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CLEAN TRANSPORTATION & ENERGY CONSULTANTS

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TO: Michelle Kinman, Los Angeles Cleantech Incubator (LACI)
FROM: Eleanor Johnstone, Senior Associate; Jason Greenblatt, Senior Project Manager; Patrick Couch, Vice President
SUBJECT: Cost estimate for Class 8 truck charging along the I-710 corridor

LACI is working with a variety of stakeholders to advance zero emissions (ZE) transportation in Southern California. To support its current review of project opportunities in the region, LACI asked GNA to estimate the quantity and cost of charging stations – both in-depot and at centralized fast charging hubs – required to support the energy needs of an all-battery electric vehicle (BEV) Class 8 truck fleet operating along the I-710 corridor and serving the San Pedro Bay Ports (SPBP). Several time- and cost- intensive studies have assessed the implications of electrifying the I-710 corridor in recent years; GNA's task was to provide a high-level estimate drawing on the most recent vehicle and truck operational data publicly available. Accordingly, this assessment provides a high-level estimate of key figures to consider – and refine further – when exploring electrification along the I-710 corridor.

As a result of this analysis, GNA estimates that meeting today's active Class 8 truck energy requirements with electricity would require the installation of approximately 12,000 low- and high- power DC fast chargers in public and private depot locations, at an equipment-only cost of between $722MM and $768MM. Utility infrastructure costs, electricity costs, and labor costs were not considered in this estimate. This memorandum describes the assumptions and methodology used to complete this task, and offers observations for how these results may inform LACI's work on transportation electrification.

I. Sources & Assumptions

Three reports have been published in the last ten years assessing the traffic patterns and fueling requirements along the I-710 corridor, as well as the vehicle and charging technology for heavy-duty BEVs (HD BEV) (Table 1). A fourth report assessing similar parameters for the SPBP drayage truck fleet was published in 2019. GNA reviewed these reports to identify the most recent, robust data points on traffic patterns, vehicle performance, fleet operations, and charging rates. The reports from CALSTART (2013) and Metro (2009) provided valuable context on historical fleet operations and traffic patterns, providing supportive context for the more recent data available in Ramboll's traffic study (2017) and SPBP's feasibility study (2019). To avoid errors of mixing and matching data sources from diverse study, GNA drew heavily on the data and findings of SPBP's report for the bulk of this estimate.

Table 1: Sources for Data and Assumptions

Study Name	Study Agency	Year Published
San Pedro Bay Ports Clean Air Action Plan: 2018 Feasibility Assessment for Drayage Trucks	SPBP, Tetra Tech/GNA	2019
I-710 Freight Corridor Traffic Study	Ramboll	2017 (2014 data year)
Key Performance Parameters for Drayage Trucks Operating at the Ports of Los Angeles and Long Beach	Los Angeles County Metropolitan Transportation Authority; Gateway Cities; CALSTART	2013
I-710 Corridor Project Environmental Impact Report	Los Angeles County Metropolitan Transportation Authority; URS	2009

To estimate today's total truck volume and truck volume by corridor segment, GNA updated Ramboll's 2014 traffic estimates in four segments of the I-710 using recent truck registration data. Ramboll's study calculated an active fleet of 9,800 port and transload trucks on the I-710 corridor in 2014 (Ramboll's estimates for domestic truck traffic was not included due to irrelevancy to scope). In 2014, the number of heavy-duty trucks registered in the San Pedro Bay Ports Drayage Truck Registry was 13,000. In 2018, the number of registered trucks in the San Pedro Bay Ports Drayage Truck Registry was 18,000 but the number of active trucks was estimated to be approximately 12,000. GNA calculated a 22% increase in the number of total active trucks since 2014, and applied this increase to Ramboll's segment-specific truck volume estimate for a total active fleet of 12,000.

The following assumptions of truck behavior and HD BEV performance were taken from the SPBP study, and are used to inform the methodology and results in the following section.

Table 2: Assumptions applied in Corridor Cost Estimate

Assumption	Unit	Value
Average Daily Miles (Single Shift)	Miles	160
Energy per Mile	kWh/miles	2.1
Average Single Shift Duration	Hours	9.5
Class 8 BEV battery capacity	kWh	450
Maximum DC Fast Charge Rate	kW	300
High-power DC Fast Charge Rate	kW	150
Low-power DC Fast Charge Rate	kW	25
Percentage of Fleet on Single Shift Schedule	%	48%
Percentage of Fleet on Double Shift Schedule	%	52%
Percentage of Fleet Fueling On-Site	%	42%
Maximum power DC Fast Charger Station Cost	$/single port	$150,000
High-power DC Fast Charger Station Cost	$/single port	$100,000
Low-power DC Fast Charger Station Cost	$/single port	$25,000
Electricity Price for Average Double Shift Truck's Charging Session	$/kWh	$0.14
Electricity Price for Average Single Shift Truck's Charging Session	$/kWh	$0.12
Electricity Price for Max Power Charging Session	$/kWh	$0.26

II. Method & Results

Traffic and Energy Distribution

Ramboll found that the average Class 8 truck makes two round-trips on the I-710 per day, with the greatest number of trips occurring in the southern portion of the corridor (Table 3). The corridor is relatively short (17 miles), and GNA assumes that the average truck (regardless of shift count) travels 240 miles per day. Using the trip lengths and frequency calculated by Ramboll for each corridor, GNA calculated the daily mileage and associated energy requirement of average trucks serving these routes (Table 3).

Table 3: Corridor traffic by segment and average truck mileage and energy consumption

	Port Truck Traffic		Transload Traffic (HD)	
	Pico/Washington	*Pico/State Route 91*	*Pico/Washington*	*Del Amo/Washington*
Round Trips/Day	12,245	6,122	1,959	3,673
Trucks/Day	6,122	3,061	980	1,837
Daily Miles/Truck: On-corridor	68	32	68	44
Daily kWh/Truck: On-corridor	143	67	143	92
Daily Miles/Truck: Off-corridor	172	208	172	196
Daily kWh/Truck: Off-corridor	361	437	361	412

The average truck estimate was developed as a general indicator for the average truck in a fleet. At a more granular level, truck mileage depends on its shift schedule, with trucks serving either one- or two- 160 mile shifts per day. The SPBP study's assumption of 2.1 kWh per mile indicates that a HD BEV requires at least 336 kWh to complete one shift, and 672 kWh to complete two shifts. These shift requirements are applied in this corridor cost estimate.

Charging Windows and Power Ratings

Based on the data represented in Tables 1 and 2, GNA disaggregated the fleet of 12,000 trucks by fueling location (private on-depot or public off-depot), and then by shifts per day (single or double) (Table 4). This informed an estimate of charging windows per truck type. A single shift lasts approximately nine hours, leaving approximately 15 consecutive hours available for charging in a 24-hour period. A double-shift truck has a charging window of approximately five hours, which may be divided between its two nine-hour shifts.

Table 4: Corridor charging station requirement

	Public Off-Depot DCFC Stations	Private On-Depot Stations
No. Single-Shift Trucks	3,341	2,419
No. Double-Shift Trucks	3,619	2,621
Hours required to re-charge – Maximum DCFC rate	1.5 hours	
Hours required to re-charge – High-power DCFC rate	3 hours	
Double-Shift Truck Charging Window	5 hours	
Hours required to re-charge – Low-power DCFC rate	13 hours	
Single-Shift Truck Charging Window	15 hours	

Using the average charging rates indicated in Table 2, GNA estimated the number of trucks that could be served by a single charging port, at various charging rates, during the charging windows. These charging rates were selected according to several criteria. First, in keeping with findings of the SPBP study that the majority of HD BEV needs can be met with a variety of charging rates below 300 kW, GNA applied a lower-powered DC Fast Charge (DCFC) rate of 25 kW to the single-shift trucks, and a higher-powered rating of 150 kW to the double-shift trucks. The benefits of low-power DC charging include reduced stress on the battery for an optimized life cycle, reduce demand fees and electricity costs, and lower cost charging equipment and infrastructure. Second, GNA selected power ratings that are considered to be both operationally feasible and commercially available. Third, to accommodate the likely need for "spot" charging at public charging hubs, or charging in a critical situation to complete a shift, GNA incorporated a 300 kW maximum DCFC option. Finally, due to the fact that manufacturers are not installing Level 2 chargers on their Class 8 trucks, this level of charging was not considered.

Charger Quantities and Distribution

For this high-level estimate, GNA assumed that all trucks will follow their current standard shift schedule, and therefore will require fueling at the same time of day. At both the 25 kW and 150 kW charging rates, both on- and off- depot charging locations would require a 1:1 ratio of trucks to chargers in a charging window in order to meet current operational requirements. If 300 kW chargers were available, the ratio would increase to approximately 3:1.

These estimates allow for trucks to meet their shift requirements after a charging session, but they do not guarantee that all trucks will reach a complete charge in a single session. A truck's single-shift energy requirement (336 kWh) can be met by the maximum HD BEV battery capacity currently advertised by manufacturers (450 kWh), but if depleted that battery cannot be fully charged within the single-shift truck's 15-hour charging window at a rate of 25 kW. It can, however, be sufficiently charged (80%, or 360 kWh) to complete its shift. Double-shift truck requirements (672 kWh) exceed the battery capacity limit by approximately 30%, but can be fully charged in less than their five-hour charging window using a 150 kW charger. Accordingly, double-shift trucks require high-power charging opportunities en-route or between shifts.

Based on the charging windows and shift energy requirements previously identified, GNA determined that on- and off- depot charging stations require one charger per active single-shift truck. Double-shift trucks would require one 150 kW DCFC station per truck, due to the fact that two trucks cannot fully charge at one station in a five-hour window. Instead, these chargers would likely have some idle time during that five-hour window, once charging is complete in approximately three hours. Use of the maximum charging rate of 300 kW would allow for stations to procure one charger to serve three trucks over a five-hour charging window. GNA estimates that the greatest need for 300 kW charging will be at public depots en-route, where large amounts of power are most likely to be required in short periods of time, potentially during a shift. Additionally, public charging depots will benefit the most from rapid turnover at their charging stations.

Charger Quantity and Cost Estimates

Using the industry estimates for charging station equipment costs listed in Table 2, GNA estimated two corridor equipment and cost scenarios in response to LACI's request (Table 5). These cost estimates assume that trucks follow the same standard shift schedules, and therefore require charging during the same charging windows in a 24-hour period.

In the first scenario, Private On-Depot stations use 2,419 low-power fast chargers for single-shift trucks overnight, and 2,621 high-power fast chargers for double-shift trucks. Public Off-Depot use 3,341 low-power chargers and 3,619 high-power chargers. This yields a total equipment cost of $768,000,000.

In the second scenario, Private On-Depot stations use the same mix of chargers as in the first scenario. Public Off-Depot stations use the same number of low-power DCFC stations for single-shift trucks, but meet the demand for 25% of the double-shift truck fleet with 302 maximum power chargers, and the remaining 75% with 2,714 high-power chargers. While speculative due to lack of available data, this 25%/75% divide is used to illustrate the possible impact of providing spot charging for priority trucking needs. This yields a total equipment cost of $722,760,000.

Table 5: Charging Scenarios and Costs

Scenario 1 - Low/High All Sites		
	No. Chargers	*Charger Cost*
Private - Single Shift (25 kW)	2,419	$ 60,480,000
Private - Double Shift (150 kW)	2,621	$ 262,080,000
Public - Single Shift (25 kW)	3,341	$ 83,520,000
Public - Double Shift (150 kW)	3,619	$ 361,920,000
Public – Double Shift (300 kW)	0	0
Total	**12,000**	**$ 768,000,000**
Scenario 2 - Low/High All Sites + Max Public		
Truck Profile	*No. Chargers*	*Charger Cost*
Private - Single Shift (25 kW)	2,419	$ 60,480,000
Private - Double Shift (150 kW)	2,621	$ 262,080,000
Public - Single Shift (25 kW)	3,341	$ 83,520,000
Public - Double Shift (150 kW)	2,714	$ 271,440,000
Public - Double Shift (300 kW)	302	$ 45,240,000
Total	**11,397**	**$ 722,760,000**

While these estimates only reflect charger equipment costs, SPBPS's 2019 study determined that the cost to install a single charger port is approximately equal to the cost of the equipment itself (SPBP, page 92). Based on this finding, and in the absence of more concrete market data, GNA estimates that the cost to electrify the I-710 corridor for heavy-duty truck charging needs is approximately $1.5 Bn.

III. Discussion and Recommendations

GNA identified several insights which provide important context for the costs provided in this estimate, and may prove valuable to LACI's endeavors to accelerate ZE truck adoption in Southern California. Further consideration after this project may focus on which subsets of this fleet can be transitioned to electric the soonest and with what methodology.

First, GNA observed that the majority of an average Class 8 truck's energy consumption occurs off of the I-710 (Figure 1). This suggests that further studies defining charging station distribution should consider the traffic patterns along arterial routes, and the impact of charging stations on traffic patterns in these areas. For example, GNA observed that while all trip cycles overlap in the Del Amo – State Route 91 section of the corridor, the majority of trips start and end in the Pico area. Meanwhile, a minority travel to the northern intersection with Route 5, near Washington Avenue.[1] This suggests that as private on-depot fueling stations are constructed at the main corridor terminals of Pico and Del Amo, public DCFC hubs would be most serviceable on either side of the State Route 91 intersection, where trucks routinely enter and return from arterial roads, and further up the corridor where fewer private depots are likely to be located. Siting these stations slightly farther away from high-density intersections can also help to smooth congestion.

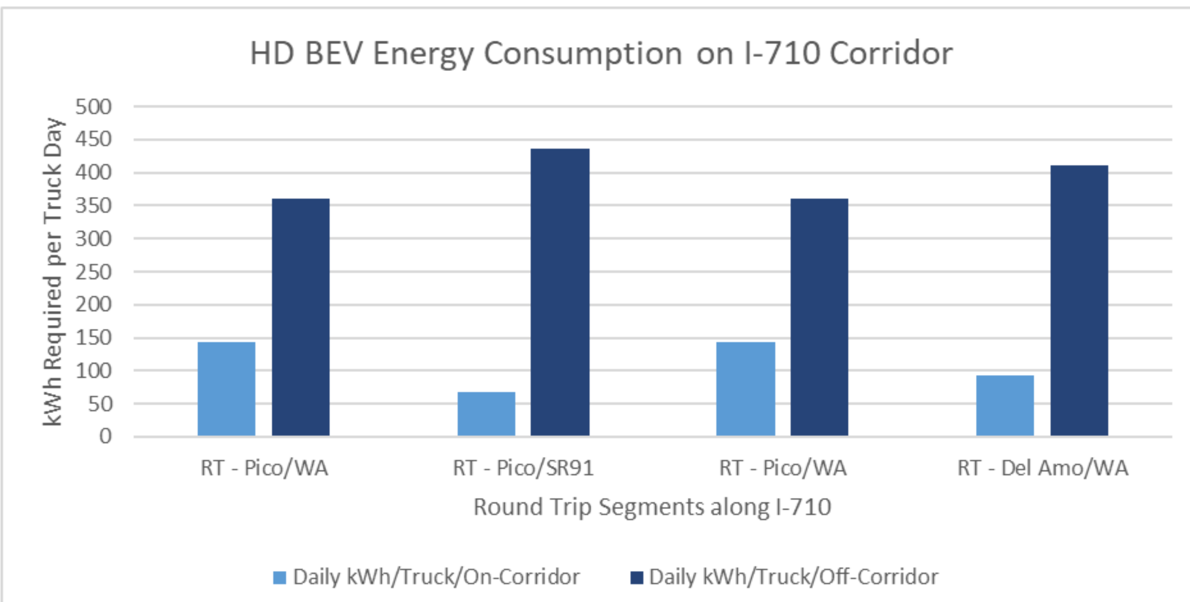

Figure 1: Average truck energy use on and off of the I-710 Corridor

Second, the truck-to-station ratios and charging windows identified indicates that public fast charging hubs will have significant spatial requirements. This is an important factor in site selection, as is the additional consideration of truck queuing and turn radius. With wait times up to three hours at public DCFC hubs, LACI's stakeholders may also consider spatial requirements for driver rest and entertainment

[1] Table 2.2 – Existing Truck Volumes on I-710 (2005). http://media.metro.net/projects_studies/I710/images/710_dr_mmr.pdf

during charging windows. Admittedly, the truck-to-charger ratios identified reflect the worst-case scenario where truck charging shifts are not staggered. Under a staggered schedule, charging stations – particularly the 150 kW stations - could be used by multiple trucks over a 24-hour period.

Third, although the cost of the second scenario is lower than the cost of the first scenario, it is crucial to keep in mind that this estimate does not incorporate higher electricity fees, demand charges, or infrastructure requirements which tend to be significantly higher for 300 kW charging stations. Using the average electricity prices listed in Table 2, the electricity costs for double-shift charging at Public Off-Depot locations in Scenario 2 is estimated to cost approximately $151MM, nearly three times as much as in Scenario 1 (approximately $58MM). The implication is that fleets will have to pay more for this spot charging, which may result in lower use and longer paybacks on the charging equipment. Similarly, the cost of maintaining the liquid cooling systems required by these charging stations is not considered.

Finally, high-powered charging (both 150 kW and 300 kW) would likely incur higher labor costs for dis/connect operations, due to the higher frequency of truck dis/connections per day per their shorter charging windows.

This estimate, and associated findings outlined in this section, recommend a few courses of action for LACI and its stakeholders.

- Facilitate stakeholder dialogue over land use strategies that optimize spaces for high-powered publicly-accessible charging, considering the human elements of labor and driver needs while on-site, without introducing inefficiencies to the area's traffic pattern.
- Identify land use restrictions that could prohibit the development of high-powered charging depots at key locations that are also serviceable to drivers' needs during what are effectively extended fueling breaks.
- Work with utilities, manufacturers, fleets, and fueling station operators to define the power rates and associated prices for fast charging at public stations, and the factors that may cause these prices to increase or decrease.