, both of which can be obtained from duty cycles. It is valuable to consider the kinetic intensity of a duty cycle because the greater the kinetic intensity, the more likely a hybrid or electric vehicle would be suitable for operation of that duty cycle compared to the internal combustion vehicle. It should be noted that kinetic intensity analysis is not exclusive to any vehicle technology, meaning that this analysis can be performed for internal combustion, battery-electric, and hydrogen fuel cell vehicles.

Different duty cycles will also impact vehicle performance differently, most commonly miles per gallon (MPG) and emissions. For example, an electric vehicle will have higher MPGe in a city-type duty cycle compared to a long-haul-type duty cycle, because there is less resistance at lower speeds and greater potential of energy recuperation via regenerative braking available on electric powertrain platforms. In Figure 13, NREL calculated the kinetic intensities of different duty cycles and compared them to their average speeds to provide supplemental perspective on what duty cycles with high kinetic intensities look like – three are labeled. Recall that duty cycles with high kinetic intensity, or a lot of “stop and go”, should intuitively have lower average speeds. The intent of this discussion is to highlight that heavy-duty trucks that perform duty cycles with high kinetic intensities are ideal candidates for transitioning into electric vehicle technologies.

Figure 13 - Kinetic Intensity of Heavy-Duty Trucks



3.2.2 Typical Vehicle Miles Traveled by Vehicle Category

The 90 heavy-duty vehicle study also provides insight on the typical range or expected distance that different types of trucks cover during normal operation. The vehicle categories pertinent to this report can be broadly grouped into four activity patterns, as listed below:

1. **Long Haul:** Long haul trucks typically travel more than 200 miles per day. The majority of VMT occur on highway and freeway roads.
2. **Short Haul:** Short haul trucks generally travel between 100 to 200 miles per day. More of the VMT occurs on city streets and low volume roads compared to long haul trucks.
3. **Pick-up and Delivery:** Delivery trucks pick up and deliver goods locally in urban areas. Their duty cycles involve a significant amount of idling for loading and unloading.
4. **Service-oriented:** This group mainly consists of single unit trucks. They have low VMT per day due to fewer and shorter trips per day, where each trip involves a long stop to perform service. Some trucks may also require power take off (PTO) during the period that they perform the service.

Data extracted from EMFAC2021 were used to calculate the total annual VMT per vehicle category and an average daily VMT per vehicle category for 2022, which is summarized in Table 3. Based on the 90 heavy-duty vehicle study and the data in Table 3, it can be inferred that California Registered International Registration Plan (CAIRP) Interstate and Out of State trucks will have long-haul duty cycles associated with their work. Drayage trucks, by suggestion, may be considered short haul trucks, whereas CAIRP Intrastate and Single Unit trucks can fall between Delivery and Service-Oriented work patterns.

Table 3 - Range of VMT for Los Angeles County Trucks in 2022

VMT (per vehicle)	Single Unit	CAIRP Intrastate	CAIRP Interstate	Drayage	Out of State
Annual	19,344	25,584	64,684	40,248	81,744
Daily	62	82	207	129	262

Percent of Total	8%	11%	28%	17%	35%
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In LA County, Single Unit trucks – those owned by private agencies and municipalities to transport 1 to 2 workers across job sites within the workday – have the lowest VMT per day per vehicle. On the other hand, California Registered Interstate and Out of State trucks dwarf Single Unit truck VMT per day, traveling at least 3.7 times greater distances than the more service-oriented Single Unit trucks.

4 Current and Projected Class 8 Truck Populations in LA County

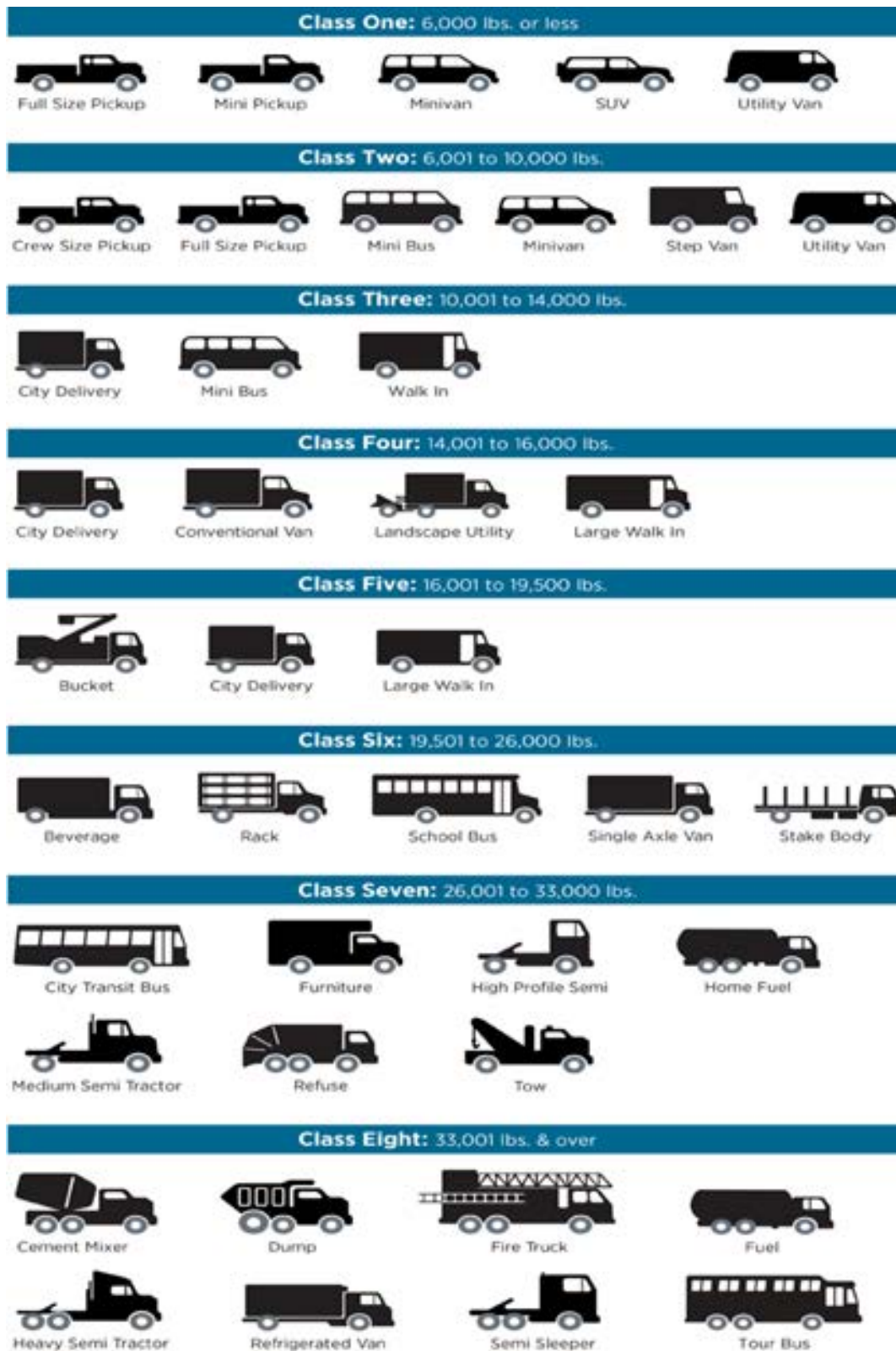
4.1 Current Class 8 Truck Population in LA County

To estimate the current Class 8 truck population, the EMFAC2021 (v1.0.2) tool¹⁷ was used to obtain an on-road mobile emissions for both criteria and GHG pollutants. To summarize, LA County summer on-road emissions for calendar years 2020 through 2050 are selected. All vehicle categories, as well as all model years of vehicles and fuel types are made available. Though all fuel types are selected, this work primarily focuses on gasoline, natural gas, diesel, and electricity fuel types. Finally, the data is processed in Excel and group filters are applied to sum vehicles or total emissions per category.

In this report, the scope of work is primarily concerned with the Class 8 truck population in LA County. Although all Class 8 trucks share the same weight class, consider the following images that come to mind - “semi-truck”, “18-wheeler”, and “big-rig”; these names are often used interchangeably to describe Class 8 trucks, though there are differences. For visual context, a table from the Alternative Fuels and Data Center is presented in Figure 14, with thumbnails for the most common vehicles between Classes 1 through 8.

¹⁷ <https://arb.ca.gov/emfac/>

Figure 14 - Types of Vehicles by Weight Class



In Figure 15, total vehicle population by category (excluding light-duty vehicles for emphasis on heavier vehicles) is illustrated (absolute numbers are shown in Table 4). Class 8 trucks and buses comprise nearly a quarter of heavy-duty vehicles considered in this analysis. More specifically, LA County currently has a Class 8 truck population of 55,626 vehicles on a daily basis¹⁸.

Figure 15 - Medium/Heavy-Duty Vehicle Populations for LA County 2022

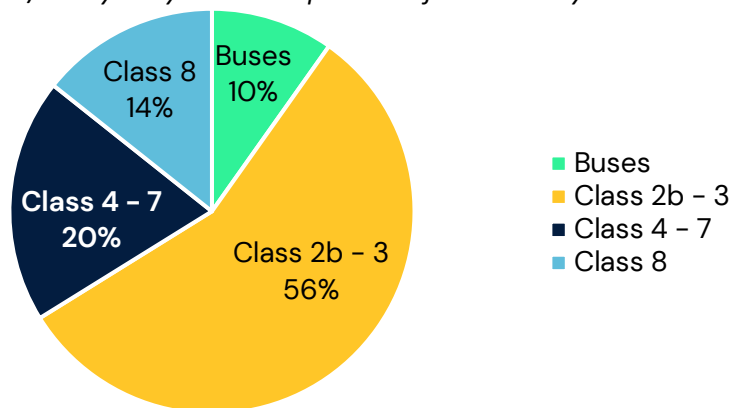


Table 4 - Medium/Heavy-Duty Vehicle Populations for LA County 2022 (Absolute Numbers)

Vehicle Class	Population
Buses	38,150
Class 2b - 3	218,995
Class 4 - 7	75,879
Class 8	55,626

In Figure 16, the types of trucks within the heavy-duty Class 8 truck population are shown (absolute numbers are shown in Table 5). The data in Figure 16 is an estimate based on operation criteria, and may not be comprehensive of trucks that perform multiple types of revenue generating services. For example, a tractor can perform drayage duties one day and food delivery the next day, and this would not be discerned by the data in Figure 16. Here, EMFAC2021 drayage trucks are defined as California registered trucks that on average visit the Ports twice a week. While these trucks can do other businesses, the selection of two visits per week is a conservative assumption to distinguish dedicated Port trucks from non-dedicated ones.

Although the Single Unit truck category represents 34 percent of the trucks examined, this category encompasses a multitude of truck types that are comparable by body type (e.g., delivery trucks, cement mixers, dump trucks, and other trucks where the whole vehicle is considered as one piece unlike tractor-trailers). Other vehicle types, such as CAIRP Intrastate and Drayage trucks, also represent significant proportions of the Class 8 truck population, falling in line with the established California freight economy.

¹⁸ This number represent the number of trucks that operate on LA County roadways on a typical day.

Figure 16 - Class 8 Trucks by Vehicle Type for LA County 2022

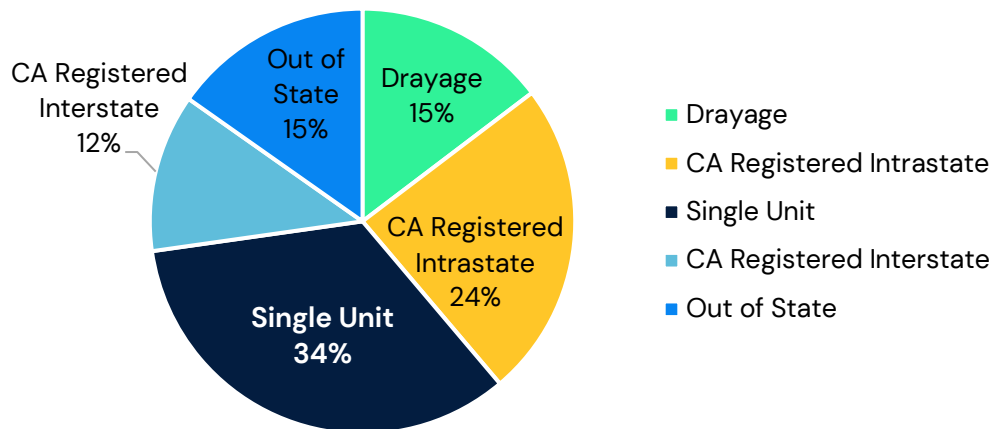
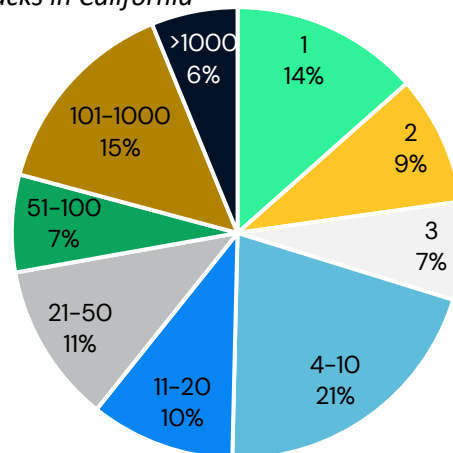


Table 5 - Class 8 Trucks by Vehicle Type for LA County (Absolute Numbers)

Vehicle Type	Population
Out of State	8,473
Drayage	8,163
CA Registered intrastate	13,430
CA Registered Interstate	6,680
Single Unit	18,880

With respect to ownership characteristics, we used data extracted from the CARB's fleet database to illustrate the fleet size distribution of Class 8 trucks operating in California. CARB's fleet database only provides fleet size information for trucks that are registered in California and does not provide data on out of state trucks. As shown in Figure 17, almost 30 percent of California registered Class 8 trucks belong to fleets of 1-3 vehicles, 42 percent belong to fleets of 4-50 vehicles, and 28 percent are associated with fleets of 51 or more trucks. This is specifically important as the upcoming CARB's proposed Advanced Clean Fleet Regulation is planning to target fleets that either have more than 50 trucks or have more than \$50 million in annual business revenue. Please note that CARB's regulation is going to cover all drayage trucks and public fleets regardless of their fleet sizes.

Figure 17. Fleet size distribution of Class 8 trucks in California

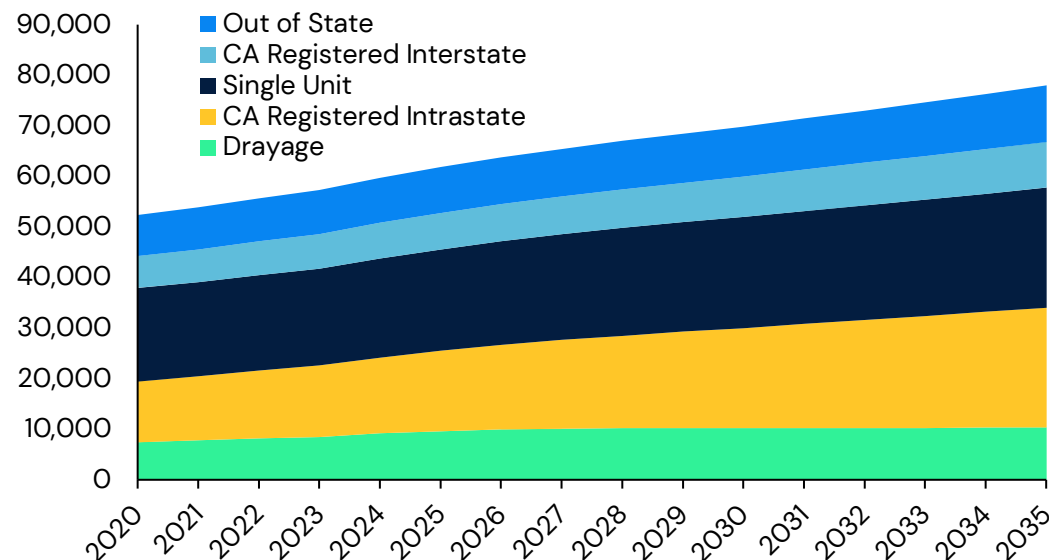


4.2 Projected Class 8 Truck Populations in LA County

The EMFAC2021 model also has the ability to forecast the population of Class 8 trucks using both national projections of trucks sales from the Annual Energy Outlook as well as the California freight travel demand

projections from the California Statewide Travel Demand Model (CSTDm). The results for forecasted Class 8 truck growth between 2020 and 2035 are shown in Figure 18. The total truck population in LA County is expected to go from 55,626 in 2022 to 77,954 in 2035, an increase by 40 percent by 2035. Within the next decade, the number of California registered Interstate and Intrastate trucks are expected to increase significantly by 35 percent and 76 percent, respectively. Unlike the other truck categories, the population of drayage trucks is expected to plateau post 2035, due to cargo capacity limitation associated with the Ports.

Figure 18 - Projected Class 8 Truck Population in LA County

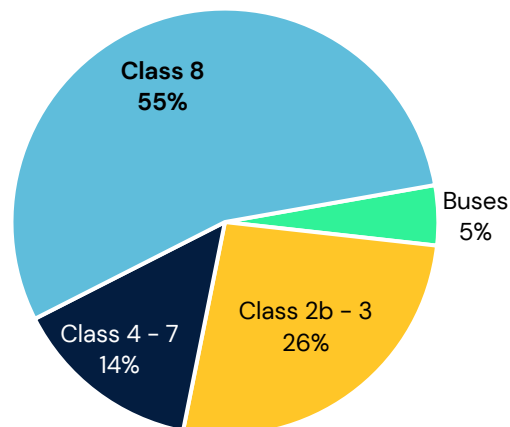


5 Current and Projected Environmental and Public Health Impacts of Class 8 Trucks by Technology

To further illustrate the current and projected climate, air quality, and health impacts of Class 8 trucks, we extracted from EMFAC2021, DPM, NOx, and GHG emissions of Class 8 trucks in LA County for years 2020 through 2035. In Figure 19, total DPM exhaust emissions by vehicle class (excluding light-duty vehicles for emphasis on heavier vehicles) are illustrated. Currently, more than half of all DPM from heavier vehicle classes comes from Class 8 truck operations.

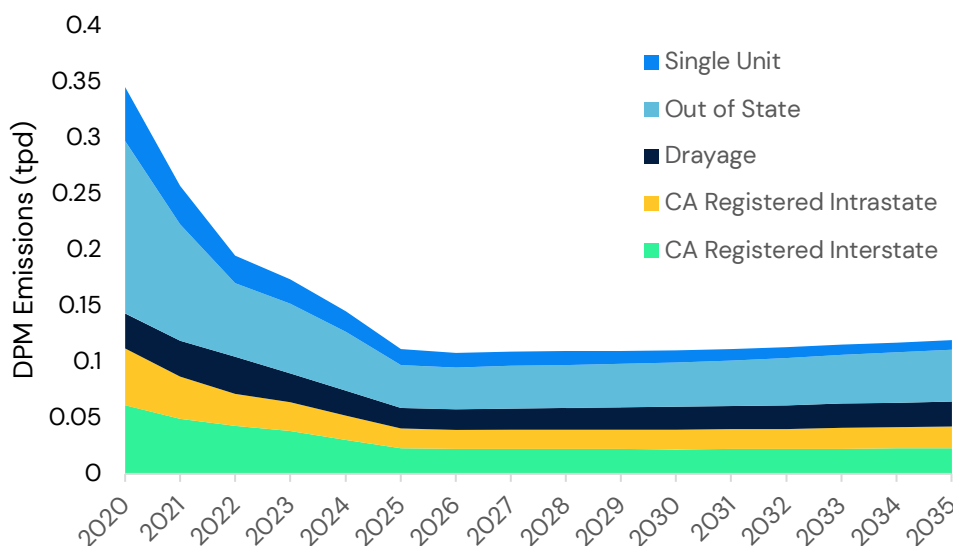
Taking a closer look at the environmental impact of Class 8 trucks, Figure 20 shows projected DPM emission breakdown by truck type between 2020 through 2035. In 2022, Class 8 trucks in LA County are estimated to emit 0.19 tons of DPM per day, and due to stringent regulations established by CARB such as Truck and Bus regulation and Advanced Clean Trucks (ACT), this emission amount is forecasted to decrease to 0.12 tons per day by 2035. Most notably, DPM contributions from both CAIRP Registered Interstate and Single Unit trucks are expected to decrease by 46 percent and 65 percent, respectively, between 2022 and 2035. These marked decreases in DPM contributions can also be attributed to the anticipated impacts of the Heavy-Duty Inspection and Maintenance Program¹⁹ (HD I&M) Program, which aims to significantly curb DPM emissions²⁰. The HD I&M program, adopted in December 2021, requires affected heavy-duty vehicles operating in California to perform periodic emissions testing to ensure and demonstrate that their emission control systems operate properly.

Figure 19 - Heavy-Duty Vehicles DPM Emissions LA County 2022



While trucks are not the only source of DPM, emissions from trucks are often occurring near schools, and residential areas as they travel through communities. Such proximity makes Class 8 trucks a significant source of air pollution exposure in these communities. The increase in DPM emissions as illustrated in Figure 20 is concerning especially from a public health standpoint.

Figure 20 - Class 8 Truck DPM Emissions LA County



¹⁹ https://ww2.arb.ca.gov/rulemaking/2021/hdim2021?utm_medium=email&utm_source=govdelivery

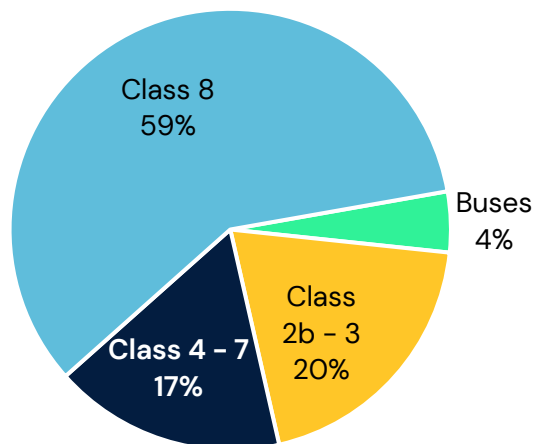
²⁰ The emissions inventory for the EMFAC2021 is adjusted with a scaling factor based on the Heavy-Duty Inspection and Maintenance Program to best reflect impact on emissions as a result of policy.

In Figure 21, total NOx exhaust emissions by vehicle class (excluding light-duty vehicles for emphasis on heavier vehicles) are illustrated. Similar to DPM emissions, Class 8 trucks comprise more than half of all NOx emissions from heavier on-road mobile sources as of 2022.

Figure 22 illustrates projected NOx contributions from Class 8 trucks by type between 2020 through 2035. In 2022, Class 8 trucks in LA County produce 24 tons of NOx per day, but this amount is forecasted to decrease to 8 tons per day by 2035 under baseline conditions. This reduction in NOx is mainly attributed to recent regulations in California requiring heavy-duty diesel engines of model year 2024 and newer to meet more stringent standards of 0.05 g/bhp-hr in between 2024 and 2026, and 0.02 g/bhp-hr for 2027 and newer model years which result in almost 90 percent reduction in NOx from today's level²¹. It is noteworthy to mention that this standard only applies to trucks sold in California.

According to CARB's estimates, almost 66 percent of Class 8 truck operation in the South Coast Air Basin is associated with trucks that were not originally sold in California – either out of state trucks or used trucks that are brought into the region. This is also apparent from the NOx emission trends for Out of State trucks where their share of NOx emission is expected to increase by 21% relative to current conditions. It is noteworthy to mention that U.S. EPA is currently considering a new set of standards for model year 2027 and newer heavy-duty engines that will reduce NOx emissions for all new trucks operating across the country²².

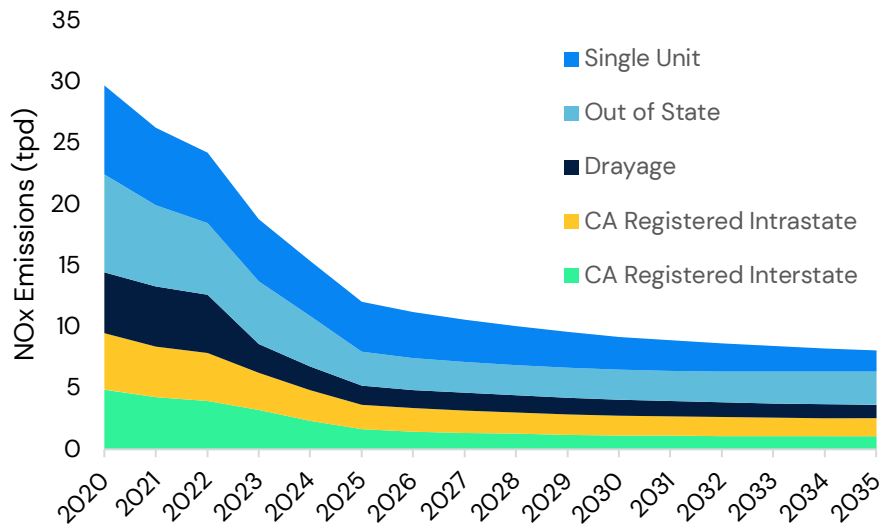
Figure 21 - Heavy-Duty Vehicles NOx Emissions – LA County - 2022



²¹ <https://ww2.arb.ca.gov/rulemaking/2020/hdomnibuslownox>

²² <https://www.epa.gov/regulations-emissions-vehicles-and-engines/clean-trucks-plan>

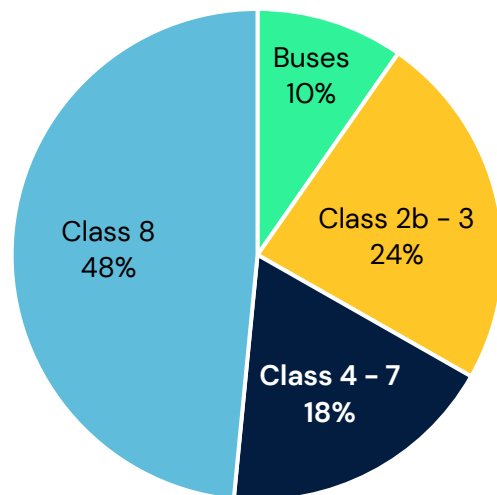
Figure 22 - Class 8 Truck NOx Emissions – LA County



In addition to high NOx and DPM contributions, heavy-duty Class 8 trucks are also responsible for a significant fraction of GHG emissions. It is interesting to note that while Class 8 trucks only comprise less than one percent of all vehicles operating on LA County roadways, they are responsible for almost 10 percent of GHG emissions from on-highway vehicles. Total GHG emissions by heavier vehicle classes are illustrated in Figure 23, where light-duty vehicles are omitted for the reasons discussed. Even considering the significant differences in population and duty cycles, Class 8 trucks contribute almost half of all GHG emissions relative to other heavier vehicle classes.

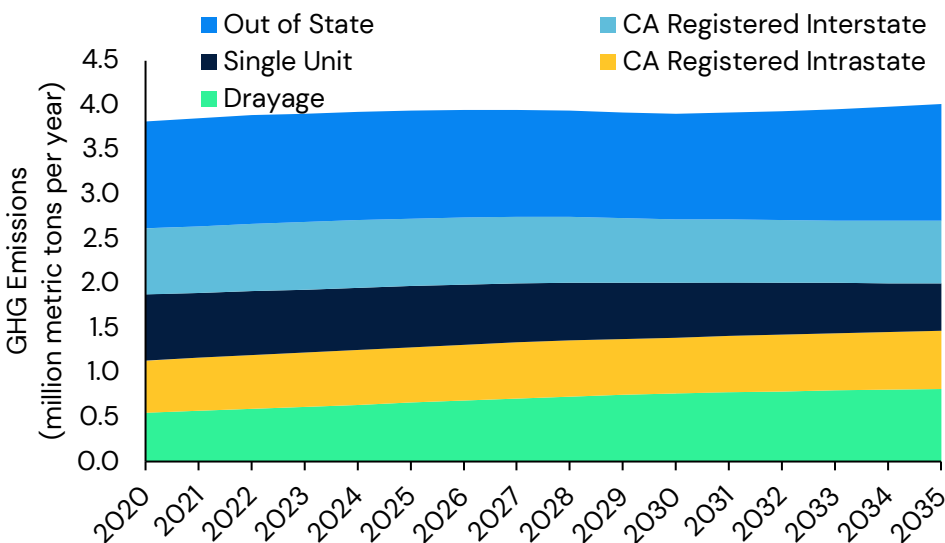
As with DPM and NOx contributions, the EMFAC2021 model enables peering into the short- through long-term GHG emissions from Class 8 trucks in LA County, as shown in Figure 24. In 2022, Class 8 trucks in the region produced 3.8 million metric tons of GHG emissions per year, and this quantity is forecasted to increase to 4 million metric tons per year by 2035 under baseline conditions; Class 8 truck GHG emissions in LA County across the board are not expected to increase significantly over time. For example, CAIRP Intrastate and Out of State truck GHG emissions increase by an average of 7.5 percent by 2035. Other truck types, such as CAIRP Interstate and Single Unit, are projected to have 7 percent and 26 percent lower GHG emissions by 2035, respectively. These reductions are mainly due to the Phase 1 and Phase 2 GHG emissions standards established by U.S. EPA, as well as the zero emission mandates

Figure 23 - Heavy-Duty Vehicles GHG Emissions LA County - 2022



established by CARB as part of the Advanced Clean Truck regulation. However, among all trucks, GHG emission contributions from drayage trucks are estimated to increase by 38 percent by 2035.

Figure 24 - Class 8 Truck GHG Emissions - LA County



The observation on drayage truck GHG emissions in Figure 24 is not surprising, especially when considering the fact that drayage trucks have some of the slowest turnover rates (i.e., typically drayage trucks are second- or third-hand trucks and are often, without policy interventions, the last sector that reflect the impact of emissions standards) and older trucks are known to pollute more. Knowing that drayage trucks are responsible for significant shares of air pollutant emissions, as well as GHG emissions, may encourage accelerated transition of near-zero and zero emission vehicle technologies at the ports to curb the environmental impacts of Class 8 trucks. The proposed ACF regulation, as well as upcoming drayage truck policies, would address this issue directly. The associated impacts on second- and third-hand truck markets may also lead to further reduced emissions, but this has yet to be determined in the scope of work.

6 Summary

This report is the beginning of a synthesis of analyses intended to inform policymakers and Metro staff on how to meet its public health and climate goals. In this report, the evolution of air quality in LA County is recounted to draw attention towards mobile sources of air pollutants and emissions. Developing a lay of the land for Class 8 truck operations in LA County shows that fleets of CAIRP Inter- and Intrastate trucks, Out of State trucks, and drayage trucks are the primary sources of criteria pollutants and GHG emissions relative to other heavier vehicle classes (single unit and buses). This report also illustrates the diversity of operations among various Class 8 trucks, and discusses that zero-emissions technology readiness could vary significantly depending on their duty cycles.

Report 2 will explore the technology status and readiness level for Class 8 trucks, and what is needed to transition the long-haul heavy-duty trucks into zero and near-zero (i.e., low NOx natural gas) emission technologies.

Key Takeaways

- The complexity of ozone chemistry means that ozone levels will respond differently to changes in NOx emissions depending on the amount of NOx in the atmosphere. CARB's extensive modeling analysis has demonstrated that the ultimate pathway to overcome ozone air quality issues in the South Coast Air Basin of California is through dramatically reducing NOx emissions.
- State agencies, such as CalEPA and South Coast AQMD have identified LA County's disadvantaged communities and performed environmental justice analyses to show that there is a strong correlation between poverty levels and air pollution exposure levels.
- Trucks that perform duty cycles with high kinetic intensities are ideal candidates for transitioning into electric vehicle technologies.
- Though LA County's most prominent criteria pollutant emissions issues are from NOx, additional policies related to GHGs should be considered to not disregard their climate impacts with the projected increases in vehicle activity.