Charging Infrastructure Strategies:

Maximizing the Deployment of Electric Drayage Trucks in Southern California

Libby Bradley • Naseem Golestani • Kazutaka Izumi • Kento Tanaka • Tsuyoshi Yamakawa

UCLA Luskin Center for Innovation

A. Client

This report is prepared for Southern California Edison (SCE), one of the nation's largest electric utilities, providing power for 15 million residents. The company has a service territory of approximately 50,000 square miles that covers many of the cities in central, coastal, and Southern California.

In June 2018, SCE received approval from the California Public Utilities Commission (CPUC) for a program to invest over $300 million on medium- and heavy-duty electric vehicle charging infrastructure (CPUC, 2018). This investment program, known as "Charge Ready Transport," is designed to help broaden California's electric transportation market over five years, from 2019 to 2024. The Charge Ready Transport program will dedicate 25% of its budget to vehicles operating out of the Long Beach and Los Angeles ports and warehouses.

B. Acknowledgments

This report would not be possible without the support and assistance of many individuals. We are eternally grateful for the time each of them took to educate and guide our analysis.

Dr. Wesley Yin, APP Adviser (Primary)
Dr. John D. Villasenor, APP Advisor (Secondary)
Katie Sloan, Eric Seilo, Mauro Dresti, Southern California Edison
Dr. J.R. De Shazo, James Di Filippo, and Colleen Callahan, UCLA Luskin Center for Innovation
Renee Moilanen, Port of Long Beach
David Reich, Los Angeles Mayor's Office of Economic Development
Michael Samulon, Los Angeles Mayor's Sustainability, Budget, and Innovation Team
Weston LaBar, Harbor Trucking Association
Austin Benzinger, Thor Trucks
Melissa Infusino, Long Beach City College
Peer Reviewers: Nikki Lewis, Shota Kenmochi, Susan Baik, Lindsey Graef, Oceana Gilliam

C. Disclaimer

This report was prepared in partial fulfillment of the requirements for the Master in Public Policy degree in the Department of Public Policy at the University of California, Los Angeles. The views expressed herein are those of the authors and not necessarily those of the Department, the UCLA Luskin Center for Innovation, UCLA as a whole, the client, or the aforementioned individuals.

D. Glossary of Terms

3PL	3rd Party Logistics company
AC	Alternating Current
CAAP	Clean Air Action Plan
CALeVIP	California Electric Vehicle Infrastructure Project
CAM	Criteria Alternative Matrix
CARB	California Air Resources Board
CEC	California Energy Commission
CNG	Compressed Natural Gas
CO2	Carbon Dioxide
CPUC	California Public Utilities Commission
DAC	Disadvantaged Community
DC	Direct Current
DPM	Diesel Particulate Matter
DRPEP	Distribution Resources Plan External Portal
Drayage Truck	Heavy duty class 8 trucks carrying cargo for short-haul distances, to and from ports to other nearby locations, including warehouses
DTNA	Daimler Trucks North America
EMFAC	CARB Emission Factor model
EPA	U.S. Environmental Protection Agency
FC	Fast-Charging
GHG	Greenhouse Gas
HDEV	Heavy-Duty Electric Vehicle
HTA	Harbor Trucking Association
HVIP	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project

IOO	Independent Owner-Operator
LNG	Liquefied Natural Gas
LADWP	Los Angeles Department of Water and Power
NGV	Natural Gas Vehicles
NOx	Nitrogen Oxides
IOO	Independent Owner Operator
OD	Origin-Destination
OEM	Original Equipment Manufacturer
PEV	Plug-in Electric Vehicle
PM	Particulate Matter
POLA	Port of Los Angeles
POLB	Port of Long Beach
SCAG	Southern California Association of Governments
SCE	Southern California Edison
SCAQMD	South Coast Air Quality Management District
SO2	Sulfur Dioxide
TAZ	Transportation Analysis Zone
VAP	Vehicle Acquisition Plan
VMT	Vehicle Miles Traveled
ZEV	Zero-Emission Vehicle

E. Table of Contents

1. Executive Summary

The ports of Los Angeles and Long Beach are the largest container shipping ports in the nation and support thousands of jobs in Southern California. Unfortunately, the emissions produced by drayage trucks that transport cargo have significant impacts on regional air quality and greenhouse gas emissions, with the greatest impact felt by surrounding communities. In response to this issue, local community leaders have been pushing for a transition to zero-emission heavy-duty trucks. In 2017, the Mayors of Los Angeles and Long Beach stated a goal of zero emissions from drayage trucks entering the ports by 2035.

In June 2018, SCE received approval from the CPUC to invest over $300 million in electric-vehicle charging infrastructure, with a portion of the budget allocated to heavy-duty trucks operating out of the ports of Los Angeles and Long Beach. Our goal is to develop a strategy for rolling out heavy-duty electric vehicle charging stations that best supports the conversion of diesel port drayage trucks to electric.

In this analysis, we created an algorithm that can be used to identify optimal placement for drayage truck electric charging stations in the short- and long-term. After establishing drayage industry travel patterns and charger and electric truck capabilities, we identified where trucks dwell overnight and assigning a likely electric truck adoption rate in the early phase of adoption. We further assessed each location by conducting a circuit analysis to identify which locations could support charging stations and whether they were located in disadvantaged communities (DACs).

In the short-term, our findings indicate that optimal placement will be in truck yards nearest to the ports, where a majority of them are aggregated. Using a constraint-optimization algorithm, we estimated that 404 trucks can be electrified in the short run, which would result in an estimated regional reduction of 46,206.75 metric tons of carbon dioxide (CO2), 43.20 metric tons of nitrous oxides (NO2), and 0.21 metric tons of particulate matter (PM) annually.

For the long term (year 2035), we identified drayage trip destinations using Los Angeles County origin/destination trip data to determine which zones in Southern California will have the highest demand for day time opportunity chargers. Our findings indicate that optimal placement should take place at both truck yards and warehouses, the primary destinations for cargo transported by drayage trucks. Destinations are mainly concentrated in the 710 Corridor and areas surrounding the I-10/I-15 interchange in San Bernardino County. We estimate that 4,941 trucks can be electrified, which would decrease CO2 emissions by 565,117.66 metric tons, NOx by 528.39 metric tons, and PM by 2.55 metric tons per year. The majority of these stations would be placed in communities that would experience the greatest health and well-being impacts of reduced emissions.

Our recommended strategy also includes a program of outreach and education to truck drivers, trucking companies, and local communities. This latter approach can help better ensure that the charging station rollout addresses trucking company and community concerns, thereby increasing the likelihood that the supply of charging stations will be met by sufficient demand via the uptake of electric trucks.

2. Introduction

The ports of Los Angeles and Long Beach, also known as the San Pedro Bay Ports, are the largest container shipping ports in the nation (San Pedro Bay Ports, 2017). Approximately 13,000 heavy-duty diesel trucks, also known as drayage trucks, work out of these ports, moving the majority of cargo that passes through them. Unfortunately, the emissions produced by drayage trucks have significant impacts on regional air quality — especially within nearby disadvantaged communities (DACs) — and on global climate change (EPA, n.d.).

The ports have made concerted efforts over the past decade to reduce emissions. However, additional measures must be taken if they are to reach the ambitious emission-reduction goals set by the state (CalEPA, 2018). Moreover, as globalization and international trading activity increase, the challenge to reduce emissions at the ports will only increase. These goals are achievable, but only if meaningful coordination takes place between the ports, government agencies, the community, and the private sector.

One solution to address the negative impacts of drayage truck emissions is to convert these fleets to electric-powered vehicles, or electric drayage trucks. These trucks would emit fewer greenhouse gases (GHG) and air pollutants when compared to diesel-powered trucks. Electric drayage trucks could offer the comparable cargo-carrying capacity to conventional drayage vehicles, while utilizing the same transportation infrastructure.

However, a significant difference between electric drayage trucks and diesel-powered trucks is fueling infrastructure. Unlike the convenient and established market of readily-available diesel stations, the electric vehicle charging station market is still in the early stages of development. Accordingly, the convenient availability of electric truck charging stations will be of paramount importance if drayage trucks are to make the switch from diesel to electric.

2.1. Policy Goal

The focus of our report is motivated by two primary factors: one, the drayage industry's outsized contribution to harmful emissions in the region; and two, the burgeoning interest in, and support for, electric vehicles as a solution to support a cleaner environment. The potential for electric vehicles to reduce emissions at the ports is, however, contingent upon the private decision to convert, which will largely be determined by investments and location of charging infrastructure.

As such, our policy analysis will seek to achieve the following: **Develop a strategy for rolling out heavy-duty electric vehicle charging stations that best supports the conversion to electric drayage trucks that serve the San Pedro Bay Ports.**

To achieve this goal, we develop an algorithm that optimizes the placement of electric truck charging stations to best support the drayage industry and its travel patterns. In addition, we provide complementary business and outreach strategies to address local community and drayage industry concerns, thereby increasing the likelihood that the supply of charging stations will be met by sufficient demand via the uptake of electric trucks.

3. Background

This chapter provides a more in-depth analysis of the substantial negative impacts imposed by port drayage activities. We explain the severity and negative societal impacts posed by pollution at the ports, as well as state and local initiatives to combat these negative impacts. Finally, we give an overview of the current drayage truck landscape and heavy-duty electric truck industry.

3.1. Emissions at the Ports

The San Pedro Bay Port complex is the single largest fixed source of air pollution in Southern California (South Coast Air Quality Management District, 2013). Freight movement accounts for about 42% of NOx emissions in this region, and drayage trucks that service the ports are the single largest source within that category (South Coast Air Quality Management District, 2015). Drayage trucks account for 0.1 percent of vehicles in the South Coast but 5 percent of NOx emissions from the transportation sector, emitting approximately 4,000 tons of NOx per year in the region (California Air Resources Board, 2017). Specific to the Ports' inventory, heavy-duty trucks are responsible for 23% of NOx emissions.

Much of the emissions come from diesel combustion, which emits carbon dioxide (CO_2), a GHG that traps heat in the atmosphere and is the primary contributor to anthropogenic climate change. The impacts of climate change are expected to have dire ramifications for Los Angeles County, including more high-heat days, increased water scarcity, extreme weather, and sea level rise (Los Angeles County Department of Public Health, 2014). Without moving away from fossil fuel combustion, CO_2 emissions are projected to increase as trade volumes increase in the future (Figure 1).

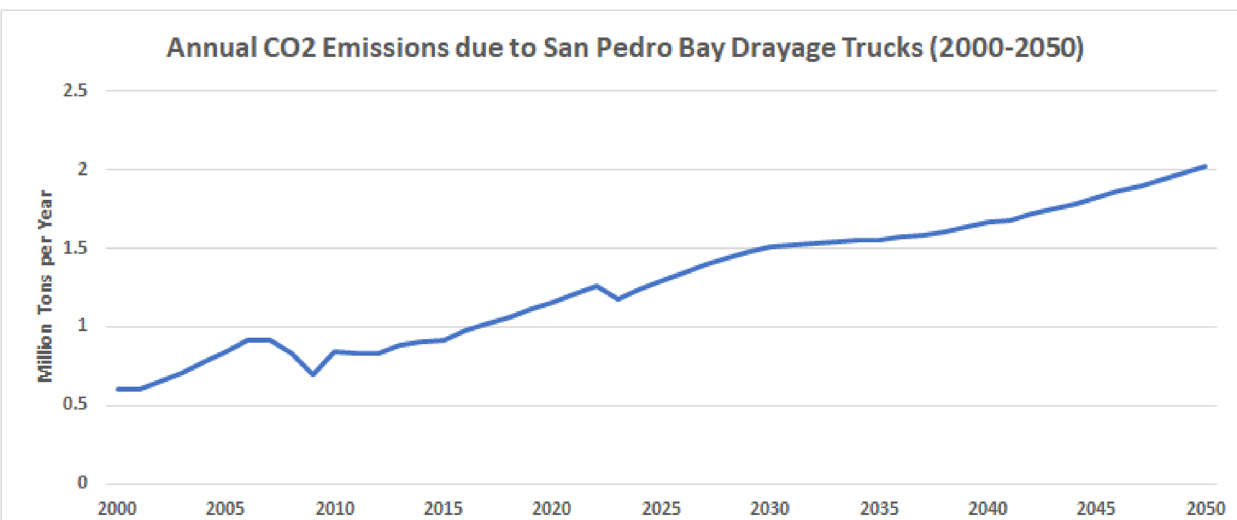


Figure 1. Past and projected CO_2 annual emissions in the SCAG region due to drayage trucks that serve POLB/POLA. Data is based on the California Air Resources Board (CARB) "Emission Factors" (EMFAC) model. Source:(California Air Resources Board , 2017)

3.2. Public Health and Disadvantaged Communities

The compromised air quality due to freight operations at the ports, including drayage truck activities, contributes tremendously to local health risks. According to the Environmental Protection Agency (EPA) (EPA, n.d.), air pollution can negatively impact public health in the following ways, both in the short term and long term:

- Aggravating respiratory and cardiovascular disease
- Reducing lung function
- Increasing the severity and frequency of respiratory symptoms and infections
- Impacting the nervous system, including the brain
- Increasing the risk of cancer
- Contributing to premature death

Due to all of these negative health externalities, residents near the ports face higher pollution-related health risks than the rest of the Southern California population. Due to this pronounced exposure to pollutants, these areas are classified as DACs under SB 535 (De Leon, Statutes, 2012). Health risk increases as one gets closer to the source of pollution, and as a result, communities closest to the ports experience greater health impacts than those further away. Figure 2 shows that the pollutants are most harmful within 1,500 feet of freeways. The population closer to freeways tends to be poorer and more nonwhite than areas not in close proximity to freeways (Figure 3). Figure 4 displays the high air toxic risk near the ports, according to MATES IV (South Coast Air Quality Management District, 2012).

Pollutant Group	Sources	Scale	Known Health Effects
Carbon monoxide	Engines	0–1,000 meters	Headaches, dizziness, nausea; death at high levels; low birth weight and premature birth during maternal exposure
Air toxics (benzene, acetylene)	Engines	Very local (<100 meters)	Eye irritation, cancer, asthma
Particulate matter (fine, ultrafine, black carbon)	Diesel engines	0–300 meters	Respiratory diseases and infections, cardiovascular disease
Nitrogen dioxide	Engines	300–400 meters	Sudden infant death syndrome, eye irritation, upper respiratory tract infections, bronchial irritation, exacerbated asthma
Hydrocarbons (ground-level ozone)	Photochemical reactions	Regional	Eye and throat irritation, exacerbated respiratory disease

Figure 2. Motor Vehicle Pollutants and Their Known Health Impacts (Manville and Goldman, 2018, Houston et al. (2004), and Brugge, Durant, and Rioux (2007))

	Poverty			Share Nonwhite			Share of Households without Vehicles		
	No Freeway	Within 1,250 Feet	Within 750 Feet	No Freeway	Within 1,250 Feet	Within 750 Feet	No Freeway	Within 1,250 Feet	Within 750 Feet
Atlanta	0.13	0.19	0.36	0.49	0.64	0.80	0.05	0.09	0.19
Boston	0.11	0.21	0.25	0.27	0.34	0.36	0.14	0.36	0.50
Chicago	0.13	0.21	0.23	0.47	0.67	0.73	0.13	0.21	0.25
Houston	0.16	0.29	0.30	0.64	0.86	0.89	0.06	0.16	0.13
Los Angeles	0.16	0.22	0.24	0.69	0.84	0.86	0.09	0.11	0.12
New York	0.13	0.22	0.26	0.51	0.72	0.76	0.31	0.51	0.58
Philadelphia	0.13	0.21	0.15	0.37	0.40	0.31	0.15	0.28	0.23
San Francisco	0.11	0.14	0.15	0.59	0.72	0.76	0.16	0.15	0.20
Seattle	0.11	0.21	0.24	0.32	0.41	0.42	0.07	0.22	0.33
Washington, DC	0.08	0.12	0.12	0.56	0.52	0.42	0.12	0.19	0.29
Average	0.13	0.20	0.23	0.49	0.61	0.63	0.13	0.23	0.28

Figure 3. Selected Characteristics of Populations within 750 and 1,250 Feet of Freeways (Manville and Goldman, 2018 and American Community Survey 2008–2012)

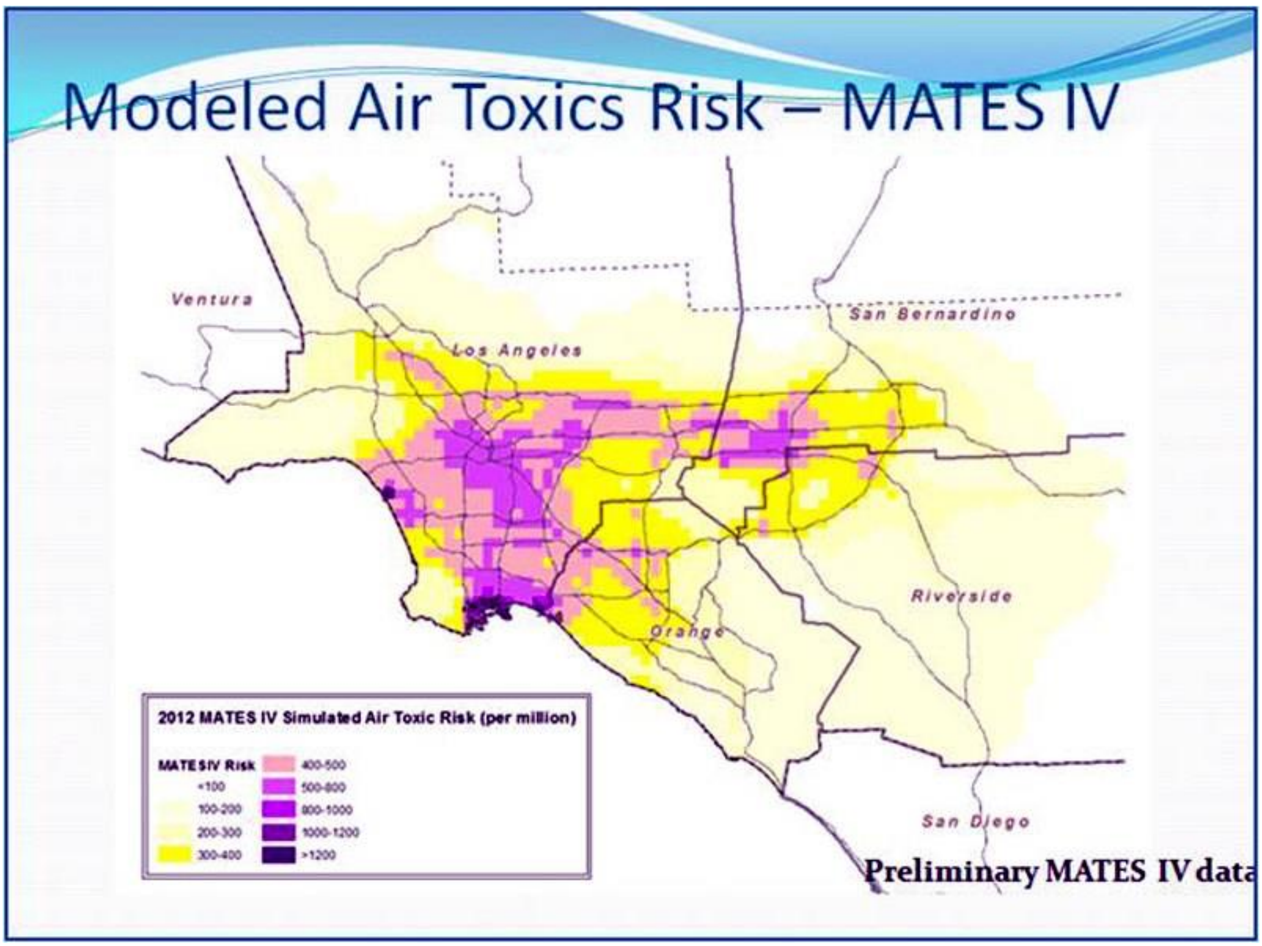


Figure 4. Modeled Air Toxics Risk (South Coast Air Quality Management District, 2012)

The harmful health effects of port activities are borne out in the numbers. Approximately 15% of children in Long Beach have asthma, compared to 9% of children in the United States (City of Long Beach Department of Health and Human Services, 2013). Also, asthma-related hospitalization rates are greater in West Long Beach near the ports and the 710 freeway than in East Long Beach. In the communities adjacent to the ports, including Wilmington, San Pedro, and the Harbor Gateway, asthma-related emergency department visit rates greatly exceed the city average, with Los Angeles totaling 39 visits per 10,000 residents and port communities seeing 72 visits per 10,000 residents (LA Healthy, n.d.). The direct costs of hospitalization are significant; the average cost of an asthma-related hospitalization was $33,749 in 2010, according to the California Public Health Department (The California Department of Public Health, 2015).

These adverse social impacts make apparent that, when it comes to addressing emissions at the ports, the cost of doing nothing is not nothing. The health and well-being impacts are paid by local communities who will continue to suffer from higher health care costs, hospitalizations, missed days of work and school, and potentially premature death in the direst scenarios. The ports recognize this, so in 2017 they created a San Pedro Bay-wide health risk reduction goal to reduce residential cancer risk from port-related diesel particulate matter (DPM) emissions by 85% by 2020 (The San Pedro Bay Ports, 2017).

3.3. Policy Support and Potential Emissions Reductions

3.3.1. Clean Air Action Plan

In its 2017 Clean Air Action Plan (CAAP), the San Pedro Bay Ports laid out emission targets to address the negative environmental impacts of port activities. These goals include a reduction in residential cancer risk of port-related diesel particulate matter (DPM) emissions by 85% by 2020, and a decrease in GHGs from port-related sources to 40% below 1990 levels by 2030 (San Pedro Bay Ports, 2017).

One of the central goals outlined in the CAAP is an all zero emission drayage fleet at the ports by 2035. The ports will charge a fee on all drayage trucks that do not convert to near- zero emissions or zero-emissions trucks by 2020 (San Pedro Bay Ports, 2017). The ports have not established the fee, but depending on the amount, it may make financial sense for a trucking company to pay the fee rather than replace the truck with a cleaner option. This possibility means it will be crucial to identify additional ways to encourage the take-up of electric trucks.

Replacing diesel-powered drayage trucks with electric-powered trucks will help significantly with the ports’ emission reduction goals. This is because electric trucks would cause far fewer adverse environmental impacts compared to their diesel counterparts. These vehicles would have zero exhaust pipe emissions of criteria and GHG air pollutants during all phases of port-related drayage operations (EPA, n.d.).

The forecasted reductions of truck-related pollutants as a result of the CAAP strategy could be immense. Figure 5 below shows the percentage reductions of these pollutants, based on anticipated emissions in the selected years compared to the emissions that would have occurred in those years without this strategy.

	2021	2024	2031	2036
NOx	48-53%	77-93%	84-96%	86-100%
CO_2	8-9%	9-21%	10-46%	56-100%
DPM	48-53%	72-85%	70-82%	81-100%

Figure 5. Forecasted Reductions of Truck-Related Pollutants from the 2017 CAAP Strategy Proposal
**Range depends on the 2023 rate, zero emissions truck penetration, and emissions standards (i.e., the Ports forecasted .02 grams NOx and .05 grams NOx).*

3.3.2. Statewide Initiatives

Fortunately, the ports' emission reduction efforts do not stand alone. They are complemented by, and in large part inspired by, similar efforts at the state level. In January 2018, Governor Brown issued an executive order calling for five million zero-emission vehicles (ZEVs) by 2030 and the installation of 250,000 electric vehicle chargers and 200 hydrogen refueling stations by 2025 (Office of Governor, 2018).

Over the past decade, California has implemented various clean truck and infrastructure incentive programs. Most recently, the state's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) is slated to receive $68 million for the 2019 fiscal year, up $41 million from 2018 (California HVIP, 2019). The funds include incentives for the purchase of medium-and heavy-duty all-electric trucks. HVIP is a part of California Climate Investments, a statewide program using cap-and-trade dollars to reduce GHG emissions (California HVIP, 2019). The program also aims to improve public health and the environment in DACs.

Additionally, in late 2017, the state's Energy Commission and Center for Sustainable Energy launched the California Electric Vehicle Infrastructure Project (CALeVIP), which provides a streamlined incentive process for installing electric vehicle charging infrastructure (Center for Sustainable Energy, n.d.). The state's Carl Moyer Program also offers funding to help vehicle fleet owners replace, repower, or convert their trucks with newer, lower-emission equipment (California Air Resources Board, 2018). As part of this program, applicants can request funding to install, convert, or expand battery-charging fueling stations.

3.4. Transition to Electric Trucks

Port drayage trucks are those used in short-haul distances to and from ports to other nearby locations, including warehouses and rail ramps. As of late 2018, there were approximately 17,500 registered heavy-duty trucks in the San Pedro Bay Ports' drayage fleet (Tetra Tech, 2018). However, only 11,000 to 13,000 trucks actively perform drayage on any given day, due to seasonal demand changes and other factors. These trucks drive approximately 238 miles per day (Tetra Tech, 2018).

3.4.1. Heavy-Duty Electric Trucks

Heavy-duty electric trucks are defined as those whose gross weight exceeds 33,000 pounds and have 3 or more axles (EPA, 2019). Heavy-duty electric trucks are characterized by their power source, an onboard battery pack. Battery pack recharging is accomplished by plugging into the electric power grid or other off-grid electric power sources to recharge the battery pack while the truck is not operating.

The earliest iterations of these vehicles have ranges from 120 to 200 miles on a single full charge and weigh around 15,000 pounds (Clevenger, 2018). All of the major original equipment manufacturers (OEMs) are investing in electric vehicle technology to compete in this emerging segment of the truck market. These OEMs include Daimler Trucks North America (DTNA), Volvo, Peterbilt Motor Co., and Navistar, Inc. However, as of early 2019, only BYD, a Chinese vehicle manufacturer, offers a commercially available heavy-duty electric truck model, with a range of 125 to 220 miles per full battery charge (Tetra Tech, 2018).

3.4.2. Heavy-Duty Electric Truck Market

Experts agree that the deployment of HDEVs of any sizable capacity is still years away. In the near term, electric trucks will be limited to specific applications that are well-suited to their technology. These applications include short-haul trips, such as urban pick-up and delivery, refuse trucks, and the topic of our policy project — port drayage.

OEMs are beginning to partner with companies in the freight and delivery business on pilot projects to test these earliest iterations of medium- and heavy-duty electric trucks (Adler, 2019). In 2017, BYD deployed 23 of these trucks to two Southern-California based customers — Daylight Transport, located in Lancaster, and BNSF Railway, which has yards in the counties of San Bernardino and Los Angeles (Field, 2017).

3.4.3. Heavy-Duty Electric Chargers

Electric charging stations for heavy-duty trucks are a rapidly-evolving landscape. In general, these stations can utilize one of three types of chargers, which are defined by their rate of charge in kilowatts (kW). The higher the kW, the faster the charger can recharge a battery.

The first type of charger is Fast-Charging (FC). While this type has the quickest time to charge, it has significant drawbacks, including expense (both the hardware and the utility costs) and battery deterioration. Most industry experts do not recommend using fast charging if their routes allow. Alternating current (AC) is another type of charger and is available for charging rates of 20 kW or less and requires both an on- and off-board charger (EV Safe Charge Inc., n.d.). Current AC charger models take about 20 hours to fully charge a heavy-duty vehicle and cost on average $2,000. Finally, a direct current (DC) charger is used for speeds of 20 kW or more and does not require an onboard charging component (EV Safe Charge Inc., n.d.). Current models of DC chargers range widely in charge rate and cost. The less expensive models cost around

$25,000 and take 14 hours to charge a heavy-duty truck. The most expensive model costs over $100,000 but can complete a full charge in 1 hour.[1]

3.4.4. Heavy-Duty Electric Charging Stations Market

Because electric trucks are still in their project test phases, there is not yet a substantial market for charging stations. However, some trucking fleets are preparing for the eventual mass production of heavy-duty electric trucks by evaluating existing power capabilities and charging station needs at their terminal locations. Both UPS Inc. and rental truck company Ryder System Inc. are working with electric car maker Tesla to develop charging infrastructure to support the Tesla trucks that these companies' fleets have preordered (Long, 2018).

[1] Another key component of the charging station is the connector. The main charging station connector used by most OEMs is the J1772, however, some manufacturers require custom or proprietary connectors.

4. Methodology

The overarching goals of our methodology were to identify the key factors and challenges to both rolling out electric vehicle charging stations for the ports, as well as encouraging the take-up of electric trucks. To do this, we carried out a set of systematic steps, including a literature review and interviews with key stakeholders. We also conducted robust research and data-gathering efforts to glean all relevant information on current technology for electric batteries, trucks, and infrastructure; capabilities within the local power grid; locations of truck yards; and, utilization of transportation analysis zones (TAZ) to determine the placement of charging stations.

A Methodology Roadmap

In later sections we provide an in-depth description of our research results. These findings relate to the drayage industry structure; the appropriate time of day to charge trucks; the benefits of privately- versus publicly-owned and operated charging stations; the presence of economies of scale for charging infrastructure; and, the need for a short- and long-term charging station deployment strategy. This information is used to inform our station placement criteria, which accounts for emissions reduction benefits, proximity to disadvantaged communities and SCE's budget.

We then present the culmination of our work from the above steps in the form of a charging station placement optimization algorithm. This algorithm utilizes a several key assumptions derived from the research described above: the types and ownership structure of trucks and chargers to be utilized, time of day for charging, as well as associated costs to identify the optimal placement of charging stations. These assumptions are integrated into a series of steps that optimize the cost and number of trucks that can be electrified within our defined target area. We also factor in electricity capacity by performing a circuit analysis of target areas.

Upon locating the optimal placement of charging stations, our final step considered business strategies: how to encourage trucking companies to convert to electric trucks, a necessary precursor to creating strong demand for electric charging stations. We relied primarily on our accrued knowledge of the drayage industry's and local community's concerns and needs to develop these recommendations. Our final recommendations are based on a uniform set of relevant criteria, which include effectiveness, financial feasibility, and administrative feasibility.

4.1. Literature Review

No port authority in the world has carried out a large-scale transition from diesel or gas-powered vehicles to heavy-duty electric vehicles within its port's fleet. While this provides an opportunity for the San Pedro Bay Ports to be at the forefront of environmental policy, it also means that there are no test cases from which to learn best practices.

Absent any real-world cases of expansive drayage fleet electrification, we reviewed the San Pedro Bay Ports' transition to natural gas vehicles (NGV). Natural gas vehicles produce 20 to 30% fewer greenhouse gas emissions than gasoline- or diesel-powered vehicles and the fuel comes in the form of liquefied natural gas (LNG), or compressed natural gas (CNG) (Southern California Gas Company, n.d.). CNGs are not a perfectly comparable test case to use, given that electric vehicles are both more costly than CNGs and require an entirely new type of "fueling" infrastructure – an electric charging station. However, this case provides valuable information on the challenges faced by trucking companies in their transition to newer, cleaner vehicles.

4.2. Interviews

Transportation electrification of Southern California's drayage sector involves many parties. The success of heavy-duty drayage electrification depends on factors such as the state of technology and its cost, infrastructure that supports travel patterns, local policies that support electrification, and the structure of the drayage industry itself. Our goal is to gain a broad representation of diverse knowledge bases and perspectives on this issue. To do this, we identified key stakeholders that will play a role in pushing electrification forward or are impacted by its consequences. They were identified as follows:

- Utility companies
- Trucking companies
- Technology manufacturers (trucks and batteries)
- Ports of Los Angeles and Long Beach
- Real estate agents, property owners
- Local government
- Local community

A combination of literature review and interviews were conducted to identify the role of each stakeholder in the heavy-duty electrification process, as well as their perspectives on what factors and challenges must be considered for electrification and optimal charging infrastructure placement.

4.2.1. Utility Company

First and foremost, we spoke to SCE to get a clear understanding of their Charge Ready Transport program. Through a series of conversations and a presentation, we identified SCE's objectives and what their goals are for the program. This helped us define what goal our charging infrastructure placement should achieve, as well as policy criteria to consider. Further discussions with SCE provided answers to technical questions regarding their electric grid, as well as relevant factors related to their administrative and policy framework.

4.2.2. Trucking Companies

When a mandate is set for emission reductions and industry fleet changes, it is crucial to have a clear understanding of how the industry functions, its daily travel patterns, and its business model. Policies must be tailored to fit the industry in question in order to be most effective. We spoke with trucking companies as well as the Harbor Trucking Association (HTA), a local trucking trade group, to understand drayage duty cycles and travel patterns.

4.2.3. Battery and Electric Drayage Truck Manufacturers

What makes heavy-duty electrification particularly challenging is that electric trucks are an emerging technology still in the project phase. We spoke to a truck manufacturing company, battery manufacturer, and charger development company to understand the current state of technology and future vehicle range projections. Specific organizations we spoke to include Thor, a heavy-duty vehicle battery manufacturer, and EVgo, a charging infrastructure company. We also relied on SCE's discussions with truck manufacturing companies.

4.2.4. Ports

As the center of the drayage industry in the Southern California Association of Governments' (SCAG) region, it was crucial to understanding the ports' perspective on heavy-duty electrification and charger placement. Discussions with Renee Moilanen, Air Quality Practices Manager at the Port of Long Beach, clarified drayage travel patterns, the frequency of visits to the ports, and pilot projects that the ports are participating in. According to Moilanen, the Port of Long Beach is not considering drayage charger placement within the port property, which narrowed the spatial boundaries of our analysis (personal communication, November 5, 2018).

4.2.5. Local Government

Given the joint directive by the mayors of Los Angeles and Long Beach to reach a zero-emissions drayage fleet by 2035, we wanted to meet with city representatives who could provide us their understanding of how the ports would achieve this goal. We met with both the Los Angeles Mayor's port representative and the lead for the city's electrification and sustainability programs. As one of our earlier meetings, this discussion created our foundational understanding of the port's drayage industry – the total number of trucks, the largest trucking companies, truck duty cycles, cargo capacity, routes, and destinations.

4.2.6. Local Community

The main goal of both SCE's transportation electrification program and the Mayors' 2035 goal is to reduce criteria pollutant emissions, particularly in communities that are most impacted by air pollution and climate change. To that end, interviews were conducted with Environmental Justice advocacy groups who are at the forefront of air quality improvements for local communities. These interviews also revealed potential consequences (positive and negative) of our analysis and charging infrastructure placement.

4.3. Data

Understanding travels pattern was a key element of determining optimal charging infrastructure placement. Electric truck deployment is maximized by placing chargers in a way that supports the drayage industry's current travel patterns. Modeled truck travel pattern data, SCE territory boundary data, SCE circuit map and DAC boundary data were obtained to constrain our analysis and understand the drayage sector spatially. Given that trucking operators and companies must be registered in order to enter the port property, the Port of Long Beach was able to provide this information.

5. Results

After carrying out the steps outlined above, we considered the overarching challenges involved in identifying the optimal placement of charging stations. We then used these specific challenges, as well as our general findings, to identify the criteria by which we would measure the success of a given policy outcome. This process informed our ultimate decision to frame the problem of charging station placement as one of constraint-optimization.

5.1. Key Challenges: Truck Adoption and Station Placement

Electric drayage truck adoption rates play a significant role in charger demand and placement. As a new technology that will impact industry operations and fueling patterns, operators have concerns that make them reluctant to switch to electric trucks despite the Mayors' 2035 zero-emission goal. This analysis addresses some of these concerns. Interviews with several trucking companies revealed that operators are concerned about the following issues (V. LaRosa, personal communication, June 18, 2018, and K. Pruitt, personal communication, January 31, 2019):

- Range and charging ability: Since drayage industry revenue depends on transporting cargo to customer locations throughout Southern California and beyond, having enough range to carry out current routes is particularly important to operators (Husing, Brightbill, & Crosby, 2007). Trucks will want to charge in convenient locations during dwell times.

- Truck and infrastructure cost: electric truck capital costs are higher than their diesel counterpart (Chandler, Espino, O'Dea, 2017). Companies are wary of the extra cost early technology adopters face and are concerned with having stranded assets if electric trucks do not perform correctly.

- Vehicle weight: according to the California Department of Transportation, heavy-duty trucks have a weight limit of 80,000 pounds on California roads (Caltrans, n.d.). This presents a trade-off: utilize a heavier battery that increases range and power but decreases cargo weight; or, use a lighter battery which allows for more onboard freight.

In addition to the challenges faced by trucking companies, we identified the following as the core hurdles in rolling out a viable and sustainable charging station program:

- Siting constraints: most diesel fleets enjoy existing onsite access to fueling infrastructure or can conveniently fuel off-site at public or private stations. However, no model or best practice for the siting of heavy-duty charging stations exists today. Establishing this new infrastructure will require tremendous land and power grid capacity, the consent of host property owners, and consideration of relevant zoning regulations.

- Cost-effectiveness: electric vehicle infrastructure would need to be installed with an extensive redesign, reconfiguration, and operational disruptions, whether publicly- or privately-located. Economies of scale will need to be considered when determining the optimal number of chargers per selected site.

- Short-term vs. long-term: two types of placement strategies – one for the short-term and one for the long-term – must also be addressed. This is due to a compilation of factors, including the type of applicants SCE is considering for its five-year program, the trucking companies most likely to adopt electric trucks within the first five years, and assumptions about the rate of technological change in electric trucks and chargers from now until 2035.

5.2. Policy Goals

Given the general challenges we identified above, we identified two goals that will serve to guide our policy recommendations. The first goal addresses the supply side issue of SCE's program: how to establish optimal charging station placement. The second goal, although related, focuses on the demand side by considering how to encourage truck drivers to adopt electric trucks.

- Goal 1: Develop a framework for optimal placement of charging stations to encourage electric truck conversion, and

- Goal 2: Create complementary strategies for the rollout of charging stations to enhance electric truck take-up

5.3. Key Findings

5.3.1. Natural Gas Vehicles at the San Pedro Bay Ports

At the end of 2008, the San Pedro Bay Ports launched the Clean Trucks Program. This program banned pre-2007 trucks to encourage the utilization of cleaner, less polluting vehicles. As an incentive to comply with the new standard, truck drivers received a subsidy from the ports to purchase new trucks.

Unfortunately, those who purchased LNG or CNG vehicles faced challenges both in the short term and long term. One key challenge was the unreliable technology of the trucks. Drivers would report new vehicles not starting, sensor malfunctions, and breakdowns within weeks of purchase (Clark, 2012). Trucks also lacked enough power to haul cargo up even the slightest grades (Clark, 2012). The ports neglected to do thorough field testing of the low emissions vehicles in real-world, drayage activities. Instead, they relied on information from regulatory agencies and manufacturers, which did not know whether the technology was capable of withstanding the rigors of hundreds of miles of heavy cargo travel per day.

The other problem was financial. Despite funding assistance from the ports, individual truck drivers faced substantial financial burdens to pay for the new trucks, oftentimes taking out expensive loans. At the time of the plan's implementation, the average cost of a natural gas truck was $200,000, approximately twice the cost of the newer diesel trucks (Nero, 2018). And, under the terms of the port's subsidy, drivers had to keep their trucks for five years, providing yet another administrative and financial burden on drivers.

Due to these challenges, the use of natural gas trucks fell dramatically at the ports, as shown in figure 6. By 2017, LNG trucks were moving 70 % less cargo at the ports than 2012 and made up only 5 % of the drayage fleet (Guerin, 2017).

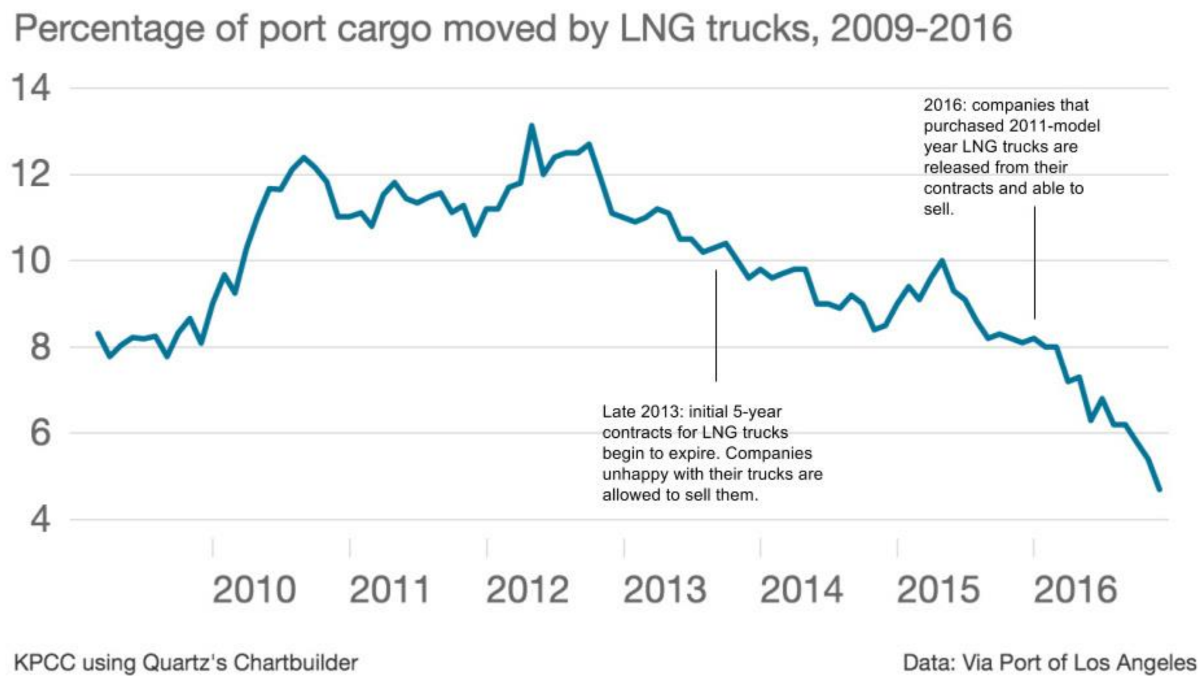


Figure 6. *Percentage of Los Angeles port cargo moved by LNG trucks, 2009-2016*

These difficulties have left drayage truck drivers reluctant to try any new vehicle technology being proposed by port officials. To convince truck drivers to adopt electric vehicle technology, it will be of paramount importance to avoid the mistakes made with natural gas vehicles.

5.3.2. SCAG, SCE, and Port of Long Beach Data

In order to designate the optimal placement for charging infrastructure, origin and destination data were obtained from SCAG Travel Demand Model (SCAG, 2012) that describe heavy-duty truck travel patterns in the SCAG region. Information was used from the model's 2020 travel pattern projections. The Origin-Destination (OD) matrix contains information on the number of trips taken between each TAZ, which was developed based on Tiger Census Block and released by SCAG. Specific area of each TAZ can be found on SCAG GIS & DATA services. Using spatial information including distances from OpenStreetMap data (Geofabrik, 2018), we were able to calculate the vehicle miles traveled (VMT) per day by drayage trucks as well as identify areas within the SCAG region that have the highest VMT. Areas with the highest VMT have the heaviest truck traffic and therefore highest demand for chargers. In order to confirm that the number of trips is related with the location of warehouses, which are the potential destination of trucks, we also use data from SCAG (2014) that shows the total building area of rentable warehouses in each TAZ.

Since this is an industry with a defined number of vehicles that carry out drayage operations, we needed information on trucking companies serving the ports and the size of each company.

Outside of the ports, there is no list or inventory of companies with drayage operations in the region. The Port of Long Beach Drayage Truck Registry (POLB, personal communication, 2018) provides a list of trucking companies that are registered and allowed to enter the port property. The list includes their address which is used to locate their truck yards. They also provided data on the number of trucks allowed to enter the ports per company as well as the number of trips or moves made to the ports per year for each company. This information was used to calculate the number of trucks that actively served the San Pedro Bay Ports and gave an estimate of the number of trucks charging infrastructure will need to support.

Southern California Edison territory and DAC region spatial data was also obtained from SCE (2019) and the California Environmental Protection Agency (2018) respectively. These data were used to establish the spatial boundaries of our analysis. Finally, grid capacity data was obtained from Southern California Edison's Distribution Resources Plan External Portal (DEREP) (2019) to indicate where sufficient power supply was located.

5.3.3. Drayage Industry Structure

5.3.3.1. Drayage Industry Business Models

According to Melissa Infusino (M. Infusino, personal communication, October 12, 2018), drayage industry labor expert, the current drayage industry business model is mixed and controversial, with several ongoing lawsuits. In the first model, companies own trucks and drivers are paid hourly and have workers compensation. The second is Independent Owner Operators (IOO), where individuals own or lease their trucks from a company and work as contractors for trucking companies. Within this model, drivers also tend to "buddy up" - two drivers tradeoff the use of one truck for each shift. The final model is mixed, where companies have employees as well as contracted operators. IOO and operators make money by the load, while company drivers are paid by the hour. However, company revenue depends on delivering cargo to customers (Husing, Brightbill & Crosby, 2007 and M. Infusino, personal communication, October 12, 2018).

5.3.3.2. Daily Duty Cycles and Travel Patterns

The typical daily travel pattern of a drayage truck is as follows. In the early morning, trucks leave company truck yards or individual rented parking and head to either the ports or other distribution warehouses to pick up cargo. Throughout the day, drayage trucks pick up cargo at the ports and drop off at customer warehouses, other 3rd Party Logistics companies (3PL), and intermodal rail yards. According to Kurt Pruitt (personal communication, January 31, 2019), Vice President of Strategy & Business Development for Pacifica Trucks LLC, customers most often own the warehouses, not trucking companies. Also, operators often travel to and from the ports for their first and second shift and then do distribution work when the ports are closed (M. Infusino, personal communication, October 12, 2018). After finishing a shift, trucks from larger fleets go back to their company truck yards while small fleet and independent owner-operators (IOOs) park their vehicles in lots or other locations.

Figure 7. Drayage Truck Duty Cycle

Although drayage operations usually refer to short-haul trips, there are several types of operations based on trip distance as shown in Figure 8 (TIAX, 2011 and W. LaBar, personal communication, October 22, 2018).

Operation type	Distance (miles) *	Number of Turns [2]**
Near dock	2-6	3-5 turns per day
Local	6-20	2-3 turns per day
Regional	20-150	2 days/turn

*Figure 8. Drayage operation, * TIAX, 2011, ** Weston LaBar*

According to the Tetra Tech Feasibility Assessment for Drayage Trucks, (Tetra Tech, 2018), the average drayage truck drives approximately 238 miles per day (Figure 9). However, the true average is likely to be less because infrequent long trips can skew the distribution, as less than 5% of one-way trips are greater than 200 miles (Figure 10). Given the industry duty cycle and down times described above, operators require the range to cover industry travel patterns and for charging infrastructure to be placed in a way that does not require operators to stray too far from routes or require long charging times outside of break times.

Operational Assumptions for Average Drayage Truck		
Average Shift Distance	miles	160
Average Shift Duration	hours	9.9
Average Shifts per Day	#/day	1.6
Average Daily Operating Time	hours	14.8
Average Daily Mileage	miles	238

Figure 9. Operational Assumptions for Average Drayage Trucks at San Pedro Bay Ports (Tetra Tech, 2018)

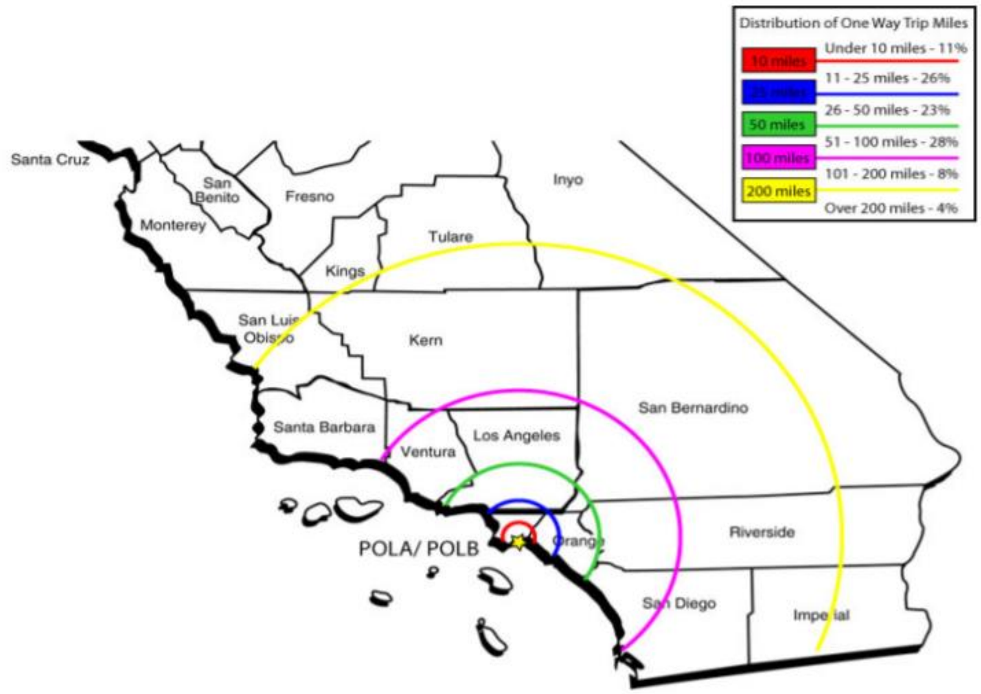


Figure 10. One Way Trip Mileage of Drayage Trucks (CGR Management Consultants LLC, 2007)

5.3.3.3. Where trucks dwell at night

An important question to answer in this analysis was where trucks dwell at night. According to M. Infusino (personal communication, October 12, 2018), company employees can park their trucks overnight on company yards while IOOs park in rented spaces or on surface streets such as in front of their homes. According to Pruitt (personal communication, January 31, 2019), for all three ownership models discussed above, company yards and IOOs parking is typically located closer to the ports in the 710 Freeway Corridor. Trucks typically do not dwell at distribution warehouses and depots.

5.3.4. Overnight and Opportunity Charging

Due to the drayage business model where many operators are paid by the load, any extra time spent charging or not driving results in lost revenue. Therefore the best time to charge are during breaks. Pruitt stated that the longest break occurs at night when the ports are closed (personal communication, January 31, 2019). According to Tetra Tech (Figure 11), the average truck begins the day at 6:00 am and finishes at 9:00 pm, therefore, the optimal charge window is during night time for nine hours (Tetra Tech, 2018).

However, Tetra Tech's analysis shows that the average number of shifts per day is 1.6. This means that 40% of operators have one shift per day and 60% have two. When there is only a single shift, trucks have a nightly dwell time of approximately 9 hours between. Two shift trucks are shared between two drivers and are in use nearly 20 hours per day. The overnight charging window for these vehicles is 1 am to 6 am. Companies will need to prioritize two shift trucks during overnight charging over the one shift trucks that have a longer nightly dwell time (Tetra Tech, 2018).

Scenario	Average Truck	1-shift Truck	2-shift Truck	Average Truck	1-shift Truck	2-shift Truck	Average Truck w/ mid-day recharge	Average Truck w/ mid-day recharge
Utility	SCE	SCE	SCE	LADWP	LADWP	LADWP	SCE	LADWP
Rate Schedule	TOU-EV-9	TOU-EV-9	TOU-EV-9	TOU A-2	TOU A-2	TOU A-2	TOU-EV-9	TOU A-2
Daily Mileage (mi)	238	161	275	238	161	275	238	238
Daily Energy (kWh)	595	403	688	595	403	688	595	595
Daily Operating Time (hours)	15	9.6	19	15	9.6	19	15	15
Charge Window	9p-6a	9p-6a	1a-6a	9p-6a	9p-6a	1a-6a	10p-6a, 4p-5p	10p-6a, 4p-5p
Total Energy (kWh)	155,295	105,183	179,568	155,295	105,183	179,568	155,295	155,295
Peak Power (kW)	66	29	138	66	29	138	223	223
Energy Charges	$10,479	$8,477	$11,431	$17,345	$12,333	$20,056	$25,347	$18,582
Demand Charges	$12,122	$5,278	$25,230	$6,164	$4,175	$12,830	$0	$38,208
Total Cost ($/year)	$14,658	$9,928	$16,949	$23,509	$15,923	$32,886	$25,374	$56,790
Average Cost ($/kWh)	**$0.094**	**$0.094**	**$0.094**	**$0.151**	**$0.151**	**$0.183**	**$0.163**	**$0.366**

Figure 11. Charge Window of Average Drayage Trucks at San Pedro Bay Ports (Tetra Tech, 2018)

Since most company and contracted trucks dwell at company truck yards at night, the best place to place charging infrastructure is at truck yards themselves. Smaller companies or IOOs do not have access to truck yards and are therefore at a disadvantage as to where they can charge overnight. This creates the need for different approaches optimal charging infrastructure sitting for large and smaller companies/IOOs.

Overnight charging would provide most of an electric truck's charging needs. If daily mileage is higher than the electric truck range, trucks will need to do opportunity charging during the day. Opportunity charging should take place in a location that minimizes deviation from a drayage truck's daily route. In the early stages of electric drayage truck adoption where there are fewer electric trucks in the fleet, there will not be many charging stations placed at warehouses operators will travel to. Since operators will not want to limit their routes before there are more charging stations available, charging infrastructure can be placed close to the ports where trucks will travel to and from on a regular basis in the near term. Opportunity charging can occur in larger company facilities that are closer to the ports (where overnight charging also takes place). IOOs and small companies can also use charging stations closer to the ports in the near term, however they will still have to contend with a lack of private property to use.

Given the drayage fleet's complex, and at times unpredictable, travel times due to traffic and other factors, there is a chance that chargers might not be available when electric trucks arrive to charge. It is a potential issue for opportunity charging at both company facilities and for other charging models. This issue is an opportunity for new technology that will optimize and schedule truck arrival to charging stations in a way that minimizes charger wait time.

5.3.5. Charging Station Business Models: Private, Public, Shared

According to Weston LaBar (personal communication, December 19, 2018), CEO of the Harbor Trucking Association, there are three different charger placement models to consider:

- Private model: chargers are placed in company-owned facilities. Companies favor this approach in order to avoid waiting in line and competing against other operators for access to chargers (Vic LaRosa, personal communication, June 18, 2018). This is model is also preferred by SCE because property owners will not have to become involved in the process.

- Companies lease locations: This has the benefit of companies not having to compete for access, however, it might not be clear who is in charge of charging station costs — property owners or trucking companies. It will also be more difficult for a Vehicle Acquisition Plan (VAP) to be completed as vehicle ownership must be established.

- Public charging infrastructure/charging lot model: This model would give small scale operators access to overnight and opportunity charging. However, challenges include funding source and what charger type would be used since universal technology is currently an issue for heavy-duty chargers.

5.3.6. Economies of Scale

When considering the number of charging stations to place at a given site, we will need to confront the inherent tradeoffs that economies of scale can present. It might be most cost-effective to place many charging stations at one site if economies of scale exist. However, this might limit the program's ability to include all interested trucking company applicants, due to the limited number of charging stations that can be placed at different sites within a constrained budget.

For charging stations, economies of scale exist because the capital expenditures necessary to build charging infrastructure - permits, grid connection, equipment, construction, installation and project management - are very expensive, costing tens of thousands of dollars (Lee and Clark, 2018). The more cost-effective option is to build many stations at one site with one high capital expenditure. The alternative is to build few stations at separate sites which all require separate capital expenditures that, when aggregated, greatly exceed the cost of the first option. Furthermore, operational expenditures on technical maintenance and cleaning are only slightly higher for sites with more stations. Energy capacity thus rises faster than costs do. Therefore the cost per kWh can decrease.

5.3.7. Short- and Long-Term Strategy

We found there are crucial aspects of the drayage industry and electrification that vary over time. Therefore, we have taken a short and long term approach to this analysis to take temporal changes into account. These factors include:

- Electric truck fleet size: The number of electric drayage trucks varies as there is higher adoption of this new technology over time. As operator concerns are addressed, adoption rates will increase. Electric drayage trucks costs will decrease and capabilities such as range will increase over time. According to Thor (A. Benzinger, personal communication, December 19, 2018), electric drayage trucks range growth is estimated to be 5% per year barring breakthroughs and advancements in battery chemistry.

- Grid capacity: According to SCE, expanding beyond current grid capacity is very expensive and has a lengthy permitting process that must be approved by the CPUC (SCE, personal communication, February 19, 2019). Therefore, going beyond the current grid capacity in the short term is not feasible and is a constraint on infrastructure placement. SCE can plan to expand grid capacity for long term energy needs.

Overall, in the short-term (the first five years), electric truck early adopters are expected to be mainly large trucking companies since they have more capability to invest in the new technologies and to apply with SCE’s stringent guidelines. For example, trucking companies need to be able to complete the VAP requirements which require information on vehicle ownership and the projected company electric truck ownership in the next ten years. Larger companies are also motivated by advertising themselves as sustainable companies according to Vic La Rosa of TTSI (personal communication, June 18, 2018).

In the long term, the majority of truck companies, including small-sized firms, will convert to electric to meet the ports’ 2035 zero-emissions goal. At this time, trucks still conduct overnight charging at truck yards, however, daytime charging can take place at warehouses for the following reasons: the mutual convenience of location; available land capacity; and, an overall increase in charging station demand.

5.4. Criteria

As a first step toward electrification of Southern California's heavy-duty drayage sector, we identified locations for SCE to place charging infrastructure in order to maximize the adoption and use of heavy-duty electric vehicles and emissions reductions as a result. Our analysis includes two types of criteria: the first is the reduction of emissions, and the second is a set of constraints within which the emissions reduction must occur.

5.4.1. Emissions Reduction

The central goal of SCE's Charge Ready Transport program is reducing emissions from the combustion of diesel fuel and to improve air quality, particularly in communities most impacted by air pollution. Therefore, the main objective of our analysis is to identify charging station locations that will reduce emissions via the transition of drayage trucks from diesel to electric. In the initial phase of SCE's program, this will occur by targeting truck companies with both the largest fleets and which own or lease truck yards near the ports with sufficient capacity to build out charging infrastructure. In the longer term, maximum emissions reduction can be achieved by building out public charging stations along drayage truck routes.

5.4.2. Constraints

Our optimal charging station locations will be identified by subjecting them to a set of constraints. These constraints include the following: (1) the program budget; (2) whether a truck yard or TAZ is located (in part or in whole) in a DAC; and, (3) the zone's grid capacity.

5.4.2.1. Program Budget

Our first constraint is the budget. SCE's Charge Ready Transport program includes over $340 million for medium- and heavy-duty charging infrastructure, however only a portion of this budget, $35 million, is allocated for drayage trucks at the San Pedro Bay Ports. The budget includes both the cost of the charging stations, of which SCE will be paying up to 50 %, as well as the costs to build out the stations. SCE is paying 100 % of the buildout expenditures, which include permitting, labor, and trenching. To determine the most cost-effective option, we will account for economies of scale; this is an especially important consideration given that buildout costs can easily cost five to ten times more than the cost of the charging station itself. Ultimately we will seek to identify the number and type of charging locations that maximize emissions reductions while staying within the budget constraint.

5.4.2.2. Locations in Disadvantaged Communities

California's DACs are often the most affected by the harmful environmental impacts associated with the transportation sector (CPUC, 2018). Not only are these communities located within areas of high air pollution caused by vehicle emissions, but the residents are typically low-income and minority groups. The near and long-term impacts of climate change are expected to fall more heavily on DACs (U.S. EPA, 2015). DACs often lack the necessary financial resources and political capital to invest in pollution-mitigating strategies (Kameri-Mbote et al., 2016). Furthermore, they may face barriers to equitable participation in environmental policymaking, which may result in fewer benefits for their communities from environmental programs (Kameri-Mtobe et al., 2016).

A determining factor in the CPUC's approval of SCE's Charge Ready Transport program was the inclusion of DACs as beneficiaries of any new charging infrastructure. Specifically, SCE has committed to reserving 40 % of its budget for investments in DACs (CPUC, 2018). This means that a key constraint criterion in determining optimal charging site locations will be to ensure that a minimum of 40 % of these sites is located in DACs.

5.4.2.3. Power Grid Capacity

Charging heavy-duty all-electric drayage trucks with large battery packs will require a tremendous amount of power and support from local utilities. Existing locations have a set capacity for how much electricity is available via the existing electricity grid. Drayage truck fleets may need to make significant upgrades to their electrical panels and the actual power lines from the poles. Also, unlike the economies of scale for fueling diesel vehicles, costs increase as fleets add scale to their electric infrastructure. Grid power is a significant issue when charging larger vehicles due to the demand of each vehicle. According to one electric truck company CEO (Long 2018), an existing grid could require the construction of an entirely new power plant just to charge 50-100 trucks.

However, given the short-term scope of our recommendations, we limit our focus to the current electrical grid capacity. Therefore, another defining constraint in our considerations will be whether a given site has the electrical grid capacity to support the electricity needs of drayage truck charging. Those sites that do not have capacity will be eliminated from consideration, while those that do will remain options for charging site placement, but then subject to the additional constraints outlined.

The policy goals outlined at the beginning of this chapter — to develop a framework for optimal placement of charging stations, as well as a complementary strategy to enhance electric truck take-up — informed our decision to develop policies aimed at following these two approaches.

6. Policy Recommendations

The policy recommendations below are segmented into two parts. While separate in practice, the two types of policies complement one another and are part of a larger strategy to maximize the use of charging stations and the take-up of electric trucks. The first part of our recommendation is an algorithm based on quantitative data analysis, and it seeks to fulfill our policy goal of identifying the optimal placement of electric charging stations. The complementary strategy to our algorithm is a set of potential business and outreach strategies, whose goal is to encourage the take-up of electric trucks, thereby creating robust demand for charging stations.

6.1. Charging Station Placement Optimization Algorithm

Our first recommendation is an algorithm for finding the optimal locations for charging infrastructure, based on the constraints discussed above as well as key assumptions. This algorithm can be used to site charging stations in both the short and long term.

6.1.1. Key Assumptions

To evaluate potential charging station placement scenarios, we used various assumptions deemed most realistic from a technological and logistical standpoint. Assumptions are based on research and interviews discussed above and the most recent data from primary sources wherever possible.

6.1.1.1. Electric Drayage Truck Specifications

This analysis uses Daimler's Freightliner eCascadia class 8 heavy-duty truck specifications (Daimler, n.d.). Daimler presented the fully-electric truck in 2018, and it is expected to be commercially available in 2021 (Wilde, 2018). The model is based on the Cascadia, the most successful heavy-duty long-distance truck (class 8) in the North-American market (Daimler, n.d.). Figure 12 lists the electric truck's specifications. Since the average monthly electricity consumption for a U.S. residential utility customer was 867 kWh (U.S. Energy Information Administration, 2018), the battery capacity of the truck is nearly 20-day electricity consumption for a household.

Battery capacity	550 kWh
Range	Up to 400 km (250 miles) at 550 kWh
Electric-truck Efficiency	0.45 miles/kWh → 250 miles/ 550 kWh

Figure 12. Daimler Freightliner eCascadia key specifications (Daimler, n.d.)

Figure 13. Daimler's Freightliner eCascadia (Daimler, n.d.)

6.1.1.2. Drayage Truck Duty Cycle

We assume the average miles traveled by electric trucks per day is 273.7 miles. It is calculated as follows:

Average miles traveled per day = Average daily miles + Safety margin

= 238 miles[2] *+ electric drayage truck range x 15%*

= 238 miles + 250 miles x 15% = ***273.7 miles***

This calculation uses the range of the eCascadia heavy-duty truck, including an additional 15% margin of safety to account for potential upward deviations in daily mileage. We also assume that trucks begin their shift at the truck yard, drive to the ports, pick up cargo, and drive to warehouses for cargo drop-off or pick-up (Figure 7). Trucks then return to the ports for additional trips. In other words, we do not assume trucks carry out direct warehouse-to-warehouse travel. This assumption is based on the limited available data on all trucking routes. After finishing a shift, trucks from larger fleets return to their company truck yards, while small-fleet and IOOs park their vehicles in lots or other locations.

6.1.1.3. Charger Type

Since we assume the overnight charging window is only nine hours, high-capacity chargers are needed to charge as many trucks as possible. Therefore, we assume trucking companies will use DC fast chargers, as opposed to the slower-to-charge AC chargers. One possible model is BTCPower L4M200 (BTCPower, n.d.). This charger has a capacity of 200 kW and costs $44,200. With this charger, heavy-duty trucks can get a full charge in a minimum of 1 hour and 45 minutes. As stated above, trucking companies will want to minimize the amount of time spent charging and will, therefore, want this type of faster charger.

[2] Source: (Tetra Tech 2018)

Figure 14. BTC Power L4M200 charger (BTCPower, n.d.)

6.1.1.4. Overnight and Opportunity Charging

As discussed in Section 5, we assume the optimal charging time for the average truck is 9 pm to 6 am, as the longest break occurs at night when ports are closed. Since we assume one DC fast charger can charge four trucks overnight in the nine-hour charge window, one truck can occupy a charger for 2 hours and 15 minutes. With the 2 hours and 15 minutes of charging, electric trucks can drive up to 202.5 miles according to the following calculation:

2.25 hour charging = 200 kW x 2.25 hour x 0.45 miles/kWh = ***202.5 miles***

For trucking companies to utilize this efficient four-truck-per-night charging model, they will need to utilize current employees or new hires for overnight attendance to the charging stations. This is because, once the first “shift” of two trucks completes their charging cycle, an attendant will need to replace this first shift with the second shift of two trucks to charge.

Since the average miles traveled by electric trucks per day is 273.7 miles, trucks would run out of battery during their daily routes without additional charging during the day. Therefore, opportunity charging must be accounted for when placing charging infrastructure.

6.1.1.5. Short- and Long-Term Charging Station Ownership and Locations

In the short term, the first five years, we assume early adopters will be larger companies that have the resources to invest in the new technologies and comply with SCE guidelines. On the other hand, owners of warehouses could have shared chargers for short, opportunity charging. Smaller companies and IOOs will electrify in the longer term. While our recommendations for opportunity charging in the long term also apply to small companies, optimal overnight infrastructure siting for smaller operators is beyond the scope of this analysis.

We assume that large companies will place chargers in their privately owned truck yards for overnight charging to avoid competition and also use them for opportunity charging during daytime if they are close to ports. As discussed in Section 5, opportunity charging at warehouses is not expected in the short term. In the long term (the year 2035), we assume that the majority of large and small trucking firms will convert to electric to meet the port’s 2035 zero emission goals. At that time, opportunity charging can take place in warehouses. Finally, we assume that the grid capacity will expand to meet this greater demand in the long run.

Chargers are not permitted on the port property due to technical and spatial constraints (R. Moilanen, personal communication, November 5, 2018). We do not consider a public shared model (e.g., a conventional gas station model), because this type is precluded by the conditions set out in SCE's Charge Ready Transport program application.

6.1.1.6. Installation Cost and Economies of Scale

We estimate the installation cost and economies of scale based on existing literature in the DGS General Service "Electric Vehicle Supply Equipment Guidance Document" (California Department of General Services, 2014) and our interview with SCE (personal communication, February 24,2019). We assume that the installation cost, which includes a site development cost separate from the actual equipment, is $150,000 to $250,000. Since the diseconomy scale caused by energy consumption greatly differs between each site, we assume that there will be economies of scale for the installation cost, but the installment cost per charger is stable if the number of chargers per site is more than five.

# of chargers per site	Installment Cost per Charger (excluding charging equipment)
1	$250,000
2	$225,000
3	$200,000
4	$175,000
5 and more	$150,000

Figure 15. Estimate of Installment Cost (California Department of General Services, 2014 and SCE, personal communication, February 24,2019)

6.1.2. Short-Term Placement Algorithm

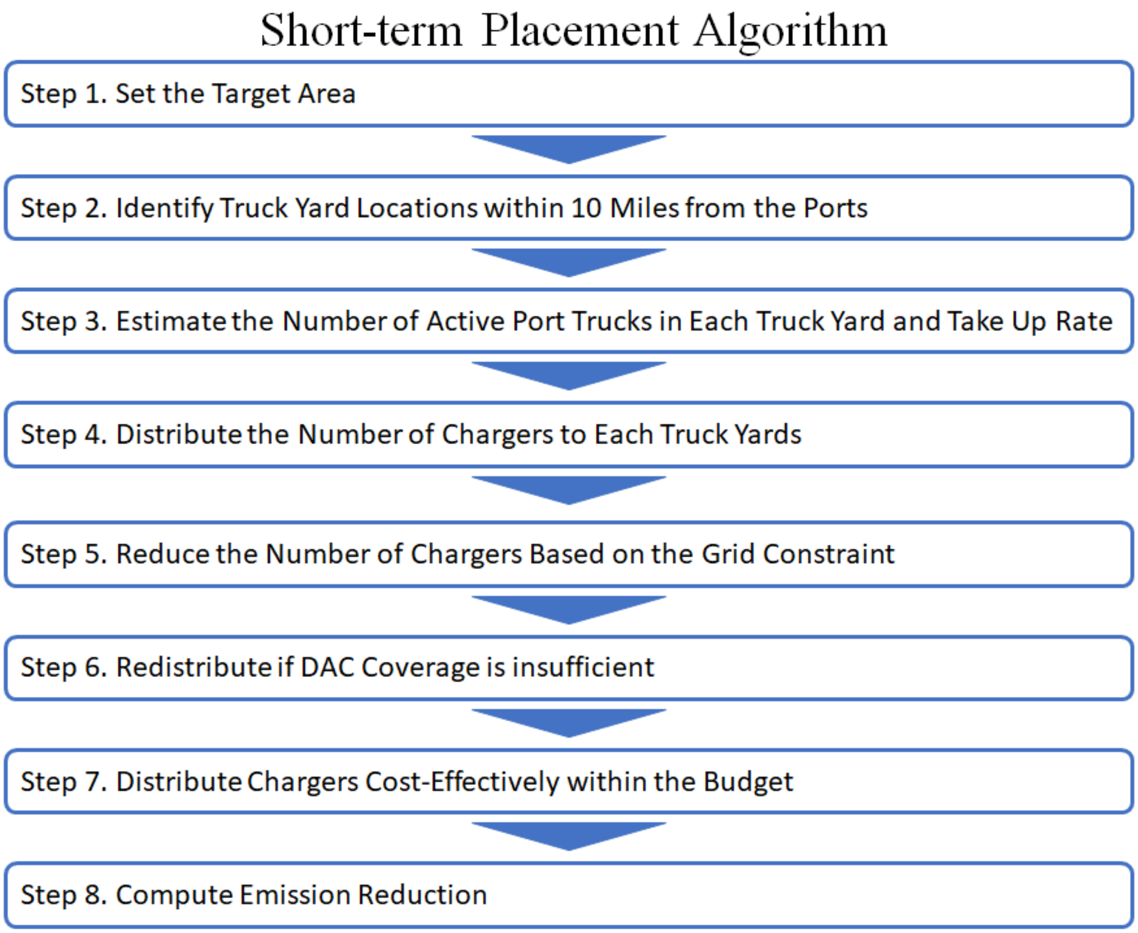


Figure 16. Overview of Short-term Placement Algorithm

Step 1. Set Target Area

Our project target area is within 100 miles of the ports. We consider three factors in choosing this range: electric truck battery capacity and range, truck travel behavior, and DAC coverage.

Our model drayage truck drives 202.5 miles, which means about 100 miles per one-way trip. Also, 88% of drayage trucks have one-way trips of under 100 miles away from the ports (CGR Management Consultants LLC, 2007). Lastly, the 100-mile radius area covers a large number of DACs, where SCE is required to invest at least 40% of its total program funding for deployment (CPUC, 2018).

Step 2. Identify Truck Yard Locations

Truck yard locations were identified using POLB’s drayage company registry which included the addresses of all of the companies registered at the ports. Company addresses were geocoded and converted into geographic coordinates by researcher James Di Filippo from the UCLA Luskin

Center for Innovation. We then visually verified truck yard coordinates using Google satellite images.

ESRI's ArcGIS spatial analysis software was then used to import coordinate points and map truck yard locations. Further analysis was conducted using these points. Truck yard locations were identified in this way based on the data we obtained. However, if SCE were able to acquire comprehensive truck yard data after speaking to individual customers, the result would be more accurate.

There is limited data on all of the truck routes and the warehouses drayage trucks travel to; moreover, these locations are constantly changing. Therefore, we cannot identify specific warehouses for opportunity charging. In the short term, opportunity charging will have to take place at a company's truck yard. To limit the extra distance trucks have to drive to go back to their yards for opportunity charging, chargers should be placed in yards that are closer to the ports (within 10 miles), the most common and consistent destination for drayage trucks.

Step 3. Estimate Number of Active Port Trucks and Take-Up Rate

The ports spreadsheet on vehicles registered to enter the ports includes infrequent visitors. Therefore the actual number of trucks per truck yard that regularly visit the ports daily is lower than the registry estimate. Based on an existing report (CGR Management Consultants LLC, 2007) and our interview with the HTA (W. LaBar, personal communication, October 22, 2018), we took the weighted average of the number of trips per day for the trucks departing from the ports. As a result, we assume each truck is taking two trips per day. The number of active port trucks per yard is calculated by dividing the total number of trips by the number of daily trips per truck. If there is a truck yard where the number of active port trucks is larger than that specific yard's registered number of active trucks, we used the number of trucks registered to the POLB instead.

Miles	Weight[3]	Number of trips[4]	Sum
10	0.11	4	0.44
11-25	0.26	3	0.78
26-50	0.23	2	0.46
51-100	0.28	1	0.28
101-200	0.08	0.5	0.04
200-	0.04	0.5	0.02
Total	1	-	**2.02**

Figure 17. Weighted Average of Daily Trips per Truck

Next, to calculate the overall truck moves for both ports, we added the number of truck moves to the Port of Los Angeles, which is 50% greater than Long Beach. The difference between the two ports was estimated using the SCAG Travel Demand OD Matrix(SCAG, 2012). Lastly, we

[3] Source: CGR Management Consultants LLC, 2007
[4] Source: W. LaBar, personal communication, October 22, 2018

assume 25% of active port trucks will convert to electric since we assume that even the larger companies will not convert their entire fleet in the first five years.

Total # of active port trucks = [Total POLB truck moves] /2 (daily trips) x 1.5 (total POLA truck moves)] x (conversion rate)

Step 4. Distribute Charging Stations

As stated above, we assume that the time window for overnight charging is nine hours, which accounts for almost fully charging four trucks. Thus, the number of chargers needed in each truck yard is calculated by dividing the number of active trucks in each truck yards by four. Then, we distribute chargers to the yards with the highest demand for chargers[5]. In this process, we eliminate those yards with less than four active trucks to omit small companies and to make sure that all chargers are fully used overnight.

Step 5. Apply Power Grid Constraint

After calculating the number of chargers needed in each truck yard, we checked the grid capacity to make sure that the electricity demand of chargers did not exceed the capacity. The electricity demand of each truck yard was calculated as shown:

Total truck yard electric demand = [Total number of chargers in each truck yard] x [200 kW]

As for the grid capacity, we searched for the "Integration Capacity (Uniform Load)" of the circuit node closest to each truck yard by using Southern California Edison's DRPEP. The electricity demand and integration capacity are compared for each truck yard, and if the integration capacity is smaller than electricity demand, the number of chargers is reduced. It is important to note that integration capacity in DRPEP assumes uniform load; however, our model assumes electricity demand for chargers increases mainly during the night time when electricity demand is low. Therefore, the grid capacity examined using this method is stricter than the actual grid constraint.

Step 6. Apply DAC Coverage Constraint

SCE is mandated to spend over 40% of its budget in DACs. If the expenditure for chargers placed within DACs is less than 40% of the total expenditure for all chargers, the chargers placed outside of DACs will be redistributed to truck yards in DACs until the requirement is fulfilled.

Step 7. Apply Budget Constraint

Since we determined that economies of scale exist, it is more cost-effective to place chargers in truck yards with higher charger demand. Therefore, chargers are placed in high-demand truck yards until the budget ($35,812,407) is reached. The installation cost for each truck yard is

[5] For the number of chargers in each yard, decimals are rounded down so that the chargers are fully used by four trucks overnight.

calculated using values introduced in Figure 15. Under SCE's Charge Ready Transport program, 100% of the electricity infrastructure and charger installation are covered. A rebate also covers up to 50% of charger cost, which the customer is responsible for purchasing. To be conservative, 100% of the installation cost and 50% of the charger's cost was included.

Sector	Estimated Cost per site - Capital	Estimated Cost per site - Expense	Estimated Cost Per Site - total	# of Sites	# of Vehicles	Capital Budget	Expense Budget	Total Budget
Forklifts	$131,897	$716	$132,613	100	1,919	$13,189,716	$71,580	$13,261,296
TSE	$98,771	$267	$99,038	8	160	$790,164	$2,138	$792,302
TRU	$184,930	$609	$185,539	156	2,964	$28,849,136	$94,977	$28,944,113
Port Cargo Trucks	$333,972	$593	$334,565	12	136	$4,007,664	$7,113	$4,014,776
Transit Bus	$340,651	$419	$341,071	140	1,680	$47,691,152	$58,724	$47,749,877
School Bus	$146,227	$502	$146,730	54	648	$7,896,284	$27,112	$7,923,396
Airport GSE	$133,427	$487	$133,913	30	600	$4,002,801	$14,603	$4,017,404
Medium-Duty Vehicles	$147,661	$435	$148,097	400	4,800	$59,064,433	$174,180	$59,238,613
Other Heavy-Duty Vehicles	$340,651	$419	$341,071	105	4,084	$35,768,364	$44,043	$35,812,407
Infrastructure Subtotal				**1,005**	**16,991**	**$201,259,715**	**$494,470**	**$201,754,185**
Program Management						$20,175,419		$20,175,419
Contingency						$20,175,419		$20,175,419
DAC Rebates SCE							$35,931,200	$35,931,200
Transit & School Bus Rebates							$64,620,000	$64,620,000
Non Infrastructure Subtotal						**$40,350,837**	**$100,551,200**	**$140,902,037**
Program Total						**$241,610,552**	**$101,045,670**	**$342,656,222**

Figure 18. SCE estimated Heavy-Duty Infrastructure Program budget (CPUC, 2018)

Step 8. Compute Emission Reductions

Replacing diesel and LNG trucks with electric trucks reduces emissions since electric drayage trucks have zero tailpipe emissions. While generating electricity for such vehicles emits pollutants, lifecycle emissions are beyond the scope of this analysis. We use the following calculation to estimate emission reductions:

$$\textit{Emission reduction (replacing diesel truck) [metric tons/year]} = T \times P_D \times (VMT/day) \times (\textit{operational days per year}) \times [EF_D - EF_E]$$

Where T = total number of electric trucks supported with charging station placement
P_D = proportion of the current fleet that is diesel
EF_D = diesel heavy-duty truck emission factor [metric tons per mile]
EF_E = electric heavy-duty truck emission factor [metric tons per mile]

$$\textit{Emission reduction (replacing LNG truck)} = T \times P_{LNG} \times (VMT/day) \times (\textit{operational days per year}) \times [EF_{LNG} - EF_E]$$

Where P_{LNG} = proportion of the current fleet that is LNG

EF_{LNG} = LNG heavy-duty truck emission factor [metric tons per mile]

We use the diesel and LNG truck emission factor in Figure 19. The CO2 emission factor is found through the following calculation:

$$CO_2\ \textit{Emission Factor (diesel truck)} = \textit{(grams } CO_2\textit{/gallon diesel combusted) / (average miles / gallon diesel)}$$

$$= (10{,}151 \textit{ grams per gallon}^{6}) / (6.5 \textit{ miles per gallon}^{7}) = 1{,}561.7 \textit{ grams/mile}$$

We also assume that 95 % of all drayage trucks replaced by electric drayage trucks are diesel-fueled, and the other 5% are LNG-fueled. This ratio is the same as a market composition in 2017 (Guerin, 2017).

Pollutant	LNG emission reduction compared to diesel trucks	Electric truck emission reduction compared to diesel trucks	New diesel truck emission rate (grams per mile)	LNG truck emission rate (grams per mile)	Electric truck emission rate (grams per mile)
CO2	27%[8]	100%	1,561.70	1132.79[9]	0
NOx	90%	100%	1.508	0.15080	0
PM2.5	16%	100%	0.007	0.00588	0

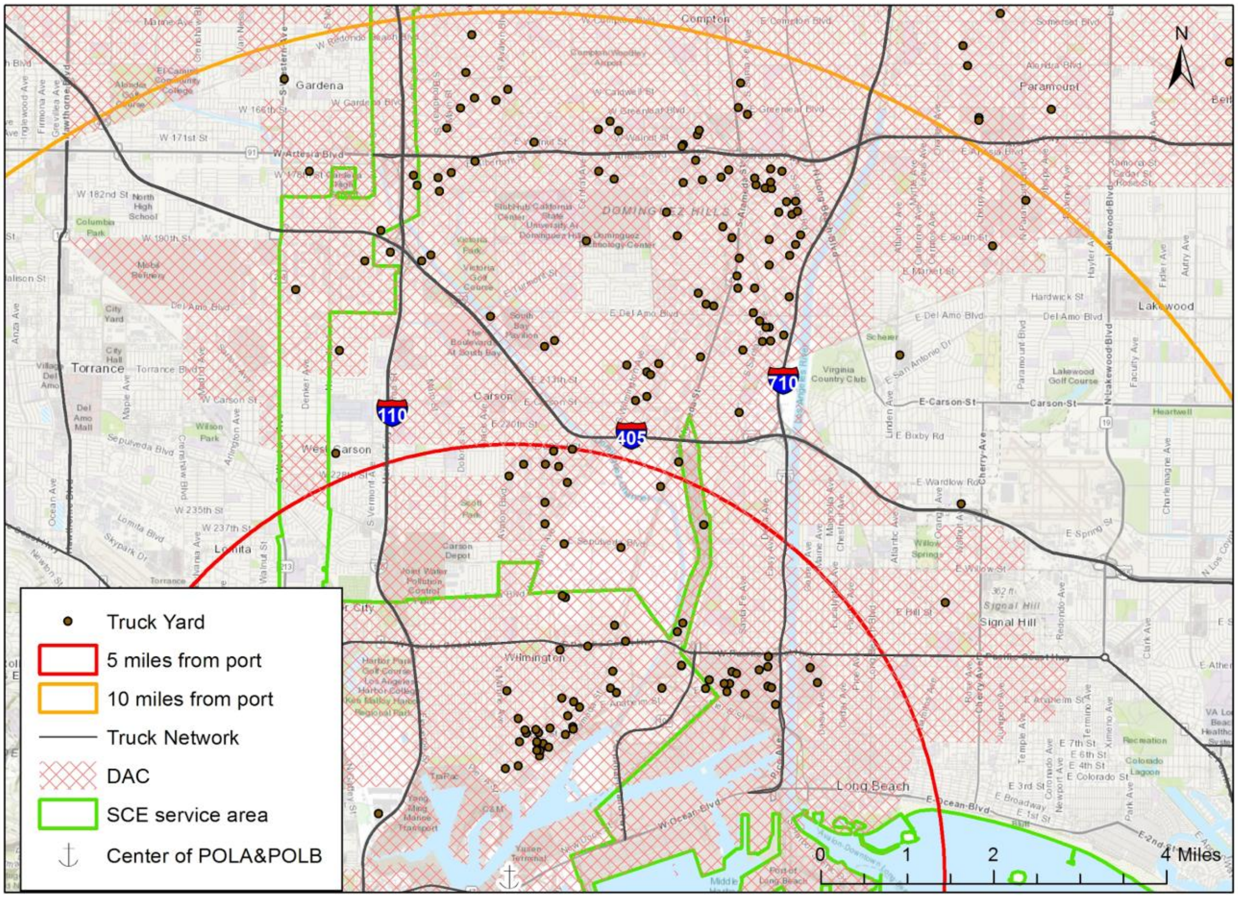
Figure 19. Average Heavy Duty Truck Tailpipe Emission Rates (grams per mile). Source: EMFAC 2017, POLA and UBUS vehicle categories were used.

6.1.3. Short-Term Algorithm Application

6.1.3.1. Truck Yard Locations

The location of truck yards with more than four active trucks is as follows. The majority of them are located within 10 miles of the ports.

[6] Source: US Energy Information Administration, 2014
[7] Source: Rentar Environmental Solutions, Inc., 2017
[8] Source: US Energy Information Administration, 2016
[9] Source: US Energy Information Administration, 2016



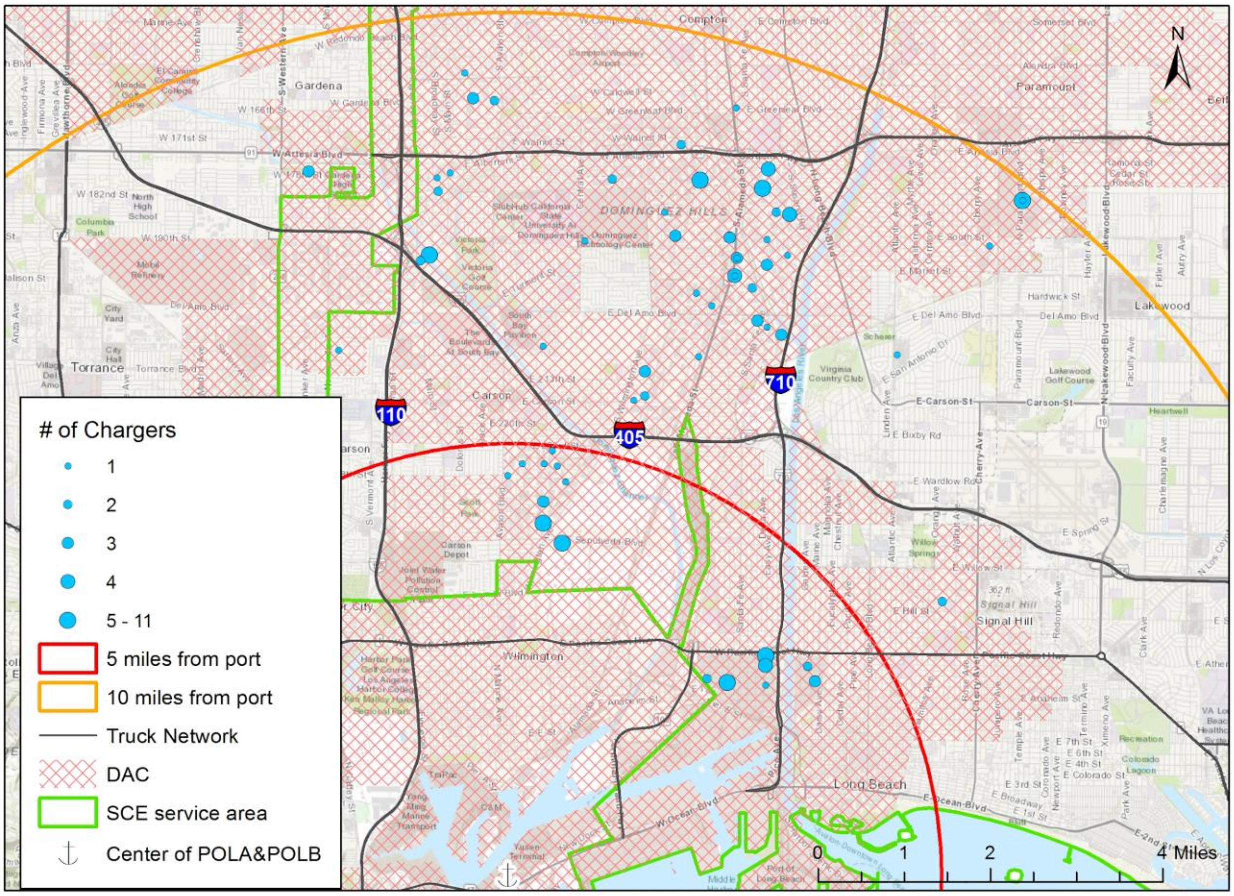
Source: POLB(2018), Caltrans(2018), CalEPA(2018),SCE(2019),SCAG(2012)

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

Figure 20. Truck Yard Location

6.1.3.2. Number of Chargers Needed in Each Truck Yard

After locating the address of truck yards, chargers were distributed in proportion to the number of estimated electric trucks in each truck yard within the SCE service area. If the overnight chargers are placed within 10 miles from the ports and the conversion rate is 25% at maximum, the total cost is under the proposed budget.



Source: POLB(2018), Caltrans(2018), CalEPA(2018),SCE(2019),SCAG(2012)

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

Figure 21. Distribution of Chargers in the Short-term Before Considering Grid Capacity

Total # of companies	Total # of chargers	Total # of trucks charged	Total cost	Total Electricity Demand
61 (5 miles: 16)	157 (5 miles: 51)	628 (5 miles: 204)	$33,404,000 (5 miles: $10,172,000)	31,400kW (5 miles: 10,200kW)

Figure 22. Summary of Charger Placement in the Short-term Before Considering Grid Capacity within a 5- and 10-mile Radius from the Ports

Company	# of chargers	# of trucks charged	Cost per Charger	Cost per Truck Yard	Electricity demand (kW)
DAMCO Distribution Services, Inc.	10	40	$172,000	$1,720,000	2,000
Shippers Transport Express, Inc.	8	32	$172,000	$1,376,000	1,600
Progressive Transportation Services, Inc.	6	24	$172,000	$1,032,000	1,200
Overseas Freight, Inc.	6	24	$172,000	$1,032,000	1,200
Trans Ocean Carrier, Inc.	4	16	$197,000	$788,000	800

Figure 23. Top 5 Companies within a 5 miles from the Ports (See Appendix A for a full list)

Company	# of chargers	# of trucks charged	Cost per Charger	Cost per Truck Yard	Electricity demand (kW)
Southern Counties Express, Inc.	11	44	$172,000	$1,892,000	2,200
DAMCO Distribution Services, Inc.	10	40	$172,000	$1,720,000	2,000
Shippers Transport Express, Inc.	8	32	$172,000	$1,376,000	1,600
Lincoln Transportation Services, Inc.	7	28	$172,000	$1,204,000	1,400
Container Freight EIT, LLC	6	24	$172,000	$1,032,000	1,200
Progressive Transportation Services, Inc.	6	24	$172,000	$1,032,000	1,200
Overseas Freight, Inc.	6	24	$172,000	$1,032,000	1,200
Sho Hai, Inc.	5	20	$172,000	$860,000	1,000
Green Fleet Systems, LLC	4	16	$197,000	$788,000	800
Trans Ocean Carrier, Inc.	4	16	$197,000	$788,000	800
National Retail Transportation, Inc.	4	16	$197,000	$788,000	800
Mano Delivery Corp.	4	16	$197,000	$788,000	800

Figure 24. Top 10 Companies within a 10-mile radius of the Ports (See Appendix B for a full list)

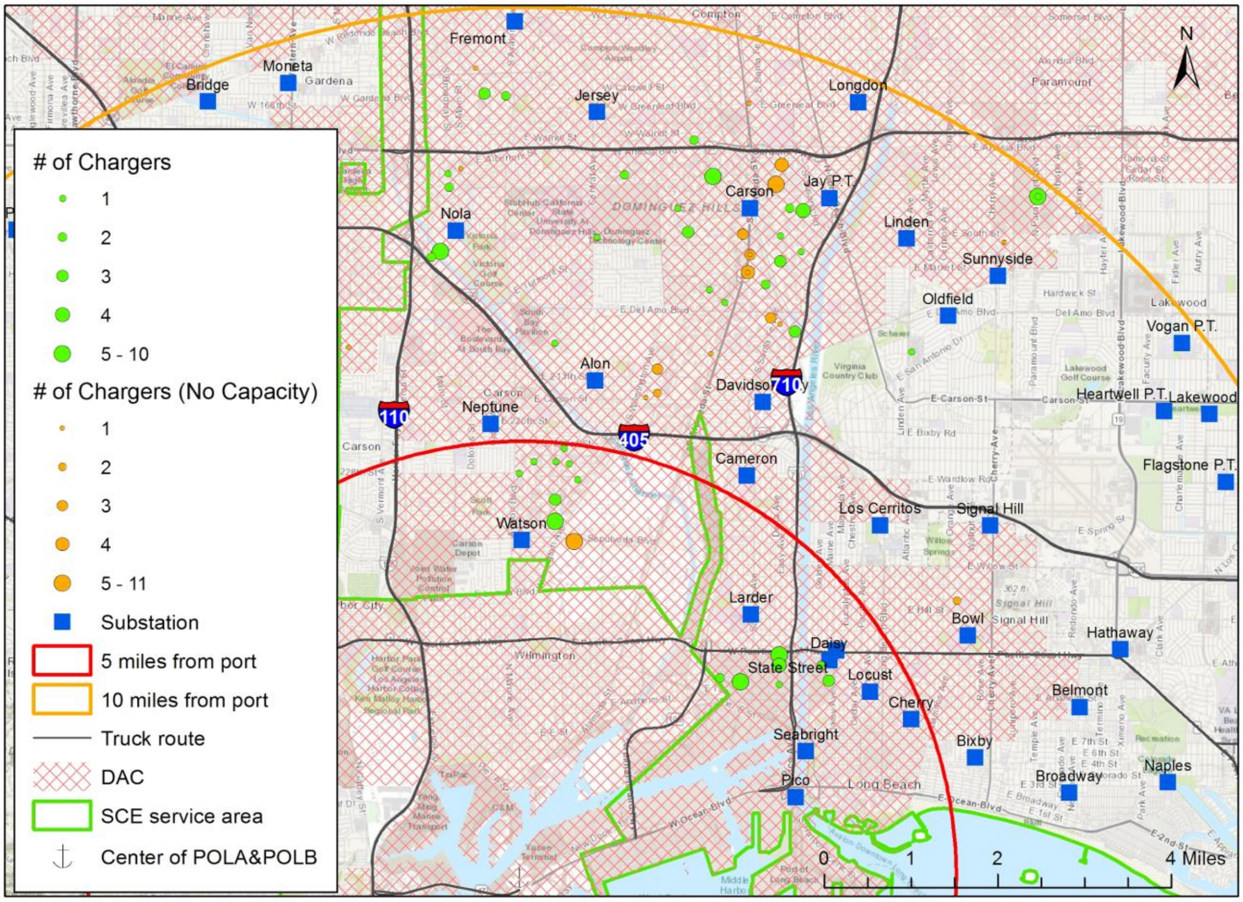
6.1.3.3. Application of Constraints (Grid Capacity / DAC / Budget)

Several truck yards were located in areas with zero additional grid capacity. As a result, the number of chargers was reduced for those locations. Many of the truck yards without grid capacity were close to the circuits connected to substations in the cities of Carson, Alon, and Watson.

As for DAC coverage, there was only one charger that was located outside of the DAC area in the short term. The DAC coverage rate was 100% within 5 miles from the ports, and 99% within 10 miles from the ports. Therefore, the placements exceed SCE's minimum 40% DAC investment requirement.

6.1.3.4. Distribution of Chargers within Budget

As mentioned above in 6.1.3.2, the total cost was less than the project budget even before considering the constraints. Therefore, all of the chargers needed were distributed within the budget in the short term. There will be 101 chargers placed in 40 truck yards, serving 404 trucks at a cost of $21,522,000 for SCE.



Source: POLB(2018), Caltrans(2018), CalEPA(2018),SCE(2019),SCAG(2012)

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

Figure 25. Distribution of Chargers in the Short-term After Considering Grid Capacity

Company	Electricity Demand (kW)	Integration Capacity (kW)	# of Chargers	# of Chargers (with Grid)	# of Trucks Charged	Cost per Charger	Cost per Truck Yard	Substation
Southern Counties Express, Inc.	2,200	0	11	0	0	$172,000	$0	Carson
DAMCO Distribution Services, Inc.	2,000	3,510	10	10	40	$172,000	$1,720,000	Watson
Shippers Transport Express, Inc.	1,600	0	8	0	0	$172,000	$0	Watson
Lincoln Transportation Services, Inc.	1,400	3,610	7	7	28	$172,000	$1,204,000	Jersey
Container Freight EIT, LLC	1,200	1,400	6	6	24	$172,000	$1,032,000	Sunnyside
Progressive Transportation Services, Inc.	1,200	1,720	6	6	24	$172,000	$1,032,000	State Street
Overseas Freight, Inc.	1,200	1,680	6	6	24	$172,000	$1,032,000	State Street
Sho Hai, Inc.	1,000	11,250	5	5	20	$172,000	$860,000	Nola
Green Fleet Systems, LLC	800	0	4	0	0	$197,000	$0	Carson
Trans Ocean Carrier, Inc.	800	1,710	4	4	16	$197,000	$788,000	State Street
National Retail Transportation, Inc.	800	0	4	0	0	$197,000	$0	Carson
Mano Delivery Corp.	800	4,470	4	4	16	$197,000	$788,000	Carson

Figure 26. Top 10 Companies within a 10-mile radius of the Ports after Considering Grid Capacity (See Appendix C for a full list)

Total # of companies	Total # of chargers	Total # of trucks charged	Total cost
40	101	404	$21,522,000

Figure 27. Summary of Short-Term Charger Placement after Considering Grid Capacity within a 10-mile Radius from the Ports

6.1.3.5. Emission Reductions

Using the number of trucks replaced through this project, the estimated emission reductions would be as follows (for full calculations, see Appendix D).

Emission reduction in metric tons per year	Short-term placement within 5 miles of the ports	Short-term placement within 10 miles of the ports	Short-term placement within 10 miles of the ports (considering grid capacity)
CO_2	23,332.12	71,826.33	46,206.75
NOx	21.82	67.16	43.20
PM2.5	0.11	0.32	0.21

Figure 28. Summary of short-term emission reductions (metric tons per year)

6.1.4. Long-Term Placement Algorithm

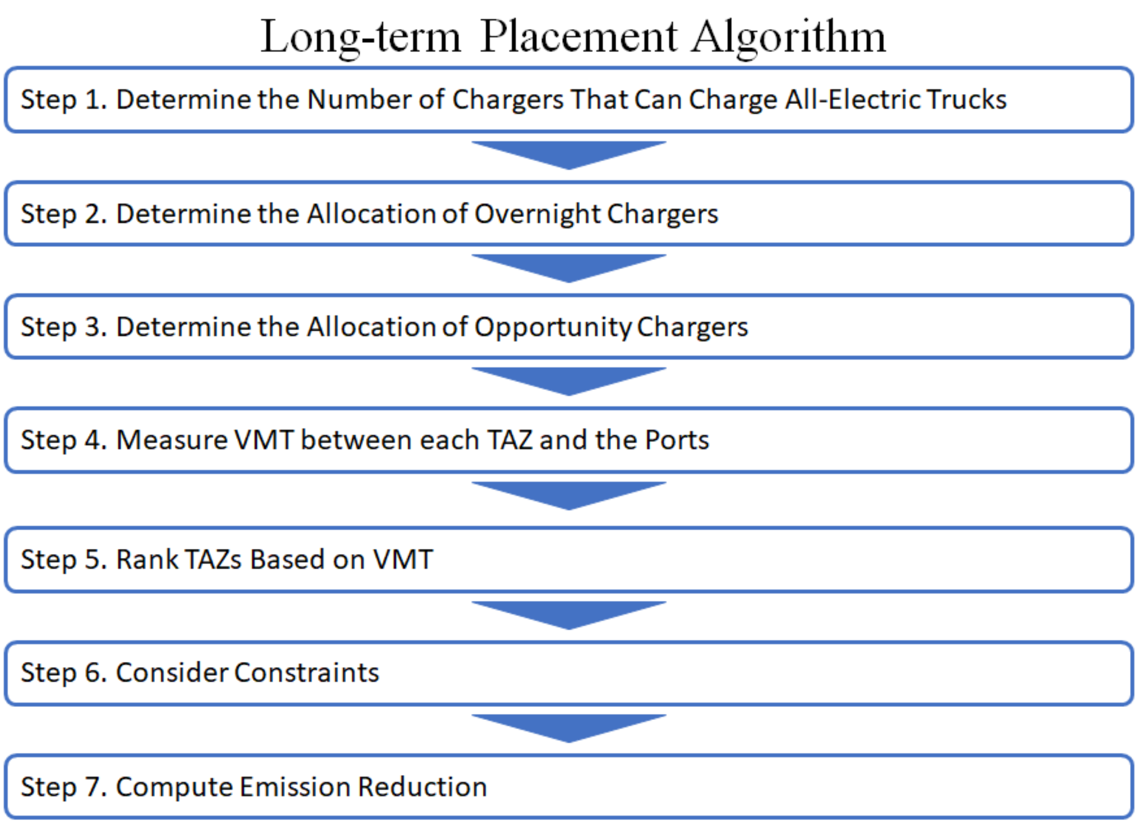


Figure 29. Overview of Long-term Placement Algorithm

Step 1. Determine Number of Charging Stations Fleetwide

For the short-term, we assume that only 25% of the trucks in each company convert to electric. For the long term, we assume that all trucks, except those owned by small truck companies, convert to electric. The location and number of active trucks for each truck yard are already calculated in the short-term application above. We use this data to then calculate the number of stations that can charge such trucks by adding the necessary number of charging stations (total number of electric trucks divided by 4) in each truck yard. Decimals are rounded up so that all the electric truck are charged overnight.

Step 2. Allocate Overnight Charging Stations to Small Trucking Companies

Ideally, all electric trucks should be covered by overnight chargers. However, each truck yard is for trucks owned by each company's own vehicles, so smaller truck companies would not be able to charge in truck yards belonging to other larger companies. Furthermore, small company yards might not be located near the ports, and it is not realistic for them to return to their yards for opportunity charging. Thus, we consider placing chargers in areas other than truck yards for small companies and IOOs.

For truck companies that own more than four trucks, we will continue to add overnight chargers to their yards with a new budget as mentioned in the previous step. For smaller trucking companies, their trucks' overnight dwelling location must be identified in order to consider the placement of overnight chargers to cover their trucks.

Step 3. Allocate Opportunity Charging Stations

After equipping all trucks with overnight chargers, we consider placing opportunity chargers in warehouses so that trucks can charge away from the ports. With this allocation, trucks with longer shifts exceeding the average mileage will be able to charge away from the port. Even though battery capacity is expected to increase in the long-term, opportunity charging will still be needed during the day because smaller companies are likely to use second-hand electric trucks which can run up to 200 miles due to battery degradation and the use of old models. For determining allocation, we conducted VMT analysis by using OD matrix data.

Step 4. Measure VMT

To determine potential demand for opportunity chargers, we calculated total VMT between the ports and each TAZ.

$$VMT = (\text{number of trips}) \times (\text{distance})$$

The number of trips between the ports to each TAZ was obtained from SCAG's Origin-Destination Matrix model(SCAG, 2012), and the distance between the center of each zone (ports and TAZ) was calculated by conducting network analysis using ArcGIS. Instead of using the simple Euclid distance between two points, network analysis calculates distances based on the actual road network, prioritizing roads with higher classification (motorway, primary, etc.) that trucks can actually travel on.

Step 5. Rank TAZs

To determine the optimal allocation for opportunity chargers, we ranked zones by VMT from highest to lowest (which indicates highest to lowest charger demand). Within the future budget, SCE can put chargers in zones with a larger volume of VMT.

Step 6. Consider Constraints

In the long term, SCE would not have to consider DAC coverage if this criterion is met in the short term and budgets will have changed in the future. Grid capacity constraints will have also changed as SCE would have time to upgrade grid systems to meet energy demands if necessary. Therefore, this step is not in our application. However, if SCE needs to consider these constraints, the methods introduced in the Short-Term Placement Algorithm Step 5- 7 can be applied.

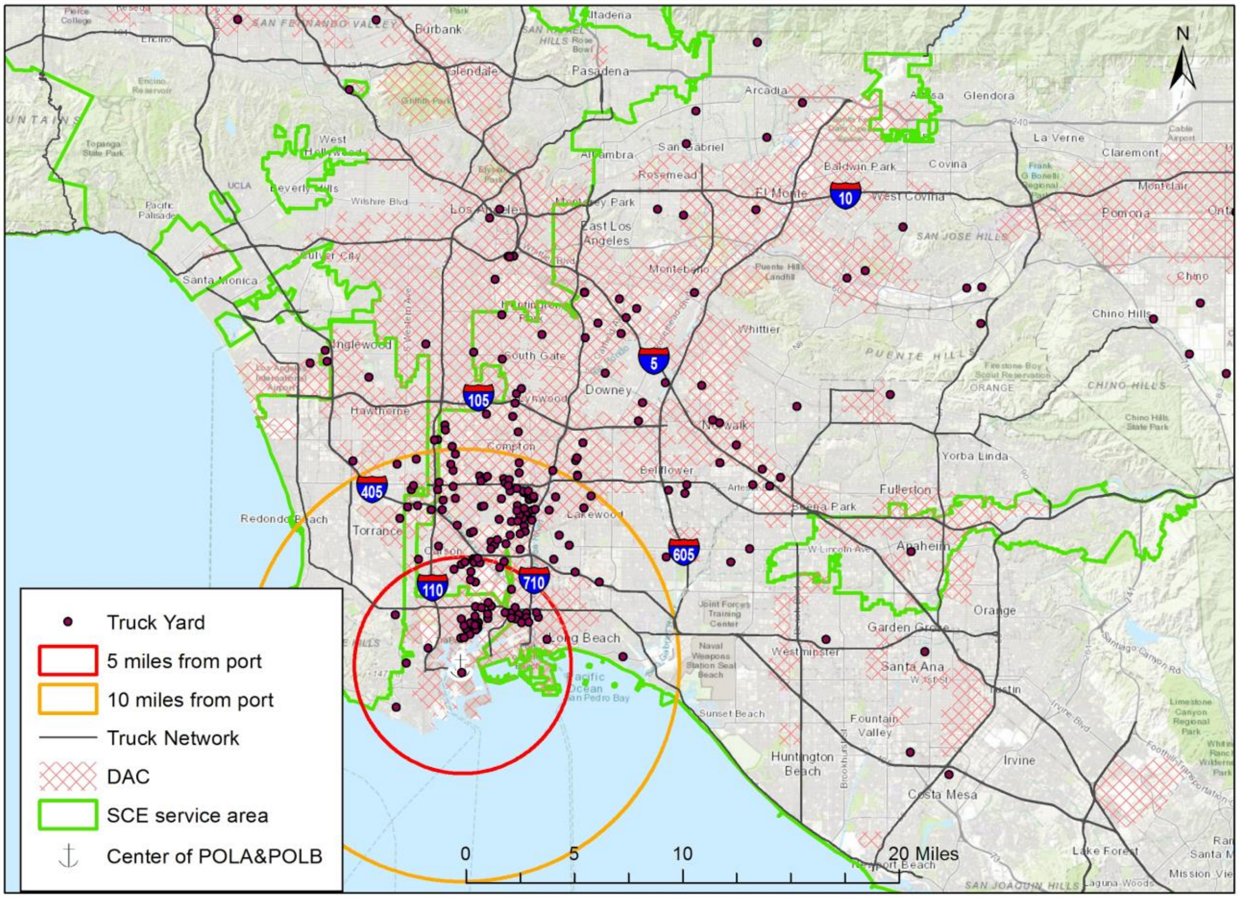
Step 7. Compute Emission Reductions

We employ the same method as explained in Step 8 in the Short-Term Placement Algorithm.

6.1.5. Long-Term Application

6.1.5.1. Location of the Truck Yards

Our short-term analysis is based on the location of truck yards within 10 miles from the ports. In the long-term, we will include all truck yards within our target area (100 miles from the ports).



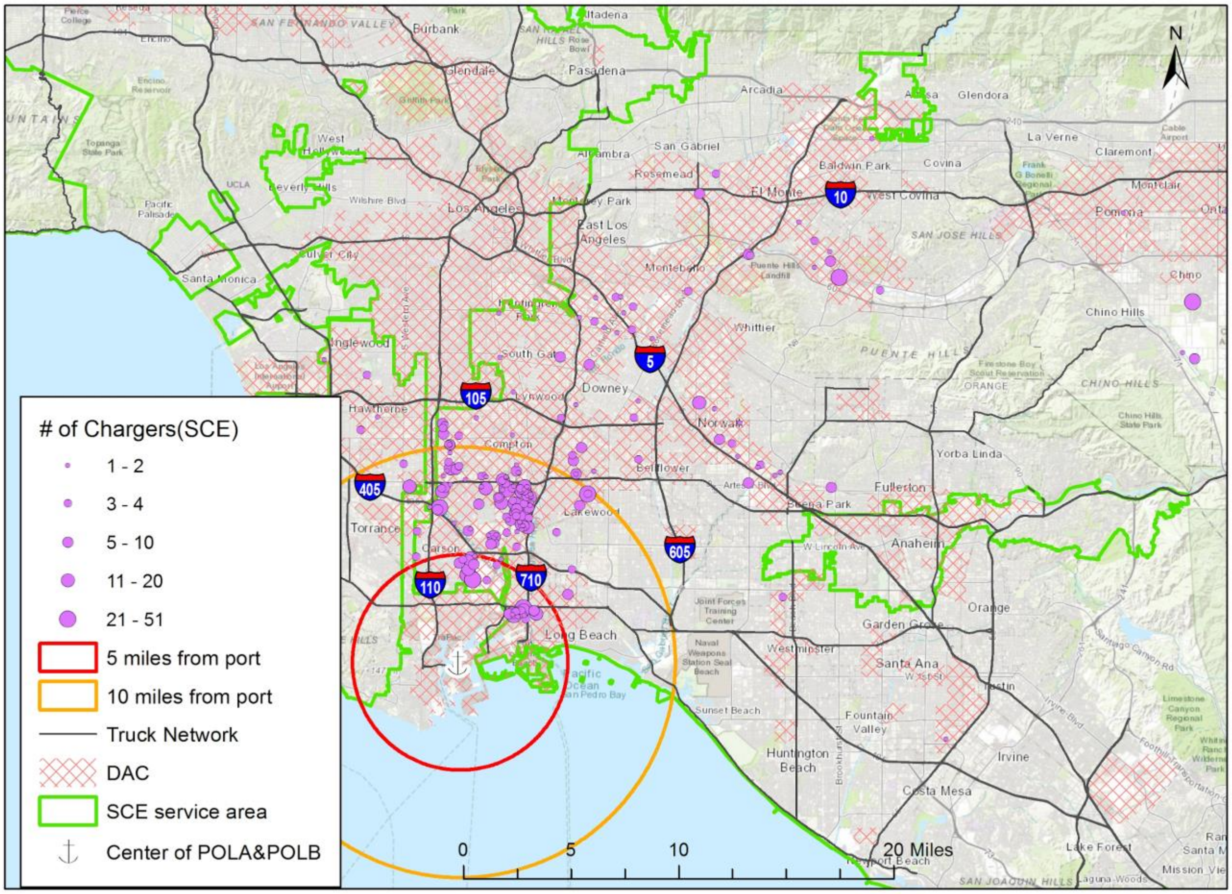
Source: POLB(2018), Caltrans(2018), CalEPA(2018),SCE(2019),SCAG(2012)
Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

Figure 30. Truck Yard Location

6.1.5.2. Number of Chargers Needed in Each Truck Yard

After locating truck yards addresses, we distribute the chargers in proportion to the number of active trucks in each yard within the SCE service area for overnight charging. For the long term, although a budget does not exist as of yet, SCE should allocate necessary overnight chargers for charging all-electric trucks entering the ports. Based on this analysis, the estimated number of electric trucks served is 4,941 with 1,313 overnight chargers needed to support those trucks in the future.

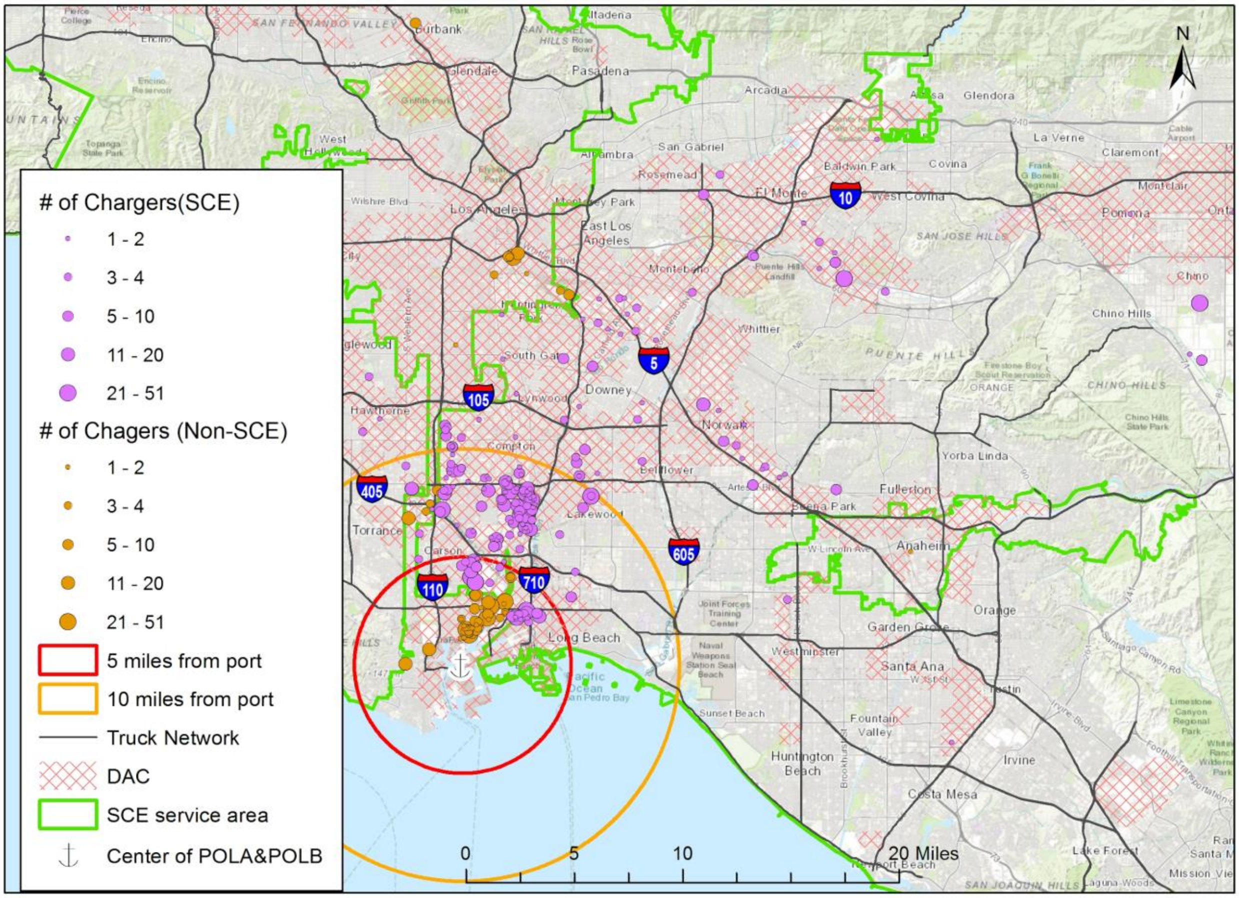
As for small truck companies without truck yards, the overnight parking locations need to be identified to consider the placement of overnight chargers. We do not consider the grid constraint for long-term placement due to its uncertainty. However, there will be 262,600 kW of electricity demand (see Figure 33) and the majority of chargers will be aggregated within 10 miles from the ports. It is highly likely that SCE will need to upgrade the grid capacity if all drayage trucks are converted to electric in the future.



Source: POLB(2018), Caltrans(2018), CalEPA(2018),SCE(2019),SCAG(2012)
Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

Figure 31. Charger Placement in the Long-term

Although it is beyond the scope of this analysis, there is also a certain amount of demand for chargers outside of SCE's service territory, since many truck yards are also located in the Los Angeles Department of Water and Power (LADWP) service area.



Source: POLB(2018), Caltrans(2018), CalEPA(2018),SCE(2019),SCAG(2012)

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

Figure 32. Charger Placement in the Long-term (including non-SCE Area)

Total # of companies	Total # of chargers	Total # of trucks charged	Total cost	Total Electricity Demand
211	1,313	4,941	$245,208,000	262,600kW

Figure 33. Summary of Charger Placement in the Long-term (within SCE service area)

Company	# of chargers	# of trucks charged	Cost per Charger	Cost per Truck Yard	Electricity demand (kW)
Deco Logistics, Inc.	51	204	$172,000	$8,772,000	10,200
Southern Counties Express, Inc.	45	179	$172,000	$7,740,000	9,000
DAMCO Distribution Services, Inc.	43	172	$172,000	$7,396,000	8,600
CMI Transportation, LLC	41	164	$172,000	$7,052,000	8,200
Shippers Transport Express, Inc.	34	133	$172,000	$5,848,000	6,800
Lincoln Transportation Services, Inc.	29	113	$172,000	$4,988,000	5,800
Container Freight EIT, LLC	27	107	$172,000	$4,644,000	5,400
Progressive Transportation Services, Inc.	27	105	$172,000	$4,644,000	5,400
Overseas Freight, Inc.	25	98	$172,000	$4,300,000	5,000
American Pacific Forwarders, Inc.	23	89	$172,000	$3,956,000	4,600
Sho Hai, Inc.	21	83	$172,000	$3,612,000	4,200
Versa Logistics, LLC	21	82	$172,000	$3,612,000	4,200
Green Fleet Systems, LLC	19	76	$172,000	$3,268,000	3,800
Trans Ocean Carrier, Inc.	19	76	$172,000	$3,268,000	3,800
National Retail Transportation, Inc.	18	72	$172,000	$3,096,000	3,600
Mano Delivery Corp.	18	70	$172,000	$3,096,000	3,600

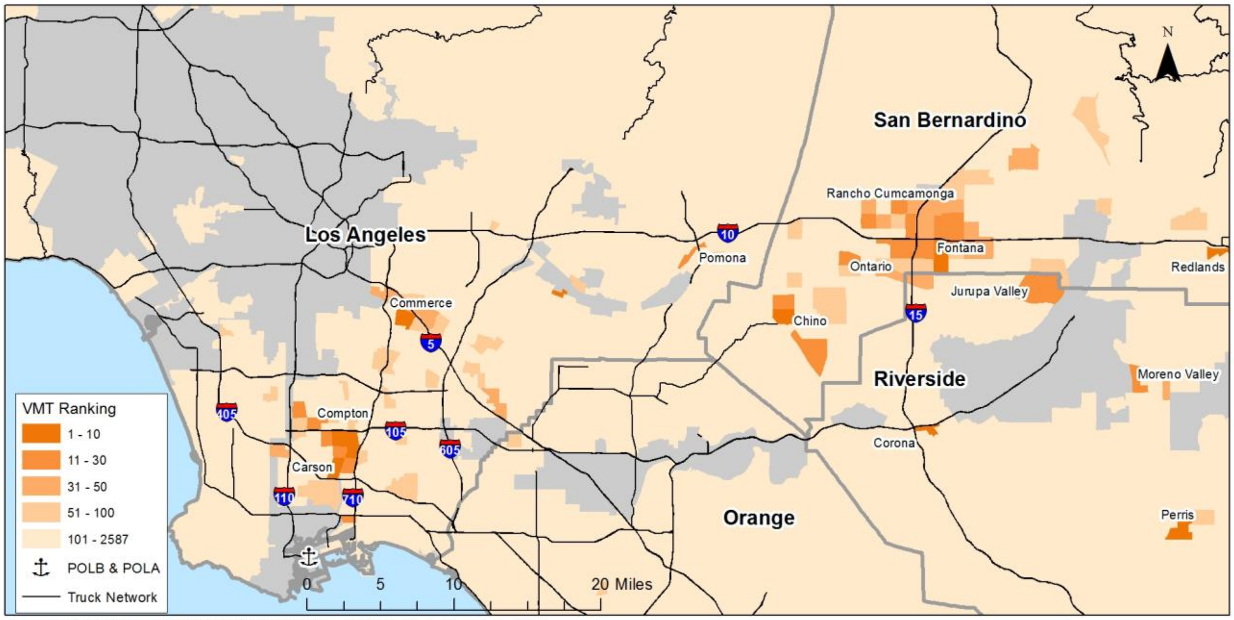
Figure 34. Top 15 Companies with Highest Demand within SCE service area (See Appendix E for a full list)

6.1.5.3. Ranking Zones by VMT for Opportunity Charger Allocation

As discussed above, the priority of location for opportunity charging at warehouses is determined by the VMT for each zone. Appendix G shows the complete list of TAZs within SCE territory ranked by VMT. Based on its future budget, SCE can allocate opportunity chargers at warehouses in TAZs with the highest VMT.

Figure 35 illustrates the distribution of zones with higher daily VMT for heavy-duty drayage trucks entering or departing the ports. The distribution of these zones is similar to Figure 36, which shows TAZs with a greater number of warehouses. Through our VMT analysis, we identified the following clusters of TAZs with high VMT that are potential locations for opportunity charger placement:

- 710 Corridor: neighborhoods surrounding the I-710 and I-5 have high VMT. These include the City of Commerce, Compton and, Carson. These cities have a high number of truck yards as well as warehouses.
- The area surrounding I-10 / I-15 interchange: the I-10 / I-15 interchange is the center of the high-VMT zones, includes the cities of Rancho Cucamonga, Ontario, and Fontana. The relatively close cities of Jurupa Valley, Chino, and Corona are also ranked high.
- Other than these two clusters, the following areas also have high VMT: Pomona, Moreno Valley, Perris, Redlands, and Victorville.



Source: SCAG(2012),Geofabrik.(2018).SCE(2019),Caltrans(2018),California Open Data (2016)

Figure 35. TAZs with High VMT of Heavy-duty Drayage Trucks Entering or Departing the Ports

Source: SCAG(2012,2014),Caltrans(2018),California Open Data (2016)

Figure 36. TAZs with High Volume of Warehouses

6.1.5.4. Emission Reductions

Using the number of trucks replaced through this project, the estimated emission reductions would be as follows (for full calculations, see Appendix F).

Emission reduction in metric tons per year	Long-term placement
CO_2	56,5117.66
NOx	528.39
PM2.5	2.55

Figure 37. Summary of Long-term Emission Reductions (metric tons per year)

6.1.6. Summary of Algorithm Results

Based on our estimate from POLB truck data, our placement algorithm can cover 628 trucks in the short term (404 trucks with grid capacity) and 4,941 trucks in the long term. However, more trucks are operating in the SCAG region. According to the CAAP, the total number of registered port trucks is about 17,500. Approximately 11,000 to 13,000 of these trucks are considered "active," meaning they make multiple daily trips to the ports (The San Pedro Bay Ports, 2018). Among them, we identified 4,941 trucks as our long-term target. These trucks are owned by companies that have four or more trucks, have truck yards located within 100 miles from the ports, and are within SCE territory. The remaining trucks would be owned by companies located outside the 100-mile radius from the ports, outside SCE territory, or owned by very small trucking companies. For these trucks, additional measures outlined in the next chapter should be considered.

<table>
<tr><th colspan="2">Number of trucks</th><th></th></tr>
<tr><td>Total number of port trucks</td><td>17,500</td><td rowspan="2">From CAAP*</td></tr>
<tr><td>Total number of active port trucks</td><td>11,000 - 13,000</td></tr>
<tr><td>Total estimated number of active port trucks</td><td>9,549</td><td rowspan="6">Our Estimate</td></tr>
<tr><td>Trucks owned by companies within 100 miles and with companies with 4 or more active port drayage trucks</td><td>8,876</td></tr>
<tr><td>Long-Term Target: Trucks owned by companies within 100 miles, have 4 or more active drayage port trucks, and yards located within SCE area</td><td>4,941</td></tr>
<tr><td>Short-Term target: within 10 miles</td><td>628</td></tr>
<tr><td>Short-Term target: within 10 miles (considering grid capacity)</td><td>404</td></tr>
<tr><td>Short-Term target: within 5 miles</td><td>204</td></tr>
</table>

*Figure 38. Summary of the Number of Trucks (*The San Pedro Bay Ports, 2018)*

6.2. Business & Outreach Strategy Options

In addition to locating the optimal placement of charging stations, our strategy provides recommendations to address our second stated policy goal: how to encourage trucking companies to convert to electric trucks, a necessary precursor to creating strong demand for electric charging stations.

SCE can play a valuable role in helping companies overcome financial, as well as administrative and logistical, concerns and barriers. While our recommendations are by no means exhaustive, they are all opportunities to bring certainty and confidence into trucking companies' decisions to transition to a cleaner, electric fleet.

Below we outline the most practical, impactful business strategies SCE can implement beginning now, and through the life of their program. We then evaluate these different strategies based on a uniform set of relevant criteria, which include effectiveness, financial feasibility, and administrative feasibility.

6.2.1. Proactive Outreach and Education

As a first step, we recommend proactively reaching out to the drayage trucking companies with the largest fleets and greatest financial resources. Most of these companies are identified in our report's analysis. Instead of waiting for individual companies to apply for SCE's charging station grants, reaching out early and often to the most likely candidates will not only encourage a quicker start to the program but also prove to these companies that SCE is a willing and enthusiastic partner.

We also recommend offering as much education to trucking companies throughout this process, but especially in the beginning. Trucking companies would benefit tremendously from SCE's knowledge of state and regional subsidies for truck ownership; reputable charging infrastructure and electric truck companies; and, opportunities and incentives offered by the ports to incentivize fleets' transition from diesel to electric.

6.2.2. Address Needs and Concerns of Disadvantaged Communities

In addition to trucking company education and outreach, SCE can ensure a more impactful and credible program rollout through early and consistent engagement with impacted communities. This type of engagement might include presentations at the neighborhood and city council meetings; dispersion of informational flyers or surveys to residents within DACs; or, invitations for site visits to potential charging station sites. Indeed, research shows that the most successful community health improvement programs are those that emphasize community participation, trust-building, and empowerment through education.

Angelo Logan, co-founder of the East Yard Communities for Environmental Justice recommends the participation of environmental justice leaders in an advisory committee where SCE can consult community leaders on where resources would be best allocated (personal communication, March 12, 2019). Potential advisory committee partners include the Moving

Forward Network and THE Impact Project, a coalition of community leaders working towards 100% zero-emission freight and goods movement in Southern California.

A primary goal of SCE's program, and state and local efforts generally, is to improve health outcomes for those most negatively impacted by pollution and emissions in and around the ports. Without feedback, trust, and buy-in from the communities SCE is attempting to help, this program will be falling short of its potential.

6.2.3. Collaboration with Ports and Regulatory/Governmental Partners

We also recommend maintaining (or, in some cases, forming) relationships and consistent communication with relevant entities during the life of this program. At the more local level, these groups include the San Pedro Bay Ports, the South Coast Air Quality Management District (SCAQMD), and the cities of Los Angeles and Long Beach. At the state and national levels, this list should include the California Air Resources Board, the California Energy Commission, and the U.S. Environmental Protection Agency.

Many of these entities have ample experience working collaboratively with one another on successful joint environmental policies and initiatives. Keeping in contact and collaborating with these groups will only serve to strengthen SCE's positioning as a key player in the regional expansion of electric-vehicle technology and infrastructure.

SCE can partner with local, state, and national entities to secure additional funding for truck owners in this program who want to convert to zero-emission trucks. Furthermore, these agencies can provide SCE with information on opportunities to work with private companies in the electric vehicle and charging station manufacturing industries, as well as current and ongoing local zero-emission truck demonstration projects. These efforts will ensure that SCE's program is not operating in a vacuum and that it can benefit from relevant regional efforts by private companies and government agencies alike.

6.2.4. Collaboration with Trucking Associations

Our application of the algorithm above relies on the best available spatial data on company truck yard addresses. However, data limitations prevent us from identifying all trucking company sites, sites that have the necessary space to fit charging infrastructure, and the grid capacity therein. We were especially limited from identifying where smaller companies and IOOs dwell at night. SCE would benefit from communication with local trucking associations (such as the Harbor Trucking Association and the California Trucking Association) which have deeper relationships with trucking companies. Trucking associations would also be a way for SCE to communicate with smaller-scale operators and learn where their trucks dwell at night. Using this information, SCE can make optimal siting decisions to provide overnight charging for this segment of the drayage fleet.

As discussed in Section 5.1, trucking companies are concerned about a lack of convenient and readily-available access to charging stations. Optimizing drayage truck routes will be paramount for companies to ensure that their trucks always have access to a charging station for opportunity charging at their facilities (see Section 5.3.4). To that end, SCE can address this concern by informing companies of available route optimization systems on the market.

6.3. Evaluation of Business & Outreach Strategies

To evaluate which business strategies best address our goal of promoting the conversion to electric trucks, we apply three key criteria: effectiveness, financial feasibility, and administrative feasibility. The point of the criteria is to set the "rules" to follow in analyzing and comparing our recommended strategies, thus giving us more measurable dimensions of our stated goal.

6.3.1. Evaluative Criteria

Below, we provide explanations of the specific criteria and their relevance to our policy goal. Next, we use a Criteria Alternative Matrix (CAM) to provide a visual comparison of the strategies, assigning values to each one based on how well it performs under each criterion.

Evaluative Criteria 1: Effectiveness

We want to know if implementing the proposed policies would promote the conversion to electric trucks at the ports, and, if so, at what potential scale. In this way, we are evaluating whether a particular type of outreach, partnership, or information-gathering tactic encourages truck companies to convert their fleets from diesel to electric. Because the strategies above vary by activity type, our evaluation considers what types of activities each strategy entails, and what is likely to be the costs and benefits. Moreover, because we are not working with specific data or dollar amounts in these evaluations, all benefits and costs are in terms of expected outcomes.

Evaluative Criteria 2: Financial Feasibility

We want to know if implementing the proposed policies would be financially feasible for SCE. An obvious limitation of this evaluation is a lack of access to SCE's annual budgets or knowledge of where this program fits among the company's many goals and priorities in the years to come. However, we can surmise where expenditures would be spent on a given program, and if the level of funding is relatively high or low compared to the alternatives.

Evaluative Criteria 3: Administrative Feasibility

Our third and final criterion measures the level of potential company administration necessary to carry out the strategy. We consider the presence and magnitude of specific administrative factors or tasks, which could include commitment and capacity. The commitment of SCE management and all relevant team members for this specific program will be crucial. The company's overall capacity – including staff, skills, and expertise – to achieve a given strategy must also be considered.

ELECTRIC TRUCK CONVERSION	Alternatives			
Decision Model	**Proactive Education & Outreach**	**Address Needs & Concerns of DACs**	**Collaboration w/ Other Entities**	**Collaboration w/ Trucking Associations**
Criterion	**Strategy 1**	**Strategy 2**	**Strategy 3**	**Strategy 4**
Effectiveness	3	3	2	1
Financial Feasibility	2	1	2	3
Administrative Feasibility	2	1	2	2
Total	7	5	6	6

Rating	Description
3	Likely
2	Somewhat Likely
1	Unlikely

Figure 39. Criteria Alternative Matrix

Using the matrix above as a framework, we can see the tradeoffs between each strategy. Strategy 1 is ranked high in effectiveness because it entails outreach to those most directly able to influence the level of electric truck conversion – the trucking companies themselves. The other options are less direct ways to reach our goal. Strategy 2, outreach to DACs, will prove effective by securing long-term support and viability for the program; however, it scores relatively low on financial and administrative feasibility due to the level of time and resources required to implement and maintain this level of outreach to a large community. The outcomes for Strategies 3 and 4 are heavily predicated on how successful SCE is at targeting the right individuals within these entities; therefore, they are less certain to be effective than the prior two strategies. Both of these strategies are somewhat likely to be financially and administratively feasible; this will depend on how much traction SCE gets with either government entities or trucking associations.

6.3.2. Business & Outreach Strategy: Final Recommendation

Comparing the four strategy options using evaluative criteria predicated on each policy's costs and benefits, our recommended policy is *Proactive Outreach and Education* ("Strategy 1"). This decision is mathematically justified because it received the highest cumulative score. The superiority of Strategy 1 emanates from its effectiveness in meeting the intended goal: electric truck conversion. We believe this to be the case because outreach and education to individual trucking companies is the most direct way to influence electric truck up-take. Ultimately, it will be this group that decides whether or not to transition from diesel to electric.

This strategy will, however, necessitate considerable time and resources. SCE must identify the trucking companies with the largest fleets, contact and provide them information about the electric charging station program, and carry out follow-up communications to encourage them to participate in the program.

7. Conclusions

The San Pedro Bay Ports' goal for a zero-emission drayage fleet by 2035 presents a tremendous opportunity for the ports and the drayage industry. SCE's electric charging station program will play a critical role in achieving this goal, by helping trucking companies overcome the formidable challenges of converting from diesel to electric.

We believe our two-pronged strategy, addressing both charging station placement and electric truck adoption, suits the complexity of the issue: rapidly-changing electric technology, coupled with a trucking industry unwilling to relive their ill-fated experiences with natural gas trucks. We hope our recommendations, and the general findings from this report, will equip SCE with the tools and understanding to make informed decisions in the rollout of its Charge Ready Transport program.

8. Appendix

8.1. Appendix A: Short-Term Placement within 5 miles from the Ports

Company	# of chargers	# of trucks charged	Cost per Charger	Cost per Truck Yard	Electricity demand (kW)
DAMCO Distribution Services, Inc.	10	40	$172,000	$1,720,000	2,000
Shippers Transport Express, Inc.	8	32	$172,000	$1,376,000	1,600
Progressive Transportation Services, Inc.	6	24	$172,000	$1,032,000	1,200
Overseas Freight, Inc.	6	24	$172,000	$1,032,000	1,200
Trans Ocean Carrier, Inc.	4	16	$197,000	$788,000	800
Quik Pick Express, LLC	3	12	$222,000	$666,000	600
Pac Anchor Transportation, Inc.	3	12	$222,000	$666,000	600
GST Transport, Inc.	2	8	$247,000	$494,000	400
Western Maritime Express, Inc.	2	8	$247,000	$494,000	400
Freight Horse Express, LLC	1	4	$272,000	$272,000	200
Sterling Express Services, Inc.	1	4	$272,000	$272,000	200
Custom Air Trucking, Inc.	1	4	$272,000	$272,000	200
Primo Express Line, Inc.	1	4	$272,000	$272,000	200
Calko Transport Company, Inc.	1	4	$272,000	$272,000	200
Sky Distribution Express, Inc.	1	4	$272,000	$272,000	200
Pierpoint Trans Line, Inc.	1	4	$272,000	$272,000	200
TOTAL	51	204		$10,172,000	10,200

8.2. Appendix B: Short-term Placement within 10 miles from the Ports

Company	# of chargers	# of trucks charged	Cost per Charger	Cost per truck yard	Electricity demand (kW)
Southern Counties Express, Inc.	11	44	$172,000	$1,892,000	2,200
DAMCO Distribution Services, Inc.	10	40	$172,000	$1,720,000	2,000
Shippers Transport Express, Inc.	8	32	$172,000	$1,376,000	1,600
Lincoln Transportation Services, Inc.	7	28	$172,000	$1,204,000	1,400
Container Freight EIT, LLC	6	24	$172,000	$1,032,000	1,200
Progressive Transportation Services, Inc.	6	24	$172,000	$1,032,000	1,200
Overseas Freight, Inc.	6	24	$172,000	$1,032,000	1,200
Sho Hai, Inc.	5	20	$172,000	$860,000	1,000
Green Fleet Systems, LLC	4	16	$197,000	$788,000	800
Trans Ocean Carrier, Inc.	4	16	$197,000	$788,000	800
National Retail Transportation, Inc.	4	16	$197,000	$788,000	800
Mano Delivery Corp.	4	16	$197,000	$788,000	800
Tri-Cap International LLC	3	12	$222,000	$666,000	600
Premium Transportation Services, Inc.	3	12	$222,000	$666,000	600
Quik Pick Express, LLC	3	12	$222,000	$666,000	600
Tradelink Transport, Inc.	3	12	$222,000	$666,000	600
Franco Trucking, Inc.	3	12	$222,000	$666,000	600
Western Freight Carrier, Inc.	3	12	$222,000	$666,000	600
Pac Anchor Transportation, Inc.	3	12	$222,000	$666,000	600
Price Transfer, Inc.	3	12	$222,000	$666,000	600
ULS Express, Inc.	3	12	$222,000	$666,000	600
Harbor Dispatch Transport, Inc.	3	12	$222,000	$666,000	600
Roadex CY, Inc.	3	12	$222,000	$666,000	600
New Connect Logistics Inc.	2	8	$247,000	$494,000	400
B&O Logistics, Inc.	2	8	$247,000	$494,000	400
Elite Logistics Corp.	2	8	$247,000	$494,000	400
Transport Express, Inc.	2	8	$247,000	$494,000	400
Green Line Express Services, Inc.	2	8	$247,000	$494,000	400
Pacific 9 Transportation, Inc.	2	8	$247,000	$494,000	400
TK Transport Services, Inc.	2	8	$247,000	$494,000	400
GST Transport, Inc.	2	8	$247,000	$494,000	400
Heavy Weight Transport, Inc.	2	8	$247,000	$494,000	400
Western Maritime Express, Inc.	2	8	$247,000	$494,000	400
KLF Logistics Inc.	2	8	$247,000	$494,000	400
Total Distribution Service, Inc.	1	4	$272,000	$272,000	200
Freight Horse Express, LLC	1	4	$272,000	$272,000	200
Sterling Express Services, Inc.	1	4	$272,000	$272,000	200
Tri-Modal Distribution Services, Inc.	1	4	$272,000	$272,000	200
Custom Air Trucking, Inc.	1	4	$272,000	$272,000	200
DHX-Dependable Hawaiian Express, Inc.	1	4	$272,000	$272,000	200
Globe Con Freight Systems, Inc.	1	4	$272,000	$272,000	200
Primo Express Line, Inc.	1	4	$272,000	$272,000	200
Calko Transport Company, Inc.	1	4	$272,000	$272,000	200
Coachwest Transportation, Inc.	1	4	$272,000	$272,000	200
Amax Trucking, Inc.	1	4	$272,000	$272,000	200

OSE Trucking, LLC	1	4	$272,000	$272,000	200
Edmunds Resources Management Corporation	1	4	$272,000	$272,000	200
Arrowlink USA, Inc.	1	4	$272,000	$272,000	200
Mainfreight, Inc.	1	4	$272,000	$272,000	200
RC Transportation, Inc.	1	4	$272,000	$272,000	200
United Global Express, Inc.	1	4	$272,000	$272,000	200
Long Beach Container Transport	1	4	$272,000	$272,000	200
Best Premium Logistics, Inc.	1	4	$272,000	$272,000	200
West Coast Container Services Inc.	1	4	$272,000	$272,000	200
World Logistics US Inc.	1	4	$272,000	$272,000	200
Hight Logistics, Inc.	1	4	$272,000	$272,000	200
Inet Trans, Inc.	1	4	$272,000	$272,000	200
Pacific Coast Cartage, Inc.	1	4	$272,000	$272,000	200
Sky Distribution Express, Inc.	1	4	$272,000	$272,000	200
Pierpoint Trans Line, Inc.	1	4	$272,000	$272,000	200
DDR Transport, Inc.	1	4	$272,000	$272,000	200
TOTAL	**157**	**628**	**-**	**$33,404,000**	**31,400**

8.3. Appendix C: Short-Term Placement within 10 miles of the Ports (Considering Grid Capacity)

Company	Electricity Demand (kW)	Integration Capacity (kW)	# of Chargers	# of Chargers (with Grid)	# of Trucks Charged	Cost per Charger	Cost per Truck Yard	Substation
Southern Counties Express, Inc.	2,200	0	11	0	0	$172,000	$0	Carson
DAMCO Distribution Services, Inc.	2,000	3,510	10	10	40	$172,000	$1,720,000	Watson
Shippers Transport Express, Inc.	1,600	0	8	0	0	$172,000	$0	Watson
Lincoln Transportation Services, Inc.	1,400	3,610	7	7	28	$172,000	$1,204,000	Jersey
Container Freight EIT, LLC	1,200	1,400	6	6	24	$172,000	$1,032,000	Sunnyside
Progressive Transportation Services, Inc.	1,200	1,720	6	6	24	$172,000	$1,032,000	State Street
Overseas Freight, Inc.	1,200	1,680	6	6	24	$172,000	$1,032,000	State Street
Sho Hai, Inc.	1,000	11,250	5	5	20	$172,000	$860,000	Nola
Green Fleet Systems, LLC	800	0	4	0	0	$197,000	$0	Carson
Trans Ocean Carrier, Inc.	800	1,710	4	4	16	$197,000	$788,000	State Street
National Retail Transportation, Inc.	800	0	4	0	0	$197,000	$0	Carson
Mano Delivery Corp.	800	4,470	4	4	16	$197,000	$788,000	Carson
Tri-Cap International LLC	600	4,860	3	3	12	$222,000	$666,000	Carson
Premium Transportation Services, Inc.	600	4,820	3	3	12	$222,000	$666,000	Carson
Quik Pick Express, LLC	600	2,920	3	3	12	$222,000	$666,000	Watson
Tradelink Transport, Inc.	600	0	3	0	0	$222,000	$0	Carson
Franco Trucking, Inc.	600	0	3	0	0	$222,000	$0	Alon
Western Freight Carrier, Inc.	600	4,850	3	3	12	$222,000	$666,000	Jersey
Pac Anchor Transportation, Inc.	600	4,190	3	3	12	$222,000	$666,000	State Street
Price Transfer, Inc.	600	0	3	0	0	$222,000	$0	Carson
ULS Express, Inc.	600	2,990	3	3	12	$222,000	$666,000	Cameron
Harbor Dispatch Transport, Inc.	600	0	3	0	0	$222,000	$0	Carson
Roadex CY, Inc.	600	0	3	0	0	$222,000	$0	La Fresa
New Connect Logistics Inc.	400	3,730	2	2	8	$247,000	$494,000	Jersey
B&O Logistics, Inc.	400	1,040	2	2	8	$247,000	$494,000	Nola
Elite Logistics Corp.	400	3,730	2	2	8	$247,000	$494,000	Carson
Transport Express, Inc.	400	3,660	2	2	8	$247,000	$494,000	Carson
Green Line Express Services, Inc.	400	3,420	2	2	8	$247,000	$494,000	Jersey
Pacific 9 Transportation, Inc.	400	0	2	0	0	$247,000	$0	Alon
TK Transport Services, Inc.	400	7,630	2	2	8	$247,000	$494,000	Carson
GST Transport, Inc.	400	1,680	2	2	8	$247,000	$494,000	State Street
Heavy Weight Transport, Inc.	400	0	2	0	0	$247,000	$0	Bowl
Western Maritime Express, Inc.	400	1,630	2	2	8	$247,000	$494,000	State Street
KLF Logistics Inc.	400	1,020	2	2	8	$247,000	$494,000	Nola
Total Distribution Service, Inc.	200	0	1	0	0	$272,000	$0	Sunnyside
Freight Horse Express, LLC	200	3,430	1	1	4	$272,000	$272,000	Neptune
Sterling Express Services, Inc.	200	3,700	1	1	4	$272,000	$272,000	Watson
Tri-Modal Distribution Services, Inc.	200	0	1	0	0	$272,000	$0	Alon
Custom Air Trucking, Inc.	200	2,730	1	1	4	$272,000	$272,000	Watson
DHX-Dependable Hawaiian Express, Inc.	200	8,270	1	1	4	$272,000	$272,000	Carson
Globe Con Freight Systems, Inc.	200	3,670	1	1	4	$272,000	$272,000	Carson
Primo Express Line, Inc.	200	2,330	1	1	4	$272,000	$272,000	Watson
Calko Transport Company, Inc.	200	1,500	1	1	4	$272,000	$272,000	Neptune
Coachwest Transportation, Inc.	200	3,610	1	1	4	$272,000	$272,000	Alon
Amax Trucking, Inc.	200	0	1	0	0	$272,000	$0	Carson
OSE Trucking, LLC	200	4,520	1	1	4	$272,000	$272,000	Nola
Edmunds Resources Management	200	0	1	0	0	$272,000	$0	Carson

Corporation								
Arrowlink USA, Inc.	200	0	1	0	0	$272,000	$0	Jersey
Mainfreight, Inc.	200	6,090	1	1	4	$272,000	$272,000	Nola
RC Transportation, Inc.	200	0	1	0	0	$272,000	$0	Nola
United Global Express, Inc.	200	0	1	0	0	$272,000	$0	Neptune
Long Beach Container Transport	200	1,400	1	1	4	$272,000	$272,000	Sunnyside
Best Premium Logistics, Inc.	200	3,950	1	1	4	$272,000	$272,000	Carson
West Coast Container Services Inc.	200	0	1	0	0	$272,000	$0	Carson
World Logistics US Inc.	200	0	1	0	0	$272,000	$0	Alon
Hight Logistics, Inc.	200	580	1	1	4	$272,000	$272,000	Oldfield
Inet Trans, Inc.	200	700	1	1	4	$272,000	$272,000	Nola
Pacific Coast Cartage, Inc.	200	0	1	0	0	$272,000	$0	Fremont
Sky Distribution Express, Inc.	200	1,710	1	1	4	$272,000	$272,000	State Street
Pierpoint Trans Line, Inc.	200	1,490	1	1	4	$272,000	$272,000	Neptune
DDR Transport, Inc.	200	3,990	1	1	4	$272,000	$272,000	Nola
TOTAL	**31,400**	**-**	**157**	**101**	**404**	**-**	**$21,522,000**	**-**

8.4. Appendix D: Short-term Emission Reduction

The following two equations were used to calculate emission reductions due to electric truck conversion:

Emission reduction (replacing diesel truck) [metric tons/year] = T x P_D x (VMT/day) x (operational days per year)[10] x [EF_D – EF_E]

Where T = total number of electric trucks supported with charging station placement
P_D = proportion of the current fleet that is diesel
EF_D = diesel heavy-duty truck emission factor [metric tons per mile]
EF_E = electric heavy-duty truck emission factor [metric tons per mile]

Emission reduction (replacing LNG truck) = T x P_{LNG} x (VMT/day) x (operational days per year) x [EF_{LNG} – EF_E]

Where P_{LNG} = proportion of the current fleet that is LNG
EF_{LNG} = LNG heavy-duty truck emission factor [metric tons per mile]

The emission factors used to calculate reductions can be found in Figure 19 above. Natural gas combustion CO2 emissions was found by multiplying diesel fuel CO2 emission factor by the following conversion factor:

Diesel fuel CO2 emission = 161.30 grams/million BTU[11]
Natural gas CO2 emission = 117.00 grams/million BTU

Conversion factor = CO2 emission factor/Natural gas emission emission factor = 72.5%

- Short-term Placement within 5 miles from the ports
    - *CO2: 204 trucks x 238 miles/day x 312 operation days/year x 0.95 x (1561.70 grams/mile - 0 grams/mile) + 238 miles/day x 312 days/year x 0.05 x (1,132.79 grams/mile - 0 grams/mile) = 23,332.12 metric tons per year*
    - *NOx: 204 trucks x 238 miles/day x 312 operation days/year x 0.95 x (1.508 grams/mile - 0 grams/mile) + 238 miles/day x 312 days/year x 0.05 x (0.1508 grams/mile - 0 grams/mile) = 21.82 metric tons per year*
    - *PM2.5: 204 trucks x 238 miles per day x 312 days/year x 0.95 x (0.007 grams/mile - 0 grams/mile) + 204 trucks x 238 miles x 312 days/year x 0.05 x (0.00588 grams/mile - 0 grams/mile) = 0.11 metric tons per year*

[10] We assume drayage trucks operate six days a week, 312 days per year.
[11] Source: US Energy Information Administration, 2016.

- Short-term Placement within 10 miles from the ports
    - *CO2: 628 trucks x 238 miles/day * 312 days/year x 0.95 x (1,561.70 grams/mile - 0 grams/mile) + 628 trucks x 238 miles x 365 x 0.05 x (1,132.79 grams/mile - 0 grams/mile) = 71,826.33 metric tons per year*
    - *NOx: 628 trucks x 238 miles/day x 312 days/year x 0.95 x (1.508 grams/mile - 0 grams/mile) + 628 trucks x 238 miles x 312 days/year x 0.05 x (0.1508 grams/mile - 0 grams/mile) = 67.16 metric tons per year*
    - *PM2.5: 628 trucks x 238 miles/day x 312 operation days/year x 0.95 x (0.007 grams/mile - 0 grams/mile)+ 628 trucks x 238 miles x 312 days/year x 0.05 x (0.00588 grams/mile - 0 grams/mile) = 0.32 metric tons per year*

- Short-term Placement within 10 miles from the Ports (Considering grid capacity)
    - *CO2: 404 trucks x 238 miles/day x 312 days/year x 0.95 x (0.202 grams/mile - 0 grams/mile)+ 404 trucks x 238 miles x 312 days/year x 0.05 x (0.0101 grams/mile - 0 grams/mile) = 46,206.75 metric tons per year*
    - *NOx: 404 trucks x 238 miles/day x 312 days/year x 0.95 x (1.508 grams/mile - 0 grams/mile)+ 404 trucks x 238 miles x 312 days/year x 0.05 x (0.1508 grams/mile - 0 grams/mile) = 43.20 metric tons per year*
    - *PM2.5: 404 trucks x 238 miles/day x 312 days/year x 0.95 x (0.007 grams/mile - 0 grams/mile)+ 404 trucks x 238 miles x 312 days/year x 0.05 x (0.00588 grams/mile - 0 grams/mile) = 0.21 metric tons per year*

8.5. Appendix E: Long-term Placement

Company	# of chargers	# of trucks charged	Cost per Charger	Cost per Truck Yard	Electricity demand (kW)
Deco Logistics, Inc.	51	204	$172,000	$8,772,000	10,200
Southern Counties Express, Inc.	45	179	$172,000	$7,740,000	9,000
DAMCO Distribution Services, Inc.	43	172	$172,000	$7,396,000	8,600
CMI Transportation, LLC	41	164	$172,000	$7,052,000	8,200
Shippers Transport Express, Inc.	34	133	$172,000	$5,848,000	6,800
Lincoln Transportation Services, Inc.	29	113	$172,000	$4,988,000	5,800
Container Freight EIT, LLC	27	107	$172,000	$4,644,000	5,400
Progressive Transportation Services, Inc.	27	105	$172,000	$4,644,000	5,400
Overseas Freight, Inc.	25	98	$172,000	$4,300,000	5,000
American Pacific Forwarders, Inc.	23	89	$172,000	$3,956,000	4,600
Sho Hai, Inc.	21	83	$172,000	$3,612,000	4,200
Versa Logistics, LLC	21	82	$172,000	$3,612,000	4,200
Green Fleet Systems, LLC	19	76	$172,000	$3,268,000	3,800
Trans Ocean Carrier, Inc.	19	76	$172,000	$3,268,000	3,800
National Retail Transportation, Inc.	18	72	$172,000	$3,096,000	3,600
Mano Delivery Corp.	18	70	$172,000	$3,096,000	3,600
Performance Team Freight Systems, Inc.	16	62	$172,000	$2,752,000	3,200
Tri-Cap International LLC	15	59	$172,000	$2,580,000	3,000
Premium Transportation Services, Inc.	15	57	$172,000	$2,580,000	3,000
Quik Pick Express, LLC	14	53	$172,000	$2,408,000	2,800
Tradelink Transport, Inc.	14	53	$172,000	$2,408,000	2,800
Franco Trucking, Inc.	13	51	$172,000	$2,236,000	2,600
Western Freight Carrier, Inc.	13	52	$172,000	$2,236,000	2,600
Pac Anchor Transportation, Inc.	13	51	$172,000	$2,236,000	2,600
Price Transfer, Inc.	13	49	$172,000	$2,236,000	2,600
ULS Express, Inc.	12	48	$172,000	$2,064,000	2,400
Harbor Dispatch Transport, Inc.	12	48	$172,000	$2,064,000	2,400
Roadex CY, Inc.	12	47	$172,000	$2,064,000	2,400
New Connect Logistics Inc.	11	44	$172,000	$1,892,000	2,200
B&O Logistics, Inc.	11	41	$172,000	$1,892,000	2,200
Elite Logistics Corp.	11	41	$172,000	$1,892,000	2,200
RPM Harbor Services, Inc.	10	40	$172,000	$1,720,000	2,000
Transport Express, Inc.	10	39	$172,000	$1,720,000	2,000
Green Line Express Services, Inc.	10	38	$172,000	$1,720,000	2,000
Ecology Auto Parts, Inc.	10	38	$172,000	$1,720,000	2,000
NGL Transportation, LLC	10	37	$172,000	$1,720,000	2,000
Pacific 9 Transportation, Inc.	9	33	$172,000	$1,548,000	1,800
TK Transport Services, Inc.	9	36	$172,000	$1,548,000	1,800
GST Transport, Inc.	9	35	$172,000	$1,548,000	1,800
IDC Logistics, Inc.	9	35	$172,000	$1,548,000	1,800
Five & Six Logistics, Inc.	9	34	$172,000	$1,548,000	1,800
Heavy Weight Transport, Inc.	9	34	$172,000	$1,548,000	1,800
Western Maritime Express, Inc.	9	34	$172,000	$1,548,000	1,800
Robert Nako Enterprises, Inc.	9	34	$172,000	$1,548,000	1,800
America Trading Service Inc.	8	30	$172,000	$1,376,000	1,600
CJAN Express, Inc.	8	29	$172,000	$1,376,000	1,600
KLF Logistics Inc.	8	32	$172,000	$1,376,000	1,600

JVC Truck Lines, Inc.	8	31	$172,000	$1,376,000	1,600
Total Distribution Service, Inc.	8	30	$172,000	$1,376,000	1,600
Henean Trucking, Inc.	7	27	$172,000	$1,204,000	1,400
Freight Horse Express, LLC	7	28	$172,000	$1,204,000	1,400
Sterling Express Services, Inc.	7	26	$172,000	$1,204,000	1,400
Tri-Modal Distribution Services, Inc.	7	25	$172,000	$1,204,000	1,400
Custom Air Trucking, Inc.	6	24	$172,000	$1,032,000	1,200
DHX-Dependable Hawaiian Express, Inc.	6	24	$172,000	$1,032,000	1,200
Globe Con Freight Systems, Inc.	6	24	$172,000	$1,032,000	1,200
Primo Express Line, Inc.	6	24	$172,000	$1,032,000	1,200
Calko Transport Company, Inc.	6	24	$172,000	$1,032,000	1,200
Coachwest Transportation, Inc.	6	23	$172,000	$1,032,000	1,200
National Distribution Centers LLC	6	22	$172,000	$1,032,000	1,200
Amax Trucking, Inc.	6	22	$172,000	$1,032,000	1,200
Phoenix PDQ, Inc.	6	22	$172,000	$1,032,000	1,200
Global Freight Services, Inc.	6	22	$172,000	$1,032,000	1,200
OSE Trucking, LLC	5	18	$172,000	$860,000	1,000
Edmunds Resources Management Corporation	5	20	$172,000	$860,000	1,000
All Ports Logistics, Inc.	5	20	$172,000	$860,000	1,000
Arrowlink USA, Inc.	5	19	$172,000	$860,000	1,000
Cano Logistics, Inc.	5	19	$172,000	$860,000	1,000
Mainfreight, Inc.	5	19	$172,000	$860,000	1,000
East Coast Transport, Inc.	5	17	$172,000	$860,000	1,000
RC Transportation, Inc.	5	17	$172,000	$860,000	1,000
Gateway Logistics LLC	5	17	$172,000	$860,000	1,000
United Global Express, Inc.	4	15	$197,000	$788,000	800
Long Beach Container Transport	4	15	$197,000	$788,000	800
Best Premium Logistics, Inc.	4	14	$197,000	$788,000	800
West Coast Container Services Inc.	4	16	$197,000	$788,000	800
La Canada Logistics, Inc.	4	16	$197,000	$788,000	800
Aracely Tapia Hernandez	4	16	$197,000	$788,000	800
Online Trucking, Inc.	4	16	$197,000	$788,000	800
World Logistics US Inc.	4	16	$197,000	$788,000	800
Hight Logistics, Inc.	4	16	$197,000	$788,000	800
Three Rivers Trucking	4	16	$197,000	$788,000	800
Precise Transport, Inc.	4	16	$197,000	$788,000	800
Fox Transportation, Inc.	4	15	$197,000	$788,000	800
Inet Trans, Inc.	4	15	$197,000	$788,000	800
Inter-City Delivery Service	4	15	$197,000	$788,000	800
Pacific Coast Cartage, Inc.	4	14	$197,000	$788,000	800
Sky Distribution Express, Inc.	4	14	$197,000	$788,000	800
Pierpoint Trans Line, Inc.	4	14	$197,000	$788,000	800
DDR Transport, Inc.	4	14	$197,000	$788,000	800
Green Trucking LLC	4	14	$197,000	$788,000	800
Talon Logistics, Inc.	4	14	$197,000	$788,000	800
CY Logistics, Inc.	4	14	$197,000	$788,000	800
Seldat Distribution, Inc.	4	14	$197,000	$788,000	800
CTC Logistics, LLC	4	14	$197,000	$788,000	800
G&D Transportation	4	13	$197,000	$788,000	800
Topland Trucking, Inc.	4	13	$197,000	$788,000	800
Dependable Freight & Container Transport, Inc.	4	13	$197,000	$788,000	800

Silver Point Trucking, Inc.	4	13	$197,000	$788,000	800
Estenson Logistics, LLC	3	12	$222,000	$666,000	600
A.J. Transport Inc.	3	12	$222,000	$666,000	600
Union County Transport, Inc.	3	12	$222,000	$666,000	600
Starling Freight, Inc.	3	12	$222,000	$666,000	600
Great Central Transport, Inc.	3	12	$222,000	$666,000	600
Cargo Logistics Services, Inc.	3	11	$222,000	$666,000	600
Freight Advisor Corp.	3	10	$222,000	$666,000	600
Prime Trans, Inc.	3	10	$222,000	$666,000	600
Global Transport Enterprise, Inc.	3	9	$222,000	$666,000	600
Main Street Fibers, Inc.	3	9	$222,000	$666,000	600
Atlas Marine, Inc.	3	12	$222,000	$666,000	600
Nova Transportation Services, Inc.	3	12	$222,000	$666,000	600
Tiptop Express, Inc.	3	12	$222,000	$666,000	600
Pier West Transportation, Inc.	3	11	$222,000	$666,000	600
KCC Global Logistics, Inc.	3	11	$222,000	$666,000	600
MTL Express, LLC	3	11	$222,000	$666,000	600
A Speed Transportation, Inc.	3	11	$222,000	$666,000	600
Arms Trans, Inc.	3	11	$222,000	$666,000	600
Golden State Express, Inc.	3	11	$222,000	$666,000	600
Sunflower Transport, Inc.	3	10	$222,000	$666,000	600
CR&R, Inc.	3	10	$222,000	$666,000	600
Westcoast Trucking, Inc.	3	10	$222,000	$666,000	600
MASA Trucking Co.	3	10	$222,000	$666,000	600
Stream Links Express, Inc.	3	10	$222,000	$666,000	600
ACI Trucking, Inc.	3	9	$222,000	$666,000	600
Ventura Transfer Company	3	9	$222,000	$666,000	600
A.D.D. Distribution	3	9	$222,000	$666,000	600
Eagle Freight Express, Inc.	3	9	$222,000	$666,000	600
Alpha Total Solutions, Inc.	3	9	$222,000	$666,000	600
Cal-West Express Co., LTD	3	9	$222,000	$666,000	600
Shoreline Transportation, Inc.	3	9	$222,000	$666,000	600
Weber Distribution, LLC	3	9	$222,000	$666,000	600
Goldenrod Equipment	3	9	$222,000	$666,000	600
Progressive Freight Systems, Inc.	3	9	$222,000	$666,000	600
Vinamar, Inc.	3	9	$222,000	$666,000	600
A-1 Trucking, Inc.	3	9	$222,000	$666,000	600
Commercial Cartage, Inc.	3	9	$222,000	$666,000	600
Pacific Global Consolidators	3	9	$222,000	$666,000	600
Krisda, Inc.	3	9	$222,000	$666,000	600
Leon's Freight Services, Inc.	2	8	$247,000	$494,000	400
Oak Transport, Inc.	2	8	$247,000	$494,000	400
Schafer Bros. Transfer & Piano Movers, Inc.	2	8	$247,000	$494,000	400
Uni Trans, LLC	2	8	$247,000	$494,000	400
LJ Express, Inc.	2	8	$247,000	$494,000	400
Aerologic, Inc.	2	7	$247,000	$494,000	400
Torres Container Connection	2	6	$247,000	$494,000	400
GG Express, Inc.	2	6	$247,000	$494,000	400
Long Beach Trucking, Inc.	2	6	$247,000	$494,000	400
Pactrans, LLC	2	6	$247,000	$494,000	400
Hot Wheels Trucking, Inc.	2	6	$247,000	$494,000	400

Union Express, Inc.	2	6	$247,000	$494,000	400
Orbit Int'l, Inc.	2	6	$247,000	$494,000	400
IMAGE Transport	2	6	$247,000	$494,000	400
Vasquez Trucking, Inc.	2	5	$247,000	$494,000	400
ASAP Trucking, Inc.	2	5	$247,000	$494,000	400
Whisk Logistics, LLC	2	8	$247,000	$494,000	400
J&M Zalez Transportation, LLC	2	8	$247,000	$494,000	400
Door 2 Door Transport, Inc.	2	8	$247,000	$494,000	400
United Logistic Services Group, Inc.	2	8	$247,000	$494,000	400
Sassy Trucking Co.	2	8	$247,000	$494,000	400
Valueplus Transportation, Inc.	2	8	$247,000	$494,000	400
E&J TL Corp.	2	8	$247,000	$494,000	400
Total Trucking Services, Inc.	2	8	$247,000	$494,000	400
States Logistics Services, Inc.	2	8	$247,000	$494,000	400
Unique Freight Transport, Inc.	2	8	$247,000	$494,000	400
High Quality Express, Inc.	2	8	$247,000	$494,000	400
MDB Transportation, Inc.	2	8	$247,000	$494,000	400
Fargo Trucking Company, Inc.	2	8	$247,000	$494,000	400
LMD Integrated Logistic Services, Inc.	2	8	$247,000	$494,000	400
HBC Distributors, Inc.	2	8	$247,000	$494,000	400
SPE Equities, LLC	2	7	$247,000	$494,000	400
Dynamic Express, Inc.	2	7	$247,000	$494,000	400
Monk Transportation, LTD.	2	7	$247,000	$494,000	400
California Intermodal Associates, Inc.	2	7	$247,000	$494,000	400
Latin American Carriers, Inc.	2	7	$247,000	$494,000	400
Scrap Hauling, Inc.	2	7	$247,000	$494,000	400
JST Systems, Inc.	2	7	$247,000	$494,000	400
All United Transport, Inc.	2	7	$247,000	$494,000	400
Nexus Pacific Transport	2	7	$247,000	$494,000	400
Future International, Inc.	2	7	$247,000	$494,000	400
Max Express, Inc.	2	7	$247,000	$494,000	400
DWC Transportation Services, LLC	2	7	$247,000	$494,000	400
Tang Logistics	2	7	$247,000	$494,000	400
LBC Logistics LLC	2	6	$247,000	$494,000	400
Absolute Freight, Inc.	2	6	$247,000	$494,000	400
Golden State Drayage Company	2	6	$247,000	$494,000	400
3T Holding, Inc.	2	6	$247,000	$494,000	400
GS Express Logistics, LLC	2	6	$247,000	$494,000	400
Kargo Transportation, Inc.	2	6	$247,000	$494,000	400
William's Logistics, Inc.	2	5	$247,000	$494,000	400
Los Angeles Superior Transportation, Inc.	2	5	$247,000	$494,000	400
James Cass	2	5	$247,000	$494,000	400
Bestway Recycling Co., Inc.	2	5	$247,000	$494,000	400
Jess Diaz Trucking, Inc.	2	5	$247,000	$494,000	400
Konaian, Inc.	2	5	$247,000	$494,000	400
Orion Freight Services, Inc.	2	5	$247,000	$494,000	400
Cloud Trucking, Inc.	2	5	$247,000	$494,000	400
Marosi, Inc.	2	5	$247,000	$494,000	400
GD Trans, Inc.	2	5	$247,000	$494,000	400
Metro Worldwide, Inc.	2	5	$247,000	$494,000	400
DLS International Services, LLC	2	5	$247,000	$494,000	400

Chady Express Corporation	2	5	$247,000	$494,000	400
Harvest Global International, Inc.	2	5	$247,000	$494,000	400
Tristate Logistics Company, LLC	2	5	$247,000	$494,000	400
Anova Transport Group LLC	2	5	$247,000	$494,000	400
Joaquin Menjivar Cruz	2	5	$247,000	$494,000	400
Pace Freight Systems	1	4	$272,000	$272,000	200
Jaspem Truck Line, Inc.	1	4	$272,000	$272,000	200
Pacific National Transportation Corp.	1	4	$272,000	$272,000	200
F.R.T. International, Inc.	1	4	$272,000	$272,000	200
Elite Lighting Corp.	1	4	$272,000	$272,000	200
Western Pacific Pulp & Paper	1	4	$272,000	$272,000	200
GB Trucking, Inc.	1	4	$272,000	$272,000	200
TOTAL	**1313**	**4941**	**-**	**$245,208,000**	**262,600**

Appendix G: High VMT Ranking for Long-term Placement (SCE Territory) *Calculated and located by the centroid of each TAZ

Rank	Total VMT / Day	TAZ	City	County
1	14,564	21359000	Unincorporated	Los Angeles County
2	13,426	22278000	Unincorporated	Los Angeles County
3	12,729	21357000	Carson	Los Angeles County
4	12,242	21363000	Unincorporated	Los Angeles County
5	11,575	53704000	Fontana	San Bernardino County
6	10,803	53834000	Redlands	San Bernardino County
7	10,115	53615000	Chino	San Bernardino County
8	9,703	43312000	Perris	Riverside County
9	9,637	43181000	Corona	Riverside County
10	9,623	21731000	Commerce	Los Angeles County
11	9,584	21355000	Carson	Los Angeles County
12	9,390	53929000	Victorville	San Bernardino County
13	9,344	53692000	Rancho Cucamonga	San Bernardino County
14	8,865	21362000	Carson	Los Angeles County
15	8,659	21495000	Unincorporated	Los Angeles County
16	8,591	60002000	Unincorporated	Ventura County
17	8,537	21358000	Unincorporated	Los Angeles County
18	7,860	53662000	Ontario	San Bernardino County
19	7,637	53687000	Ontario	San Bernardino County
20	7,142	21530000	Compton	Los Angeles County
21	6,984	53630000	Chino	San Bernardino County
22	6,838	53706000	Unincorporated	San Bernardino County
23	6,720	21369000	Long Beach	Los Angeles County
24	6,713	53613000	Chino	San Bernardino County
25	6,682	53699000	Ontario	San Bernardino County
26	6,664	53694000	Rancho Cucamonga	San Bernardino County
27	6,361	53674000	Rancho Cucamonga	San Bernardino County
28	6,353	43144000	Jurupa Valley	Riverside County
29	6,126	22414000	Pomona	Los Angeles County
30	6,113	43264000	Moreno Valley	Riverside County
31	6,080	53702000	Rancho Cucamonga	San Bernardino County
32	6,000	53685000	Ontario	San Bernardino County
33	5,820	21702000	Commerce	Los Angeles County
34	5,658	21745000	Montebello	Los Angeles County
35	5,644	53680000	Rancho Cucamonga	San Bernardino County
36	5,587	43277000	Moreno Valley	Riverside County
37	5,459	21724000	Commerce	Los Angeles County
38	5,344	53675000	Rancho Cucamonga	San Bernardino County
39	5,311	21312000	Unincorporated	Los Angeles County
40	5,295	53713000	Fontana	San Bernardino County
41	5,257	21872000	Santa Fe Springs	Los Angeles County
42	4,866	53700000	Rancho Cucamonga	San Bernardino County
43	4,722	21739000	Commerce	Los Angeles County
44	4,469	53721000	Fontana	San Bernardino County
45	4,396	53741000	Rialto	San Bernardino County
46	4,336	43125000	Jurupa Valley	Riverside County
47	4,255	60056000	Unincorporated	Ventura County
48	4,077	53715000	Unincorporated	San Bernardino County

49	4,040	53708000	Unincorporated	San Bernardino County
50	4,021	53696000	Rancho Cucamonga	San Bernardino County
51	3,801	21695000	South Gate	Los Angeles County
52	3,794	21852000	Santa Fe Springs	Los Angeles County
53	3,693	21740000	Commerce	Los Angeles County
54	3,688	53753000	Rialto	San Bernardino County
55	3,653	21227000	Gardena	Los Angeles County
56	3,610	21843000	Santa Fe Springs	Los Angeles County
57	3,594	21169000	Inglewood	Los Angeles County
58	3,587	21496000	Carson	Los Angeles County
59	3,550	53686000	Ontario	San Bernardino County
60	3,511	60070000	Oxnard	Ventura County
61	3,457	32917000	Santa Ana	Orange County
62	3,428	21865000	Whittier	Los Angeles County
63	3,377	22300000	La Puente	Los Angeles County
64	3,357	21621000	Compton	Los Angeles County
65	3,345	22213000	El Monte	Los Angeles County
66	3,309	53771000	San Bernardino	San Bernardino County
67	3,296	21714000	South Gate	Los Angeles County
68	3,272	60049000	Santa Paula	Ventura County
69	3,222	21734000	Commerce	Los Angeles County
70	3,157	53698000	Ontario	San Bernardino County
71	3,129	32479000	Buena Park	Orange County
72	3,098	53663000	Ontario	San Bernardino County
73	3,084	20225000	Unincorporated	Los Angeles County
74	3,077	53688000	Rancho Cucamonga	San Bernardino County
75	3,039	53619000	Montclair	San Bernardino County
76	2,960	21381000	Long Beach	Los Angeles County
77	2,949	60092000	Oxnard	Ventura County
78	2,947	21569000	Compton	Los Angeles County
79	2,941	33082000	Irvine	Orange County
80	2,875	21353000	Carson	Los Angeles County
81	2,854	53761000	San Bernardino	San Bernardino County
82	2,814	21597000	Compton	Los Angeles County
83	2,755	22420000	Pomona	Los Angeles County
84	2,707	53825000	Redlands	San Bernardino County
85	2,694	21445000	Long Beach	Los Angeles County
86	2,627	53653000	Ontario	San Bernardino County
87	2,600	53621000	Chino	San Bernardino County
88	2,580	53644000	Chino	San Bernardino County
89	2,555	53652000	Ontario	San Bernardino County
90	2,544	53711000	Unincorporated	San Bernardino County
91	2,452	21443000	Long Beach	Los Angeles County
92	2,355	21339000	Carson	Los Angeles County
93	2,281	21623000	Compton	Los Angeles County
94	2,208	53773000	San Bernardino	San Bernardino County
95	2,206	43320000	Perris	Riverside County
96	2,191	21795000	Pico Rivera	Los Angeles County
97	2,174	53717000	Fontana	San Bernardino County
98	2,157	21759000	Paramount	Los Angeles County
99	2,129	53710000	Fontana	San Bernardino County
100	2,107	21791000	Downey	Los Angeles County

Appendix F: Long-term Emission Reduction

- Long-term Placement
  - *CO_2: 4,941 trucks x 238 miles/day x 312 days/year x 0.95 x (1,561.70 grams/mile - 0 grams/mile)+ 4,941 trucks x 238 miles x 312 days/year x 0.05 x (1,132.79grams/mile - 0 grams/mile) = 565,117.66 metric tons per year*

  - *NO_x: 4,941 trucks x 238 miles/day x 312 days/year x 0.95 x (1.508 grams/mile - 0 grams/mile)+ 4,941 trucks x 238 miles x 312 days/year x 0.05 x (0.1508 grams/mile - 0 grams/mile) = 528.39 metric tons per year*

  - *$PM_{2.5}$: 4,941 trucks x 238 miles/day x 312 days/year x 0.95 x (0.007 grams/mile - 0 grams/mile)+ 4,941 trucks x 238 miles x 312 days/year x 0.05 x (0.00588 grams/mile - 0 grams/mile) = 2.55 metric tons per year*

9. References

Brugge D., Durant J. L., Rioux C. 2007. "Near-Highway Pollutants in Motor Vehicle Exhaust: A Review of Epidemiologic Evidence of Cardiac and Pulmonary Health Risks." Environmental Health 6 (1): 1–12.

BTCPower (n.d.). 150kW-350kW DCFC - BTCPower. Retrieved March 14, 2019, from http://www.btcpower.com/index.php?action=150kw_350kw

California Air Resources Board. (2017). Emission Factor (EMFAC) model. Retrieved from https://www.arb.ca.gov/emfac/2017/

CalEPA (2018). SB 535 ArcGIS Geodatabase [geodatabase]. Retrieved March 1, 2019, from https://calepa.ca.gov/envjustice/ghginvest/

California Department of General Services (2014, January). Electric Vehicle Supply Equipment Guidance Document. Retrieved March 16, 2019, from https://www.documents.dgs.ca.gov/resd/pubs/EVSEGuidanceDocument012814.pdf

California Open Data (2016). CA County Boundaries[shapefile]. Retrieved December 14,2019, from https://data.ca.gov/dataset/ca-geographic-boundaries/resource/091ff50d-bb24-4537-a974-2ce89c6e8663

Caltrans (n.d.). Weight Limitation. CA.gov. Retrieved March 16, 2019, from http://www.dot.ca.gov/trafficops/trucks/weight.html

Caltrans (June 13, 2018). Truck Network(2018) [shapefile]. Retrieved December 14, 2018, from http://www.dot.ca.gov/hq/tsip/gis/datalibrary/Metadata/Trknet.html

Center for Sustainable Energy (n.d.). Southern California Incentive Project (SCIP). Retrieved March 16, 2019, from https://calevip.org/incentive-project/southern-california

CGR Management Consultants LLC (2007, March 26). A SURVEY OF DRAYAGE DRIVERS SERVING THE SAN PEDRO BAY PORTS. Port of Long Beach. Retrieved March 16, 2019, from http://www.polb.com/civica/filebank/blobdload.asp?BlobID=3724

CGR Management Consultants LLC (2007, March). A survey of Drayage Drivers Serving the San Pedro Bay Ports, Page 14

S. Chandler, S., Espino, J., O'Dea, J. (2017). Delivering Opportunity: How Electric Buses and Trucks Can Create Jobs and Improve Public Health in California. *Union of Concerned Scientists*, 1-51

City of Long Beach Department of Health and Human Services (2013). "Health Statistics 2010." 2013. City of Long Beach Department of Health and Human Services. Retrieved March 15, 2019, from http://www.longbeach.gov/globalassets/health/media-library/documents/planning-and-research/reports/2010-health-statistics/2010-health-statistics

Clark, Krissy (2012, January 18). Cleaner Air In L.A. Ports Comes At A Cost To Truckers: NPR. Retrieved March 16, 2019, from https://www.npr.org/2012/01/18/145338359/cleaner-air-in-l-a-ports-comes-at-a-cost-to-truckers

CPUC (2018, June 6). DECISION ON THE TRANSPORTATION ELECTRIFICATION STANDARD REVIEW PROJECTS. CA.gov. Retrieved March 15, 2019, from http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M214/K985/214985772.PDF

Daimler (n. d.). E-Mobility Group and two electric trucks for the US market. - Daimler. Retrieved March 14, 2019, from https://www.daimler.com/products/trucks/freightliner/e-mobility-group.html

EV Safe Charge Inc. (n.d.). DC Fast Charging Explained. Retrieved from https://evsafecharge.com/dc-fast-charging-explained/

EPA (2008, October). Average In-Use Emissions from Heavy-Duty Trucks. The EPA National Library Catalog. Retrieved March 16, 2019, from https://nepis.epa.gov/Exe/ZyPDF.cgi/P100EVY6.PDF?Dockey=P100EVY6.PDF

EPA (n.d.). Draft A Ports Primer for Communities 2016. United States Environmental Protection Agency. Retrieved March 15, 2019, from https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100P1UQ.pdf

EPA (2019, February 11). Vehicle Weight Classifications for the Emission Standards Reference Guide. Retrieved from https://www.epa.gov/emission-standards-reference-guide/vehicle-weight-classifications-emission-standards-reference-guide

Esri (2019, March 13). World Topographic Map[basemap]. Retrieved March 19, 2019, from https://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f

Geofabrik. (2018).OpenStreetMap Northern California [shapefile]. Retrieved November 26, 2018, from http://download.geofabrik.de/north-america/us/california.html

Guerin, Emily (2017, March 13). Slideshow: How local ports reduced pollution but lost trust among truck drivers along the way. KPCC. Retrieved March 16, 2019, from https://www.scpr.org/news/2017/03/13/69667/how-local-ports-reduced-pollution-but-lost-trust-a/

Houston Douglas, Hu Jun, Ong Paul, Winer Arthur. 2004. “Structural Disparities of Urban Traffic in Southern California.” Journal of Urban Affairs 26 (5): 565–92.

Husing, J.E., Brightbill, T. E, Crosby, P.A. (2007). San Pedro Bay Ports Clean Air Action Plan - Economic Analysis: Proposed Clean Truck Program. *Economics & Politics, Inc. Redlands, CA, USA. CGR Management Consultants, LLC, Los Angeles, CA, USA*

LA Healthy (n.d.). “Health Profiles – Harbor Gateway.” Plan for a Healthy Los Angeles. Retrieved March 15, 2019, from http://healthyplan.la/interactive/neighborhoods/#id=11

Lee, Henry and Clark, Alex (2018, September). Charging the Future: Challenges and Opportunities for Electric Vehicle Adoption. HKS Faculty Research Working Paper Series. Retrieved March 16, 2019, from https://projects.iq.harvard.edu/files/energyconsortium/files/rwp18-026_lee_1.pdf

Manville, M., & Goldman, E. (2018). Would Congestion Pricing Harm the Poor? Do Free Roads Help the Poor? Journal of Planning Education and Research, 38(3), 329–344. https://doi.org/10.1177/0739456X17696944

Nero, Edward Mark (2018, November 23). LA, Long Beach ports poised to give up to $100,000 each to truck drivers for cleaner rigs. Press Telegram. Retrieved March 16, 2019, from https://www.presstelegram.com/2018/11/23/la-long-beach-ports-poised-to-give-up-to-100000-each-to-truck-drivers-for-cleaner-rigs/

Office of Governor (2018, January 26). Governor Brown Takes Action to Increase Zero-Emission Vehicles, Fund New Climate Investments. CA.gov. Retrieved March 16, 2019, from https://www.ca.gov/archive/gov39/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/index.html

Rentar Environmental Solutions, Inc. (2017, December 21). The MPG of Diesel Trucks Largely Unknown. And, Varies Greatly Based on a Number of Factors. Retrieved March 19, 2019, from https://rentar.com/diesel-truck-miles-per-gallon-mpg/.

South Coast Air Quality Management District (2012). “Multiple Air Toxics Exposure Study in the South Coast Air Basin, MATES IV.”

South Coast Air Quality Management District (2013) “Air Quality Management Plan 2012: Appendix IV-A. Page IV-A-37. http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2012-air-quality-management-plan/final-2012-aqmp-(february-2013)/appendix-iv-(a)-final-2012.pdf

South Coast Air Quality Management District (2015). “2016 Air Quality Management Plan: Goods Movement White Paper.” Pages 7 and 8. www.aqmd.gov/docs/default-source/Agendas/aqmp/white-paper-working-groups/wp-goodsmvmt-final.pdf?sfvrsn=2

South Coast Air Quality Management District (2017, March). “Final 2016 Air Quality Management Plan,”South Coast Air Quality Management District. Retrieved March 16, 2019, from http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2016-air-quality-management-plan/final-2016-aqmp/final2016aqmp.pdf

Southern California Gas Company (n.d.). Benefits of Natural Gas Vehicles | SoCalGas. Retrieved March 16, 2019, from https://www.socalgas.com/for-your-business/natural-gas-vehicles/benefits

Southern California Edison (n.d.). Distribution Resources Plan External Portal (DEREP)” Retrieved March 15, 2019, from https://ltmdrpep.sce.com/drpep/

Southern California Edison (2019, March 16). SCE Service Territory ”[shapefile]. Retrieved March 19, 2019, from http://data-sce2.opendata.arcgis.com/datasets/93bdba093c7f43e09fe14c37b033d179_4

Southern California Edison (2019, March 16). Substations ”[shapefile]. Retrieved March 19, 2019, from http://data-sce2.opendata.arcgis.com/datasets/93bdba093c7f43e09fe14c37b033d179_0

Southern California Association of Governments (2014). “Warehouses in SCAG region” Unpublished raw data

Southern California Association of Governments (2012). “SCAG Regional Travel Demand Model” Unpublished raw data

Tetra Tech (2018, December). DRAFT 2018 FEASIBILITY ASSESSMENT for DRAYAGE TRUCKS. Retrieved March 16, 2019, from http://www.cleanairactionplan.org/documents/draft-drayage-truck-feasibility-assesment.pdf

The California Air Resources Board (2018, March 26). Carl Moyer Memorial Air Quality Standards Attainment Program. Retrieved March 16, 2019, from https://www.arb.ca.gov/msprog/moyer/moyer.htm

The California Department of Public Health (2015). “Strategic Plan for Asthma in California 2015-2018.” Retrieved March 15, 2019, from https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/EHIB/CPE/CDPH%20Document%20Library/SPAC2014_7-28-15APR.pdf

The Port of Long Beach (2018). “Trucking Companies” [Data file]. Retrieved from http://www.polb.com/environment/cleantrucks/

The San Pedro Bay Ports (2017). “2017 Clean Air Action Plan Update.” Retrieved March 15, 2019, from http://www.cleanairactionplan.org/documents/final-2017-clean-air-action-plan-update.pdf/

The San Pedro Bay Ports (2018). “Clean Air Action Plan Draft 2018 Feasibility Assessment for Drayage Trucks.” Retrieved March 18, 2019, from http://www.cleanairactionplan.org/documents/draft-drayage-truck-feasibility-assesment.pdf/

TIAX (2011). “Characterization of Drayage Truck Duty Cycles at the Port of Long Beach and Port of Los Angeles”, page 1 and 2.

US Census Bureau . 2014, November. “Summary File.” In 2008–2012 American Community Survey. Washington, DC: US Census Bureau’s American Community Survey Office. http://ftp2.census.gov/.

U.S. Energy Information Administration (2014, May 21). How much carbon dioxide is produced by burning gasoline and diesel fuel?. Retrieved March 19, 2019, from http://www.patagoniaalliance.org/wp-content/uploads/2014/08/How-much-carbon-dioxide-is-produced-by-burning-gasoline-and-diesel-fuel-FAQ-U.S.-Energy-Information-Administration-EIA.pdf.

U.S. Energy Information Administration (2016, February 2). “Carbon Dioxide Emission Coefficients.” Retrieved May 1, 2019, from https://www.eia.gov/environment/emissions/co2_vol_mass.php;

U.S. Energy Information Administration (2018, October 26). “How much electricity does an American home use?” Retrieved April 30, 2019, from https://www.eia.gov/tools/faqs/faq.php?id=97&t=3;

Wilde, Dominik (2018, June 10). Daimler Unveils Freightliner eCascadia, A Tesla Semi Rival - Inside EVs. Retrieved March 14, 2019, from https://insideevs.com/daimler-freightliner-ecascadia-tesla-semi-rival/