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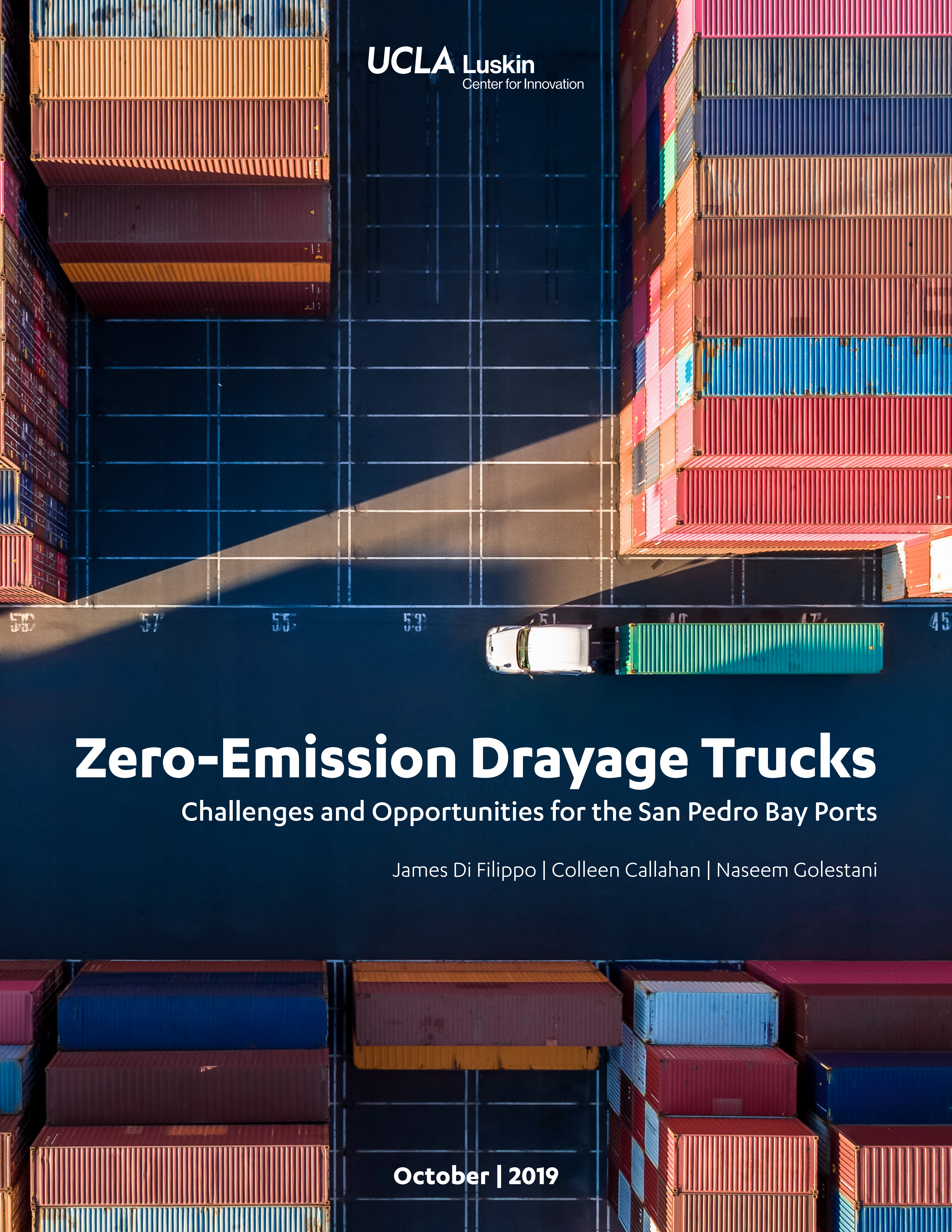

Zero-Emission Drayage Trucks

Challenges and Opportunities for the San Pedro Bay Ports

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October | 2019

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Acknowledgements
This report was made possible by two separate funding sources: 1) a partnership grant from the Strategic Growth Council's Climate Change Research Program and 2) members of the Trade, Health, and Environment Impact Project (THE Impact Project) collaborative. We thank the various members of the collaborative for their insights and guidance. This includes Adrian Martinez of Earthjustice as well as Melissa Lin Perrella and Heather Kryczka of NRDC for their support.

Thank you also to staff at the following entities for providing information that went into this report: Port of Long Beach, City of Los Angeles' Mayor's Office of Sustainability, Tetra Tech, Gladstein Neandross & Associates, Harbor Trucking Association, Southern California Edison, Los Angeles Department of Water and Power, and the Union of Concerned Scientists.

We also appreciate the following individuals who provided helpful feedback on a previous version of this report (in alphabetical order):

Paul Arneja, California Air Resources Board
Gisele Fong, The California Endowment
Genevieve Giuliano, METRANS Transportation Center, University of Southern California
Michelle Kinman and Alex Mitchell, Los Angeles Cleantech Incubator
Matt Miyasato, South Coast Air Quality Management District
Joseph Lyou, Coalition for Clean Air and former Governing Board Member of the South Coast Air Quality Management District
Jerilyn López Mendoza, Coalition for Clean Air and former Commissioner of the Port of Los Angeles
Martha Matsuoka, Occidental College
Jon Zerolnick, Los Angeles Alliance for a New Economy

The authors appreciate the guidance, direction, and review from LCI Director J.R. DeShazo.

Thank you to Nick Cuccia for copy editing and report design.

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The analysis presented is those of the authors and not necessarily those of UCLA, the funders or other aforementioned agencies and individuals. LCI appreciates the contributions of the above-listed reviewers; however, their review of this work does not imply any endorsement of the report's content or conclusions. Any mistakes or errors are solely attributable to the authors.

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executive summary

Every workday, thousands of heavy-duty diesel trucks move freight to and from the ports of Los Angeles and Long Beach. Known together as the San Pedro Bay Ports (the Ports), they handle more cargo volume than any other port in North America. The Ports are an important economic engine for Southern California. However, they are also the largest fixed source of air pollution in a region where air quality is among the worst in the nation. That poor air quality, caused in part by drayage trucks, imposes serious harm to the health of residents across the region.

The Ports' 2006 Clean Air Action Plan and subsequent 2007 Clean Trucks Program, aided by state and regional policies, have achieved significant reductions in drayage truck pollution over the last decade. Yet port and city leadership recognize the need for further action. In 2017, the mayors of Los Angeles and Long Beach signed a joint declaration with a goal that the drayage trucks serving the Ports be zero emission by 2035. Also, in 2017, the Ports released an update to the Clean Air Action Plan. The new plan targets adoption of near-zero-emission (NZE) trucks in the near term. The plan targets transition to zero-emissions (ZE) trucks later in the program, closer to the 2035 goal.

This report examines both the need for and current state of ZE trucks and the barriers and opportunities involved in moving toward zero emission drayage trucking. It then proposes a set of short-and-medium-term policies and strategies that address main barriers and opportunities. The authors describe why an accelerated transition in the 2020s could help achieve the 2035 zero emissions goal while providing other benefits.

While uncertainly exists, if the Ports and other stakeholders comprehensively address both barriers and opportunities, an accelerated transition to zero-emission trucks that starts in the 2020s could be both feasible and advantageous.

Public Health Need for Zero-Emission Trucks

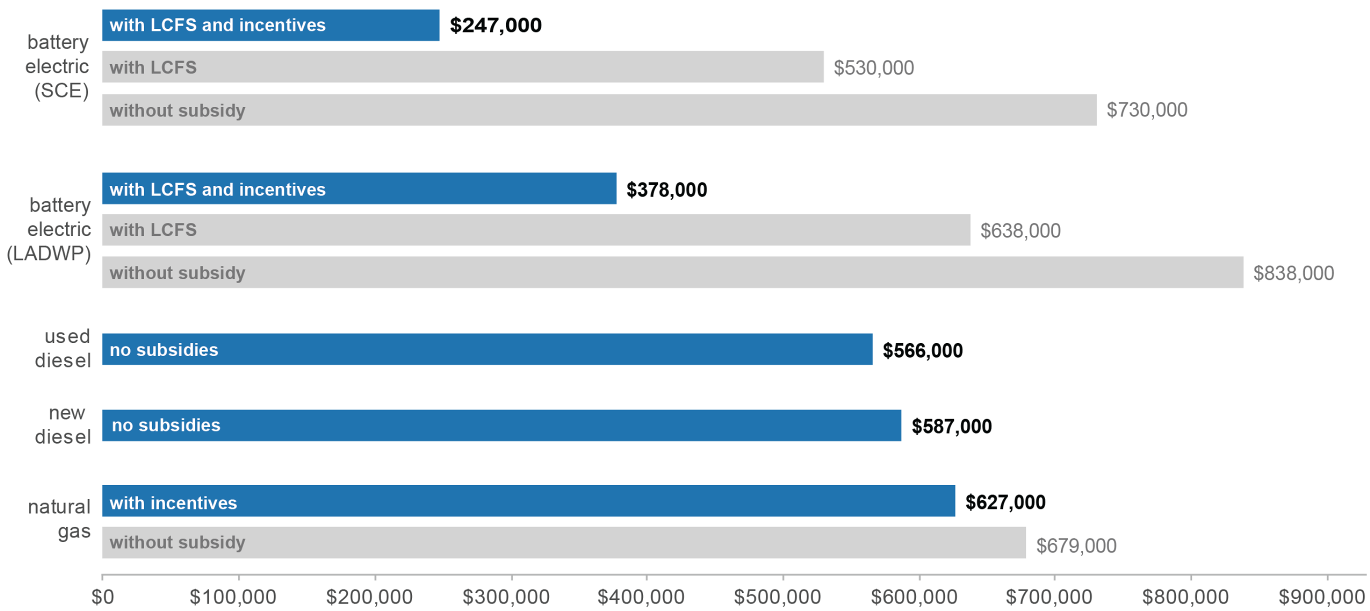
Concerns about the public health effects of air pollution and climate change drive adoption of the aforementioned zero-emission truck goals. A large body of literature establishes links between air pollution and risk of adverse health impacts. These include death, cancer, asthma, heart attack, and cognitive impairment. The Los Angeles region regularly exceeds federal air quality standards. Meeting goals for ZE drayage trucks will support air quality compliance efforts.

Much of the freight passing through the Ports — shipping containers full of everything from sneakers to soundbars — is destined for places outside Southern California. However, the majority of drayage truck pollution is concentrated in the region. The communities along freight corridors and nearby the Ports, intermodal facilities, and warehouses feel the heaviest effects of this pollution burden.

Technology Assessment

Zero-emission (ZE) Class 8 trucks use any fuel-technology combination that does not directly emit any regulated pollutants. ZE trucks use electric motors that run on energy from batteries or hydrogen fuel cells. ZE trucks can run on electricity or hydrogen that is produced by renewable energy sources like wind or solar.

Figure ES1: **Total Cost of Ownership for Average Drayage Truck**



Note: Incentives include vehicle purchase incentives and charging infrastructure rebates where applicable.

Electric vehicles are more energy efficient and emit fewer pollutants than natural gas vehicles or particularly diesel trucks. Moreover, they will become cleaner as California transitions to a zero-carbon electricity grid.

ZE trucks have yet to be proven in large-scale drayage operations, but the technology is advancing rapidly. ZE trucks suitable for drayage have reached the early commercialization stage with the BYD® battery electric 8TT. All six of the major heavy-duty truck manufacturers are working to bring Class 8 battery electric trucks (BETs) to market in the 2020s. At least one major Class 8 manufacturer plans to begin offering a BET as early as 2021.

This report primarily focuses on BETs. While demonstrations exist, hydrogen fuel cell trucks are less likely to reach a commercialization stage during the early 2020s. However, continued demonstrations of ZE trucks at the Ports could help to accelerate commercialization and deployment of other ZE technology.

Operational and Infrastructure Assessment

The range of ZE trucks is suitable for many drayage service needs. Early stage BETs will provide driving ranges of 125 to 300 miles, based on advertised specifications. This is less than the maximum shift distance of 600 miles reported in a recent survey of drayage drivers who serve the Ports. However, most drayage trips are short hauls to local destinations. Moreover, picking up cargo at the Ports takes time, limiting the number of trips per shift. Therefore, typical operations rarely require trucks that can travel such long distances.

While driving a BET is similar to driving a diesel truck, fueling with electricity is a paradigm shift. Challenges include charging times that require trucks to remain stationary for extended periods. For the near term, charging will likely occur overnight at truck yards. Financing and installing charging equipment will necessitate overcoming cost and ownership challenges.

Despite the challenges, fueling with electricity can be financially advantageous. Because electric motors are very efficient, the per-mile costs for electricity are one-third the price for diesel. Furthermore, using electricity for fuel generates valuable compliance credits under California's Low Carbon Fuel Standard (LCFS) Program. Selling LCFS credits is a significant secondary revenue opportunity for drayage operators. Other incentives, such as Southern California Edison's Charge Ready Transport Program, can offset infrastructure development costs.

Financial Analysis

Drayage operators are eligible for incentive programs designed to facilitate emission reductions and introduce ZE trucks. These incentives are important because BETs have a higher total cost of ownership (TCO) than their alternatives. However, the value of LCFS credits alone can make BETs less expensive than natural gas trucks. Moreover, after applying truck and infrastructure incentives, BETs become the cheapest option. The higher cost of electricity in Los Angeles Department of Water and Power (LADWP) territory makes ownership costs there more expensive than in Southern California Edison territory. However, those BETs are still a better value than alternatives, despite higher fueling costs.

Battery electric trucks can be financially viable for drayage service in the early 2020s.

Fleet Analysis and Proposed Path to Zero-Emission

In the 2017 Clean Air Action Plan, the Ports lay out a range of scenarios for NZE and ZE fleet transitions. By the Ports' own projections for ZE trucks by 2036, they may fall far short of the mayors' target for zero emissions by 2035.

In the Ports' proposed roadmap where the mayors' target is achieved, there are two sharp fleet transitions first to an NZE majority fleet and then a ZE majority fleet in about 10 years. Such transitions can cause disruptions and unnecessary costs.

Such a pattern does not have to be the case. Truck manufacturers predict that BETs with the range to cover a meaningful amount of drayage shifts will come to market between 2020 and 2024. Moreover, a bump in truck retirements — caused by natural turnover and California's Truck and Bus Rule's 2023 compliance deadline — presents a significant opportunity for early ZE adoption. Approximately 7,000 trucks, about half the fleet, are likely to retire in the early 2020s. Most of the other half will likely turn over later in the 2020s.

A turnover of nearly the entire fleet in the 2020s presents a major opportunity to reduce emissions. Action from the Ports and others could cause a significant portion of those retiring vehicles to be replaced with ZE trucks.

A transition to ZE vehicles starting in the early 2020s could deliver several benefits. The first, obvious, benefit is a faster reduction in harmful tailpipe emissions. This would provide rapid relief for communities near the ports and along freight corridors.

Second, adoption of ZE trucks in the 2020s could avoid early retirement of some NZE trucks and infrastructure. If NZE natural gas vehicles dominate in the 2020s as the Ports' predictions indicate, the region will need more natural gas fueling stations. Given goals to transition to ZE trucks, these investments may be stranded. An earlier transition to ZE could mean fewer short-term investments and more focus on long-term development of charging infrastructure for BETs. Also, by starting the transition in the early 2020s, stakeholders can take advantage of generous incentives available to early adopters.

Industry Barriers and the Opportunity for Zero-Emission Trucks

The structure of the drayage industry creates two barriers to ZE truck transitions.

First, it is uncertain which entity could shoulder the high up-front costs of ZE trucks and apply for incentives. This is not a new uncertainty. While designing the original Clean Trucks Program (CTP) in the early 2000s the Ports and others were concerned that independent contractors would not have the capital or credit to buy compliant trucks. In response, the Port of Los Angeles included an employee mandate in its initial CTP. This would have shifted ownership responsibility to better-capitalized licensed motor carriers (LMC). However, this requirement failed legal challenge and was never implemented. Out of necessity, LMCs bought trucks and leased them to their drivers. Today, in the wake of costly employee misclassification lawsuits, the LMCs are less likely to enter into similar arrangements.

Second, there is no incentive for specialization in shorter electrifiable routes. Without a mechanism that ensures that shorter-range BETs get assigned conducive routes, LMCs and independent drivers will prefer vehicles that do not risk revenue loss. Moreover, because of independent contractor rules, drayage companies may be reluctant to dedicate certain drivers and their trucks to routes conducive to BETs.

Recent legal and legislative developments have called into question the continued legality of the independent contractor model that dominates the drayage industry. If the independent contractor model loses prominence in the industry, some of the barriers to deployment of BETs will be resolved. However, the restructuring of the industry may cause other unforeseen effects.

Regardless of what the future holds, there is potential in the industry to better optimize and specialize in ways conducive to electrified trucks, especially if the Ports and others provide incentives to do so.

Policy and Strategy Options for the Ports and Partners

This report proposes actions to address the barriers and opportunities that exist for a ZE truck transition that begins in the early 2020s. The drayage industry is complex, and interacting landscapes of technology and policy are evolving quickly. Thus, no one entity, policy, or strategy could overcome all barriers and leverage all opportunities in the short and medium terms. There are also no silver bullets or easy answers. Strategies need to work in tandem because addressing only one challenge will not be enough. Key stakeholders must tackle the challenges together in order for the transition to be fully successful.

A multifaceted and agile approach coordinated among stakeholders will be necessary.

To narrow down potential actions to those most likely to be viable, we employed the following criteria: the policy or strategy 1) is within the purview, legal authority, and abilities of the Ports; 2) is possible in the near or medium term, and 3) would address one or more main barriers and/or opportunities to accelerate ZE truck adoption.

In order to promote a transition to ZE trucks that is as smooth as possible, the Ports should specifically incentivize ZE truck adoption beginning in the near term. The foundation of the Ports' actions could be the creation of a Zero-Emissions Drayage Plan that includes interim targets for ZE truck adoption prior to 2035. These incremental targets should be flexible to account for technological and operational progress. To meet ZE transition targets, multiple policies and strategies should also be included in this plan. We introduce three such policies and strategies within the Ports' purview:

- Set a three-tiered truck rate that incentives zero-emission trucks above all other alternatives in the 2020s — thereby sending an important financial signal to trucking companies to utilize ZE trucks;
- Implement system optimization strategies — thereby facilitating the efficient use of ZE trucks and maximizing the associated benefits; and
- Coordinate a "one-stop-shop" wraparound approach to provide outreach and technical assistance to drayage trucking companies and independent drivers — thereby providing information and support to help private decision-makers adopt ZE drayage trucks.

The report also offers specific suggestions outside the Ports' purview related to:

- Utility-level infrastructure incentives;
- Air agency-level truck purchase incentives; and
- Collaboration to overcome ZE truck and infrastructure financing barriers through innovative financing mechanisms.

These six steps should be seen as a starting point but not a comprehensive list of actions for the Ports and other stakeholders. If taken in the short and medium terms, these and other strategies could achieve a transition to ZE drayage trucks that is as smooth and as early as possible, while maximizing the benefits of doing so.

chapter 1
introduction

The adjacent ports of Los Angeles and Long Beach are the largest in the United States. Together referred to as the San Pedro Bay Ports (the Ports), they handle about 40% of the waterborne imported cargo into the nation (Ports 2017a). They are also one of the highest-volume container port complexes in the world. Their importance to trade will continue, as the volume of containers going through the Ports is projected to increase over time. Specifically, freight truck miles traveled are estimated to increase 80% (from 2008 levels) by 2035 (SCAG 2012).

Given their operational scale, the Ports have a large impact on the regional economy and infrastructure, as well as a large environmental footprint. To accommodate the millions of containers flowing into the Ports each year, fleets of ships, cargo-handling vehicles, rail cars, and heavy-duty trucks are employed daily. These fleets produce local air, noise, and water pollution that contribute to health disparities in communities closest to port-related operations. The pollution also significantly affects air quality throughout the South Coast Air Basin, home to more than 16 million people, and global climate change.

Close to 40% of the containerized goods that enter the Ports are destined to areas outside the South Coast Air Basin (SCAQMD 2015a). As such, residents are disproportionately affected by pollution from trucks and trains moving freight through the South Coast region to benefit the rest of the nation (SCAQMD 2015a).

Report Purpose and Scope

This report focuses on the heavy-duty trucks, called drayage trucks, which service the San Pedro Bay Ports and then travel throughout the region. Approximately 13,000 to 14,000 heavy-duty trucks regularly work out of these Ports, moving the majority (approximately 80%) of the containers entering the Ports (Lai et al. 2006). These drayage trucks then move the cargo to off-dock rail transfer facilities, transloading facilities for repackaging for long-haul transport, or directly to final destinations.

This chapter describes how drayage trucks contribute to air pollution and how policies have led to emission reductions. The chapter also introduces new policies, targets, and proposals from the Ports and other stakeholders to further reduce emissions contributing to public health and associated financial costs. A goal of the Ports, the Los Angeles and Long Beach mayors, and regional and state air regulators is the transition to a zero-emission truck fleet, in order to address the serious threat that air pollution poses locally, regionally, and at a state level.

An objective of this report is to explore the main challenges and opportunities for zero-emission trucks to provide drayage services at the Ports. The other is to introduce policy and strategy options that the Ports and other key decision-makers could consider to address those challenges and opportunities in order to support a transition as quickly and smoothly as possible. As such, this report sets the stage of future research that could analyze more specific policy design details and model their expected outcomes.

Air Pollution Problem

The San Pedro Bay Ports are the single-largest fixed source of air pollution in Southern California (SCAQMD 2013). A thriving freight movement industry among other factors continue to produce the worst ozone (smog) pollution in the nation (SCAQMD 2016). The South Coast Air Basin is out of compliance with health-based, federal air quality standards for ozone and particulate matter. To meet national ambient air quality standards for ozone, the South Coast Air Basin will require an approximate 70% reduction in nitrogen oxides (NO_x) from today's levels by 2023 and 80% NO_x reduction by 2031 (CARB 2018). This will require wide-scale deployment of technologies that achieve near-zero or zero emissions (SCAQMD 2015a).

> "Zero-emission trucks are needed to achieve clean air standards in Southern California communities."
> — South Coast Air Quality Management District (SCAQMD 2015a)

Freight movement accounts for about 42% of NO_x emissions in the South Coast Air Basin, with heavy-duty trucks that service the Ports the single-largest source within that category (SCAQMD, 2015a). Drayage trucks account for 0.1% of vehicles in the South Coast but 5% of NO_x emissions from the transportation sector, emitting approximately 4,000 tons of NO_x per year in the region (CARB EMFAC Model 2017). Specific to the Ports' inventory, heavy-duty trucks are responsible for 23% of NO_x emissions (Ports 2017b). This is true even after progress in reducing drayage truck emissions, which will be discussed in the upcoming Policy Background section.

Heavy-duty drayage trucks are also a major source of greenhouse gas (GHG) emissions that contribute to climate change. Heavy-duty trucks are responsible for a plurality (40%) of port-related GHG emissions. Furthermore, diesel trucks generate toxic air emissions, including diesel particulate matter, which the World Health Organization classifies as a carcinogen and the California Air Resources Board identifies as a toxic air containment (CARB 2019a).

Health Impacts From Freight Movement and Trucks

A large body of literature establishes the link between air pollution associated with trucks and a range of health effects. These include increased risk of the following (U.S. EPA 2016a):

- Premature death
- Cancer
- Asthma
- Aggravation of respiratory and cardiovascular disease (heart attacks and asthma attacks)
- Respiratory infections
- Increased frequency and severity of respiratory symptoms such as difficulty breathing
- Effects on the nervous system, including the brain, such as IQ loss and impacts on learning, memory, and behavior

Certain populations are especially vulnerable to the effects of air pollution, including children, pregnant women, senior citizens, and people with chronic illnesses. Children, for example, are particularly vulnerable because their lungs are developing and their exposure is greater due to quicker breathing speeds and more active hours spent outdoors. The Children's Health Study conducted by the University of Southern California is one of the largest and most detailed studies of the long-term effects of air pollution on the respiratory health of children (USC 2019). Findings include that:

- Children living near busy roads have increased risk for asthma (Gauderman et al. 2004).
- Living in communities with higher pollution levels — including nitrogen dioxide that comes from vehicle emissions — causes measurable lung damage (reduced growth and poorer lung function) (Gauderman et al. 2005).
- Days with higher air pollution levels increase short-term respiratory infections, and these infections lead to more school absences (Gilliland et al. 2001).

> A recent study links nearly 50% of childhood asthma cases in Los Angeles County to traffic-related nitrogen dioxide pollution.
> — (Khreis 2019)

Emissions from freight movement in California are associated with approximately 2,200 premature deaths, 330 hospitalizations, and 950 emergency room visits for respiratory and cardiovascular ailments (State of California 2016). Although these numbers represent impacts from the statewide freight system, drayage trucks at the San Pedro Bay Ports undoubtedly contribute, given that the majority of the freight entering the state comes through one of these two ports.

While freight-related pollution affects Californians in general, pollution exposure is highest near ports, rail yards, and along high-volume truck corridors. Health risk increases with proximity to the source of pollution, and thus people who live, work, and go to school near the Ports and truck corridors face greater health impacts than those farther away (Ports 2017a). This includes elevated cancer and asthma risks. For example, about 15% of children in Long Beach suffer from asthma compared to 9% of children in the United States (City of Long Beach, 2013). A recent study links nearly 50% of childhood asthma cases in Los Angeles County to traffic-related nitrogen dioxide pollution (Khreis 2019).

> **"The Californians who live near ports, rail yards, and along high traffic corridors, are subsidizing the goods movement sector with their health."**
> — (California Air Resources Board 2005)

As the health effects of air pollution increase with proximity to roads and traffic, so do racial and economic disparities. Residents of low-income communities and communities of color are more likely to live near busy roads and freight hubs, where exposure to pollution from heavy-duty trucks is greater (Houston et al. 2014; Hricko et al. 2014). Nearly two-thirds of those living near the busiest roads — those carrying more than 200,000 vehicles on an average day — are people of color, and median household income in these areas is roughly 20% below the county average (Rowangould 2013).

Living near a busy road is not the only means of exposure; time spent in busy traffic while commuting to work is another significant source of exposure (Chandler et al. 2017). As a result, drayage truck drivers themselves are disproportionately at risk of the health effects from diesel particulate matter and other pollutants emitted from heavy-duty diesel trucks.

Health Effects of Air Pollution

Nitrogen Oxides

Vehicles are a primary source of nitrogen oxides. Nitrogen oxide gases are harmful to human health, with nitrogen dioxide (NO_2) of greatest concern when inhaled. NO_2 exposure leads to respiratory symptoms such as coughing, wheezing, and difficulty breathing, as well as hospital admissions and visits to emergency rooms (U.S. EPA 2019a). Long-term exposure increases the likelihood of developing asthma (U.S. EPA 2016b). In the presence of sunlight, NO_2 reacts with other compounds in the air to form nitrate particulate matter and ozone.

Ozone

Tropospheric, or ground-level ozone, is created by chemical reactions between oxides of nitrogen and volatile organic compounds. Ozone is a harmful air pollutant because of its effects on people and the environment, and is the main component of smog. Even relatively low levels of ozone can cause health effects. Ozone can cause the muscles in the airways to constrict, trapping air in the alveoli. This leads to wheezing and shortness of breath. Ozone can aggregate lung diseases, increase the frequency of asthma attacks, and cause chronic obstructive pulmonary disease (COPD) (U.S. EPA 2019b).

Particulate Matter

Particulate matter are aerosol air contaminants. The size of particles is directly linked to their potential for causing health problems. Small particles less than 10 micrometers in diameter pose risks to human health because they are capable of penetrating cell walls and the blood–brain barrier and can easily be absorbed by vital organs (Delfino et al. 2005). Heightened ambient levels of fine particles ($PM_{2.5}$) have consistently been associated with increased rates of mortality and respiratory illness (Englert 2004; Lippmann et al. 2003). Numerous scientific studies have also linked particle pollution to nonfatal heart attacks and irregular heartbeats (U.S. EPA 2019c).

> **Diesel particulate matter is a toxic air contaminant responsible for about 70% of total known cancer risk related to airborne toxins in California.** — (CARB 2019b)

Diesel exhaust in particular also contains more than 40 cancer-causing substances. The solid material in diesel exhaust is known as diesel particulate matter. In 1998, California identified diesel PM as a toxic air contaminant based on its potential to cause cancer (CARB 2019b). Studies show a causal relationship between lung cancer and long-term occupational exposure to diesel PM (CARB 2019a). Workers — who are driving or otherwise in close proximity to diesel trucks and other diesel vehicles — are particularly vulnerable. About 70% of total known cancer risk related to air toxics in California is attributable to DPM.

Organic Gases

Volatile organic compounds (VOCs) are chemical compounds whose composition makes it possible for them to evaporate. Emissions of VOCs to the outdoors are regulated by EPA mostly to prevent the formation of ozone. However, many VOCs are known or probable carcinogens, such as formaldehyde and the pesticide DDT. CARB regulates a subset of organic compounds called Reactive Organic Gases (ROGs) (CARB 2004). Reducing the concentration of ROGs indoors and outdoors is an important health and environmental goal (U.S. EPA 2017).

Economic Costs of Air Pollution

The health impacts of air pollution have economic consequences, in part because of the link to hospital admissions and worker productivity losses (Zanobetti et al. 2000; Ziven and Neidell 2012). Higher health care costs and lost productivity directly impact the economic well-being of individuals and businesses affected by drayage truck pollution.

Moreover, the economic costs imposed by increased mortality risk are very high. Although a controversial metric, value of statistical life (a measure of the value of avoided risk of death) is commonly used in financial decision-making. The value of avoiding a single pollution death can be quite substantial, with estimates in the academic literature ranging from $0.5 million to $50 million (Bellavance et al. 2009).

> **Air pollution imposes health costs estimated at about $1,250 annually for each resident of Southern California.**
> — (Hall and Brajer, 2008)

A study of the South Coast and San Joaquin air districts estimated that air pollution costs the California economy more than $28 billion annually (Hall and Brajer, 2008). This study by scholars at Cal State Fullerton also zeroed in on the South Coast and found that air pollution costs more than $1,250 annually per Southern California resident, for an annual total savings of nearly $22 billion if federal air quality standards were met. The study also states that in Los Angeles County, pollution-related deaths are more than double the number of motor vehicle-related deaths.

National estimates of the average value of benefits-per-ton of PM and NO_x emissions reductions from mobile sources were $400,000 and $8,300 respectively (Fann et al. 2012). Because Los Angeles is much more densely populated on average than the U.S. those values are likely an underestimate for the value of emissions reduction benefits from drayage trucks.

A value of emissions reductions depends on where those emissions occur relative to population centers. Because mobile sources of pollution (e.g., diesel trucks) operate inside populated areas, their impact is disproportionately high. An accurate estimate of the value of emissions reductions associated with the use of ZE trucks would require a detailed air quality modeling effort.

Policy Background: Clean Trucks Program

The harm inflicted on local communities from air pollution caused by port activity has long been understood and the Ports have faced legal and political pressure to clean up their operations. In 2006, the Ports collaborated to develop the first Clean Air Action Plan (CAAP), a sweeping plan to reduce health risks and emissions from a variety of port activities, while accommodating port development. The CAAP assesses port emissions and outlines goals and actions to be taken to achieve emission and health-risk reductions due to port activities. Under the CAAP, the Ports contributed to early emission reductions and compliance with government regulations. This includes the state's Drayage Truck Regulation, adopted by the California Air Resources Board (CARB) to phase out trucks with model year engines older than 2007.

The Ports adopted the Clean Trucks Program (CTP) in 2007. Taking effect in 2008, the CTP included a progressive ban on the oldest, higher-polluting trucks (pre-1989 models) and a Clean Trucks Fee to incentivize rapid replacement of pre-2007 trucks. The CTP successfully accelerated compliance with the state's Drayage Truck Regulation and 2007 engine emission standards. All trucks entering port property were compliant by 2012, two years ahead of CARB's compliance date (Ports 2017c). The Ports report that since 2005, diesel PM emissions have decreased by 87%, NO_x by 56%, and greenhouse gas emissions by 18% (Ports 2017b).

While this progress is significant, the Ports acknowledge that there is still need for further emission reductions through additional measures in order to help meet federal clean air standards as well as new state and local environmental policy goals (Ports 2017b). In addition, industry instability and operational inefficiencies continue today.

To address these longstanding issues, in 2008, the Ports adopted a concession agreement system in which Licensed Motor Carriers (LMCs) could apply to provide drayage service. The Port of Los Angeles applied more criteria than the Port of Long Beach for LMCs to obtain a concession, most notably the requirement that firms seeking a concession use employee drivers as opposed to independent contractor drivers. Consultants for the Port of Los Angeles stated that the use of employee drivers would improve industry stability, operational efficiency, safety and environmental compliance, in part because better capitalized LMCs are more likely to be able to finance and properly maintain cleaner, more expensive trucks (Boston Consulting Group 2008).

Questions remain about what entity could finance the next round of cleaner trucks and apply for the incentives in an industry that continues to rely heavily on independent contractors. In addition, given the number of small companies providing drayage service, questions exist about capacity and ability to optimize routes most conducive to zero-emission trucks. These issues are further addressed in chapters 3 and 4.

Policy Goals and Updated Clean Air Action Plan

The Ports have released the Clean Air Action Plan 2017, the third version of the CAAP after the original in 2007 and the 2010 version. The 2017 CAAP Update establishes new goals to continue to reduce air pollution. These goals are informed by the following policies and goals at the state and local levels (Ports 2017b).

The state set targets for reducing greenhouse gas emissions (GHGs) through Assembly Bill 32, executive orders, and Senate Bill 32. Per the 2017 CAAP Update, the Ports set GHG reduction goals that align with state targets: by 2030, reduce GHGs to 40% below 1990 levels (Governor's Executive Order B-30-15 and Senate Bill 32), and by 2050, reduce GHGs to 80% below 1990 levels (Governor's Executive Order S-3-05).

Pursuant to former Governor Edmund Brown's Executive Order B-32-15, California also established aggressive goals for more sustainable movement of goods to meet air quality and greenhouse gas reduction goals. Among these goals, the Sustainable Freight Action Plan of 2016 established a target of deploying over 100,000 freight vehicles and equipment capable of zero-emission operation.

In 2017, the mayors of the cities of Los Angeles and Long Beach signed a joint declaration affirming the commitment to move toward zero emissions at the Ports. This includes the goal of "zero emissions for on-road drayage trucks serving the Ports by 2035" (Garcetti and Garcia 2017). The mayors committed to a CAAP that includes new investments in clean technology and a zero-emissions drayage truck pilot program.

In the 2017 CAAP Update, the Ports set the goal to transition the current drayage truck fleet to near-zero technologies in the near term and ultimately zero-emissions technologies by 2035. The Ports propose to do so through the following updates to the Clean Trucks Program:

- Beginning in mid-2018, new trucks entering the Ports' Drayage Truck Registry (PDTR) must have a 2014 engine model year (MY) or newer. Pre-2014 MY trucks already registered in the PDTR can continue to operate.
- Beginning in early 2020, following promulgation of the state's near-zero-emission heavy-duty engine standard (see below), all heavy-duty trucks will be charged a rate to enter the ports' terminals, with exemptions for trucks that are certified to meet this near-zero standard or better.
- Starting in 2023, or when the state's proposed low-NOx heavy-duty engine standard will be required for new truck engine manufacturers, new trucks entering the PDTR must have engines that meet this near-zero emissions standard or better. Existing trucks already registered in the PDTR can continue to operate.
- A modification of the truck rate that, by 2035, exempts only those trucks that are certified to meet zero-emissions.

The proposed 2017 CAAP Update makes clear that a rate charged to trucks that enter the property of either Port is a critical tool available to incentivize cleaner trucks. The Ports' initiation of this rate will be contingent on several elements, including a near-zero emission standard that CARB will promulgate. This will be a manufacturing standard for all new heavy-duty engines. (See chapter 2 for details.)

The rate amount will be established based upon an economic study that will evaluate the capacity of the industry to absorb this expense in light of existing costs and other fees, including an assessment of how the rate will affect the Ports' economic competitiveness and the potential for cargo diversion. All funds collected through the assessment of the rate will be used for trucking initiatives, for example, for incentives to the trucking industry for purchase of near-zero and zero-emission trucks. The Ports also intend to work closely with the federal, state, and local governments to secure incentive funding for near-zero-emission trucks in the near term.

This paper could complement the forthcoming rate study by offering analysis and an initial framework for a smooth transition to meet the goal of zero-emission trucks. First, we review key considerations for this transition, including technology status and commercial availability. As such, chapter 2 summarizes the Ports' commissioned Draft 2018 Technology Assessment for Drayage Trucks and other related literature.

chapter 2

technology assessment

Diesel engine trucks have dominated the trucking industry for as long as the industry has existed. It has only been recently that alternative powertrain technologies have become viable substitutes for diesel engines in heavy-duty applications. The use of these new technologies can be beneficial for a number of reasons, but the primary impetus for substituting away from diesel engines is that competing technologies can offer meaningful reductions in both air pollutant and greenhouse gas emissions.

Unlike diesel engines that are a mature technology, zero-emission alternatives are in a nascent development phase. While technology is rapidly advancing, there is uncertainty about the timelines for technology development and release, and whether these new trucks will be able to meet projected performance parameters. This chapter provides a look at the present state of both near-zero and zero-emission technology fuel platforms and their potential development in the near term.

Near-Zero and Zero-Emission Technologies

Neither the California Air Resources Board (CARB) nor the U.S. Environmental Protection Agency have formally issued emissions standards that define a zero-emission (ZE) Class 8 truck specification. For the purposes of this report, we define zero-emission as any fuel-technology combination for heavy-duty Class 8 trucks where the powertrain does not directly emit any regulated pollutants,[1] a designation that effectively disqualifies any platform that relies on onboard fuel combustion. This working definition is consistent with the Draft 2018 Technology Assessment for Drayage Trucks, commissioned by the San Pedro Bay Ports (Tetra Tech and GNA 2019).

There are currently two primary ZE fuel-technology platforms that are commercialized or in development:

- Battery electric trucks (BET), which are powered by an electric motor that is supplied energy from a rechargeable battery pack.
- Hydrogen fuel cell electric trucks, which are powered by an electric motor that is supplied energy from a hydrogen fuel cell stack.

Like ZE, the designation *near-zero-emission* does not refer to any specific emissions performance standard. Currently, the standard that most closely resembles a near-zero-emission (NZE) specification is CARB's Optional Heavy-Duty Low NO_x standard of 0.02 grams per brake horsepower hour (g/bhp-hr), which is 10 times less than the regular standard. However, as part of its Heavy-duty Low NO_x Omnibus Rulemaking, CARB expects to promulgate mandatory NO_x and $PM_{2.5}$ standards in 2020 to go into effect in the mid-2020s. The Ports have signaled that they will base their NZE standard on this rule. Based on the most recent CARB staff white paper (not approved by CARB's Board) the Federal Test Procedure NO_x standard will likely be set between 0.05 and 0.08 g/bhp-hr and the PM standard at 0.005 g/bhp-hr (CARB 2018).

There are currently two primary NZE fuel-technology platforms that are commercialized or in development:

- Ultra-low-NO_x natural gas trucks, which are powered

[1] ZE trucks emit some particulate matter pollution as the result of tire and brake wear.

by spark-ignited natural gas engines equipped with advanced emissions control technologies
- Advanced diesel trucks, which are powered by diesel engines equipped with advanced emissions control technologies.

In addition to the above-mentioned ZE and NZE technologies, a number of novel solutions are under development. These include:

- Catenary electric truck systems that connect to overhead power systems via pantograph similar to a streetcar. When not directly connected to power, these trucks rely on onboard power from either battery electric or internal-combustion powertrains.
- Hybrid-electric trucks that combine combustion engines with electric motors. The plug-in hybrid variety incorporate externally chargeable batteries that enable short-range ZE operations.

Technologies Considered

Among the near-zero and zero-emission alternatives to Class 8 diesel trucks, NZE natural gas and ZE battery electric trucks have demonstrated the highest levels of technological readiness (TRL).[2] NZE natural gas trucks have the highest technological readiness with a TRL 8, which indicates that the platform has reached a final or near-final stage and has exhibited technical viability through testing and demonstration. ZE battery electric trucks are quickly catching up and are currently at a TRL 6-7, a demonstration and initial systems conditioning stage. By the very early 2020s, NZE natural gas trucks are expected to reach the last stage of technological readiness, while the educated prognosis is that battery electric trucks will achieve TRL 8 by or before 2021 (Tetra Tech and GNA 2019).

Unlike NZE natural gas and ZE battery electric, the alternative technologies have not progressed as rapidly and are unlikely to be competitive in the near to medium term. Like the port-commissioned drayage truck feasibility study, this report focuses on battery electric and natural gas as the most likely technology-fuel platforms for early adoption of ZE and NZE drayage trucks. (Tetra Tech and GNA 2019),

It is important to note that, while NZE advanced diesel technology is currently at TRL 5, because NZE diesel technology represents an incremental improvement on current diesel engines using more sophisticated emissions controls, they may be able to leapfrog development levels and reach commercial availability in the mid 2020s. At that point they will compete with natural gas vehicles in the NZE truck market.

Emission Comparisons Across Truck Technologies

We compare emissions at two levels: 1) those directly emitted from the vehicle tailpipe, and 2) emissions from both the tailpipe and the fuel/electricity source, referred to as a well-to-wheels comparison. The emission comparisons focus on standard diesel, NZE natural gas, ZE battery electric, and ZE fuel cell electric technologies. All of these technologies have entered a technology demonstration or commercialization phase that allows for emissions testing or informed projections.

The other two fuel-technology platforms, advanced diesel and hybrid-electric, are in development. However, it is likely that the emissions profile of an advanced diesel truck would be similar to a natural gas truck that meets the same emission standards, except that unlike NZE natural gas trucks, NZE diesels will emit toxic diesel particulate matter. Hybrid-electric trucks would produce no tailpipe emissions when in electric mode and would otherwise have the emissions profile of its internal-combustion engine.

Tailpipe Emission Comparisons

Drayage trucks serving the Ports operate in densely populated areas. Pollutants such as diesel particulate matter (PM) are concentrated along associated freight movement corridors, contributing to toxic hot spots where Southern Californians live, work, and go to school. While power plants that provide energy to ZE trucks also produce PM pollution, it is typically not cancer-causing diesel PM. In addition, power plant emissions tend to cause less harm than mobile source emissions because they are generally not located in close proximity to large populations. On average in the United States, an equivalent mass of PM pollution will cause 2.4 times more harm from a mobile source than a power plant (Fann et al. 2012). The differential is likely to be even higher in the Los Angeles area because of particularly dense populations along traffic corridors. Reducing emissions from freight movement and other mobile sources will therefore have significant public health benefits.

[2] Readiness is assessed using the U.S. Department of Energy's commonly used system for assigning technology readiness levels (TRL) which is a nine-point scale, where a 9 designates full technical viability (DOE 2011).

Accordingly, this paper first focuses on tailpipe emissions levels. Battery electric and fuel cell trucks produce zero tailpipe emissions, a 100% reduction in pollution compared to standard diesel trucks. NZE compressed natural gas (CNG) trucks reduce nitrogen oxide emissions by 90% compared to diesel trucks. This is a significant reduction but not one that applies to other types of emissions associated with local health impacts, such as PM or reactive organic gases (ROG).

While diesel PM is not emitted from either ZE trucks or NZE natural gas trucks, the latter do emit PM. There are no optional or mandatory PM or ROG standards applicable to NZE trucks, unlike as there is for California's Optional Low NO_x standards. Thus, it can be assumed that there is no difference between NZE and diesel trucks for those two types of emissions, as Table 2 illustrates. (In reality, there is likely an improvement in PM emissions with NZE trucks compared to diesel trucks, as there is for CNG buses compared to diesel buses. For example, the California Air Resources Board (CARB) models an average $PM_{2.5}$ emission rate reduction of 16% between CNG buses compared to diesel buses.)

Modeled criteria pollutant factors for a new 2019 diesel truck operating in drayage service at the San Pedro Ports are summarized in Table 1, followed by Table 2, which illustrates the reduction factors for NZE and ZE Class 8 trucks.

Table 1: Diesel emission factors (tailpipe) per new diesel truck per mile (CARB EMFAC Model 2017)

Pollutant	Emissions in grams per mile
NO_x	1.508
$PM_{2.5}$	0.007
ROG	0.015

† CARB EMFAC Model 2017

Source: Estimated by the UCLA Luskin Center for Innovation using the EMFAC2017 model maintained by the California Air Resources Board. Used average per mile emissions for a 2019 model year diesel truck operating at the San Pedro Bay Ports. (POLA code in EMFAC).

Table 2: Tailpipe emission reduction factors compared to a baseline new diesel truck

Technology	Reduction Factor NO_x	Reduction Factor $PM_{2.5}$	Reduction Factor ROG
NZE CNG†	90%	0%	0%
ZE Battery Electric	100%	100%	100%
ZE Fuel Cell Electric	100%	100%	100%

†Optional Low-NO_x Standard Compliant

Well-to-Wheels Emission Comparisons

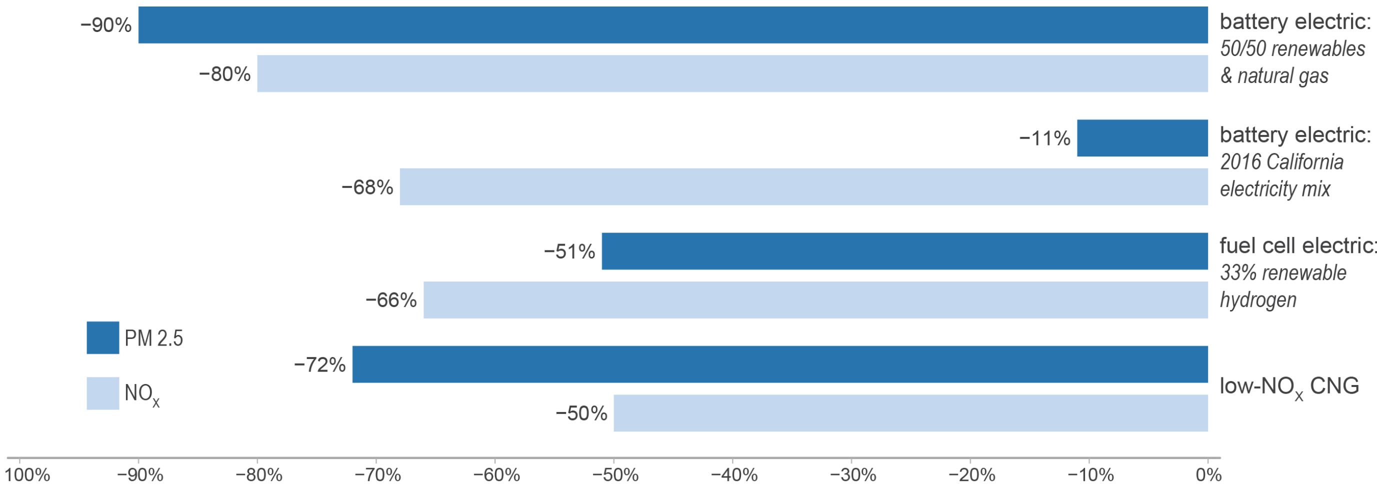
The emissions impacts of electricity, hydrogen, natural gas, and diesel all depend on tailpipe emissions, the feedstock used to produce the fuels/electricity, and the efficiency of the vehicle technology (ICF 2015). In addition to producing zero-emissions in operation, ZE trucks could run on electricity or hydrogen produced using renewable (i.e., solar and wind) or other forms of carbon-free energy (i.e., hydropower).

In 2017, just over 50% of California's electricity came from sources that produce no direct air pollution (California Energy Commission 2018). The state's electricity grid is rapidly becoming cleaner and is expected to continue to do so under legislative mandates. The California Public Utility Commission (CPUC) forecasts that the state will reach its 50% renewable portfolio target in 2020, five years before the legislative deadline (CPUC 2018). Per Senate Bill 100 (SB 100, de León), 60% of electricity must be powered by renewable energy by 2030, with a zero-carbon electricity grid by 2045. Thus, the upstream, or well-to-wheel, emissions associated with ZE trucks will continue to decrease.

Even when considering the national average electricity grid mix today — which is more emissions heavy than the California mix today — a majority of the literature estimates that electrified vehicles will result in greenhouse gas, NO_x, and PM emissions reductions compared to both conventional diesel and fossil natural gas (ICF 2015).

While the authors of this paper are not aware of well-to-wheel emission comparisons between a ZE Class 8 truck compared and other platforms, a proxy is transit buses. The Union of Concerned Scientists (UCS) estimates that battery electric buses emit approximately 70% less NO_x on a per-mile basis compared to diesel buses, when powered by California's 2016 power mix — approximately 50% natural gas, 25% renewable, 10% nuclear, 8% hydropower, and 7% coal (Chandler et al. 2017). This same study estimates an 80% decrease in NO_x and a 90% decrease in PM pollution compared to diesel buses, when electricity is produced from 50% renewables and 50% natural gas, a simplified scenario that is not very different from today's reality. See Figure 1 for other comparisons.

Figure 1: $PM_{2.5}$ and NO_x emission reductions (incorporating fuel production and vehicle use) compared to new diesel buses



Source: Chandler, C, J. Espino, J. O'Dea (2017 updated from 2016 version). "Delivering Opportunity: How Electric Buses and Trucks Can Create Jobs and Improve Public Health in California." Union of Concerned Scientists and the Greenlining Institute; Page 18 ucsusa.org/sites/default/files/attach/2016/10/UCS-Electric-Buses-Report.pdf

A battery electric bus running on electricity from a natural gas plant can travel up to twice as far as a conventional natural gas bus using the same amount of fuel. Using renewable natural gas that is captured from biological processes can reduce GHG emissions relative to fossil natural gas. Some of the natural gas pathways certified by CARB even have negative carbon intensities; however the bulk of CARB-certified pathways have carbon intensities that exceed electricity (CARB 2019). The relative GHG performance of natural gas vehicles and electric vehicles is a contested and controversial topic.

While the emission trend will be the same, the exact emission levels will differ somewhat between transit and drayage trucks because efficiencies, travel speeds, and other factors differ somewhat between these two types of vehicles. With that caveat, the efficiency ratios for an electric transit bus compared to an electric Class 8 drayage truck are quite similar (CARB 2018b).

> **Electric vehicles are more efficient than diesel and natural gas vehicles, emit fewer pollutants, and will continue to get cleaner.**

Battery electric vehicles are considerably more efficient at converting energy to motion than conventional diesel vehicles, holding true across different weight classes, vehicle types, and duty cycles. Battery electric vehicles have an energy efficiency ratio that is about 3.5 times greater than conventional diesel vehicles at highway speeds and five to seven times the efficiency of conventional diesel vehicles when operated at lower speed duty cycles typical of drayage services, where idling and coasting loses from conventional engines are highest (CARB 2018b).

Beyond Tailpipe Emissions: Other Benefits of Zero-Emission Trucks

Aforementioned goals for ZE trucks are driven by their clean tailpipes and the associated benefit to local public health. Thus, this paper focused on that aspect as well. However, it is worth noting the following other benefits (per CARB 2017b):

- Durable emission reductions (not vulnerable to emission increases due to engine maintenance problems or tampering of diesel particulate filters and other emission controls)
- Reduced brake wear/dust that contributes to PM emissions
- Noise reduction
- Petroleum use reduction
- Less potential for hazardous fluid/gas leaks
- Potential benefits to electrical grid
- Opportunity to use all forms of renewable energy
- Synergies with other innovative transportation systems

Thus, there is a wide array of local, regional, and statewide benefits of zero-emission trucks. Many of these benefits — including reduced noise and air pollution — will accrue most significantly to drivers who operate them over a long time, and community members who live, work, and go to school near freight corridors.

Technology Availability and Performance

Original equipment manufacturers (OEMs) have significantly accelerated their efforts to commercialize ZE and NZE Class 8 trucks that can be used in drayage applications (Tetra Tech and GNA 2019). Of particular note is the speed at which all six of the mainstream heavy-duty truck OEMs are working to develop, demonstrate, and commercialize battery electric Class 8 tractors suitable for drayage in the near future.

ZE Battery Electric Trucks

At the time of publication for this report, there is one Class 8 truck model available for regular commercial purchase: the BYD 8TT, which has an advertised range of 124 miles at full load and 167 miles at half load. Tesla is also taking orders for its battery electric Class 8 Semi Truck but has not initiated production.

Looking forward, all six of the major heavy-duty truck OEMs are working to commercialize a ZE battery electric Class 8 truck in the 2020s. In addition to market incumbents, a small number of start-ups and recent market entrants are working on developing BETs. As is typical in the early commercialization stage, initial production run volumes will be limited.

Table 3: OEM involvement in pre-commercialization demonstrations of BETs

Make	Model	Advertised Range (miles)†
Freightliner (Daimler)	eCascadia	250
Peterbilt	Model 579	150
Tesla Inc.	Semi	300–500
Thor	ET-One	300
TransPower	ElecTruck	70–100
Volvo	VNR Electric	Unknown

†Original source: OEM websites and publicly available literature

The primary distinction between the capabilities of prospective BET models is vehicle range. Range is primarily determined by battery size but is also influenced by design factors that improve aerodynamics. Limited range is the most significant nonfinancial impediment to BET adoption among drayage, particularly when combined with long recharging periods. Range and fueling challenges and opportunities are explored in the following chapter.

It bears noting that vehicle ranges advertised by OEMs and reported in Table 3 are based on optimal driving conditions. Similar to internal-combustion engine (ICE) trucks powered by fossil fuels, BET fuel economy will be reduced on routes with steep grades or when driven aggressively. Unlike ICE trucks, the limited range of BETs makes operations more sensitive to variability in energy use. In addition, because fueling options for BETs are limited, truck drivers are likely to prefer to reserve some energy in case of emergency, reducing the effective range of the vehicle.

In addition to range concerns, there are other risks in adopting BETs. Early adopters in particular will take on technology risk. Early ZE pilots demonstrated incidents where design flaws took trucks out of service for long periods (Transpower 2016). While identifying and fixing such flaws is part of the purpose of early pilots, risks that design or manufacturing flaws will sideline a vehicle are more common for immature technologies. A truck that is out of service is not earning revenue for its owner, and that lost revenue usually cannot be recovered.

The unproven longevity of BET batteries represents another risk for early adopters. Batteries degrade over time, effectively reducing maximum range. Because they are sensitive to heat, batteries are known to degrade faster when subjected to the high-power charging that would be required for BETs. Replacement batteries can cost tens of thousands of dollars. If batteries aren't warrantied by manufactures to cover the useful life of the truck, their replacement would be a considerable maintenance cost that could erase any reduction in maintenance costs provided by the reduced complexity of electric drivetrains.

ZE Fuel Cell Trucks

At the time of publication for this report, one OEM — Nikola Motors — is taking orders for its Class 8 tractors powered by its fuel cell electric technology. The company expects that production will begin in 2021.

At least 16 ZE fuel cell trucks are being demonstrated in and around the San Pedro Bay Ports. Since 2017, Toyota has tested a prototype Class 8 tractor that is powered by hydrogen fuel cell technology and hybridized with a small battery pack. In mid-2018, Toyota launched a second "beta" model, which reportedly offers longer range (increased from 200 to 300 miles).

The trucks have been tested in drayage service from Toyota's Port of Long Beach facility. Related to Toyota's Portal

Project, CARB has awarded funding from the state's Zero-Emission and Near Zero-Emission Freight Facilities (ZANZEFF) program to the Port of Los Angeles to develop and demonstrate 10 ZE Class 8 fuel cell tractors using Kenworth's T680 platform and in collaboration with Toyota. The goal is to develop these fuel cell trucks to move cargo from Port of Long Angeles terminals to local distribution centers and ultimately to inland locations and Merced.

Table 4: OEM involvement in pre-commercialization demonstrations of BETs

Make	Model	Advertised Range (miles)†
Kenworth	ZECT T680	150
Nicola Motors Co.	Nikola One and Two	500 – 1,000
Toyota	TBD by OEM	300+

†Original source: OEM websites and publicly available literature

NZE Natural Gas Trucks

As with technological viability, NZE natural gas trucks are the dominant commercially available alternative to Class 8 diesel trucks. They are the closest direct replacement for diesel trucks with performance metrics such as range, fueling frequency and speed generally comparable to diesel trucks. Range on natural gas trucks is dependent on fuel tank size and typically falls in the 400- to 1,000-mile range.

All six major OEMs offer variants of their Class 8 truck models powered by the 12-liter Cummins ISX12N natural gas engine. The following natural gas truck models are available as of 2018: Freightliner Cascadia, Mack Pinnacle, Kenworth T440, Navistar Inc. Transtar 8600, Peterbilt Model 579, and Volvo VNL 300.

chapter 3
operational and infrastructure analysis

The Drayage Industry

Drayage trucks operate locally and regionally, ferrying cargo and empty containers between shipping terminals at ports and train yards, warehouses, and distribution centers. Drayage trucking firms operate as licensed motor carriers (LMCs). LMCs usually hire independent contractors to carry cargo. A minority of LMCs use employee drivers, either exclusively or alongside independent contractors.

According to survey data collected in 2007, 88% of responding drivers serving the ports of Los Angeles and Long Beach (the Ports) reported that they were independent contractors (CGR 2007). While more recent survey data is unavailable, there is no sign of a meaningful change in that figure since the 2007 survey. The contractor model shapes the structure and operations of the drayage industry, causing considerable implications for truck purchase decisions.

As the name implies, independent contractors provide trucking services to LMCs on an independent basis. Drivers are responsible for providing a truck and covering operating expenses such as fuel and maintenance. Instead of paying an hourly wage, LMCs compensate independent contractor drivers on a per-load basis. Also, independent contractors are not entitled to fringe benefits such as health care. After expenses, drivers do not earn much more than minimum wage (Guiliano and Linder 2013).

Before the first Clean Truck Program (CTP), income-constrained drivers would buy inexpensive used trucks. After CTP implementation, low-paid drayage drivers were unable to finance purchases of costly CTP-compliant trucks. Out of business necessity, the LMCs offered trucks to drivers on a lease-to-own basis. In effect, decisions on which trucks to purchase became the domain of the drayage companies, not their contractors. Recently, lease-to-own agreements have been central to employee misclassification lawsuits against LMCs. Because of that legal risk, LMCs may discontinue the practice. The question of which party will finance future CTP-compliant truck purchases remains open.

Under the independent contractor model, drayage companies act like brokers. Clients contract with LMCs to move cargo and then they subcontract that load to one of their drivers. Drivers earn money on each load they carry and LMCs take a cut for facilitating the cargo move. This impacts truck choice because both drivers and LMCs prefer trucks with the range to make as many turns (trips) per shift as possible.

Last, rules governing whether a worker is an independent contractor place limits on how closely drayage companies can control driver operations. The effect of these limitations on truck technology suitability are introduced in the next section and further explored in chapters 5 and 6.

Uncertainty in the Drayage Industry

Recent developments have called into question whether the independent contractor model that currently dominates the drayage industry will persist. Drayage trucking firms have recently lost a number of employee misclassification lawsuits, which have resulted in some of those firms adopting an employee-driver model (Philips 2015).

Further complicating the landscape is a ruling by the California Supreme Court in the case Dynamex v Superior Court of Los Angeles. The Dynamex decision establishes a legal standard for whether or not workers can be classified as independent contractors that may make it difficult for LMCs to continue employing independent contractors (Roosevelt 2019).

In September, 2019, Governor Gavin Newsom signed into law Assembly Bill 5 (Gonzales), which codified the Dynamex ruling. The trucking industry was unable to secure an exemption and will be subject to new rules governing employee classification.

The drayage industry structure has remained relatively unchanged since the Motor Carrier Act deregulated trucking in the early 1980s. However, between past and ongoing lawsuits, and recent changes in state laws addressing independent contractor rules, the drayage industry labor model will likely shift toward employee-driver dominance. With a loss in prominence of the independent contractor model, some of the industry barriers we characterized will likely be eliminated, at least in the long term. However, the prospect of a major restructuring of the drayage industry creates uncertainty in the short term as it may cause other unforeseen effects.

Truck Specifications for Drayage Use

Thus far, two studies have sought to define the necessary performance benchmarks that trucks must achieve in order to successfully engage in drayage service at the San Pedro Bay Ports: 1) Key Performance Parameters for Drayage Trucks Operating at the Ports of Los Angeles and Long Beach (commissioned by Metro) and 2) Drayage Truck Feasibility Study (commissioned by the Ports). The Metro report (by Papson and Ippoliti 2013) and Ports-commissioned report (by Tetra Tech and GNA 2019) refer to "full-service trucks" and "broadly applicable trucks (BAT)," respectively, as those that meet performance benchmarks.

The two reports include similar practical performance criteria related to engine power. Trucks must be able to haul typical drayage load weights, at highway speeds on flat terrain and at set minimum speeds over typical grades. The previous 8.9-liter natural gas engine was underpowered for drayage service. Today, both current NZE and ZE drivetrains easily meet operational criteria for drayage trucks (Tetra Tech and GNA 2019).

While engine power requirements are a relatively straightforward pass/fail filter, requirements for vehicle range are more complicated. In terms of drayage operations, diesel, natural gas, and hydrogen fueled trucks generally have comparable range and fueling performance, which allows them to cover practically all potential drayage needs. In comparison, ZE battery electric trucks are relatively limited both in maximum range and refueling time, and will remain so in the near term. Thus, the operational feasibility of battery electric trucks rests on the mileage requirements of drayage trucks.

It is on the question of range that the two reports differ significantly. The Metro study based its range requirement of 200+ miles on survey responses about their expected range needs, whereas the Ports' study defined the range requirement of a BAT at 600 miles, based on the maximum shift distance reported in their own survey. Regardless of the wide difference in reported range requirements, both the Ports and Metro reports base minimum ranges on the premise that, to be a viable substitute, an NZE or ZE truck must be "able to complete any run" and perform "the vast majority of drayage operations" (Papson and Ippoliti 2013; Tetra Tech and GNA 2019).

Range and Operational Challenges and Opportunities for ZE Trucks

The aforementioned specification sets a very high bar for drayage truck range at 600 miles (Tetra Tech and GNA 2019). No current or proposed battery electric truck can meet that requirement in the near term. However, the daily operations of most drayage trucks do not require that range. Thus, when considering avenues for expediting the adoption of ZE drayage trucks, it is important to develop an understanding of the extent to which drayage service could be electrified using early, relatively range-limited ZE options.

While incomplete data on drayage operations makes drawing definitive conclusions about the extent to which drayage service could be electrified impossible at this time, what data do exist provide insight into the magnitude of that potential. For example, while conducting the Ports-commissioned feasibility study, the consultant surveyed truck operators and asked them to self-report maximum and average shift mileage as well as average

Table 5: Results from Truck Operator Survey: Percent of respondents with mileages that could be met by range of battery electric trucks[a]

Battery electric truck model	Maximum shift mileage	Average shift mileage	Average daily mileage
BYD 8TT & TransPower ElecTruck	17.4%	23.4%	22.0%
Peterbilt Model 579	30.7%	40.3%	39.2%
Daimler eCascadia	39.3%	70.0%	48.3%
Thor ET-One & Tesla Semi 300	55.9%	86.9%	56.9%
Tesla Semi 500	67.2%	100.0%	90.4%

† Because mileage requirements are binned, this percentage represents the minimum. Respondents were weighted by represented number of trucks.

Source: UCLA Luskin Center for Innovation analysis of the Truck Operator Survey in the 2018 Feasibility Assessment for Drayage Trucks, pages 54 and 55, figures 7 and 8.

daily mileage. While underlying data is not reported, the report published binned results within 50-mile increments (Tetra Tech and GNA 2019). Table 5 shows what fraction of respondents' range figures can be satisfied by each of the available or upcoming ZE battery electric trucks (BETs) discussed earlier in this chapter. While none of the metrics in Table 5 are perfect indicators of suitability for BETs, they do show that current or forthcoming BETs may be operationally feasible for a meaningful fraction of responding drayage firms, even at the earliest commercialization stage. It should be noted that the survey is not necessarily representative of the universe of drayage providers, so these numbers may not be generalizable to drayage trucking companies as a whole.

Insofar as they only operate a single shift in a day, BETs with ranges that meet maximum shift mileage should be able to easily replace diesel trucks in those respondents' operations. Average shift and daily mileage figures are more difficult to interpret. Self-reported averages are a fuzzy metric, and without knowing the underlying distribution of trip mileage, few firm conclusions can be made. However, it can be safely assumed that trucks with ranges that meet the average mileage estimates of drayage operators would be capable of completing a sizable fraction of those respondents' shifts.

By showing how BETs might fit into current operations as revealed by the Truck Operator Survey, the percentages in Table 5 illustrate only part of the potential for use of BETs. The more ambitious question is to what magnitude of early BETs might be employable if the industry adapted to their use.

Using 2019 GPS data obtained from port trucks serving the Ports, researchers You and Ritchie employed a novel framework to categorize truck spatial data into truck tours (You and Ritchie 2018). Their findings show that the vast majority of all tours are less than 130 miles, with a significant peak around 30 miles. While the operational data underlying this analysis is limited to 545 trucks, 88% of which were 8.9-liter natural gas vehicles that were generally underpowered for drayage service, the study's results are suggestive that the maximum drayage shift distances reported in the Truck Operator Survey are relatively uncommon and that the distribution of shift distances is heavily right-skewed, with the bulk of that distribution centered on shorter mileage shifts.

This suggests that the ranges of BETs that will become available in the near term are likely to be suitable for most drayage needs. Because trip distances are often very short, and long wait times at the Ports restrict the number of loads trucks take per day, shifts rarely require a truck to travel the 600 miles suggested by the GNA report.

> In summary, the range of early stage BETs is sufficient for most drayage service needs.

Industry Level Effects on Operational Challenges

While the range of ZE battery electric trucks is suitable for most daily drayage driving needs, there is variability in the maximum range a truck might need to drive. For example a truck that drives a manageable 100 miles on one day might be called to drive a range-exceeding 400 miles the next. This concern could be mitigated by selectively tasking trucks to loads that their range can manage. However, the industry currently has little incentive to optimize routes to create shifts that are always conducive to BETs. This means that a driver with a BET would risk losing revenue opportunities.

Therefore, drayage drivers have an incentive to choose vehicles that will not risk them having to turn down a load because the trip exceeds their range or if range limits the number of jobs they can complete during their shift. Experience in early pilot programs has shown that the use of BETs that limited the number of turns that could be made in a day were deeply unpopular with drivers (Transpower 2016). Moreover, drayage companies are legally limited in their ability to specify how their independent contractors operate and thus would be reluctant to dedicate certain drivers and their trucks to routes conducive to BETs (Papson and Ippoliti 2013).

See chapter 6 for a discussion about how the Ports' truck rate could incentivize trucking companies to subfleet or specialize in a way that involves ZE trucks in the near term. Even later when the fleet is 100% zero-emission, subfleeting would be cost containing. Because long-range BETs will cost more than shorter-range BETs, companies will want to buy/lease fewer trucks with longer ranges and more of the ZE trucks with a shorter range.

Infrastructure and Fueling Challenges and Opportunities for ZE Trucks

While the driving characteristics of BETs are generally similar to diesel trucks, fueling with electricity represents a paradigm shift that involves a number of challenges for drayage operators. Electricity is considerably different than hydrocarbon fuels. The fueling time for electricity is much slower than other fuels and thus requires trucks to remain stationary for extended periods. As many as 60% of drayage trucks are shared between two drivers, and thus may be in operation for 18-20 hours a day, leaving as little as four hours to fuel each night (Tetra Tech and GNA 2019). Fueling time may be reduced by employing higher-power chargers, but that comes at the cost of higher effective energy prices, more expensive charging equipment, potential costly utility upgrades, and additional strain on vehicle batteries.

Perhaps the most significant shift is with the ownership of the fueling infrastructure itself. Whereas the cost of building and maintaining commercial hydrocarbon fueling stations is built into the unit cost of fuel, there are no existing commercial electric fueling options for BETs. It is unclear whether such facilities could ever exist in numbers commensurate with current hydrocarbon fueling infrastructure. We predict that initially most charging will occur at night where trucks dwell, mainly at truck yards. While this on-site fueling can be convenient for operators and will likely reduce fuel costs, purchasing and installing the infrastructure to do so comes with challenges not faced with conventional vehicle fueling.

The installation and maintenance cost of heavy-duty charging infrastructure can be quite expensive but varies depending on the characteristics of the location at which the charger is being placed (Bradley 2019). Historically, truck yards have not been set up to fuel on-site, and generally did not need to serve large electrical needs. Charging vehicles on-site may require significant reconfiguration of physical space, loss of real estate for charging equipment, electrical service upgrades, and further electrical work. Current estimates for infrastructure installations can cost up to $250,000 per heavy-duty vehicle charger (Bradley 2019). This financial commitment can be an important barrier against electric truck adoption for drayage operators.

The second challenge regards charger ownership and responsibility. If an independent contractor desires to purchase a BET, they will need to be able to charge it where the truck is domiciled overnight. Commonly, that location is an LMC truck yard. Accordingly, the independent contractor would need to coordinate with the LMC to be able to secure charging. However, generally the LMCs do not own the property where they operate, so they will then have to coordinate with the property owner, who would have to authorize the construction and electrical work necessary to install a charger. This becomes complicated when questions of financing the chargers arise.

Charging equipment has a service life of approximately 28 years (CARB 2017). While the driver would be the main beneficiary of the charger, it is unlikely they would be interested in shouldering the entire cost of a long-term investment on the property. Similarly, the LMC is not likely to want to pay for the equipment either. However, the property owner may also not be interested in funding a high-cost improvement to the property, when it is unclear whether it will provide them a return on their investment. For LMCs that own their own trucks but do not own their own yard, the split-ownership challenge can still exist. Split ownership could cause complications with securing incentive funding for charging infrastructure, an issue that is expanded upon in the next chapter.

Estimates of the percentage of trucks that return to LMC truck yards overnight vary from 72% to 90% (Tetra Tech and GNA 2019; Papson and Ippoliti 2013). Those that do not return to yards park in an assortment of different locations, including on residential streets near the homes of independent contractors (Tetra Tech and GNA 2019). With no affordable, super-fast charging infrastructure, either as a commercial service or at LMC yards, drivers who are unable to access overnight charging are unlikely to be able to convert to BETs in the near future.

The final major challenge comes from constraints in the electrical grid. A single BET can consume as much energy in one day as the average household consumes in more than two weeks. Recovering that much energy in a single night requires high power levels. While trucks are likely to charge almost exclusively at night when electricity load is at its lowest, many trucks, clustered on a single distribution circuit could overwhelm the capacity of that circuit. Where capacity is insufficient to meet needs, drayage operators seeking service upgrades could face delays as utilities work on upgrading power infrastructure, which can cost millions of dollars while taking several years to plan, permit, and construct.

chapter 4
financial analysis

Drayage truck operators are eligible for several government and utility incentive programs designed to facilitate emission reductions and introduce zero-emission (ZE) and near zero-emission (NZE) Class 8 trucks. These existing incentive programs significantly lower the capital costs of ZE trucks. This chapter illustrates how incentives make commercially available ZE battery electric trucks more economical than diesel and natural gas alternatives on a total cost of ownership basis. First, we introduce the incentives and estimate the maximum number of ZE drayage trucks that could benefit.

Incentives: Opportunities and Limitations

There are currently three state and regional programs to reduce the capital costs of ZE Class 8 trucks:

1. The Hybrid and Zero-Emission Truck and Bus Voucher Incentive Program (HVIP) administered by the California Air Resources Board;
2. The Carl Moyer Program (CMP) administered in the South Coast Air Basin by the South Coast Air Quality Management District; and
3. The Volkswagen (VW) Mitigation Fund, which the California Air Resources Board will administer once funds become available starting sometime in 2019.

The VW Mitigation Fund has a dedicated budget for ZE Class 8 freight and port drayage trucks, while the HVIP and the CMP have a funding scale based on the class of truck being purchased and as such provide enhanced incentives for ZE vehicles. The programs define zero-emission vehicles as those having either battery electric or hydrogen fuel cell technology. Additional incentives are also given for fleets that will operate in disadvantaged communities disproportionately impacted by pollution and poverty, as defined by the California Environmental Protection Agency (CARB 2018c). Communities adjacent to the Ports and the 710 corridor are classified as disadvantaged communities.

Table 6 (see following page) summarizes how much is potentially available for drayage trucks at the San Pedro Bay Ports, assuming that the full amount of funds could go to this purpose. However, in reality none of these programs are dedicated solely to drayage trucks at the San Pedro Bay Ports. Thus, the following estimates represent the maximum number of trucks that could be potentially funded under the most optimistic scenario. Based on our estimated costs of truck ownership (see following section for details), we then estimate how many drayage trucks serving the Ports could potentially benefit. As Table 6 illustrates, existing incentive programs will not be sufficient to incentivize a full transition to zero-emission trucks. At maximum, approximately 1,500 trucks a year could benefit given current funding levels, which is more than the number of trucks being replaced in a typical year to serve the Ports (see chapter 5 for details).

See the Appendix for more information about these three existing incentive programs plus a program designed to reduce financing costs for zero-emission trucks.

The Low Carbon Fuel Standard Program

The Low Carbon Fuel Standard (LCFS) is a performance standard policy with a market-based mechanism for compliance. The standard is set relative to the carbon intensity of the baseline transportation fuel (i.e., diesel fuel in the

Table 6: How existing incentive programs could affect transition to ZE drayage trucks at ports

Incentive program	What it covers, who can apply for funds	Total funding for port drayage	Incentive amount per zero-emission truck	Maximum number of drayage trucks that could potentially benefit
HVIP	Statewide, zero-emission and natural gas trucks and buses	$125 million (annual)†	Up to $165,000 per truck (or up to 90% of vehicle cost)	757 trucks (annual)
CMP	South Coast Air Basin, cleaner heavy-duty vehicles and equipment	$30 million (annual)	Up to $165,000 per truck (or up to 50% of vehicle cost)	240 trucks (annual)
VW Mitigation Trust Fund	Statewide, zero-emission heavy-duty trucks	$90 million (total) †	Up to $200,000 per truck (or up to 75% of vehicle cost)	480 trucks (total)
Total	Approximately 1,500 trucks maximum could benefit annually in the near term.			

† This annual budget applies to the 2018-19 fiscal year. The final HVIP budget was not approved at the time of publication but is expected to be slightly higher than the 2018-19 budget. Future annual budgets could vary.
†† The VW Mitigation Trust Fund is first come, first served starting sometime in 2019.

case of trucks) and requires all producers of those fuels to reduce their carbon intensity by a growing percentage, up to 20% in 2030[3]. Credits are generated by the use of fuels with carbon intensities lower than the LCFS standard. Those credits can then be sold to producers of noncompliant fuels to offset LCFS deficits. Both natural gas (renewable or fossil) and electricity generate LCFS credits; however, as LCFS becomes more stringent, fossil natural gas will begin to generate credit deficits in 2024.

LCFS reporting and recordkeeping procedures vary between fossil-source natural gas and renewable natural gas (RNG). Fossil natural gas credits are generated by the fueling equipment owner, whereas RNG credits are generated by the fuel producer. In large procurement contracts (where buyers have more negotiating power), some buyers have been successful in securing a large portion of the LCFS value for themselves. For example, in a recent RNG purchase contract, Los Angeles Metro was able to negotiate renewable natural gas LCFS credit sharing worth $22 million on a contract to procure $56 million in natural gas.

However, most drayage fleets are typically much smaller and do not require such large purchases of fuel. Fleet operators or independent contractors who do not have the negotiating power of large fuel purchasers will not be able to capture as much of the RNG LCFS credit value from suppliers. Furthermore, those that rely on retail sales will face pricing that is primarily based on natural gas commodity markets. What value retail customers do capture will be priced (discounted) into the cost of the fuel at the pump.

Unlike RNG-generated LCFS credits, electricity LCFS credits can be generated directly by fleet operators and not by electricity providers. This allows fleet operators to capture the entirety of the LCFS credit value. Because the design of the program rewards both the low-carbon intensity and the high-efficiency inherent in using electricity as a transportation fuel, LCFS credit generation has the potential to be a considerable value stream for electric truck operators.

Because the value of LCFS credits are determined by the market, it is difficult to precisely predict the ultimate value of the credits generated by BETs. However, in the rulemaking process for the latest LCFS program amendments, CARB staff forecast the market value of LCFS credits up to 2030 (CARB 2018d).[4] Notably, as of April 2019, LCFS credits were trading at $188 a ton (CARB 2019c), much higher than the average of $125 a ton originally forecast by CARB staff, indicating that their predictions are likely conservative.

Local Utility Infrastructure Incentive

Utilities have a history of supporting the deployment of electric vehicle charging equipment in the light-duty sector. Southern California Edison (SCE) has expanded its efforts by creating the Charge Ready Transport Program to offer financial assistance to its commercial customers to install charging infrastructure for medium-

3 As of the time of publication, the LCFS program is authorized only through 2030.
4 Table 10 in this chapter shows the predicted value of LCFS credits generated by BETs up to 2031.

and heavy-duty vehicles. Under this program, SCE pays for all make-ready costs at customer sites and provides a rebate covering up to 50% of the charger cost (Bradley et al. 2019). In the first phase of the program (2019 to 2024), the Charge Ready Transport Program has a budget of $342.7 million, of which $36 million is dedicated to heavy-duty trucks (CPUC 2018b).

As currently specified, in order to sign on to the program, customers must own or lease (with a preference toward outright ownership) the property where charging stations will be installed, demonstrate intent to own and operate BETs with incentivized chargers for at least 10 years (CPUC 2018b; Bradley et al. 2019). These conditions mean that SCE's Charge Ready Transport Program favors companies that own both the property they occupy and the trucks they operate. Few drayage operators fit that bill. However, if the structural challenges can be overcome, the option to have the service upgrades and installation costs entirely covered and equipment cost significantly reduced should make property owners much more amenable to upgrading their lots with charging equipment.

The Los Angeles Department of Water and Power (LADWP) has also instituted a rebate program for commercial heavy-duty vehicle chargers. Like SCE's, LADWP's program also requires the purchase of a BET and so might run into similar split ownership problems that are of concern with SCE's program. Also, like SCE, LADWP's rebate program can be used to offset costs for both the make-ready and the charging equipment itself. However, unlike SCE, LADWP's program indexes rebate values to the power type and level of the charger that is installed. Rebates range from $10,000 at the low end for a <50kW AC charger to $125,000 for a 150+ kW DC charger (LADWP 2019).

Financial Comparison Across Fuel-Technology Platforms

The up-front costs of BETs are high relative to standard diesel trucks and even newer, natural gas models. However, the upfront truck cost is only part of the equation determining financial feasibility. Other costs, such as fuel and maintenance, favor BETs. This section compares the lifetime or total cost of ownership between different truck technologies over three truck-use scenarios, described below. While the mileages assumed in these scenarios are more than the capacity of the Class 8 electric truck that is available now, all are well within the range of trucks on the immediate horizon. We based the three scenarios on data reported in the Ports-commissioned truck feasibility assessment (Tetra Tech and GNA 2019).

1. **Average daily miles truck:** Travels 238 miles each day over 14 hours, based on the average daily mileage and operating length reported by drayage operators.
2. **Single-shift truck:** Travels 160 miles over 9 hours on a single shift, based on the average shift mileage and length reported by drayage operators.
3. **Two-shift, limited-mileage truck:** Travels 200 miles each day over two shifts totaling 18 hours. This scenario represents an ideal use-case in which the truck is used exclusively for short cargo moves to destinations near the ports.

Total Cost of Ownership

Total cost of ownership (TCO) is a financial method that organizations commonly employ to guide decision-making on asset purchase decisions. TCO is a single value representing the sum of all relevant capital and operating costs of using a piece of equipment over its useful life. TCO analyses are best suited to compare costs across the same-use case, or in this case scenario. Less informative are comparisons between different trucks in different use cases (e.g., comparing a diesel truck in one scenario to a BET in another). However, examining how the relative performance of one class of trucks changes across scenarios is a useful exercise as it can illustrate how sensitive costs are to changes in operating parameters. The TCO model scenarios presented in this report are meant to be an approximate representation of the total cost of ownership of a truck that operates within scenario parameters. The varying individual characteristics of drayage operators mean that individual companies or drivers might face much different cost scenarios.

The TCO models described in this section calculate the capital and operational expenditures for hypothetical drayage trucks over a 12-year operating period beginning in 2020. This could be a conservative operating assumption. In the absence of policy requirements affecting truck retirement (e.g., pre-CTP), 35% of the San Pedro Bay Ports' drayage fleet composition was older than 12 years. But more recently, a 12-year operating period has been used in related TCO models, including in the 2018 Feasibility Assessment for Drayage Trucks commissioned by the Ports. Thus, for consistency, our models also use a 12-year operating period. We assume that new diesel, natural gas, and BETs are operated for the entirety of the 12-year period and then retired. To remain consistent with a 12-year service life, the used-truck scenarios are based on the assumption that trucks are 6 years old at the age of purchase in year one. Those trucks are then retired and replaced at the end of year 6, when they are 12 years old.

Because the costs of owning a truck are spread out unevenly across the operating life of a vehicle, TCO analysis discounts the stream of costs back to a single present value. Discounting is a common accounting practice that accounts for the time value of money by discounting future costs by a set rate. Individuals' time-preferences vary, but for the purposes of financial modeling, the discount rate is set at the 7% recommended by the U.S. Office of Management and Budget.

Capital Expenses

The primary capital expenditure is the truck itself. According to responses by surveyed drayage operators, they pay $105,599 and $50,236 on average for new and used diesel trucks respectively (Tetra Tech and GNA 2019). Unlike diesel trucks that have a more established market, the best data about prices for new natural gas trucks using the Cummins Westport 12-liter engine come from interviews from industry representatives. They reported that incremental cost of approximately $55,000 over new diesel trucks (Tetra Tech and GNA 2019). This means that final costs for natural gas trucks will be approximately $160,559.

BETs also have no established market by which to estimate costs. Furthermore, few prospective market entrants have advertised potential sale prices. Price information that does exist varies widely. Notably, Tesla has begun taking orders on its least expensive Tesla Semi line, which the company expects to sell for $150,000.[5] However, it is unclear how many trucks will be sold at that price. While BYD does not advertise prices for its 8TT, the New York Voucher Incentive Program's list of eligible vehicles lists the vehicle at $300,000.[6] As the only currently commercial Class 8, it is the best option to baseline price for BETs in the TCO model. Table 7 includes available advertised pricing information for upcoming Class 8 truck models as of the time of publication.

Table 7: Class 8 truck pricing information

Make	Model	Cost
BYD	T9	$300,000[a]
Tesla	Semi	$150,000–$200,000[b]
Thor Trucks	ET-One	$150,000–$250,000[c]
TransPower Inc.	ElecTruck	$350,000[d]

[a] https://truck-vip.ny.gov/NYSEV-VIF-vehicle-list.php
[b] https://www.tesla.com/semi
[c] https://newatlas.com/thor-trucks-et-one/52627/
[d] https://truck-vip.ny.gov/NYSEV-VIF-vehicle-list.php

Infrastructure

The cost of commercial fueling infrastructure for diesel fuel and compressed natural gas is built into the sale price of those fuels. However, as described in chapter 3, the nature of electric fueling makes commercial heavy-duty truck charging an unlikely business model in the near future. Therefore, fueling a BET will likely require the purchase and installation of charging equipment in truck yards where trucks dwell at night.

As explained in chapter 3, installation costs can vary significantly depending on site-specific factors such as what electrical upgrades are needed at a property to support high-power charging. In their analysis of charging costs for their Innovative Clean Transit rule, CARB staff estimated that the average per-charger cost at a transit yard is $105,000 (CARB 2017). While not a perfect comparison, transit yards and truck yards share enough similarities for this to be an appropriate estimate for truck charger installation costs. CARB estimates that charging equipment has a 28-year service life and therefore could serve multiple trucks. However, because the cost is upfront, the TCOs include the full cost of the chargers.[7]

Taxes and Financing

In addition to the purchase price of trucks and charging equipment, operators must pay sales and excise taxes. All trucks and charging equipment are subject to local sales tax, which in Los Angeles County is at least 9.5%. In addition, purchasers of new trucks pay a 12% federal excise tax.

Drayage companies and independent contractors will finance the cost of their trucks, infrastructure and taxes, net any applicable purchase incentive discussed in the previous section of this chapter. In workshops at the Ports,

[5] https://www.tesla.com/semi
[6] The Voucher Incentive Program price lists the price for the 2016 T9 truck, which has since been re-designated as the 8TT. We expect the price for the 8TT to be the same as or closely similar to the previous T9 models. https://truck-vip.ny.gov/NYSEV-VIF-vehicle-list.php
[7] Further discussion about the complexity of paying for charging infrastructure is presented later in this chapter.

Table 8: Summary of capital expenditures and annual loan payments for diesel and natural gas trucks

	Diesel (used)	Diesel (new)	Natural gas	BET (SCE)	BET (DWP)
CapEx	$55,008	$128,303	$195,128	$469,500	$469,500
CapEx w/ incentives	...	...	$150,127	$224,500	$244,500
Down payment	$8,251	$19,245	$29,269	$70,425	$70,425
Down payment w/ incentives	...	...	$22,519	$33,675	$36,675
Loan payment	$12,623	$29,443	$44,778	$107,740	$107,740
Loan payment w/ incentives	...	...	$34,451	$51,518	$69,876

drayage operators provided information on their typical loan terms with average interest rates of 12.5% over a five-year loan period. Down payments on commercial truck loans vary; however, financial guidance information for independent contractors indicate that typical down payments are around 15% (Wylie 2018; Fundera 2019). For simplicity, the TCO cost model uses these loan terms to amortize the cost of both trucks and charging equipment.[8]

Some of the capital expenses will be offset by the incentives for truck purchases and charging infrastructure, which will reduce down payments and loan terms. See Table 8 for a summary of capital expenditures. The incentives factored into the analysis are the HVIP (reduces BET cost by $165,000), SCE's Charge Ready Transport Program (reduces infrastructure cost by $80,000 in SCE territory), and LADWP's Commercial Charging Rebate Program (reduces infrastructure cost by $60,000[9] in LADWP territory).

Fuel Costs

The largest operating expense over the lifetime of a truck is fuel. Fuel use is determined by distances driven and the fuel economy of each truck technology. Drayage truckers report that their diesel trucks average six miles to the gallon (Tetra Tech and GNA 2019). Emissions testing on the new Cummins Westport 12-liter natural gas engine platform conducted at UC Riverside found the engine averaged 5.48 miles per diesel gallon equivalent (DGE) and 3 miles per DGE for cruising and urban driving test cycles respectively (Johnson and K 2018). Because drayage trucking involves both cruising-speed and urban driving, the TCO model uses the average of the two values (4.24 miles per DGE) as the baseline fuel economy assumption.

Data on BET fuel economy is limited, and vehicle manufacturers rarely directly advertise that specification. The best available test data on BET fuel economy was gathered by UC Riverside from testing on a TransPower truck. In that testing, fuel economy ranged from 2 to 2.4 kWh/mi. However, because those estimates do not include losses from charging, the higher end of the range at 2.4 kWh/mi is a more appropriate estimate for the purposes of evaluating fuel costs.

Diesel and Natural Gas

Diesel and CNG prices are volatile, causing fuel price forecasts to have very wide confidence bands. Because fuel prices are unpredictable, the TCO cost model uses 2018 diesel and CNG prices averaged over the year to smooth out seasonal variations. The average retail price of diesel fuel in California in 2018 was $3.87 per gallon (U.S. EIA 2018 data). The average CNG price in the West Coast region was $2.81 per diesel gallon equivalent.[10]

In addition to fuel, diesel trucks consume diesel exhaust fluid (DEF), which is necessary for the operation of selective catalytic reduction emissions controls. Diesel trucks consume DEF at a dose rate of approximately 3% relative to fuel consumption (Discover DEF 2019). Currently DEF prices are approximately $2.90 a gallon (Tetra Tech and GNA 2019).

[8] We use loan financing in the TCO instead of lease-to-own due to the uncertainty in the continued use of that financing model.

[9] LADWP's rebate awards are indexed to charger type and power level. Due to truck charging needs we assume that likely charger capacity needs will be between 50 and 100kW DC, which qualifies for a $60,000 rebate.

[10] Fleets that purchase fuel on long-term procurement contracts are able to negotiate lower prices. However, data on the magnitude of contract discounts is not generally available.

Electricity

Depending on where the trucks are domiciled, BETs would likely charge in either SCE or LADWP territory.[11] Compared to diesel fuel and CNG, electricity prices are stable. However, unlike those fuels, the cost of electricity is dependent on time of use (TOU) and peak usage. Volumetric (per kWh) energy rates vary by time of use to reflect the cost of delivering electricity in periods of high or low demand. Demand and facility charges are assessed on highest peak usage and can be a significant part of average energy costs for high peak-usage chargers.

Drayage trucks will likely charge entirely at night because that is when the Ports are closed and electricity prices are off-peak or lowest.

SCE's newest commercial electric vehicle TOU rates forgo demand charges for higher volumetric energy charges.[12] The seasonally adjusted average off-peak energy price for SCE's EV-TOU-9 rate is $0.097 per kWh (SCE 2019).

DWP's commercial rate includes a demand charge for its peak period but no off-peak demand charge (based on Primary Service A-2(B) TOU).[13] In all scenarios, there is a facility fee of $8.49 per kW assessed monthly. The seasonally adjusted average off-peak energy price for DWP is $0.104 per kW, which includes the base rate, adjustments, and a $0.02 discount for EV charging. DWP's effective energy cost is equal to the cost of energy plus the cost of the monthly facility fee (LADWP 2018).[14]

There are two important caveats to the methods used to estimate effective energy costs. The first is that the TCO model assumes that charging will be managed to minimize peak demand. This represents the optimum cost-containing strategy, but there is no guarantee that it will be possible to achieve for all truck operators.

The second caveat is that the TCO calculates peak load based on average energy recovery needs. If there is significant variation in daily energy recovery requirements, demand charges could be higher because they are assessed on absolute highest peak demand on a meter. This issue becomes less prominent as more trucks charge and begin to average out daily variation in charging demands.

Because each TCO scenario varies by how much power must be delivered, and how much time each truck has to charge, each scenario will impose different peak demands for charging and effective per kWh charging costs differ for LADWP customers. (LADWP 2018). Table 9, which follows, lists DWP and SCE charging costs under each scenario. Due to higher volumetric energy costs and its facility fee, charging in DWP territory is significantly more expensive than in SCE territory, particularly in the two-shift limited scenario in which high peak energy demand results in a large facility fee.

It should be noted that LADWP has very recently introduced a set of pilot rates for electric fleet vehicle charging service. The new rate options (particularly the new time of use rate) should reduce costs for drayage operators but the extent of the change is not clear at the time of this report's publication.

Maintenance Costs

Maintenance costs are the second major operating expense for drayage trucks. The average maintenance costs for new and used diesel trucks as reported by surveyed drayage operators are $0.16 and $0.22 per mile respectively. Because they have not yet seen widespread adoption, maintenance costs for trucks built on battery electric or 11.9-liter natural gas engine platforms are only estimates. In a 2016 report, the U.S. Department of Energy estimated incremental natural gas truck maintenance costs of $0.017 per mile (U.S. DoE 2016).

Given that electric drivetrains are less complicated than internal combustion alternatives, maintenance for BETs is likely to be less costly than diesel or natural gas trucks. But without significant real-world experience, precise estimates are impossible. In a 2015 report, CARB estimated that BET maintenance costs are 25% to 80% lower per mile than diesel (CARB 2015). Taking the central estimate of that range puts battery electric costs at $0.08 cents per mile. However, that estimate rests on the assumption that batteries will not need replacement during mile than diesel (CARB 2015). Taking the central

11 A marginal number of trucks may be located in the territory of other small municipally owned utilities.

12 The demand charge holiday will end in 2024. However, there is currently no information about how much demand charges will add to electricity prices. The TCO does not incorporate the reintroduction of the demand change and thus likely underestimates SCE energy costs after 2024.

13 The Los Angeles Department of Water and Power is developing a pilot rate program for charging heavy-duty electric vehicles. Pilot rates have not been finalized at the time of publication and have not been incorporated into the TCO analysis.

14 Effective per-kWh energy costs equal volumetric energy cost plus the facility fee multiplied by maximum energy demand and divided by total energy used per month.

Table 9: Effective energy costs by utility and scenario

		Average daily truck	Single shift	Two shifts limited
LADWP	Energy price (kWh)	$0.104/kWh	$0.104/kWh	$0.104/kWh
	Monthly energy use	11,486 kWh	7,722 kWh	9,652 kWh
	Peak demand	71 kW	39 kW	114 kW
	Facility fee/ demand charge	$599.90	$326.67	$972.22
	Effective energy cost	**$0.182/kWh**	**$0.167/kWh**	**$0.254/kWh**
SCE	Energy price (kWh)	$0.097/kWh	$0.097/kWh	$0.097/kWh
	Monthly energy use	11,486 kWh	7,722 kWh	9,652 kWh
	Peak demand	73 kW	40 kW	119 kW
	Facility fee/ demand charge	$0	$0	$0
	Effective energy cost	**$0.097/kWh**	**$0.097/kWh**	**$0.097/kWh**

Table 10: Summary of annual operating expenses for truck fuel-technology platforms across scenarios

		Diesel (used)	Diesel (new)	Natural gas	SCE Battery Electric	DWP Battery Electric
Average daily	Fuel†	$40,967	$40,967	$41,167	$14,472	$27,149
	Maintenance	$13,666	$9,939	$10,995	$5,384	$5,384
	Total	**$54,632**	**$50,906**	**$52,162**	**$19,856**	**$32,533**
Single shift	Fuel†	$27,541	$27,541	$27,676	$9,729	$16,761
	Maintenance	$9,187	$6,682	$7,392	$3,756	$3,756
	Total	$36,728	$34,222	$35,067	$13,485	$20,516
Two shift limited	Fuel†	$34,426	$34,426	$34,595	$12,161	$31,920
	Maintenance	$11,484	$8,352	$9,239	$4,591	$4,591
	Total	$45,910	$42,778	$43,834	$16,752	$36,511

† Includes DEF for diesel trucks

estimate of that range puts battery electric costs at $0.08 cents per mile. However, that estimate rests on the assumption that batteries will not need replacement during the life of the truck.

LCFS Credit Value

BETs may be able to create value from generating LCFS credits through the use of electricity as a transportation fuel. As described previously in this chapter, the value and amount of credits will change over time. Table 11 (see following page) summarizes the LCFS credits that BETs would generate for each TCO scenario.

It should be noted that the use of RNG can also generate significant LCFS value. However, unlike with electricity, that value is typically only captured by larger fleets that are able to negotiate a sharing agreement. Because those agreements are generally proprietary, there is not enough information to estimate the LCFS revenue opportunities that might be available to drayage operators.

Fees, Insurance, and Depreciation

Because they are assessed on truck value, the relatively more expensive BETs will have higher registration and insurance costs than lower-priced natural gas and diesel alternatives. California vehicle license fees of 0.65% are assessed annually on the purchase value of the vehicle

Table 11: Annual BET LCFS credit value 2020-2031[15]

Year	Average daily	Single shift	Two shifts limited
2020	$25,680	$17,264	$21,580
2021	$25,259	$16,981	$21,226
2022	$24,838	$16,698	$20,873
2023	$24,418	$16,415	$20,519
2024	$23,997	$16,132	$20,165
2025	$21,690	$14,581	$18,227
2026	$21,303	$14,321	$17,901
2027	$20,915	$14,061	$17,576
2028	$22,313	$15,001	$18,751
2029	$21,892	$14,718	$18,397
2030	$23,189	$15,589	$19,487
2031	$23,189	$15,589	$19,487

†LCFS credit values calculated based on estimated energy consumption using the credit calculation equation found in section 95486 of the Low Carbon Fuel Standard Regulation and future credit values forecast by CARB staff. See pages 22-23 for more information about the LCFS program.

Table 12: License fees and insurance

Year	Diesel (used)	Diesel (new)	Natural Gas	Battery Electric
1	$1,834	$3,854	$5,862	$10,950
2	$1,650	$3,469	$5,276	$9,855
3	$1,467	$3,083	$4,689	$8,760
4	$1,284	$2,698	$4,103	$7,665
5	$1,100	$2,313	$3,517	$6,570
6	$917	$1,927	$2,931	$5,475
7	$1,834	$1,542	$2,345	$4,380
8	$1,650	$1,156	$1,755	$3,285
9	$1,467	$964	$1,465	$2,737
10	$1,284	$771	$1,172	$2,190
11	$1,100	$578	$879	$1,642
12	$916	$578	$879	$1,642

(less depreciation) that is licensed (California Legislative Analyst's Office 1998). Although dependent on other factors such as driver record, physical damage insurance rates are driven by the value of the truck. Typical insurance rates are approximately 3% of the market value of the truck each year (Tetra Tech and GNA 2019).

See Table 12 for a schedule of insurance and registration fees over the life of each truck following California's vehicle license fee depreciation schedule (California Legislative Analyst's Office 1998.

Depreciation of the value of a truck is an allowable business expense that can be used to deduct business income.[16] This makes truck depreciation a valuable tax shield that will reduce the owner's taxable income by the value of the truck. Tax deductions are worth whatever the tax bill would be on the deducted income, or in other words the amount of the deduction multiplied by the tax rate. Independent contractors typically operate as a sole proprietorship, LLC, or other pass-through entity. This means that business income is taxed at individual income tax rates that will differ depending on their revenue. In 2007 (the year of the most recent earnings survey of drayage drivers), average net operating income for drayage truck drivers was $29,645 (CGR 2007). If driver earnings have kept pace with inflation, a current average driver would have a net operating income of $36,344. That income would put drivers in the 12% and 4% marginal income tax brackets for federal and state taxes respectively, for a combined tax rate of 16%.

Section 179 of the Internal Revenue Code allows for the depreciation of a semi-truck over a three-year period. However, the tax appetite of drayage operators, and in particular independent contractors, is not likely able to absorb those deductions within three years. Section 179 allows for the carryover of deductions into future years, so drayage drivers can count the depreciation against future earnings, though the years when they might claim it are uncertain (IRS 2018). The TCO cost model accounts for this uncertainty by simply distributing the value of the deduction over the entire life of the truck.

Total Cost of Ownership: Results and Considerations

Without incentives, BETs are still considerably more expensive on a TCO basis than all other alternatives on all scenarios. However, when the value of LCFS credits are applied, BETs in SCE territory become less expensive than natural gas trucks and competitive with diesel for the two-shift limited and average daily mileage truck scenarios. However, due to the higher cost for electricity

[15] LCFS credit values calculated based on estimated energy consumption using the credit calculation equation found in section 95486 of the Low Carbon Fuel Standard Regulation and future credit values forecast by CARB staff. See page 30-31 for more information about the LCFS program.

[16] In lease-to-own arrangements common to the industry

Figure 2a: TCO for Average Daily Truck Scenario

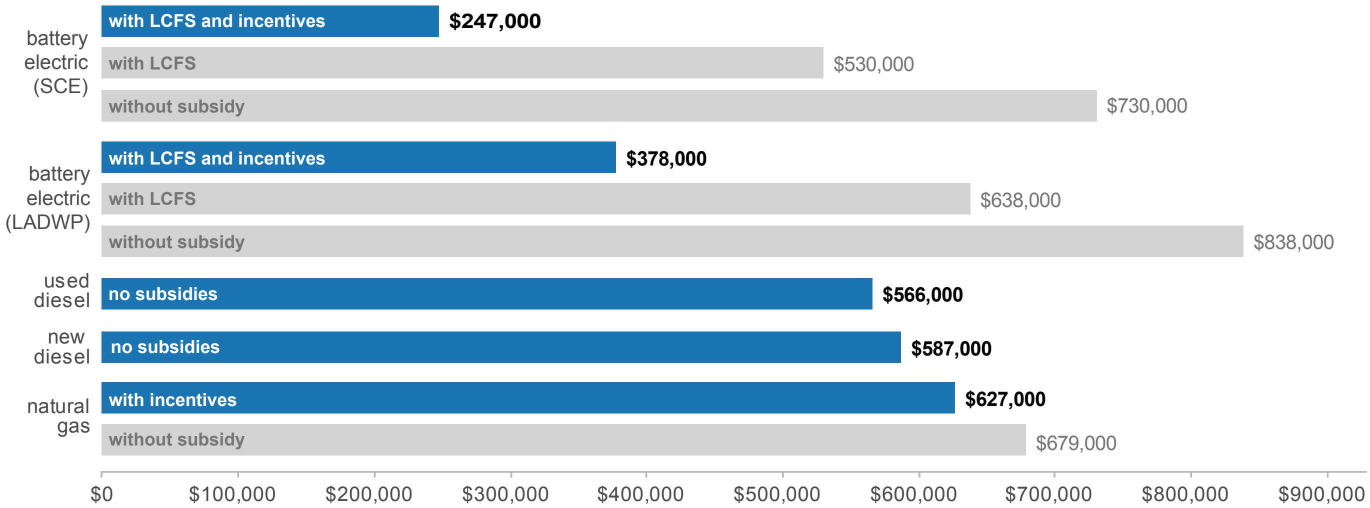


Figure 2b: TCO for Single-Shift Truck Scenario

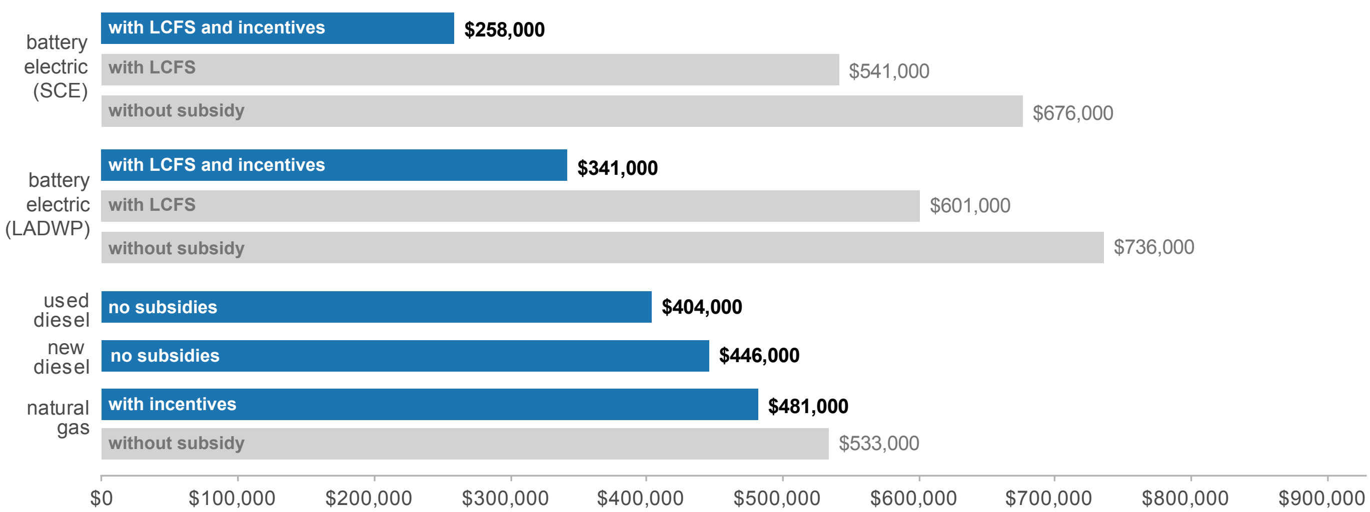
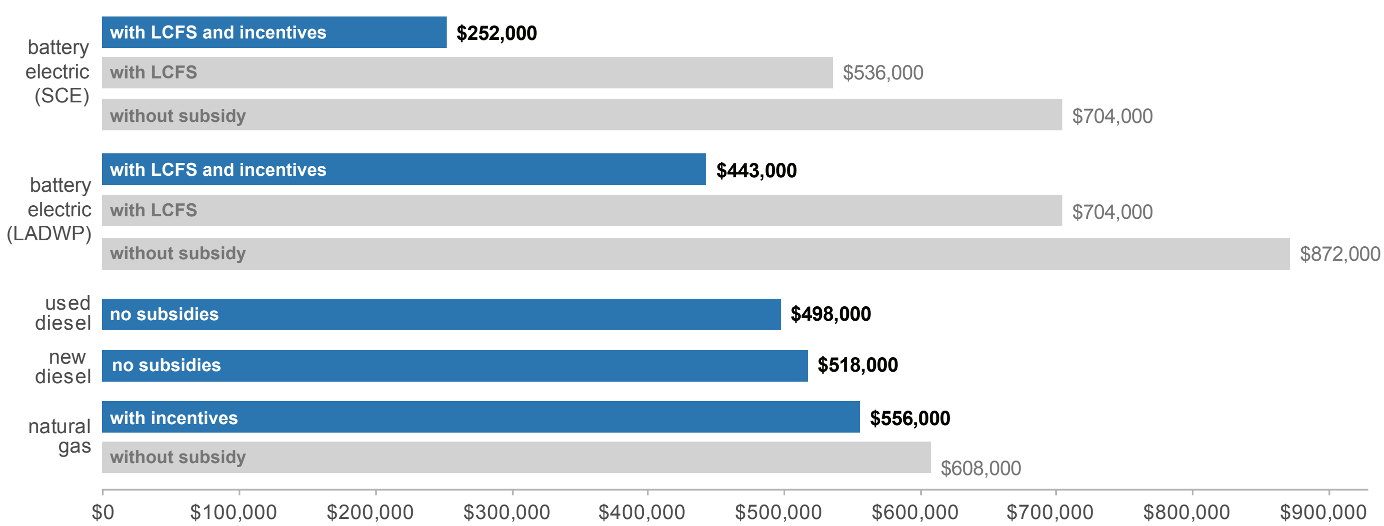


Figure 2c: TCO for Two-Shift, Limited-Mileage Truck Scenario



Note: Incentives include vehicle purchase incentives and charging infrastructure rebates where applicable.

in LADWP territory, LADWP-based BETs remain the most expensive option when incentives are not applied.

When the value of purchase incentives is applied, the TCOs for BETs on all scenarios fall significantly below the cost of even used diesel trucks. Again, because LADWP electricity is significantly more expensive, LADWP BETs significantly exceed SCE BET costs.

> **As this analysis shows, BETs can be financially viable in the 2020s. With purchase incentives, the total cost of ownership for BETs in both LADWP and SCE territory are lower than even the cost of used diesel trucks.**

As expected, BETs fare best against their diesel and natural gas counterparts in the scenarios in which mileage is higher. This is because there are more fuel and maintenance cost savings in those scenarios to offset the high upfront cost of BETs. Interestingly, for the BETs in SCE territory that earn LCFS credits, the entire TCO decreases the more miles the truck is driven. This is because, even at conservative estimates, the value of the LCFS credits generated exceed all operating costs. In DWP territory, the higher cost of electricity precludes that outcome.

The results of our TCO analysis are a simulation of what the comparative costs of the differing truck technologies are likely to be. Though the model relies on a reasonable set of assumptions about operations and potential costs, future truck purchase costs are uncertain and charging infrastructure costs can be extremely variable. However, given the generous subsidies available and the value of LCFS credits, truck or charger costs could increase by as much as $50,000 in LADWP territory or $125,000 in SCE territory and BETs would still remain cost-competitive with other powertrain technologies.

In addition to uncertainty about capital costs, SCE electricity costs in the TCO model are based on rates that include a demand charge holiday set to expire in 2024. At the date of publication, SCE has not publicized what demand charges might cost when they are phased back in. However, our modeling suggests that battery electric drayage trucks charging in SCE territory could absorb effective energy price increases of as much as 275% and still remain less expensive than alternative trucks.

Financial and LCFS Participation Barriers

While BETs can be cheaper than counterpart diesel or natural gas trucks when incentives are factored in, there are still steep financial barriers for independent operators wishing to acquire a BET. Even with purchase incentives, a $300,000 new BET will cost approximately $200,000 with taxes. Without good credit and a long business history, down payments for commercial truck loans are typically 10%–20% which, for a BET, could be as much as $40,000. Given that drayage drivers may not earn that much in a year, it will be hard for independent contractors to afford the down payment, ruling out traditional financing for independent contractors. It should be noted that drayage independent contractors are similarly hard-pressed to be able to afford the $19,000 or $29,000 down payment on a new diesel or natural gas truck.

When the 2007 CTP pushed drayage drivers to upgrade to newer model year trucks, LMCs used their comparatively better access to capital to acquire trucks in order to lease to their drivers. However, in the wake of several costly employee misclassification lawsuits, the LMCs are unlikely to be as amenable to similar arrangements. This means that there will likely be a significant need for risk-tolerant capital to provide low-money-down loans or lease-to-own financing for drayage drivers.

Another consideration is whether independent contractors may be able to participate in the LCFS program. Although the newly reauthorized LCFS program allows for private fleets to generate and sell LCFS credits, it may be difficult for independent contractors to participate in the market. As set up, LCFS opt-in rules are primarily geared toward operators of large fleets. Independent contractors wishing to participate would have to be incorporated as a business or otherwise have a federal employer identification number. They would also have to reliably track their electricity use, submit to audits, and navigate the complex LCFS marketplace to sell their credits to regulated parties. While the enormous value of the LCFS credits makes this a worthwhile endeavor, many drivers would likely need assistance to take advantage of such credits.

Incentive Considerations

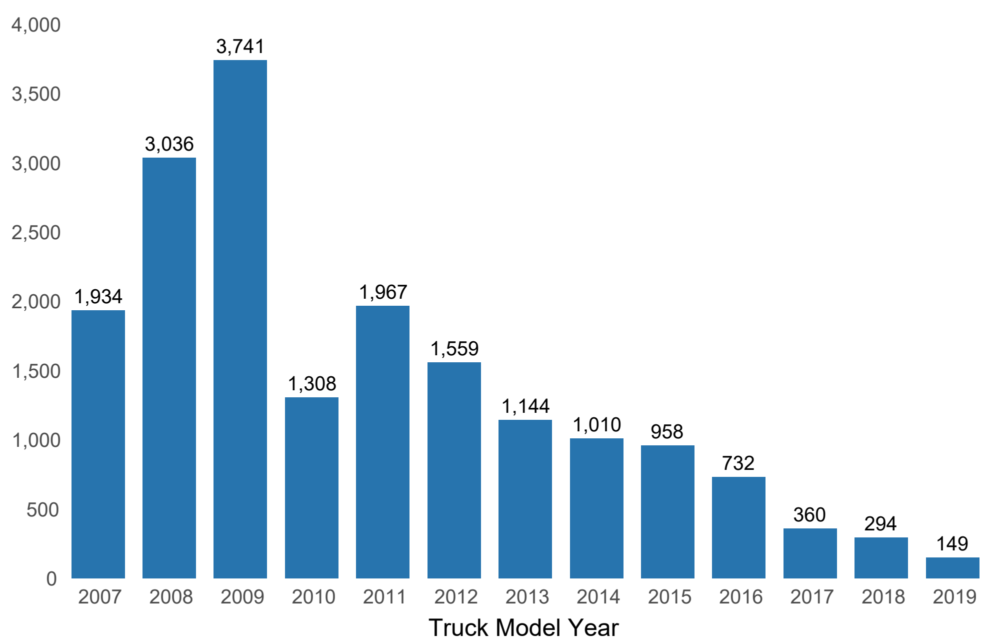
We conclude that early adopters will benefit from incentive funds that make ZE trucks more financially appealing than alternatives on a TCO basis. Large companies will be more likely to have the capacity to apply for these incentive programs. Current funding levels will limit the number of trucks that could benefit.

It is unlikely that the generous subsidies provided by commercialization support programs like HVIP will persist indefinitely. However, given California's commitment to transportation electrification, it is unlikely that incentives will disappear entirely. Notably, the value of the purchase incentives could be cut in half, and BETs charged in SCE territory would still be less expensive than diesel trucks in the higher-mileage, average daily (scenario #1) and two-shift limited (scenario #3). The idea of reducing purchase incentive levels but increasing the number of benefiting trucks is explored in chapter 6 in conjunction with the idea of designing the Ports truck rate so that it incentivizes ZE trucks to make many short-trip turns daily for overall higher mileage (within the range of the truck.)

chapter 5
fleet analysis and opportunity for zero emission

Due to natural turnover and state policy, nearly the entire drayage fleet serving the San Pedro Bay Ports could turn over in the 2020s — presenting a huge opportunity to reduce truck emissions. This chapter describes the current fleet, how it may change in the absence of new policy from the Ports, and then the Ports' projections for fleet transitions under their proposed Clean Truck Program. The Ports' currently proposed roadmap to zero-emission trucks could result in two sharp fleet transitions — first to a near zero-emissions (NZE) majority fleet and then a zero-emission (ZE) majority fleet — in about 10 years. We present an alternative path to ZE that could start sooner, and describe the benefits of doing so.

Figure 3: Number of drayage trucks by model year, as of November 2018



Source: UCLA Luskin Center for Innovation, using data from the San Pedro Bay Ports Truck Registry obtained in November 2018

Fleet Turnover Projection: Baseline

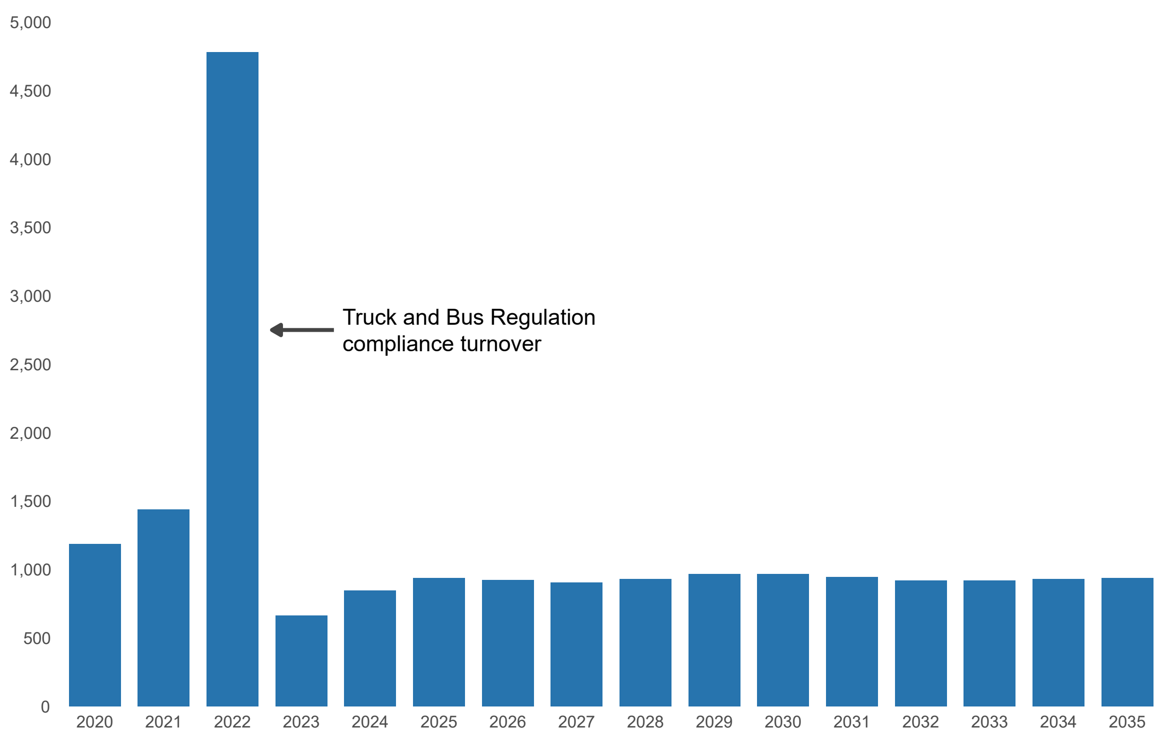
To understand how policy incentives could impact adoption of ZE trucks, it is important to describe the current drayage fleet serving the San Pedro Bay Ports (the Ports), and how the fleet could change over time in the absence of policy. Fleet dynamics is important context because vehicle turnover presents a natural point during which adoption of new technology can occur. It is more difficult to encourage the replacement of a vehicle before it has reached the end of its economic life. Any incentive to encourage the accelerated retirement of a vehicle must account for the remaining value of the retired vehicle, in addition to any incremental cost of the replacement ZE truck. This is made even more salient if the owner is not allowed to sell their previous truck, or if the retired truck is relatively new.

Figure 3 shows the drayage fleet composition by model year at the end of 2018. Because the 2007 Clean Trucks Program prohibited pre-2007 model trucks from serving the ports after 2012, there are no trucks in the current registry older than 12 years. However, evidence of the San Pedro Bay Ports' drayage fleet composition collected by the California Air Resources Board (CARB) prior to implementation of the 2007 CTP reveals a much older fleet, with approximately 35% of vehicles older than 12 years (CARB 2007). This indicates that drayage trucks often serve long operational lives. Therefore, absent the impact of further policy, the drayage fleet average truck age would likely grow considerably older.

Because of narrow margins and low wages, drayage operators typically economize by purchasing from secondary markets. Ports' fleet data show that between 2013 and 2018, only 30% of trucks added to the drayage registry were current models and that the average age of a newly added truck was 2.5 years. Overall, approximately half of all trucks added to the registry between 2013 and 2018 were at least 3 years old at the time of entry. Combined with extended service lives, the propensity of drayage operators to purchase used trucks contributes to a fleet that lags behind the state-of-the art in vehicle technology. It was in fact these drayage fleet dynamics that necessitated the actions taken in the first Clean Trucks Program (CTP).

Figure 4 shows our baseline forecast of annual truck turnover based on trends observed in recent fleet turnover data and in-place policies statewide and at the Ports. We project that annual truck turnover will steadily increase through 2022, as trucks purchased in compliance with

Figure 4: Projected number of drayage trucks by model year 2019 to 2035: Scenario without new Clean Trucks Program



Source: UCLA Luskin Center for Innovation, using data from the San Pedro Bay Ports Truck Registry the 2007 CTP increasingly retire from service. In 2022 (or slightly earlier), turnover will likely spike as the statewide Truck and Bus Regulation forces pre-2010 trucks out of service. After that large compliance-related retirement, turnover could drop sharply after 2022 and then begin to climb again, leveling out after the middle 2020s. With the exception of compliance-related turnover, annual turnover stays between 800 and 1,600 trucks, or 6% to 11% of the fleet, on an annual basis.

Fleet Turnover Projections: Proposed Clean Trucks Program

In the proposed Clean Air Action Plan 2017, the Ports lay out a range of scenarios for NZE and ZE fleet transitions. Based on our understanding of the Ports' proposal and the drayage operators preferences, the likely scenario would result in steep transitions to NZE trucks in the early 2020s and then another steep transition to ZE in the 2030s. There are obviously costs associated with transitioning the vast majority of their fleet twice in less than 20 years, which we discuss in the following section. First, we breakdown the Ports' projections.

The Ports project that their proposed Clean Trucks Program, along with the statewide policies, will encourage the conversion of 69% to 90% of the drayage fleet to NZE vehicles between 2020 and 2024. As of the end of 2018, only 3% of drayage trucks were NZE. Assuming that the drayage fleet stays approximately the same size between 2018 and 2024, the conversion could translate into the retirement and replacement of 9,200 to 12,200 trucks over the 2020-2024 period.

This means that the Ports would need to establish an aggressive CTP rate to push the early retirement of as many as 3,000 additional trucks. This is because some of the retirement and replacement of 9,200 to 12,200 trucks will occur due to natural turnover (approximately 6,000) and compliance with the CARB's Truck and Bus Rule (an additional 3,000 pre-2010 trucks to retire early), with the remaining 3,000 or more trucks pushed by the Ports through the rate to retire early.

By 2024, the Ports also project that ZE trucks will grow from zero to between 1% and 14% of the fleet, or 140 to 2,000 vehicles given a similar fleet size. The lower end of this range reflects a scenario in which ZE trucks are still relegated to pilot-scale demonstration projects whereas the higher end suggests adoption of ZE trucks in regular drayage service.

State and regional incentives could help to push the ZE truck percentage closer to the higher end of the range, but without port-level incentives targeted for zero-emissions during the 2020s, this scenario is not likely. As currently proposed in the CAAP 2017, the Ports do not distinguish between ZE and NZE emission drivetrains before 2035, meaning that ZE and NZE trucks are compliance substitutes. The Ports project that because of range and fueling constraints of early ZE battery electric trucks, natural gas trucks will likely be more attractive to drayage operators in the near term. If an advanced diesel truck is able to be certified to meet the state's forthcoming NZE standard, then very likely diesel will continue to dominate throughout the 2020s and into the 2030s.

By 2031, the Ports project that with the CTP, the portion of the fleet using NZE emissions vehicles could range from 55% to 90%. At the same time, the Ports project that 5% to 44% of the fleet could be ZE. Like the 2024 projections, these ranges are wide, and represent a tradeoff between ZE and NZE emission vehicles, with the share of NZE trucks potentially declining as some are replaced with ZE alternatives in response to the NZE rate exemption expiring in 2035.

By 2036, the Ports anticipate that ZE trucks will constitute 55% to 100% of the drayage fleet. The also Ports project needing a 45% to 95% turnover of the fleet between 2031 and 2036. The following section describes why a more gradual transition to zero-emission trucks, incentivized by Port-level targeted incentives in the 2020s, could be beneficial.

Benefits of a Path to ZE That Incentivizes Early Adoption

By the Ports' own projections for ZE trucks by 2036, they may fall significantly short of the mayors' target for a 100% zero-emission fleet by 2035. Even if they come close, the Ports' currently proposed roadmap to a zero-emissions fleet includes two sharp fleet transitions — first to an NZE majority fleet and then a ZE majority fleet — in about 10 years. Sharp transitions cause disruptions and unnecessary costs.

Such a pattern does not necessarily have to be the case. ZE battery electric trucks with sufficient range to cover the majority of drayage truck shifts will be commercially available in the 2020 to 2024 timeframe.

With incentives in place that encourage some operators to specialize in shorter, electrifiable routes, a substantial portion of the trucks replaced in the 2020s could be ZE battery electric vehicles.

As explored in chapter 6, the Ports could set health-protective targets for pollution reduction that would translate into ZE drayage truck goals and could be adjusted over time depending on parameters such as technological progress. To help achieve the targets, the Ports could adjust its truck rate. Specifically, the Ports would not have to wait until 2035 to incentivize ZE above NZE through its truck rate. The Ports' own policy signals could help to create an earlier and more gradual phase-in of ZE trucks than is currently envisioned by the Ports CAAP 2017.

An anticipated bump in truck retirements — due to natural turnover and leading into the State Truck and Bus Rule's 2023 compliance deadline — presents a significant opportunity for early ZE adoption. About 7,000 trucks will retire in the early 2020s, and the majority of the remaining amount will turn over later in the 2020s. With action from the Ports and others, a significant portion of those retiring vehicles could be replaced with ZE trucks. However, if this opportunity is missed, those trucks will be replaced with non-ZE vehicles that could continue to operate and pollute well into the 2030s.

A turnover of nearly the entire drayage truck fleet in the 2020s presents a major opportunity to reduce emissions.

An earlier phase-in of ZE vehicles could deliver several benefits. The first, most obvious, benefit would be a more rapid reduction in tailpipe emissions that harm Southern California and particularly communities along truck routes. With more ZE vehicles on the road in the early 2020s, tailpipe emissions of nitrogen oxides, particulate matter, and other emissions will be appreciably diminished relative to the use of traditional diesel and even NZE vehicles (see chapter 2). Electric trucks fueled by California's increasingly clean electricity supply will also emit less greenhouse gas emissions per mile than fossil fueled NZE trucks. If an advanced diesel engine is certified to meet the upcoming state standards for NZE, diesel could continue to be the dominant fuel in the 2020s. This would mean another generation of children is exposed to toxic diesel pollution, albeit at lower levels than today.

If, instead, the NZE-compliant vehicles that make up the fleet in the 2020s are primarily natural gas vehicles, demand for natural gas will significantly surpass local station capacity (see chapter 3). This would require more fueling capacity from a mixture of additional or expanded public fueling stations, as well as private fueling infrastructure located at truck depots. When the fleet transitions again to ZE drivetrain technology, these investments in natural gas fueling infrastructure could largely be stranded. If most of the ZE-compliant trucks that the Ports expect to enter the fleet rapidly in the first half of the 2030s are electric, charging demands might quickly overtake the growth in local electrical distribution capacity needed to charge heavy-duty vehicles. Expediting grid upgrades will increase overall costs, and capacity constraints may limit drayage operators' ability to transition to ZE trucks.

Thus, short transitions to NZE and then ZE — as is proposed in the CAAP — could pose infrastructure challenges. An earlier and more gradual transition to ZE could mean fewer short-term investments in natural gas infrastructure, and more focus can be put on long-term development of charging infrastructure for battery electric trucks, avoiding some unnecessary costs.

In addition, earlier adoption of ZE trucks could avoid early retirement of some NZE trucks. If the Ports wait until the 2030s to distinguish between ZE and NZE, it could mean that in the early 2030s the oldest of thousands of NZE trucks — which the Ports predict will be purchased in the 2020s — would be no older than 11 years old. Only a small percentage would be approaching the end of their useful life, while newer trucks would have years of life left. Yet because of the rate structure changing, companies and independent contractors may be compelled to retire their NZE trucks before their end of life.

Another benefit of adoption of ZE trucks in the 2020s is generous state and regional incentives, and the learning that can occur through early adoption while utilizing these financial safety nets. Current state and regional incentives make the total cost of ownership for ZE trucks more favorable than diesel and natural gas trucks (see chapter 4). These funds are either first come, first served and are thus expected to be exhausted in the 2020s, or appropriated on a regular basis and thus future incentives at the current generous levels are not guaranteed. Maximizing the number of early adopters in the early 2020s will facilitate learning and truck price reductions over time. This is particularly important for operators with the lowest risk tolerance and least access to capital, as they too later follow early adopters and transition to ZE trucks.

chapter 6
policy and strategy options

Summary of Barriers and What Entities Could Address Them

This report described several challenges for integrating zero-emission (ZE) trucks into drayage service at the San Pedro Bay Ports (the Ports). Current constraints include nascent technology that creates uncertainty; limited vehicle range; high capital costs for trucks and charging infrastructure; uncertainty about which entities would shoulder upfront costs and have the personnel capacity to apply for incentive funding; as well as space and time constraints for vehicle charging.

There is also significant potential for ZE drayage trucks. ZE Class 8 truck technology is quickly advancing and is already commercially available from one manufacturer, while five other leading manufacturers believe they will have a battery electric truck (BET) that can be sold by 2021. Operationally, the range of even early stage BETs is suitable for most drayage needs. Charging incentives along with truck purchase incentives make BETs more economical than diesel or natural gas on a total cost of ownership basis.

Therefore, there is potential in the short and medium term to electrify a significant portion of the fleet, if those trucks were dedicated to shorter routes. There is also a tremendous opportunity given that nearly the entire fleet is expected to turn over in the 2020s.

Industry Barriers and the Opportunity to a Transition to ZE Trucks

The employment and vehicle ownership structure of the drayage industry creates two fundamental barriers to a ZE truck transition. It affects both the operational range constraints described in chapter 3 as well as the financing uncertainty described in chapter 4.

First, there is uncertainty about which entity could both manage high upfront costs of ZE trucks and apply for generous incentives to make the trucks financially viable. While BETs can be cheaper than counterpart diesel or natural gas trucks when incentives are factored in, there are still financial barriers for independent operators wishing to acquire a BET. After purchase incentives, a $300,000 new BET will cost approximately $200,000 with taxes. Without stellar credit and a long business history, down payments for commercial truck loans are typically 10% to 20%, which for a BET could be as much as $40,000. Given that drayage drivers may not net that much in a year, it will be hard for independent contractors to afford the down payment, ruling out traditional financing for independent contractors. It should be noted that drayage independent contractors are similarly hard-pressed to be able to afford the $19,000 or $29,000 down payment on a new diesel or natural gas truck.

When the 2007 Clean Trucks Program pushed drayage drivers to upgrade to newer model year trucks, licensed motor carriers, with comparatively better access to capital, had to step in and acquire trucks in order to lease to their drivers. However, in the wake of several costly employee misclassification lawsuits, the LMCs are unlikely to be as amenable to similar arrangements. This means that there will likely be a significant need for risk-tolerant capital to provide low-money-down loans or lease-to-own financing for drayage drivers.

Another consideration is whether independent contractors may be able to participate in the Low Carbon Fuel Standard program. Although the newly reauthorized LCFS program allows for private fleets to generate and sell LCFS credits, it may be difficult for independent contractors to participate in this market. As set up, LCFS opt-in rules are primarily geared toward operators of large fleets. Independent contractors wishing to participate would have to be incorporated as a business or otherwise have a federal employer identification number. They would also have to reliably track their electricity use, submit to audits and navigate the complex LCFS marketplace to sell their credits to regulated parties. While the enormous value of the LCFS credits makes this a worthwhile endeavor, many drivers would likely need assistance to take advantage of that opportunity.

Second, while the range of ZE battery electric trucks is suitable for most drayage needs, currently the industry has little incentive to optimize routes conducive to ZE trucks. Independent contractors, who must decide what type of vehicle to purchase or lease, are paid by the load. Under the current drayage operations paradigm and all else equal, drayage drivers have an incentive to choose vehicles that will not risk limiting their revenue opportunities, such as would occur if they must turn down a load because the trip exceeds their range or if range limits the number of jobs they can complete during a shift. Moreover, drayage companies are legally limited in their ability to specify how their independent contractors operate and thus would be reluctant to dedicate certain drivers and their trucks to routes conducive to BETs (Papson and Ippoliti 2013).

However, there is potential in the industry to better optimize. Results of the Truck Operator Survey indicate that some companies — likely as a result of clients with specific destinations relatively close to the Ports — are already operating in a way that is conducive to integrating ZE trucks. It may be possible for other trucking companies regardless of their employee model to decide to strategically specialize, if they are incentivized to do so.

There may also be opportunities for companies that employ drivers to subfleet to allow some of their routes to be dedicated to ZE trucks. In a subfleet scenario, assignments could consider vehicle range and prioritize BETs for the more common short-range trips while reserving combinations of the less common longer trips for those trucks that have longer ranges but are not ZE. If subfleeting can be sufficiently incentivized by policy in a way that is compatible with applicable labor law, there could be a significant potential to electrify much of drayage service in the short term, even while vehicle ranges remain relatively limited.

Policy and Strategy Identification

Significant challenges and big opportunities exist for a transition to zero-emission drayage trucks for the San Pedro Bay Ports. No one entity, policy, or strategy could overcome all barriers and leverage all opportunities in the short and medium terms.

> **A multifaceted, agile, and collaborative approach to overcome barriers and seize sizable opportunities will be necessary for both the Ports and its collaborators.**

This chapter introduces a menu of policies and other strategies that key stakeholders could pursue to support the transition to ZE trucks as quickly and smoothly as possible. The proposed strategies are organized by entities already committed in some way to supporting a ZE drayage fleet: 1) the Ports and 2) electric utilities, air regulators, and other government entities.

Coordination between these stakeholders is critical. A Ports Working Group comprising staff from the Ports, city departments, and other stakeholders already meets regularly. A subcommittee of this group, or a new working group, could form to coordinate on strategies in order to comprehensively address barriers and leverage opportunities to zero-emission drayage trucks.

To narrow down potential solutions to those most likely to be viable, we employed the following criteria:

1. The policy or strategy is clearly within the purview, legal authority, and abilities of the Ports or other key collaborators;
2. It could be accomplished in the near or medium term; and
3. It would address one or more main barriers and/or opportunities to accelerate ZE truck adoption in the 2020s.

While it is outside the scope of this report to closely specify policy design details or model the potential outcomes associated with those design alternatives, each policy and strategy outlined in the following section deserve a rigorous analytical treatment.

Policy and Strategy Options in Ports' Purview

To accelerate the adoption of ZE drayage trucks in the 2020s, the Ports should provide ZE-specific adoption incentives beginning in the very near term. Given the barriers for ZE trucks, their adoption will be limited if there is no distinction between adoption incentives for ZE and NZE trucks.

As part of its Clean Trucks Program, the Ports could create a Zero-Emissions Drayage Plan that would set targets for pollution reduction from the drayage industry. Starting the 2020s, these interim targets would translate into ZE truck goals that could be adjusted over time depending on technological progress and other parameters. Multiple policies and strategies should also be included in the plan to help meet zero-emission transition goals. We introduce three such policies and strategies. They should be seen as a starting point but not a comprehensive list of options for the Ports to proactively support a transition to zero-emission drayage trucks as quickly and smoothly as possible to maximize benefits.

Truck Rate Structure: Overview

As demonstrated by the rapidly successful 2007 Clean Truck Program (CTP), the strongest lever in the Ports policy toolbox is the ability to assess differentiated fees to trucks collecting or delivering cargo based on compliance with emissions standards. There are three major design considerations for the truck rate program. First, the Ports must set the compliance standard or standards upon which fees will or will not be assessed (in this case aligning the standard with the state's respective standard). Second, the Ports must set a fee rate or schedule of rates. Finally, the Ports will have to determine how to use fee revenues. As a policy instrument, the fee has two mechanisms:

1. Insofar as the fee impacts the revenue of the independent contractor or drayage firm, the fee provides a financial incentive to obtain a compliant truck, and
2. The fee generates revenue that the Ports can use to subsidize the purchase of compliant trucks.

The effectiveness of the fee to encourage adoption of compliant trucks will be in large part a function of the fee amount. To encourage adoption, the truck fee must add enough costs to moving cargo that purchasing a compliant truck is the better business option. For example, if the fee is set at the same $35 per TEU rate as the last CTP, a truck that averages three (two TEU) trips per day will incur $54,600[17] in fees over a year. Such a rate would impose costs that quickly offset the incremental costs of truck replacement. Because more fees would be incurred at any level, the fee will always be more effective at encouraging adoption for trucks that more frequently call on the ports.

There is a trade-off between fee-induced compliance and revenue generation. A fee that is set so low as to not provide impetus to replace vehicles could generate significant revenues as the industry chooses to pay the fee rather than upgrade its trucks. On the other side, an aggressive fee would encourage quick turnover of trucks and potentially push some drayage truckers out of business, without generating significant revenues. In this way, the revenue potential of the fee program follows a curve where initially income rises as the fee increases, but then hits a tipping point after the fee starts to encourage truck turnover, causing overall revenues to fall.

Proposed Clean Trucks Fund Rate: Two-Tier Approach

In the 2017 update to their Clean Air Action Plan, the Ports propose a new Clean Trucks Plan aimed at increasing the use of ZE and NZE trucks in drayage operations. It proposes to charge a rate to enter the Ports' terminals, with exemptions for trucks that are certified to meet forthcoming ZE and NZE truck standards. The Ports plan to use fee revenues to provide subsidies to drayage operators that purchase ZE and NZE trucks.

The Ports' proposal effectively creates a two-tier truck fee rate structure that provides a price signal to shippers and drayage operators to induce a switch to either ZE or NZE vehicles to save on truck fee costs. The CAAP proposes to restrict fee exemptions to ZE by 2035. If in fact the Ports do delay until the 2030s, this would mean no additional incentive for the cleanest ZE vehicles in the near term.

Alternative Clean Trucks Fund Rate: Three-Tier Approach and Plan to Transition to Other Revenue Options

A policy could preserve the fee structure proposed in the 2017 CTP with one augmentation: Revenues could be

[17] $35 a TEU multiplied by two TEUs, 15 times a week and 52 weeks a year

recycled to fund a rebate for ZE trucks that move cargo to or from the Ports. This rebate would be provided on a per-loaded-trip basis, meaning that ZE trucks would earn an extra bounty for each cargo turn. This rebate design provides an additional level of incentives to the CTP, explicitly differentiating between the economics of NZE trucks compared to ZE electric trucks.

The Ports could establish this third tier in conjunction with setting targets for pollution reduction from the drayage industry, which would translate into ZE truck goals and could be adjusted over time depending on technological progress and other parameters. The Ports could adjust its truck rate to help meet the targets.

> **The Ports would not have to wait until 2035 to incentivize ZE above NZE through its truck rate. The Ports' own policy signals could help to create an earlier and more gradual phase-in of ZE trucks than is envisioned by the Ports' CAAP 2017.**

Recycling truck fee revenues into a rebate system has a number of advantages. The simplest is that it, by design, links subsidy amounts to frequency of truck use. Drayage operators will thereby be incentivized to use their BETs at the Ports as frequently as possible. This means that the Ports can limit subsidizing trucks that are not used often in drayage service without additional compliance measures.

The rebate system also creates incentives that are compatible with the deployment of an early subfleet of lower-range BETs. Drayage routes that are low mileage are associated with a larger number of short trips to and from intermodal yards and other nearby destinations. BETs deployed on those routes will have the opportunity to earn the most rebates while avoiding tailpipe pollution in some of the most impacted communities.

The rebate system is not without drawbacks. Doling out rebates on a continuous basis is administratively complex and would likely require new staff to oversee rebate procedures. Furthermore, the ongoing nature of the program would create risks for both the Ports and drayage operators. Unexpected ZE truck uptake or shortfalls in CTP revenue could jeopardize rebate funding, both risking port finances and making it difficult for drayage operators to predict the long-term value of the rebate.

A basic remediation for this funding risk would be to limit the lifetime rebate value (i.e., an upper limit on how much rebate money a single truck could earn). A second approach would be to limit the number of trucks that can participate in the program. The program could also be structured in tranches based on number of trucks deployed, where the lifetime value of the rebate per truck declines as more ZE trucks are deployed.

Beyond the truck rate, the Ports could also seek other, more stable sources of revenue to ensure gate entry rebate incentives for ZE trucks exist for a sufficient amount of time to motivate trucking companies and operators to subfleet or optimize routes conducive to ZE trucks. There are three main funding sources: 1) fees on freight, 2) fees on polluting businesses beyond the freight sector, and 3) taxes on residents.

From a welfare economics perspective, fees placed most directly on the source of an environmental externality will be most effective at reducing that externality. Thus, the Ports could explore other ways to raise revenues from beneficial cargo owners that send freight through the Ports.

Second, the state could partner with the Ports to provide a funding source to incentive gate entries in ZE trucks. As described in chapter 4, revenues from the state's carbon Cap-and-Trade Program, via California Climate Investments, funds the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Program, which can reduce by up to 90% the cost of purchasing a ZE truck. In addition, the Low Carbon Fuel Standard Program results in credits that lower the cost of fueling or recharging ZE trucks. However, neither incentive gets at the barrier that most drayage operators do not currently have an incentive to specialize in shorter routes conducive to electric trucks. By taking a small portion of California Climate Investments, the state could fund rebates for ZE trucks. This would allow the state to directly address a fundamental barrier to adoption of ZE trucks in the near and medium term, before ZE truck range is expected to be sufficient for every possible truck trip.

Third, taxpayers could choose to tax themselves to fund incentives for ZE trucks. For example, proposed Vision 2020: The Southern California Clean Air, Climate Health, and Transit Enhancement Measure could be a four-county half-cent sales tax expected to raise about $1.5 billion per year, if approved by voters (currently planned for a vote in 2020). The funding would be under the auspices of the South Coast Air Quality Management District. The proposal calls for investments in ZE and NZE heavy-duty vehicles, truck-only lanes with tolls to encourage cleanest trucks, and other air quality improvements at the Ports.

System Optimization

Drayage truckers spend a significant amount of time queueing and waiting to pick up or deliver cargo. The Ports plan to examine the feasibility of systemwide programs to move freight more efficiency and quickly, thereby reducing congestion and the associated pollution and financial costs. Systems optimization is a broad concept involving a range of intelligent transportation systems and other strategies for improving efficiency. In the context of this report, it is focused on allowing for optimization and specialization that would maximize the use of ZE trucks.

Currently, nine of the 12 container terminals at the Ports use reservation systems for import containers, and four of those terminals also use such systems for export containers. For terminals with reservation or appointment systems, truckers who arrive at the gate with an appointment are expected to receive prompt service during that time window. However, there are no consequences for a trucker missing an appointment or reservation or a terminal failing to serve a truck on time. Another challenge is that individual terminals and trucking companies use their own software systems to manage their gate operations and there is no consistent platform (Ports 2017b).

A uniform portal for securing all aspects of a truck transaction could improve the functionality of the system in general and also provide a platform for which subfleeting and specialization could be supported to maximize the use of ZE trucks. As such, assignments could consider vehicle range and prioritize ZE trucks for the more common short-range trips while reserving combinations of the less common longer trips for those trucks that have longer ranges. If subfleeting can be sufficiently supported and incentivized, there could be a significant potential to electrify much of drayage service in the short term, even while vehicle ranges remain relatively limited.

To implement such a system would require the use of new technologies. Current pilots could provide information about whether and what could be feasibility scaled. For example, the Port of Los Angeles is using a nearly $1 million grant from the California Energy Commission to support the ongoing large-scale testing of an intelligent transportation system called Freight Advanced Traveler Information System (FRATIS). FRATIS analyzes data from multiple sources to come up with the most efficient schedule, route and container information for drivers, dispatchers and cargo owners. Specific technologies that are being tested include: real-time traffic information, automated estimated-time-of-arrival messaging to the terminals one day in advance of truck arrival, and deployment of an algorithm that will optimize drayage throughout the day and region. The system is designed to reduce travel times inside and outside the terminals, which in turn reduces congestion, emissions and fuel consumption. The Ports could explore how it could be used to support subfleeting and specialization to maximize the use of ZE trucks.

Another way to incentivize ZE trucks is to offer them priority access to pick up and drop off loads, and thereby increase their number of turns and associated revenue. Sometimes referred to as green lanes, this type of strategy creates incentives that are compatible with encouraging a subfleet of shorter-range trucks on short routes. Drayage trucks serving local routes make the most trips to the Ports, spend the most time in line, and thus will have a stronger incentive to use ZE trucks. However, among other considerations, the strategy requires extra lanes and thus additional space at the terminals where space is limited. Therefore, it may be most feasible in the short term to first explore opportunities to expand on the Ports' existing goals for optimization technologies and systems.

Coordinated, Wraparound Strategy for Technical Assistance and Outreach

In order to transition to a ZE fleet at the Ports, myriad strategic decisions need to be made by private entities. Given the multifaceted and complex challenges and opportunities, it is clear that no one entity, public or private, can address all of them. A comprehensive, wraparound approach that addresses the main barriers and opportunities for ZE trucks is necessary to fully realize their substantial benefits.

More specifically, the goal could be a wraparound system that helps licensed motor carriers (LMCs) and independent contractors receive comprehensive information and support from a variety of entities interested in the deployment of ZE drayage trucks. The Ports could coordinate such a strategy working with industry stakeholders, other city departments and offices, local electric utilities, air quality regulators, and other government entities.

There are several programs that could serve as models. For example, the California Air Resources Board's one-stop-shop pilot program seeks to expand education and outreach on clean transportation and mobility options for low-income residents (CARB 2018e). The board's broader vision is to streamline access to clean energy, transportation, housing, and other related consumer-based incentives and augment existing outreach and education on clean transportation and mobility options.

Likewise, the Ports could streamline information about, access to, and technical assistance on applying for truck and infrastructure incentives. For example, the Ports could facilitate and host workshops to provide companies and drivers with information about truck options, fueling strategies, and cost structures. Then, the Ports could help connect companies and drivers to incentives and financing options. Small trucking companies and independent contractors with limited capacity will likely need support to apply for many of the incentive programs described in chapter 4, and the Ports could provide or facilitate technical assistance.

The Ports could also work with partners to fill information gaps and inform an outreach strategy. This could include working with local utilities to identify which truck yards might be well-suited for charging infrastructure. The authors of this paper supported a baseline analysis for Southern California Edison that involved creating an algorithm to identify which truck yards may be viable candidates for installing charging infrastructure based on geographic, size, grid, and other considerations (Bradley et al. 2019). This algorithm could be updated to meet evolving needs and refined for LADWP territory. The results could be used to prioritize outreach strategies around charging infrastructure and related incentives.

It would also be helpful to survey trucking companies to help identify their ZE truck perspectives and interests, and which have characteristics that make them good candidates for early adoption of ZE trucks. For example, a survey could seek to identify which trucking companies have clients that reliably require short-distance truck trips (without the trip length variation that sometimes occurs in the industry). Of these companies, it would be helpful to know which have employee drivers, as this is also a characteristic that could most easily specialize in routes conducive to early stage ZE trucks. This information could inform the Ports' outreach strategy as part of a wraparound approach. Of course, the approach will be more effective if the Ports create an incentive and system for specialization, as described in the previous two sections.

Policy and Strategy Options Outside Ports' Purview

Utility Level: Infrastructure Incentives

Providing fueling or charging infrastructure to support use of ZE battery electric trucks throughout the region will take major planning and funding. Southern California Edison's (SCE) Charge Ready Transport Program and Los Angeles Department of Water and Power's (LADWP) commercial EV charging station rebate program are positioned to provide significant funding to offset investments in charging infrastructure. However, because the programs' participation requirements are designed to favor applicants with control over charging sites and vehicle choice, it likely will be difficult for much of the drayage industry to take advantage of the program currently. While it is understandable for SCE and LADWP to desire long-term commitments to own and use electric trucks before investing funds in long-term infrastructure, the utilities should consider revisiting their commercial EV charger incentive programs to better align them with drayage industry needs.

Air Agency Level: Truck Purchase Incentives

The California Air Resources Board (CARB) and the South Coast Air Quality Management District (SCAQMD) offer incentives that significantly reduce the upfront costs of ZE trucks. Specifically, both the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Program (HVIP) administered by CARB and the Carl Moyer Program (CMP) administered by SCAQMD can reduce up to $165,000 from the base price. Factoring in this price reduction, along with Low Carbon Fuel Standard credits, our total cost of ownership (TCO) analysis found that BETs are less costly than even used diesel trucks. Two types of reforms could ensure that these important incentive programs are maximizing benefits.

We predict the possibility of strong demand for these incentive programs from the drayage industry that would far exceed current funding levels. This is because the value of the purchase incentives could be cut in half and BETs would still be less expensive than new diesel trucks under several realistic scenarios that we model in chapter 4. Per the 2018-19 budget for HVIP and CMP, only 757 and 240 trucks respectively can benefit from the incentive per year. Moreover, these funds are not dedicated to drayage trucks, and so the number of trucks serving the Ports that could benefit per year would likely be lower. Yet we predict that about 7,000 trucks could turn over in the early 2020s. The opportunity to transition a sizable fraction of them to ZE will not be realized if only a handful can take advantage of the generous HVIP or CMP incentive programs.

Therefore, the administering agencies may want to consider reducing the incentive levels, as long as ZE trucks would still have a more favorable total cost of ownership (TCO) compared to alternative trucks. Administering agencies could set incentive levels based on evolving TCO calculations over time, seeking to keep the TCO of ZE trucks lower than other alternatives while seeking to incentivize the greatest number of ZE truck purchases. Identifying the incentive level that maximizes effectiveness would require additional research beyond the TCO analysis to factor in other considerations for potential investors such as technology risk and driver preference. Alternatives could be compared in terms of 1) the number of additional ZE trucks expected to be purchased, 2) cost-effectiveness per additional vehicle purchase induced, and 3) total program cost.

In addition to subsidy level per truck, the number of trucks incentivized will also depend on the total budgets of the incentive programs and their longevity. Increased program budgets would allow for ZE potential to be more fully realized at a faster rate. In addition, more certainty of program longevity would provide important market signals and allow for investment planning. While incentive amount per truck may well decrease over time, administering agencies could seek to guarantee over the medium term that incentives will be available to keep the TCO of ZE trucks lower than other alternatives.

CARB and SCAQMD could also consider other program changes to address ownership and technology issues. For example, the agencies could update eligibility requirements to allow for third parties to purchase and lease the trucks. This may be important given previously described uncertainty about which entities will purchase or lease the trucks (the trucking companies, independent contractors, or a third party).

In addition, the agencies may want to differentiate ZE incentive levels based on performance criteria. This could be used to incentivize the development of longer-range BETs and their use in higher mileage applications. For example, the federal tax credit provides different incentive levels for light-duty ZE cars based on their battery capacity.

Collaboration to Overcome Financing Barriers

State, regional, or port authorities may need to further address the barrier that independent contractors and small companies face accessing capital for the purchase or lease of new trucks. It would be helpful to have the Ports or an agency such as CARB fund a study to explore whether new financing models are needed, or need to be expanded, given the aforementioned challenges with existing models (i.e., LMCs are being sued; independent contractors have very limited credit). The Ports have conducted such an analysis in the past and taken action but given changing conditions, a new analysis may be needed.

The CARB and the California Pollution Control Financing Authority in the State Treasurer's Office offers the Truck Loan Assistance Program. Implemented through the California Pollution Control Financing Authority's California Capital Access Program (CalCAP), the program provides financing opportunities to qualified small-business truckers and fleets (with 10 or few heavy-duty vehicles) that fall below conventional lending criteria and are unable to qualify for traditional financing for cleaner trucks.

The program seeks to address two main needs. The first is the need for credit enhancement: anything a government entity can do to improve the chances that financing will be repaid and thus encourage private lenders to put money into unfamiliar markets or products. In the case of this program, state funds are deposited as "contributions" (based on a percentage of each enrolled loan amount) into a loan-loss reserve account for each participating lender to cover potential losses resulting from loan defaults. (For example, a 5% loan-loss reserve on a $60 million loan portfolio would cover up to $3 million of a capital provider's losses on that portfolio.) By providing credit enhancements, the state absorbs some risk of loss, which at least in theory could convince private lenders to reduce interest rates and relax loan terms (U.S. DoE 2019a). How this is working in practice could be explored further. The program currently includes an interest rate cap of 20%, which is quite high, and higher than rates that LMCs with higher credit ratings and more capital receive.

Second is the need to address the down payment barrier that small trucking companies may face. Borrowers using the Truck Loan Assistance Program can use a Carl

Moyer Voucher Incentive Program grant or a Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project grant as a down payment on a truck purchased with a loan. If fleet owners have received other forms of grant assistance, they should check with the issuing agency to make sure the grant agreement does not restrict them from receiving loan assistance from the program. Again, an analysis could explore how this is working in practice and whether there are unmet needs.

If needed as a potential complement, the Ports could create a revolving loan fund (RLF) to help trucking companies with down payment assistance. Revolving loan funds are pools of capital from which loans can be made for clean energy and transportation projects. A government entity puts in upfront capital and then, as loans are repaid, the capital is reloaned for another project/truck. Assuming that defaults remain low, RLFs can be evergreen sources of capital that are recycled over and over again to fund projects well into the future (U.S. DoEb 2019).

chapter 7

conclusions and next steps

A transition to zero-emission (ZE) drayage trucks for the San Pedro Bay Ports presents significant challenges and big opportunities. No one entity, policy, or strategy could address all in the short and medium terms. This report introduces a menu of strategies for a transition to ZE trucks that could begin in the early 2020s, when we expect an increase in truck turnover.

As demonstrated by the rapidly successful 2007 Clean Truck Program (CTP), the strongest lever in the Ports' policy toolbox is the ability to assess differentiated fees to trucks entering the Ports based on compliance with emissions standards. The Ports plan to use the fee to differentiate between near-zero emission trucks and ZE by 2035. Doing so in the 2020s would help initiate a transition to reduce pollution sooner, avoid the expense and disruption of two sharp technology transitions in about 10 years; and would take advantage of generous state and regional incentives for ZE trucks offered now that make battery electric trucks less expensive than all other alternatives (including used diesel trucks) on a total cost of ownership basis.

Other viable options within the Ports' purview include systems optimization and a coordinated, wraparound strategy for technical assistance and outreach. Suggestions outside the Ports' purview relate to 1) utility-level infrastructure incentives and heavy-duty electrification friendly rates, 2) air agency-level truck purchase incentives, and 3) collaboration to overcome financing barriers. All of these proposed strategies could be taken in the short and medium term to achieve benefits of a transition to zero-emission trucks that is as smooth and as early as possible.

It is outside the scope of this report to offer specific policy and strategy design details and evaluate those design alternatives based on criteria such as cost-effectiveness. This report lays the foundation to do so. This report could also complement the forthcoming economic study that the Ports commissioned to inform the truck rate. Additional research will also be warranted, for example, to explore alternative financial models for ZE trucks.

Only recently have ZE trucks become feasible for drayage service, but ZE truck technology is rapidly evolving. Policy incentives and strategies will need to keep up. With a multifaceted, agile, and collaborative approach to overcome barriers and seize the sizable opportunities, the Ports and other stakeholders can help ensure a cleaner, safer, and more sustainable future.

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appendix a
incentive programs

Hybrid and Zero-Emission Truck and Bus Voucher Incentive Program (HVIP)

Funded through the Greenhouse Gas Reduction Fund (GGRF) from the Cap-and-Trade Program, HVIP aims to offset the incremental cost of cleaner technologies compared to conventional diesel vehicles.[18] The Cap-and-Trade program has been extended until 2030, providing a more stable funding source for this program.

HVIP provides $125 million to zero- and near-zero emission trucks and buses statewide for the fiscal year 2018-19[19]. New zero-emission Class 8 trucks can receive base funding vouchers of $165,000 per vehicle for the first 100 vehicles per company.[20] The program sets an aggregated limit of public fund investment — supporting up to 90% of total truck cost, including base HVIP, enhancement HVIP funds based on warranty levels, and any other public funding.[21] To ensure that California benefits from emission reductions, funded trucks must be operated 100% in California for the first three years of use.[22]

Carl Moyer Program (CMP)

Senate Bill 1107 establishes a statewide program to incentivize the purchase of heavy-duty vehicles and equipment that are cleaner than state regulations require, with the intent to further reduce NO_x, PM and VOC emissions. Funding is available across the state, where funds are allocated to local air pollution control agencies that have nonattainment status in terms of air quality.

Under SB 1107, $61 million per year is provided statewide and $26 million to Southern California's South Coast Air Quality Management District (SCAQMD). Additional funding was granted through Assembly Bill 134, and approximately $50 million of the original AB 134 allocation is still available to SCAQMD. Additionally, SCAQMD's budget is increased by smog check and tire fees. In total, $30 million is available for the 2018-19 fiscal year in the South Coast Air Basin.[23] A portion of the SCAQMD's CMP funding source is set to sunset in 2028.

The CMP provides rebates of up to $165,000 per zero-emission vehicle. CMP requires operators to scrap old diesel vehicles as part of the funding process. To ensure air quality benefits from the public funding, the replacement trucks must operate at least 75% of the time in SCAQMD jurisdiction.

The cost of installing and purchasing charging infrastructure is one of most important factors in expanding the number of electric drayage trucks in Southern California. In this program, funding is available for charging infrastructure, with SCAQMD funding up to 50% of eligible costs for all infrastructure projects that meet certain criteria. The percentage covered increases if it is accessible to the public and if solar- or wind-powered systems are used.

Owners that apply for and receive CMP funding are not eligible for additional public funds.

Proposition 1B – Goods Movement Emission Reduction Program (GMERP)

Proposition 1B was funded through a California ballot initiative, which set aside $1 billion for an emission

[18] https://www.californiahvip.org/wp-content/uploads/2018/01/Final-IM-01172018.pdf (page 4)
[19] https://www.arb.ca.gov/msprog/aqip/fundplan/proposed_1819_funding_plan.pdf (page 60)
[20] https://www.californiahvip.org/wp-content/uploads/2018/01/Final-IM-01172018.pdf (page 22)
[21] https://www.californiahvip.org/wp-content/uploads/2018/01/Final-IM-01172018.pdf (page 29)
[22] https://www.californiahvip.org/wp-content/uploads/2018/01/Final-IM-01172018.pdf (page 35)
[23] www.aqmd.gov/docs/default-source/aqmd-forms/moyer/moyer-pa2018-06.pdf (page 1)

reduction program targeting the goods movement sector. The goal of GMERP is to quickly decrease emissions along California's major trade corridors, and projects are funded until the $1 billion in funding runs out.[24] GMERP funds the replacement of diesel trucks with vehicles that have model year engines of 2015 or newer. Engines can be natural gas, hybrid, low-NO_x, hybrid or zero-emission. To prevent old diesel trucks from being used elsewhere, scrapping is required as part of the program.

Zero-emission heavy duty trucks can receive up to $200,000 per vehicle.[25] Overall, applicants who will replace diesel vehicles with alternative fuel ones receive higher funding priority.

Infrastructure is also funded under GMERP. Truck stop electrification, charging station and hydrogen fueling station projects can receive up to 50% of eligible costs in funding.[26]

Volkswagen (VW) Environmental Mitigation Trust

The VW mitigation trust is another program that takes dirty vehicles off the road by requiring scrapping of old trucks once replacement vehicles are purchased.

The overall goal of the mitigation fund is to reduce NO_x emissions in order to offset the NO_x emission impacts from VW vehicles in the 10 years that vehicle emission factors were falsified.

California is to receive $423 million of the VW settlement, with $90 million allocated to freight projects for zero-emission Class 8 freight and port drayage trucks.[27] Their goal in funding the freight project is to reduce the capital costs associated with the introduction of zero-emission heavy-duty vehicles and help that market achieve economies of scale.

Owners can bring in an old truck with an internal combustion engine model year 1999-2002 and receive a grant for a replacement cleaner truck. Firms or individuals are eligible for up to $200,000 per zero-emission truck, with a limit of 75% of the cost per vehicle. Funds can also be used for supporting infrastructure.[28] The VW program ends when all funds have been allocated and spent.

Truck Loan Assistance Program

Funded through the Air Quality Improvement Program (AQIP), the purpose of this program is to assist small fleets upgrading to newer and cleaner heavy-duty vehicles when they are usually unable to qualify for financing.[29] Unlike the incentive programs above, this loan program helps operators comply with the existing Truck and Bus Regulation. Approximately $25 million is available in loans in the 2018-19 fiscal year with an interest rate cap of 20%. This program is not set aside specifically for zero-emission heavy-duty vehicles and is available statewide.[30]

[24] https://www.arb.ca.gov/bonds/gmbond/gmbond.htm
[25] www.aqmd.gov/home/programs/business/goods-movement-heavy-duty-truck-projects1/funding-tables (table 1).
[26] www.aqmd.gov/home/programs/business/goods-movement-heavy-duty-truck-projects1/funding-tables (table 3).
[27] arb.ca.gov/msprog/vw_info/vsi/vw-mititrust/meetings/proposed_bmp.pdf (page 4).
[28] arb.ca.gov/msprog/vw_info/vsi/vw-mititrust/meetings/proposed_bmp.pdf (page 23-24).
[29] arb.ca.gov/msprog/aqip/fundplan/060118_discussion_doc.pdf (page 51)
[30] arb.ca.gov/msprog/aqip/fundplan/060118_discussion_doc.pdf (page 51-53)

appendix b
methods

B.1 Calculating Low Carbon Fuel Standard Incentive Value

California's Low Carbon Fuel Standard program sets limits on the carbon intensity (CI) of transportation fuels. Fuels sold in California must meet an increasingly stringent CI (g-CO_2e/MJ) standard. The program includes a novel, market-based compliance mechanism where below-CI-standard fuel generates credits that can be used by sellers of noncompliant fuels to satisfy compliance obligations. Because it is difficult and expensive to reduce the carbon intensity of fuels such as gasoline and diesel, LCFS credits generated by the use of low-CI fuels (such as electricity) are very valuable.

Recent amendments to the LCFS program enable operators of electric vehicle fleets to participate in the LCFS market by generating credits through the use of electric fuel. The value of those credits over the life of a truck depend on the market price for the credit and the amount of credits the truck generates by using electricity as a fuel. For the purposes of this analysis, UCLA assumes that the market price for credits will follow the projections made by CARB staff during the rulemaking process.[31] The number of credits a truck generates is determined by equation B-1 which can found in the LCFS regulation.[32]

Equation B-1

$$Credits = \left(CI_{Standard} - \frac{CI_{elctricity}}{EER_{BET}}\right) \times \left(E_{Displaced} \times EER_{BET}\right) \times \frac{1}{1{,}000{,}000}$$

Where:

- The carbon intensity (g-CO_2e/MJ) standard for the year in which the credit is generated
- The carbon intensity (g-CO_2e/MJ) of electricity, which is currently 81.49[33]
- The energy economy ratio (EER) for BETs, which is set by statute at 5.[34]
- The quantity of energy (in MJ) displaced by the alternate fuel, in this case electricity. 1 kWh = 3.6 MJ.

[31] https://www.arb.ca.gov/regact/2018/lcfs18/isor.pdf
[32] California Code of Regulations, Title 17. Division 3. Subchapter 10, Article 4. Subarticle 7. Low Carbon Fuel Standard. § 95486.1
[33] The carbon intensity of electricity is based on the mix of energy sources on California's grid. While this number will decrease over time (marginally increasing the value of the credit) as the electricity mix gets cleaner, for simplicity, UCLA's calculations hold this value constant.
[34] The EER is a ratio that compares energy use by one fuel/technology to another. An EER of 5 means that BETs use five times less energy than a diesel truck to travel the same distance.

Table B-1 shows the forecast credit value, the CI standard, and the amount and value of LCFS credits generated using one kWh in each year between 2020 and 2031.

Table B1: LCFS Value

Year	Forecast credit value	CI Standard	Credit per kWh	Value per kWh
2020	$125.00	92.92	0.0017	$0.21
2021	$125.00	91.66	0.0016	$0.21
2022	$125.00	90.41	0.0016	$0.20
2023	$125.00	89.15	0.0016	$0.20
2024	$125.00	87.89	0.0016	$0.20
2025	$115.00	86.64	0.0016	$0.18
2026	$115.00	85.38	0.0015	$0.18
2027	$115.00	84.13	0.0015	$0.17
2028	$125.00	82.87	0.0015	$0.19
2029	$125.00	81.62	0.0015	$0.18
2030	$135.00	80.36	0.0014	$0.20
2031	$135.00	80.36	0.0014	$0.20

B.2 Calculating Total Cost of Ownership

This section details the total cost of ownership (TCO) analysis methods UCLA used to estimate the total cost of ownership of different truck technology fuel platforms in chapter 4. TCO analysis is a financial decision-making tool that provides a common metric for comparing the cost of two or more assets over a standard time frame. This allows decision-makers to purchase the asset that will cost the least over time, instead of the asset that is least expensive at the point of purchase.

UCLA's TCO analysis employs a 12-year truck operating life, which is a common assumption for a new truck. Comparing used trucks to new trucks is a more difficult proposition. Used trucks are less expensive to purchase but have a shorter average lifespan. To simplify the analysis and remain consistent with the 12-year time frame for the other trucks, the used-diesel truck TCO assumes the purchase of a 6-year-old truck that survives for six years and then is replaced with a second 6-year-old truck.

TCO costs are compared across three duty-cycle scenarios which are based on reported mileage by drayage operators:

1. **Average truck:** This truck drives 238 miles a day, five days a week, over 14.9 hours based on the average mileage and up-time of drayage trucks.
2. **Single-shift truck:** This truck drives 160 miles a day, five days a week, over 9.4 hours based on the average mileage and up-time of a single drayage truck shift.
3. **Two-shift, limited-mileage truck:** This truck travels 200 miles over two shifts over 18.5 hours based on the modal shift mileage of drayage truck shifts.

For each duty-cycle scenario, UCLA evaluates the TCO for the following truck types:

- Used diesel
- New diesel
- Natural gas
  - o With and without purchase incentives
    - · Battery electric
  - o Charged in Los Angeles Department of Water and Power or Southern California Edison territory.
  - o With and without:
    - § Low Carbon Fuel Standard
    - § Purchase incentives

UCLA's TCO financial model follows the standard accounting practice of discounted cash flow analysis (DCF). DCF is premised on the concept of the time-value of money; that is, a dollar earned or spent in the future is worth less than if it were earned or spent today. In a DCF analysis, streams of future costs and revenues are discounted to a present value (PV) using the standard PV formula.

We use a 7% real discount rate, which is recommended by the Office of Management and Budget Circular A-94 as consistent with recent returns on private capital.[35] In other words, this is the return purchasers of an asset would expect to receive on the market with the money they would otherwise invest in an asset.

Cost Parameters

Because relevant cost parameters are different depending on the asset in question, there are no standard procedures or common criteria with which to determine which costs should or should not be included in a TCO analysis. Because the primary purpose of the TCO analysis is to compare between platforms, we sought to account for all capital and operating costs that would vary between the different fuel-technology platforms such as purchase price, taxes, fuel cost and ad valorem fees. Other

[35] https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/circulars/A94/a094.pdf

costs such as liability insurance coverage will not vary by truck type and are therefore excluded from the analysis. Furthermore, because salvage value for natural gas and electric trucks are unknown, they are also excluded from the analysis.

Chapter 4 includes detailed descriptions of the TCO inputs, which include:

a) Costs
   - Vehicle purchase price with taxes
   - Infrastructure purchase price with taxes
   - Financing
   - Fuel
   - Maintenance
   - Vehicle registration fees
   - Comprehensive property insurance

b) The value of incentives and tax benefits, including:
   - Vehicle purchase incentives
   - Infrastructure incentives
   - Low Carbon Fuel Standard credits
   - Depreciation tax shield

Estimating Cash Flows

In order to appropriately discount costs to present value, DCF analyses rely on an accounting of when costs such as loan payments and fuel expenditures are incurred over the lifetime of the asset. For this TCO analysis, we estimate total costs on an annual basis over an assumed 12-year life of the truck.

Annual costs of capital outlay and financing	Vehicle purchase Infrastructure purchase/install Sales and excise taxes Vehicle purchase incentives Infrastructure incentives	UCLA assumes that upfront costs for the purchase of trucks and any required infrastructure, plus taxes and less any available incentive funding are financed according to loan terms laid out in Chapter 4. To calculate annual payments, we assumed trucks and infrastructure would be financed with simple amortizing loans. The loan down payment is paid in year one and the loan is paid off after year five. Note: In the used truck case, a second truck is financed in year seven and paid off in year 11.
Annual costs/ revenues as a function of mileage	Fuel Maintenance Diesel exhaust fluid (DEF) LCFS	Operational costs for fuel and maintenance are a simple function of scenario annual miles traveled multiplied by per-mile fuel or maintenance costs. DEF consumption is a function of diesel consumption. LCFS credit values are calculated by miles traveled multiplied by the yearly per-mile value of LCFS credits listed in Table B-1. Credit revenues are treated as a negative cost for the year they occur.
Annual costs as a function of vehicle value	Registration fees Insurance	Registration fees and insurance costs are calculated as the fixed percentage of the depreciating value of the truck.

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