Introduction

The Volvo Low Impact Green Heavy Transport Solutions (LIGHTS) project is an innovative and important freight electrification project deploying heavy- duty battery electric vehicles into goods movement operations in Southern California. Working with fleet partners Dependable Highway Express and National Freight Inc. (NFI), and dealership partner TEC Equipment, LIGHTS seeks to reduce emissions at warehouses and freight facilities in some of the region's most disadvantaged communities. These reductions are realized through the use of zero emission on-and-off-road equipment and warehouse energy efficiency improvements, including Volvo's North American market introduction of Class 8 battery electric trucks capable of drayage service.

In 2017, the Port of Los Angeles (Port, POLA), in partnership with the Port of Long Beach (POLB), adopted the 2017 Clean Air Action Plan Update, setting a goal to transition to a 100 percent zero-emission drayage fleet by 2035. Achieving this goal will require extensive regional charging infrastructure for Class 8 zero-emission trucks to support the majority of the drayage fleet. In support of that goal, the Port has partnered with Volvo on the LIGHTS project to demonstrate the potential of battery-electric trucks and further the understanding of the operational capabilities and charging infrastructure needed for zero-emission drayage trucks.

As of late 2021, approximately 20,000 Class 8 trucks are registered in the Ports Drayage Truck Registry (PDTR). The active drayage fleet on any given day ranges roughly between 9,000 and 13,000 trucks. Drayage trucks making frequent or semi-frequent calls (2.5 times per week or more) number approximately 14,000, suggesting that a range from 14,000 to 20,000 trucks is a reasonable rough estimate of the required drayage fleet needed to support the San Pedro Bay ports (SPBP) gateway.

The Port anticipates that most of the charging infrastructure required to charge the 14,000 to 20,000 zero-emission trucks expected by 2035 will be located at private fleet facilities or at future retail charging facilities located outside of the Port. Indeed, the Port has an interest in encouraging drayage trucks not to dwell in the Port area or surrounding communities to minimize impacts on these communities and avoid congestion in the gateway. However, there is potentially a need for charging infrastructure in the Port region to support a fraction of truck trips, especially early adopter trucks deployed through grant programs, that would have insufficient charge to return to their regular charging facilities. Ultimately, the charging facility would be intended to be utilized for supplemental charging and would not be intended to provide space for overnight parking or charging of trucks.

This report evaluates the potential for a charging facility located near the Port to support a significant portion of these truck trips, defines currently available charging interfaces, and considers the available utility rate structures that would be most beneficial to electric vehicle (EV) charging.

Estimating Facility Demand

The premise of this current study is the development of a facility intended to support a fraction of truck trips that would have insufficient charge to return to their regular charging facilities. This need is expected to occur most often for inland-based drayage fleets that can have one-way trip distances of 40 miles or more. Current Class 8 battery-electric trucks have estimated ranges of 130 to 230 miles and near-term battery electric trucks from Volvo are estimated to have up to 275 miles of range. While these capacities are sufficient to allow an inland drayage truck to make one or two round trips between charges, additional trips or additional shifts could require limited charging near the Port to complete a return trip.

Very little detailed data on drayage truck trip activity are available in public literature. However, a recent study of NFI's telematics data for their drayage truck operations in 2019 provides a unique example data set for an inland fleet facility.[1] The study evaluated the potential to transition NFI's 2019 drayage fleet of approximately 50 trucks to battery-electric trucks under several scenarios, including the use of a notional truck with a 500-kilowatt hours (kWh) battery pack supported by a 150-kilowatt (kW) charger. This scenario is roughly consistent with existing and near-term Class 8 truck offerings from major truck original equipment manufacturers. A review of the data and analysis for this scenario revealed that 15 percent of trips leaving the San Pedro Bay ports gateway would run out of charge before reaching the Chino facility, which is located 55 miles from the Port.

The distribution of failed trips, by hour of departure from the Port, is shown in Figure 1. The majority of failed trips would have departed the Port between midnight and 04:00, suggesting that trucks used in two-shift operations and in the second half of their second shift are most likely to require supplemental charging to return to their inland facility.

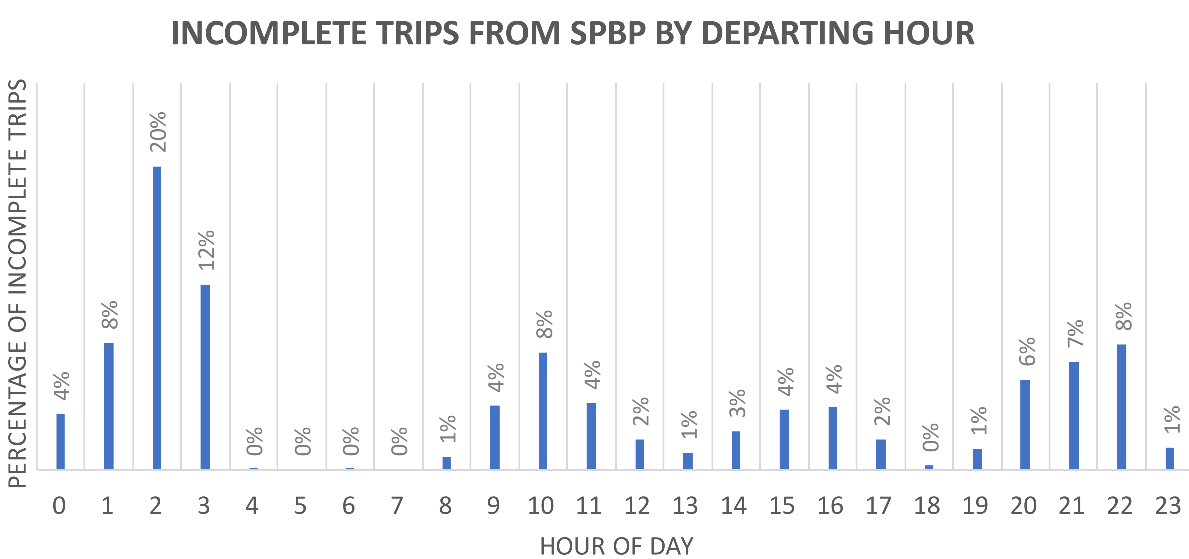

Figure 1. Hourly Distribution of Failed Trips Originating from the Port Gateway

To estimate the potential number of Port-wide truck trips that would require supplemental charging at the Port, the hourly distributions in Figure 1 were applied to the hourly distribution of gate moves as reported in the PDTR (Figure 2) for 2019. The resulting distribution of the annual average daily incomplete trips is shown in Figure 3 and represents approximately 2,000 departing trips per day. Similar analysis was completed for the maximum daily moves in 2019 and represented approximately 3,100 departing trips.

[1] Gladstein, Neandross & Associates, "California Heavy-Duty Fleet Electrification," prepared for Environmental Defense Fund, March 2021. https://www.gladstein.org/research/california-heavy-duty-fleet-electrification/

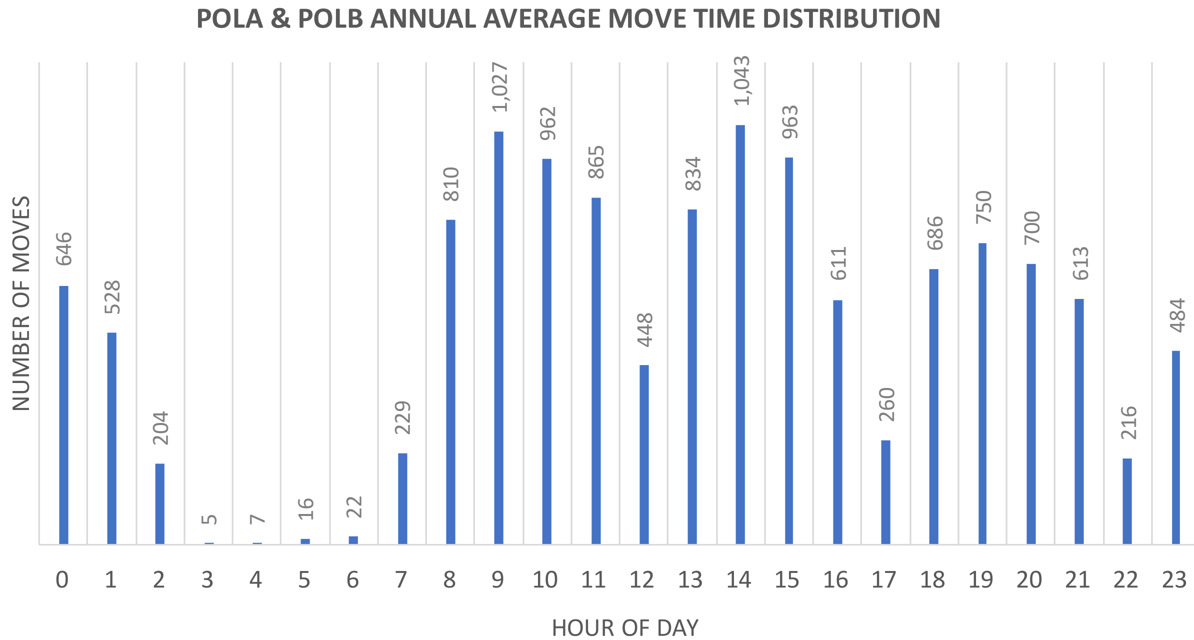

Figure 2. Annual Average Distribution of Gate Move Times

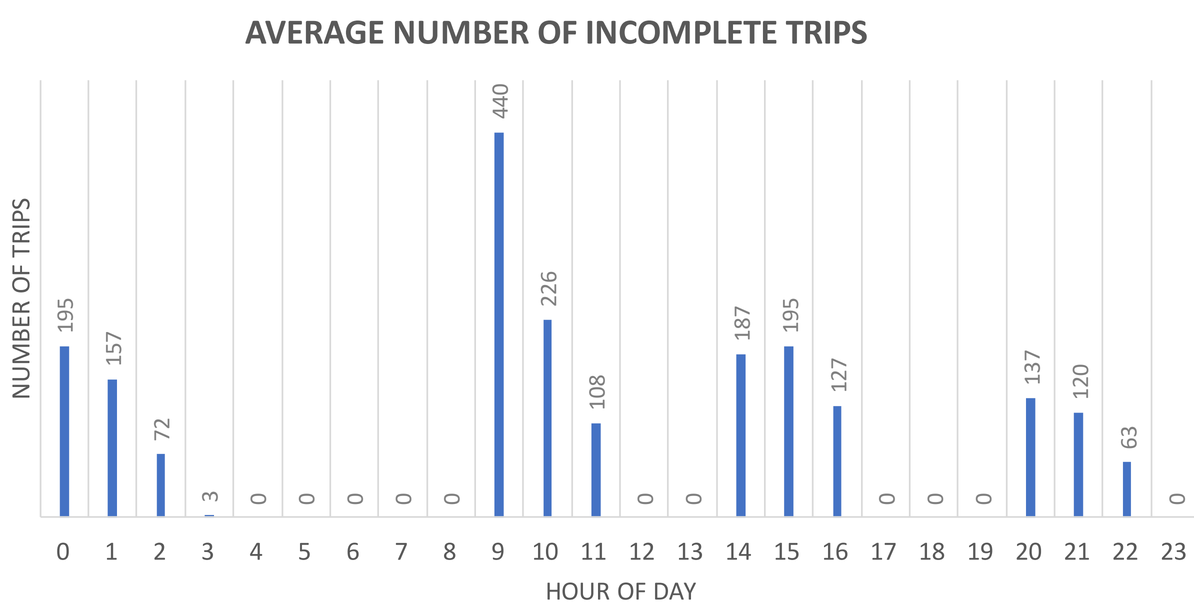

Figure 3. Incomplete Trip Distribution for an Annual Average Day

Potential Site Identification and Design

In parallel with the development of charging demand estimates, the Port surveyed available parcels around the Port for potential use as a public access charging facility. Because the charging facility is intended to support trucks departing the Port gateway, it was determined that the facility configuration should support charging of both bobtail trucks and trucks with connected trailers. The two adjacent parcels on POLA-owned property were identified at Alameda Street and I Street in Wilmington with the potential space and access to power to support these needs.

The two parcels, located at 900 Alameda Street and 1480 East I Street, and the conceptual layout of charging stalls and equipment are shown in Figure 4. These parcels are located just north of the CA-47 and CA-103 interchange at the Heim bridge. Both CA-47 (Alameda Corridor) and CA-103 are major truck routes serving the Port gateway and are conceptually well located to drayage truck charging.

- 900 Alameda Street – 0.8 acres, 15 charging stations, rated at 150 kW each (upgradable to 400 kW) Class 8 trucks, bobtail only.
- 1480 East I Street – 1.5 acres, 25 charging stations, rated at 150 kW each (upgradable to 400 kW), Class 8 trucks with 40 ft containers.

Queuing Assumptions and Analysis

Each parcel's layout maximizes the number of charging stations but limits the available space for queuing of trucks on the parcel. Consequently, a queuing analysis was conducted to determine the maximum number of trucks that could be charged based on the trip distributions shown in Figure 3 and restrictions on the number of trucks queuing for each parcel. Figure 5 and Figure 6 show the assumed queuing locations for each parcel. At the Alameda Street parcel, it is assumed up to three bobtail trucks could queue on the parcel with no on-street queuing. At the I Street parcel, up to two tractor-trailers are assumed to queue on I Street where street parking already occurs.

Due to public concern regarding safety, additional traffic, and pollution in the community, the Port is committed to addressing any negative impacts resulting from this conceptual project. Although no emissions will be associated with battery-electric heavy-duty trucks, the Port recognizes the potential safety and traffic congestion concerns. For this reason, a traffic safety study should be conducted if such a project moves forward.

The queuing analysis is dependent on the arrival rate of trucks, but also on the dwell time of each truck during charging. These dwell times were estimated assuming a constant 150 kW charging rate for the time required provide sufficient charge for the truck to return to its inland facility where it could utilize its regular charging infrastructure. The assumption of a 150-kW constant charge rate is considered reasonable because the use of this facility is expected to largely charge within the bulk charge region of the battery (i.e., not charging from a very low state of charge or charging to near 100 percent state of charge). The energy required to be delivered is based on an assumed 2.4 kWh per mile energy consumption and a required one-way trip length using the trip length distributions for trips of 50 miles or more shown in Figure 7.[2] This approach is shown as an equation below.

[2] Analysis of trip distribution assumptions used in the Port's 2019 Emissions Inventory.

$$\text{Dwell Time} = [\text{Miles Needed}] * \left[2.4\ \frac{\text{kWh}}{\text{mi}}\right] * [\frac{1\ \text{hour}}{150\ \text{kW}}]$$

Using this method, a truck requiring 50 miles would receive the necessary charge in 48 minutes. The trip length distributions shown in Figure 7 indicate that most of the inland trips are less than 50 miles away, meaning that only 12% of trucks would need to charge longer than 48 minutes. Based on the queuing space assumptions, trip distribution profiles, and energy demand estimates, the queuing analysis indicates that the potential facility layouts at the two identified parcels could serve 96 percent of charging demand on an average day and 88 percent of charging demand on a peak day.

Figure 4. Conceptual site layout for the public access charging facility

Figure 5. 900 Anaheim Street Parcel with Queuing Locations

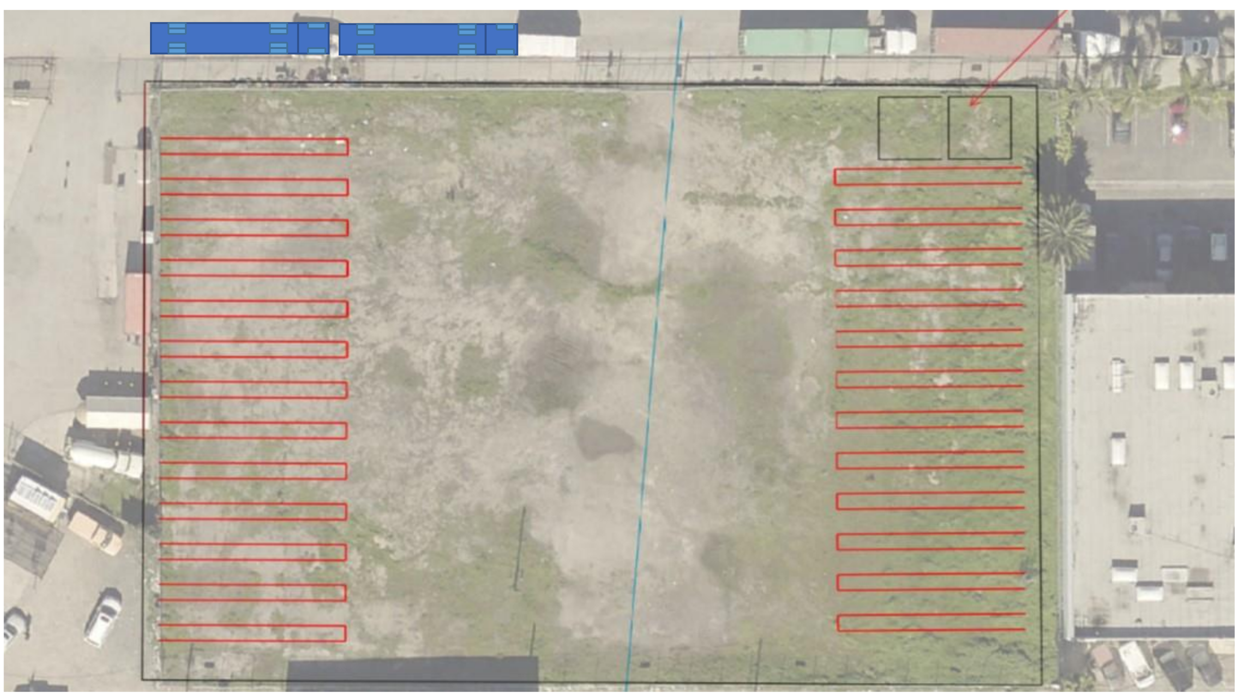

Figure 6. 1480 East I Street Parcel with Queuing Locations

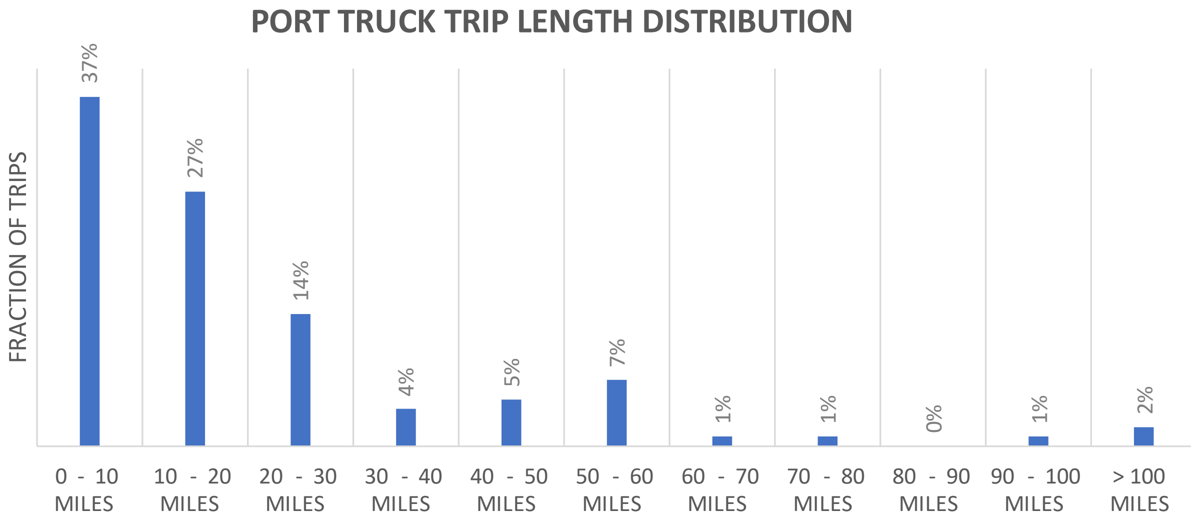

Figure 7. Distribution of Port Truck Trip Lengths

Charging Interface Assumptions

Heavy-duty vehicles in the US currently rely on the Combined Charging System (CCS) interface or manufacturer-specific proprietary interfaces. The North American version of the CCS interface, known as CCS Type 1 or CCS-1, is currently the most commonly used interface for Class 8 battery-electric trucks as manufacturers have moved away from proprietary interfaces. The current version of the CCS standard allows for charging rates of up to 350 kW. Charging rates in excess of approximately 175 kW typically require special liquid cooled cables. These cooled cables also tend to be limited in length, making head-in stall parking of the type assumed in the current site design more difficult to accommodate. Consequently, charging rates of 150 kW, using non-cooled cables, at nominal charging voltages of 750-1,000 volts direct current (VDC) are assumed in the current design. This charging rate is consistent with current Class 8 battery-electric trucks, though the Volvo VNR electric is anticipated to increase its charging rate to 250 kW in the near future.

It is also recognized that a coalition of vehicle and infrastructure manufacturers are currently developing the Mega Charging Standard (MCS) that would define requirements for charging rates of up to 3,000 kW. The timing for commercial release of any truck capable of utilizing the MCS is unknown but anticipated to be at least two years away. Further, no on-road truck utilizing the MCS is expected to support charging rates of 3,000 kW initially. However, the evolving landscape of charging standards and power levels highlights the need for charging facilities to be designed to accommodate future upgrades to new charger/dispenser technologies and higher power levels.

Site Access to Power

The proposed sites do not currently have sufficient installed power capacity to support the conceptual charging infrastructure design. The site is in the vicinity of a 34.5 kilovolts (kV) distribution circuit owned by Los Angeles Department of Water and Power (LADWP). Preliminary estimates for the parcels indicate that the required utility supply could reach 6,000 kW during average or peak days (Figure 8 and Figure 9). Discussions with LADWP indicate that the 34.5 kW circuit should have sufficient power to supply the site. However, LADWP rules effectively limit the maximum power supplied to a single 480V service to 3,750 kW. To meet each parcel's power demand, separate service entrances for each parcel would be required to limit power delivery to 3,750 kW, or the sites would be required to receiving utility supply at 4,160V or higher. Receiving power at higher voltages is technically possible but entails greater footprints for service entrance equipment, transformers, and switchgear, potentially reducing the number of charging stalls at each location. Alternatively, energy storage could be deployed to mitigate peak loads but would still require additional footprint that may reduce the number of charging stalls.

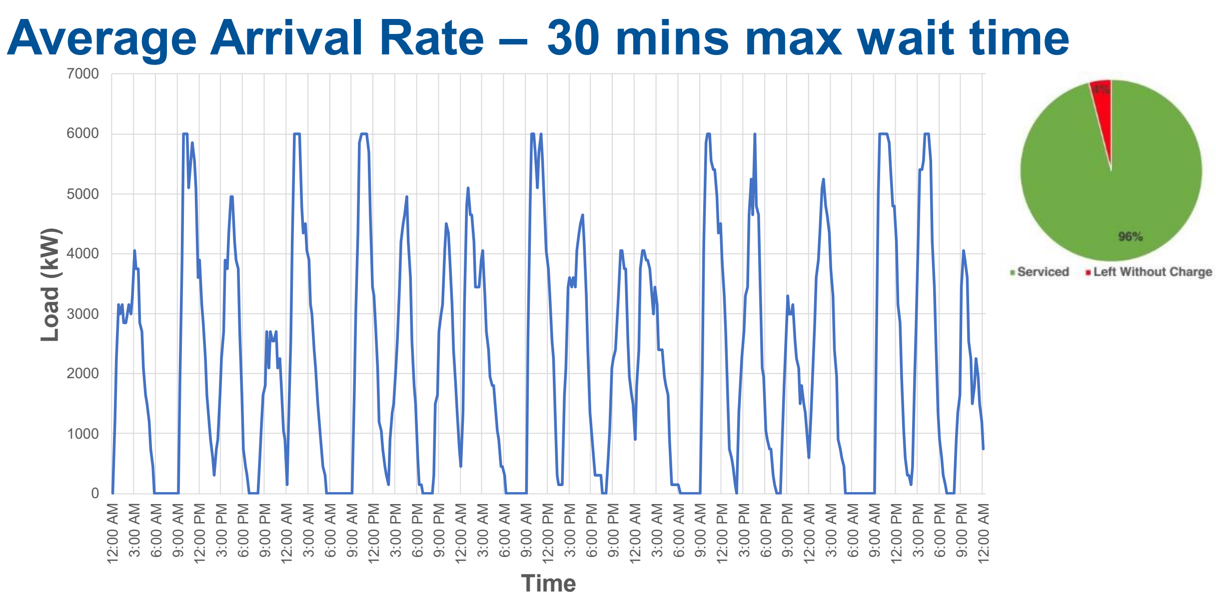

Figure 8. Modeled Aggregate Load Profile and Fraction of Trucks Served – Average Day

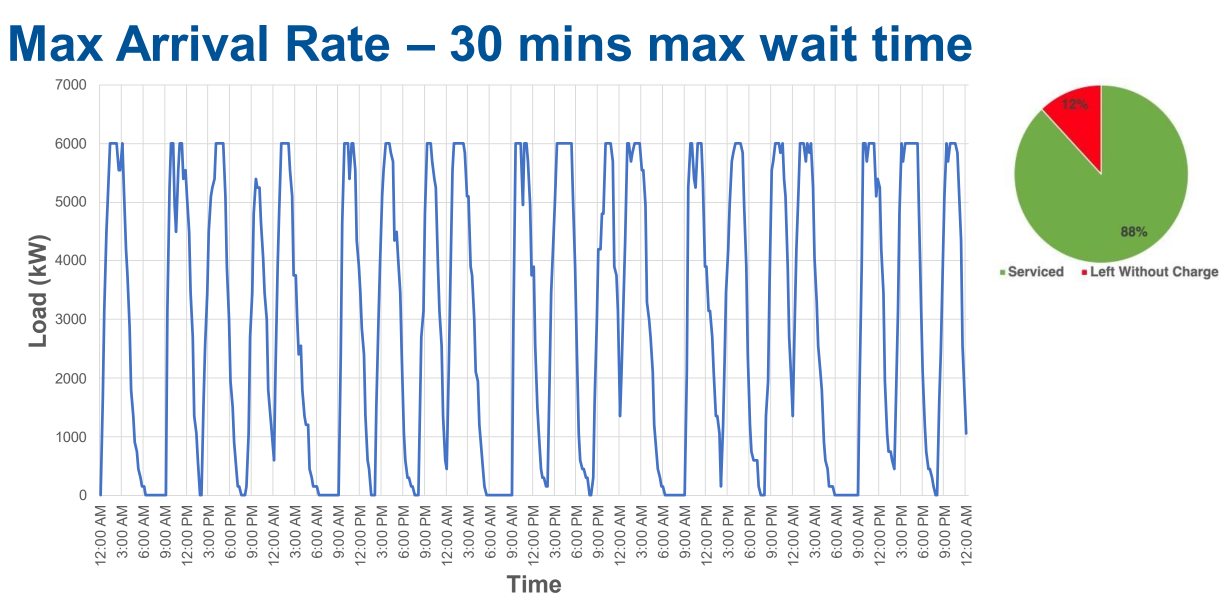

Figure 9. Modeled Aggregate Load Profile and Fraction of Trucks Served – Peak Day

Grid Impacts from the Potential Site

LADWP currently operates utility infrastructure serving 1.5 million residents. In 2020, the system peak load was 6,502 megawatts (MW) and annual average load was approximately 2,400 MW. The peak load of the potential site represents less than 0.1 percent of LADWP's peak load in 2020, consequently the site is not expected to have any significant systemwide impacts. Locally, LADWP anticipates that sufficient power is available from the 34.5 kV distribution system, again indicating that the site will not create significant grid impacts.

Table 1. LADWP System Statistics

Size Indicator	Los Angeles Department of Water and Power[3]
Service Territory (mi^2)	464
Service Population (ppl)	1,500,000
2020 retail sales (MWh)	21,130,000
2020 peak load (MW)	6,502[4]
2020 Capital Projects Budget ($)	1,600,000,000[5]

More broadly, full electrification of the drayage fleet is likely to create significant regional electrical grid impacts. Current estimates by the Ports indicate that much of the daily energy requirements for the drayage fleet would be supplied overnight, with some trucks operating only single shifts and having as much as 14-16 hours available for charging.[6] Based on the weighted average charging rates required for the fleet, it is estimated that total power demand could peak at 2.5 gigawatts (GW) for a 14,000-truck fleet and 3.4 GW for a 19,000-truck fleet. While this is clearly a substantial new electrical load, it only represents about four to 10 percent of the combined peak load of 30 GW in the LADWP and Southern California Edison territories. Additionally, because much of this load is likely to occur predominantly during off-peak periods, EV charging can serve to level the overall demand curves for each utility and potentially reduce costs across the system. Despite these benefits and the relatively small increase in region-wide aggregate load represented by a potential electric drayage fleet, it must also be recognized that these loads would be concentrated in regions where trucks currently park and would create more acute utility infrastructure challenges than if they were spread across utility service territories.

Site Construction Costs and Timelines

The potential site considered in this study represents a type of charging facility that does not currently exist in the United States. Limited examples of public access charging facilities for Class 8 trucks are in operation, including:

- Pier S (Port of Long Beach) – 2 lane, pull through style[7] charging facility.
- Energy Island (Portland, Oregon) – 4 lane, pull through style charging facility with 150-350kW dispensers. Expansion to demonstrate MCS equipment in progress.

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[3] Los Angeles Department of Water & Power, "Briefing Book: 2019-2020", https://www.ladwp.com/cs/idcplg?IdcService=GET_FILE&dDocName=OPLADWPCCB629209&RevisionSelectionMethod=LatestReleased.
[4] This peak was set in 2017. Demand reductions since 2017 have reduced this figure in 2020 but specific values were not readily available.
[5] LADWP reported this amount of its budget dedicated to capital projects.
[6] San Pedro Bay Ports, "Drayage Truck Feasibility Assessment", 2022
[7] Refers to chargers located on a central island between the charging lanes, similar to the configuration of diesel and gasoline pumps seen at traditional fueling stations.

Further, companies such as WattEV are developing sites intended to eventually act as high power, electric "truck stops" providing rapid charging for up to 40 trucks. However, the Port recognizes there are many unknowns and concepts left to be proven out for facilities at this scale. The potential site configuration examined by the Port may need to be augmented by access controls, attendant facilities, signage and point-of-sale systems, and other details not explicitly considered in the current study. Given these caveats, the Port estimates that the minimum construction costs for the site would be $5.8 million, with COVID-related impacts potentially increasing this total by as much as 20%. These costs could be significantly higher should additional site features be required and/or site specific issues arise (e.g., traffic impacts, site remediation, adjacent incompatible uses, etc.). The estimated timeline for design, permitting, and utility supply is two years. Additional one year is anticipated for construction and commissioning of the facility.

Charging Cost Estimates

The average cost of electricity to the site was estimated using the load profiles shown in Figure 8 and Figure 9 under LADWP's applicable commercial A-3 rate. LADWP provides $0.015 per kWh discount for electricity supplied to EV charging and this discount was included in the cost analysis. The resulting cost of electricity for average arrival rates over the year is summarized in Table 2. Total annual costs are $2.63 million and an average cost of $0.187 per kWh.

Table 2. Estimated Electricity Costs under TOU-A3 Tariff

Energy Charges	Demand Charges	Fixed Charges	Total Bill	Energy (kWh)	Average Cost ($/kWh)
$1,474,081	$1,156,320	$900	**$2,631,301**	14,102,513	**$0.187**

The cost of electricity is assumed to be the dominant operating cost. Equipment maintenance costs, attendant salaries, point of sale charges, and other costs would add to the total operating cost of the facility. However, as these costs are not well known for first of its kind facility such as the one considered in this study, only electricity costs are considered. In addition to operating costs, capital recovery must be considered. Assuming a 10-year recovery period and a discount rate of 3 percent, capital recovery adds approximately $0.036 per kWh to the delivered cost of electricity, resulting in an estimated cost of $0.22 per kWh. Construction costs are not well known at this point and could be significantly underestimated, but would likely place the delivered cost of charging in the range of $0.22 to $0.30 per kWh. These costs do not include profit or savings for future system upgrades or equipment replacements. It is noteworthy that these costs are not significantly lower than pricing charged by commercial network operators like Electrify America ($0.31 per kWh at the time of this report) and may suggest that such facilities could most efficiently be constructed and operated by established network operators.

Summary

The Port's established goal of zero-emission drayage by 2035 will require extensive investments in zero-emission charging infrastructure in Southern California. While the majority of charging is likely to occur overnight at fleet facilities and at retail charging stations, there is a potential benefit to a limited use, public access station in or near the Port that serves to support inland trip destinations. Specifically, the facility would be intended to provide sufficient supplemental charging to allow a truck to return to an inland facility or retail charging location where routine charging could occur. The estimated charging needs estimated in this study to support inland trips is well matched to the potential site configuration proposed at the two parcels located at 900 Alameda Street and 1480 East I Street in Wilmington. Charging capacity met 96 percent of estimated charging demand on an average day and 88 percent of demand on a peak day using a total of forty 150 kW chargers using a CCS-1 interface. While charging standards and truck designs are likely to significantly increase charging speeds, such increases at the site do not appear necessary to support inland trips for the current fleet, as 87% of trucks would require fewer than 48 minutes of charging to reach their destination under this charging configuration.

Current utility circuits near the site appear to have sufficient power to support the projected power demands. However, the delivery of electricity to each parcel will be limited to 3,750 kW at 480V, placing an upper limit on the site power of 7,500 kW. Higher power levels could be delivered to each parcel using higher delivery voltages of 4,160V or greater, but receiving power at these levels will likely entail reductions in the number of charging stalls to accommodate additional medium voltage equipment. Higher power levels are not currently anticipated to be required unless the peak charging rates supported at the site are increased above approximately 150 kW.

The delivered cost of electricity is estimated at $0.22 per kWh but this pricing is based on high level cost estimates that could be significantly underestimated. Because this facility would be the first of its kind in the United States, it is difficult to provide more precise estimates without extensive site design efforts. Consequently, a range of $0.22 to $0.30 per kWh is considered more likely and would be similar to some commercial charging network operators, suggesting that a commercially developed facility could be a viable or even preferable option.