SANDAG

Medium & Heavy-Duty Zero Emission Vehicle Blueprint

May 2023

MD/HD ZEV Technology & Siting Criteria

ABSTRACT

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EXECUTIVE SUMMARY

Successful adoption and operation of medium- and heavy-duty (MD-HD) zero emission vehicles (ZEV) in the San Diego region will require a robust plan for developing the charging and hydrogen fueling infrastructure necessary to support these vehicles. Equally important, fleet operators need technology criteria, such as range, cost, and power capability of various MD-HD ZEVs to assist them with making purchasing decisions for replacing their fleets with ZEV. This report is separated into two parts: 1) siting criteria for charging and hydrogen fueling infrastructure, and 2) technology criteria for fleets.

In this report, the project team conducted research to highlight some of the key criteria that regional planners and infrastructure developers should consider when siting the MD-HD EV charging and hydrogen fueling infrastructure. The project team identified five broad groups of siting criteria: utilization, land, equity, grid capacity and environmental conditions, and specified sub-criteria to consider within each. The first criterion is ***Utilization***, referring to the demand for charging or hydrogen fueling. This refers to how much the station is used, an indication of the station's financial viability. For instance, low utilization can lead to poor Return on Investment (ROI) and affect the station's economic viability. Therefore, it is important to estimate the demand for charging and fueling to maximize utilization. This involves considering the type of vehicles operating in the area, their origins and destinations, travel patterns, routes, rest/layover locations, parking duration, etc. There may be opportunities to increase utilization by accommodating multiple vehicle types at sites with known parking space availability. Mixed use charging and fueling diversifies the user portfolio and can sustain a viable business model to accommodate many people.

The second criterion is ***Land***, encompassing the availability of suitable sites for charging/fueling stations and compatibility with surrounding land uses.

ZEV Infrastructure Siting Criteria

- **Utilization (Potential Demand)**
  - Vehicle volume (i.e., proximity to major routes)
  - Origin/Destination
  - Dwelling time
- **Land**
  - Land space
  - Existing Parking Facility
  - Land use/zoning
  - Land price
  - Access, Congestion & Safety
  - Amenities
  - Scalability
  - Proximity to other ZEV infrastructure
  - Proximity to hydrogen supply chain
- **Equity**
  - Distance to DACs
  - Direct Benefit to DACs
- **Grid Capacity**
  - Capacity/Upgrade/Scalability
  - Ability to Integrate DER
- **Site Specific Environmental Conditions**
  - Flood Risk
  - CEQA/NEPA
  - Soil Contamination/Brownfields

Land value, ownership, demand, and community impacts such as safety and congestion must also be evaluated. Station development has been identified as one of the most critical needs for fleet operators, and it is also one of the most difficult elements to implement due to land costs, community concerns, and the entitlement process. The project team identified land development and land use criteria that planners/developers should consider.

The third criterion is ***Equity***, designed to ensure that the deployment of charging and fueling infrastructure does not adversely impact disadvantaged communities (DACs). Furthermore, it is important that DACs derive both immediate and enduring benefits from such initiatives. Here, immediate benefits imply a net positive enhancement to quality of life and environmental justice due to the adoption of ZEVs. The concept of Equity encompasses replacing existing internal combustion engine (ICE) vehicles currently in use within DACs with ZEVs, not simply installing charging stations within these communities.

The fourth criterion for ZEV infrastructure siting is ***Grid Capacity***. Considering that MD-HD vehicles have higher energy needs, high-power charging stations (often greater than 150 kW) will be required to support these vehicles. Development of charging stations for MD-HD vehicles is often limited by the availability of grid interconnection and capacity. In addition to charging, on-site clean hydrogen production also poses significant power demand. Close coordination with the utility provider, primarily SDG&E in the San Diego region, is necessary to confirm power availability and identify grid infrastructure investments that may be needed to support charging/hydrogen fueling station development. Additionally, integrating distributed energy resources (DER) into the station development is recommended to ensure MD-HD ZEV infrastructure resiliency and to avoid costly grid upgrades.

The fifth and final recommended criterion is ***Environmental***. This criterion considers potential environmental conditions that could impact construction or operations of a charging/hydrogen fueling station. It also considers potential environmental impacts that the station could pose on the community. On the station development side, conditions of the site, such as flood risk, land cover, and soil contamination should be considered. This report recommends various data sources and methods that could be leveraged to quantify each criterion and recommends an evaluation framework that could be used to facilitate site selection decision making.

As part of this work, the project team also proposed an infrastructure siting analysis framework based on Multi-Criteria Decision Analysis (MCDA) to identify the optimal locations for charging and fueling infrastructure. The MCDA methodology involves assigning weights to each of the siting criteria based on their importance and then calculating the overall weighted average score for each site. The proposed methodology enables respondents to emphasize or dismiss the relevance of a criterion by assigning it a weight.

The second part of this report provides fleet technical assistance for fleet owners/operators to inspire confidence in new MD-HD ZEV investments. Specifically, this report provides information on the following vehicle technology criteria:

- ***Range***: Can the replacement MD-HD ZEV meet the daily mileage demand?
- ***Payload Capacity***: Can the ZE vehicle carry the same amount of payload?
- ***Cost of Ownership***: What is the life cycle cost (capital and operations/maintenance)?
- ***Charging Acceptance Rate***: How fast does the vehicle need to be charged? Can the vehicle accept the charging power needed?
- **Charging/fueling frequency**: How long and how frequently do the ZE vehicles need to be recharged or refueled? How does this differ from the current fleet? (Additional time to charge may add labor costs and impact Cost of Ownership category.)
- ***Power Take Off (PTO)***: A power take off (PTO) is a mechanical device that is used to transfer power from a power source, such as an engine or motor, to an external application. PTOs are commonly used in commercial and industrial settings to drive equipment such as pumps or generators. A common example of a vehicle with PTO is a bucket truck, to move operators and tools using the boom arm. With respect to the fleet, if there are currently any vehicles in the fleet that rely on PTO, this criterion will determine whether the replacement ZEV must have equivalent PTO capabilities or not.
- **Access to charging and fueling infrastructure**. Fleets need to consider the availability of both depot and public charging/fueling infrastructure to ensure they can fully charge/fuel their vehicles to meet the demands of their duty cycles.

The report also presents an example decision tree as a structured approach for a fleet to make a choice on selecting proper ZE MD-HD vehicle models for their fleet. This decision tree helps to organize and weigh various factors, such as vehicle use, charging/fueling infrastructure, payload restrictions, and more.

The primary aim of this report is to function as a valuable resource for a diverse array of stakeholders, including site developers, regional planners, fleet owners, commercial operators, and community leaders. The in-depth guidelines enclosed in this document are born out of rigorous research and analysis of the factors that should be evaluated when setting up a ZEV infrastructure or when converting a fleet to ZEV. These guidelines are devised with the intention to guide the successful introduction and implementation of ZE MD-HD vehicles and their corresponding charging or refueling infrastructure throughout the region.

1. INTRODUCTION

Despite the growing availability of zero emissions (ZE) medium- and heavy-duty (MD-HD) vehicles, the lack of charging and fueling infrastructure is one of the significant barriers to adoption of these vehicles. MD-HD electric vehicles use two primary charging models: depot charging and en-route charging. The return to base duty cycles (e.g., delivery vehicles) often utilize depot charging, whereas long-haul trucking requires opportunity charging or en-route opportunity charging. To clarify, for the purposes of this report, opportunity charging occurs during stationary periods when the vehicle is parked, characterized by longer charging times at central locations, while en-route charging takes place over shorter times at decentralized locations. Depending on the type of MD-HD vehicles, the chargers can be located at the central home base (warehouse, distribution center, or headquarters), the customer's site for return-to-base vehicles with long routes to charge while unloading, or on major freight corridors using public charging infrastructure.

Similarly, battery electric buses can be charged along routes while in service (en-route charging) or while parked (often overnight) at a depot. En-route opportunity charging tends to be more expensive and logistically challenging, requiring fast chargers and the acquisition of land or rights of way. According to study conducted by Atlas EV Hub[1], the consensus among experts is to charge as much as possible at depots and only use en-route opportunity charging for longer routes or for short circulator routes where continuous service is needed. Depot charging is seen as the "low-hanging fruit" before tackling more challenging on-route charging. However, en-route opportunity charging could be beneficial for agencies with limited space at depots and it creates a more resilient charging ecosystem due to decentralization.

There are only limited options for the location of depot charging and the utilization of these chargers could significantly vary depending on the duty cycle and dwelling time of vehicles within that fleet. However, this is not necessarily the case for public charging infrastructure (i.e., en-route opportunity charging) and therefore proper siting of these chargers could play a very important role in the economics of these stations. Aside from battery-powered electric MD-HD vehicles, which rely on charging infrastructure, MD-HD ZEVs are also expected to increasingly rely on hydrogen fuel cell electric vehicle (FCEV) technology, meaning regions should consider hydrogen fueling infrastructure development at the same time they are working on their charging infrastructure network. Additionally, transitioning to ZE technology is a new experience for most fleets who for decades have been relying on diesel vehicles. Establishing guidelines and technology selection criteria is key for fleets to confidently enter

[1] https://atlaspolicy.com/wp-content/uploads/2022/05/Deploying-Charging-Infrastructure-for-Electric-Transit-Buses.pdf

the ZE market space and pick the type of ZE technology that will serve their needs. This report is intended to identify technology and infrastructure siting criteria that can be used to support the transition of MD-HD fleets in the San Diego region to ZE technologies.

The project team conducted research on the type of criteria that could be used by MD-HD ZEV infrastructure planners and developers to determine appropriate sites for deployment of charging and fueling infrastructure. For example, recommendations for charging and fueling site deployment should be informed by utilization, or how effectively the infrastructure within those sites could be utilized by ZE MD-HD vehicles. Other factors, such as equity, consider the possible socio-economic benefits or repercussions of infrastructure deployment, especially within disadvantaged communities[2]. The project team also proposed an infrastructure siting analysis framework, using siting criteria as decision factors. The infrastructure siting analysis framework will help guide public agencies and private developers into establishing their greatest priorities surrounding MD-HD ZEVs and accompanying infrastructure.

Upon determining the appropriate siting criteria, the project team proposed vehicle technology criteria for fleets, based on expected needs and lessons learned within other demonstrations. These guidelines can be curated for fleet owners operating in the San Diego region, informed by various fleet electrification studies and attention to unique fleet operation characteristics.

[2] Disadvantaged communities in this context are defined as regions which most suffer from a combination of social, economic, health and environmental burdens. These burdens include poverty, social exclusion, discrimination, violence, air or water pollution, presence of hazardous waste, as well as high incidences of asthma or heart disease.

2. ZEV INFRASTRUCTURE SITING CRITERIA

The project team investigated best practices for determining the appropriate siting criteria for charging and fueling infrastructure to support the transition to ZE MD-HD vehicles. Information collected previously during development of the Regional MD-HD ZEV Needs Assessment informed the criteria research through its outcomes on San Diego's planning efforts and regional infrastructure needs. Determining factors include MD-HD vehicle travel patterns, grid interconnection/capacity, land use, environmental conditions, and equity. The motivation behind establishing these siting criteria is to streamline informed decision making for locations of charging and fueling infrastructure. ZEV infrastructure, as is, implicates significant costs that fleet and site owners will have to bear; planning for ZEV infrastructure deployment requires methodical site assessments to maximize return on investment (ROI) and minimize social or environmental harm. At the same time, each site that is deemed eligible for charging or fueling infrastructure will have unique needs or challenges to overcome. These priorities may be interpreted differently by planners and developers. Aligning the perspectives of everyone involved is necessary to guide the decision making process for the most optimal ZEV infrastructure locations.

These guidelines provide criteria for determining the appropriate charging and fueling sites for both buses and trucks. It is worth mentioning, however, that there are considerable differences between these two sectors of MD-HD vehicles, as they fall under different vehicle market segmentations. For example, transit agencies looking into electric bus deployments face challenges with plug-in charger management. To overcome these challenges, some of these agencies are turning to inverted pantograph dispensers for charging. These dispensers simplify the charging process and eliminate cord management issues. However, they are more expensive, require more structural support, and have less reliable communication compared to plug-in chargers. Another option that some agencies are exploring is the use of wireless inductive charging, which offers benefits like ease of use and aesthetic appeal, but is still a nascent technology, with high capital costs. On the other hand, MD-HD trucks are expected to mainly use plug-in chargers, and it is unlikely that OEMs will develop MD-HD trucks that can use wireless inductive charging used by electric buses. As a result, even if a site meets the criteria for both transit and truck charging, the fundamental differences may not allow shared use of chargers.

The project team evaluated siting criteria that could be used to determine the site with maximum feasible utility of charging and fueling stations based on location. Because MD-HD battery electric vehicles (BEV) and FCEVs are distinct technologies, different approaches are recommended to identify charging and fueling infrastructure locations. In the trucking industry, fueling times unavoidably impact revenue generation time, so it is important that charging and fueling do not significantly increase average scheduled vehicle downtime. The same principle applies to transit agencies. The bus routes are designed for the most efficient passenger transportation through the region. To the extent possible, transit agencies prefer to minimize the downtime resulting from vehicle charging, and instead utilize the existing downtime (e.g., time between routes) for charging. Therefore, to maximize the utility of a station, the project team proposed several criteria including the MD-HD traffic volume near the site, the need for charging (e.g., do trucks and buses stop at that location after completing a long trip?), and most importantly, the typical dwelling time in those locations.

Grid capacity is another important factor. Charging infrastructure is routinely limited by the lowest-capacity component within a site's electric grid system. Charging infrastructure deployment costs can balloon rapidly if grid interconnection or capacity are not accounted for ahead of time. Additionally, improving site capacity in advance acts as a futureproofing measure, granting flexibility to site owners who may wish to upgrade to higher-power chargers. To this end, the project team recommended how to leverage publicly available data on the region's distribution system capacity and how to coordinate with facilities to establish high-power public charging networks along major freight corridors.

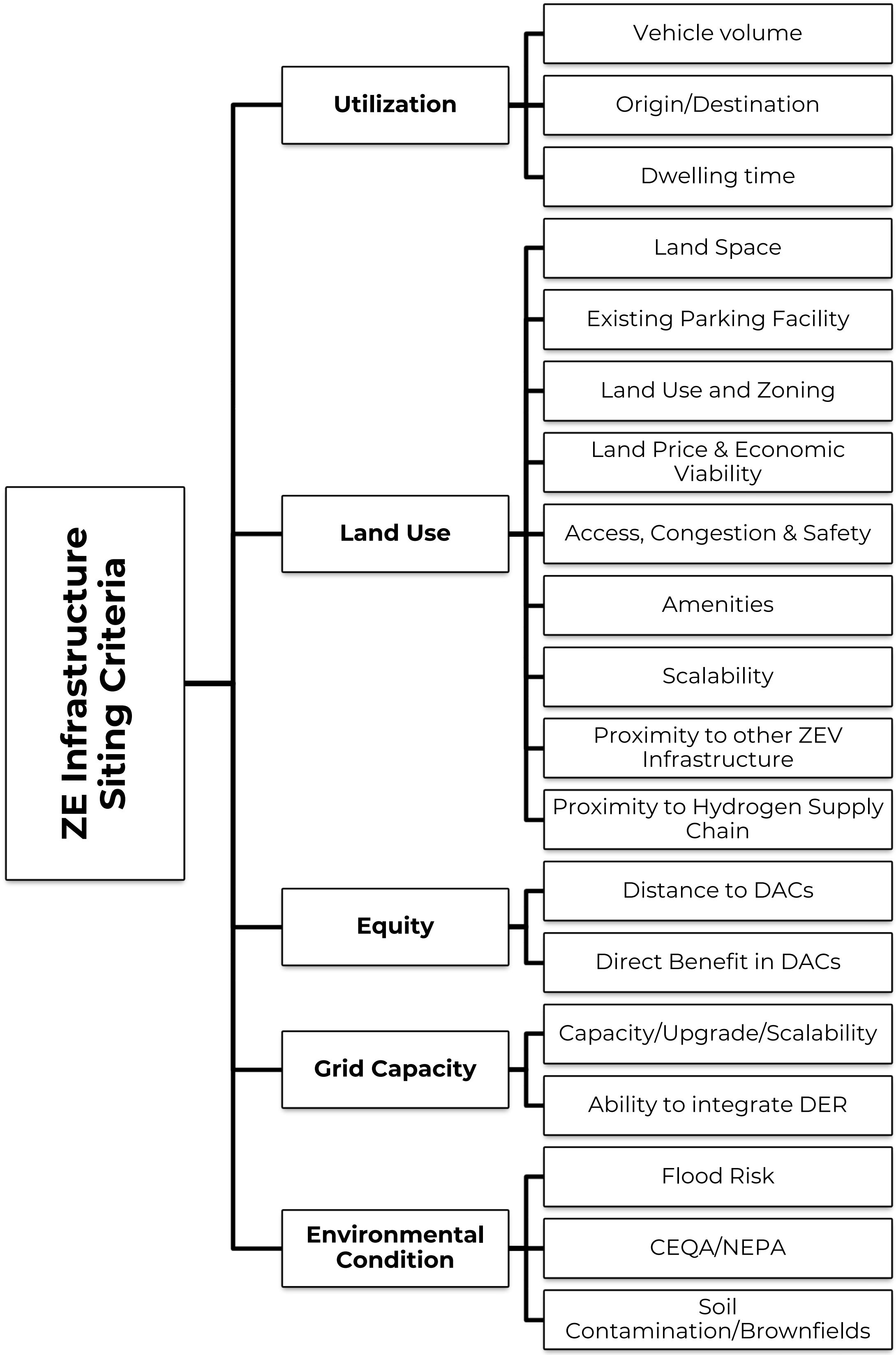
With respect to hydrogen fueling infrastructure, assessments should focus more on hydrogen delivery pathways that best meet the needs of the region. Hydrogen is mainly distributed from centralized production facilities to fueling stations, primarily through gaseous tube trailers and increasingly through liquid tankers. Production and delivery of hydrogen fuel, as it is now, can equate to high costs for comparatively low energy acquisition per delivery. Therefore, the project team suggested assessments of the spatial distribution of hydrogen facilities and evaluated cost components for the most viable delivery pathways in the region. Additionally, the project team proposed that hydrogen fueling stations integrate futureproofing or self-sustaining measures, such as the incorporation of distributed energy resources (DERs) over time. DERs, such as solar, battery energy storage systems (BESS), and backup generators, can help overcome grid constraints. Hydrogen fueling infrastructure coupled with DERs, such as solar and wind, can enable sites to achieve renewable on-site production.

Regardless of the methodology employed to optimize charging and fueling infrastructure by capacity and location, some barriers outside of technical assessments may impede deployment. Physical land acquisition is a critical step and often a bottleneck for deployment of charging and fueling infrastructure. Additionally, charging and fueling infrastructure should not be recommended in locations where traffic congestion would significantly increase, even if that location satisfies all other siting criteria. Land area and traffic activity data should be leveraged to narrow down the number of permissible sites. Furthermore, the project team proposed that existing MD-HD vehicle rest stops be leveraged as much as possible. MD-HD vehicle rest stops are established commercial facilities that provide amenities to drivers during hours-of-service (HOS) breaks. MD-HD vehicle rest stops, including truck stops, are ideal candidates for integration or retrofitting for siting charging and fueling infrastructure. Earlier, it was mentioned that transit agencies prefer to deploy charging infrastructure within their depots. However, in some cases, en-route opportunity charging may be necessary. In these situations, using land areas where the buses make stops for an adequate amount of time can be advantageous.

Across these siting criteria and potential pathways towards deployment of MD-HD ZEV infrastructure, it is crucial to ensure that the benefits are extended towards low-income and disadvantaged communities (DAC). As developed, the transportation sector has disproportionately burdened these vulnerable populations, contributing to poor air quality and exacerbated climate change. Technical assessments often understate the tangible benefits ZEV infrastructure can have on DACs. At the same time, deployment of ZEV infrastructure could have consequential impacts, such as increased traffic, higher cost of living expenses, gentrification, and residential displacement. The ideal charging and infrastructure deployment plans are those that collect community input to understand their needs and perspectives. The project team utilized high-level screening tools and State policies to identify equity metrics that can establish a framework to maximize benefits in these communities. The project team also recommend community engagement strategies intended to dispel ZEV infrastructure development and highlight potential benefits.

In addition to utilization, land use, grid capacity, and equity, the project team also proposed several criteria pertaining to environmental conditions, so that planners and developers consider the environmental impacts and resiliency of the ZEV infrastructure development as site evaluations are conducted. The subsequent sections further describe each of these criteria and provide insights on how they could be leveraged to inform proper siting of ZEV infrastructure. A comprehensive list of these potential siting criteria are provided in Figure 1.

Figure 1. Potential Infrastructure Siting Criteria



Utilization

A major barrier in deployment of ZEV infrastructure is uncertainty related to the utilization. The utilization of ZEV infrastructure is correlated to the economics of the infrastructure. Low utilization may not provide the needed ROI, which could put developers under financial hardship and discourage them from making the needed investment. Additionally, the revenue from California Low Carbon Fuel Standard (LCFS) programs which offers significant subsidy to public charging and hydrogen fueling infrastructure is highly dependent on the utilization of the stations[3]. Unfortunately, there is not sufficient data to estimate average utilization of MD-HD vehicle charging infrastructure; as a proxy, consider currently available utilization data from light duty vehicles. The average utilization rate of public DC fast chargers in the US, according to data from EVWatts[4], is about 7 percent, while the utilization rate for Level 2 chargers is higher at 18 percent. These rates were derived from charging data collected from more than 34,000 charging stations across the country. Note that these numbers are mainly reflecting the charging infrastructure for light duty vehicles and may not be relevant for MD-HD vehicles. They are mainly provided as a reference point. To optimize the utilization of the charging and fueling site locations, one needs to understand the travel patterns of MD-HD vehicles, their origin-destinations, pass through traffic, their existing refueling patterns, and their dwelling time within rest stops. Similarly, an analysis of passenger and commuter bus routes and operations would be required to understand how to maximize utility of charging and fueling infrastructure. Of course, the optimization methodology will be different for siting charging vs. hydrogen fueling infrastructure. Charging technology requires a longer duration stop, which reduces vehicle utilization and efficiency. Therefore, long-haul trucks will most likely seek to recharge while they are taking long (e.g., >2 hours) HOS breaks. Conversely, refueling hydrogen vehicles is quicker, which enables greater flexibility in the location of refueling infrastructure. With these considerations in mind, the project team proposed the following criteria:

MD-HD Vehicle Volume and Proximity to Major Routes

When selecting sites for charging and fueling stations, it is crucial to consider site proximity to major routes and the number of MD-HD vehicles operating nearby that would likely stop to refuel. The higher the number of vehicles, the higher the likelihood that developing a charging/refueling station could have a higher utility. As a criterion, vehicle volume can be evaluated using travel demand models, as well as big data transportation analytics. These

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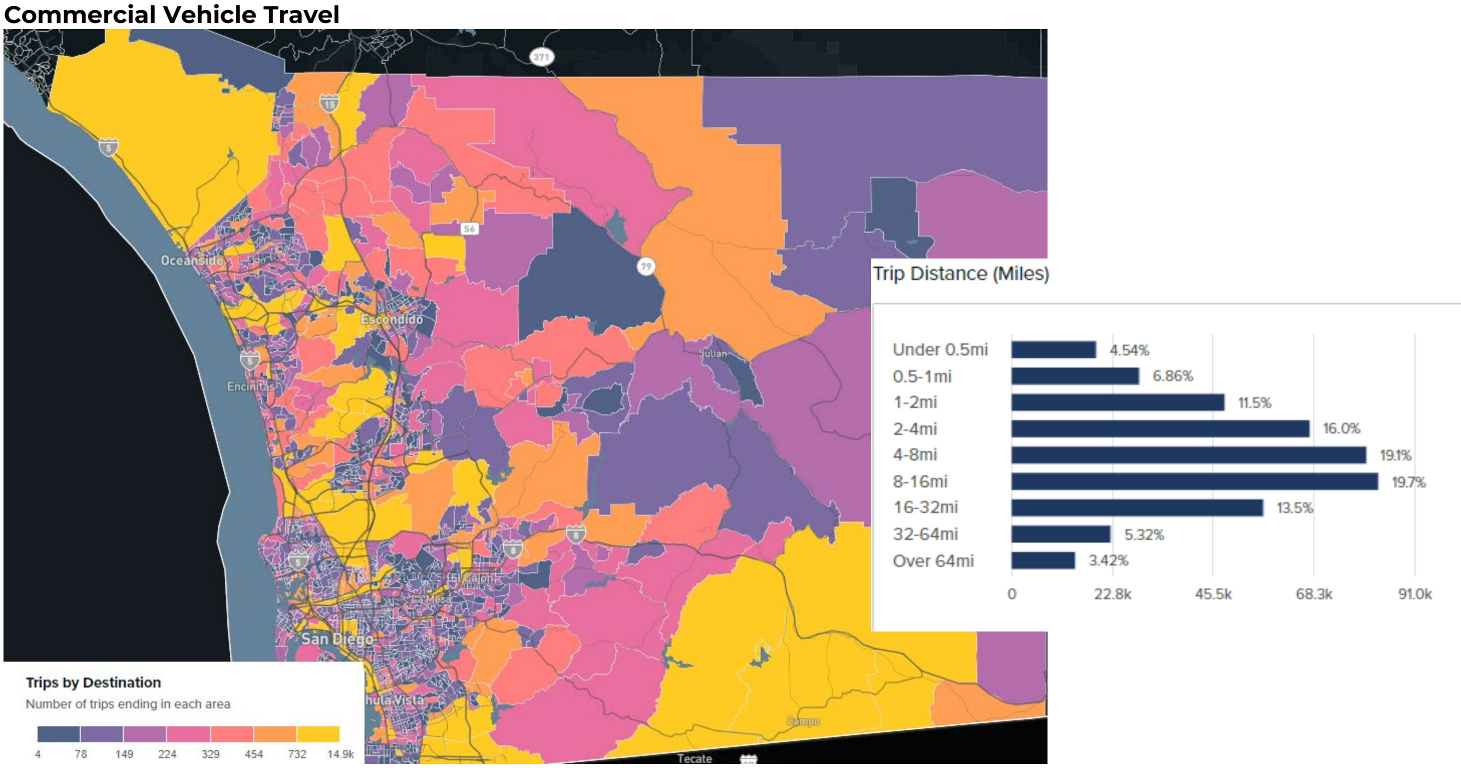
[3] The 2018 amendments to the LCFS program created provision to support the deployment of infrastructure for zero-emission vehicles like electric and hydrogen vehicles in the absence of demand. This provision allows Hydrogen Refueling Infrastructure (HRI) and Direct Current (DC) Fast Charging Infrastructure (FCI) to generate credits based on their capacity, minus the fuel dispensed. This means that a hydrogen station or fast charger can earn credits not only for the fuel they sell but also for the capacity they provide to support zero-emission vehicles. Currently the Infrastructure Capacity Credits is only available to light duty stations, however, CARB staff have indicated that they are considering amendments to the LCFS program to extend these credits to medium and heavy-duty stations as well.

[4] https://www.energetics.com/evwatts-station-dashboard

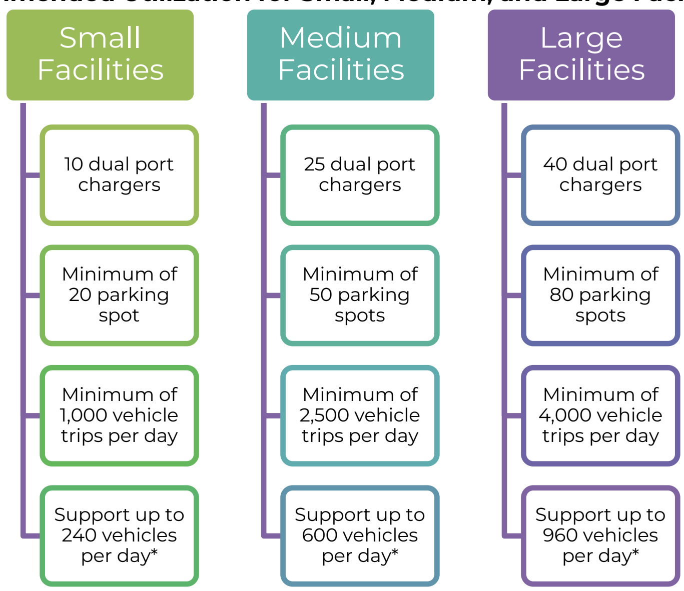
tools can provide origin-destination data to quantify vehicle volume at different geographic resolutions. Figure 2 below shows an example of commercial vehicle volume and trip data that can be extracted from Replica, a big data transportation analytics framework. Tools such as Replica could identify regions in the county that might be suitable candidates for charging and fueling stations based on vehicle volume or proximity to major routes. While big data can provide valuable insights, it is important to remember that it comes with inherent uncertainties due to factors such as data quality, completeness, and potential biases, which should be taken into account when interpreting the results and making strategic decisions.

Figure 2. An Example of Trip Data extracted from Replica (a Big Data Transportation Analytics Platform) for Commercial Vehicle Travel



This type of vehicle volume and trip data is a valuable tool for maximizing the utilization of charging or fueling facilities. One approach to sizing these facilities is by evaluating the expected number of vehicles in need of charging based on the percentage of vehicles that cannot reach their destination without an interim charge. For example, if the vehicle volume through an area is 1000 vehicles per day, it may be that 10% of these vehicles (e.g., 100 vehicles) may need to stop in the area to charge. Knowing the temporal distribution of these traffic volumes one could determine the peak charging demand at that location. If the peak demand is 10 vehicles, then that location might be suitable for a small charging facility. Here, a small charging facility could be a rest stop which has 10 dual port chargers, with enough power to support ≤2-hour charge times per vehicle. A small facility configured with this charging capacity would adequately support the 100 vehicles in need of a charge, and up to 240 vehicles per day (each port can support 12 vehicles). In other cases, where the vehicle volume and the percentage of vehicles in need of a charging station exceed 240 vehicles per day, "medium" and "large" facilities with incrementally scaled infrastructure can be recommended. Figure 3 summarizes the small, medium, and large facility configurations and the number of vehicles that each can support.

Figure 3. Example of Recommended Utilization for Small, Medium, and Large Facilities



** Assuming an average of 2 hours per charge*

Origin/Destination

Similar to gasoline and diesel vehicles, MD-HD ZEVs will refuel/recharge after taking long distance trips. Therefore, placing ZE infrastructure in locations where MD-HD vehicles take appointed rests after long distance trips will increase the likelihood of that infrastructure being further utilized. Similar to traffic volume, travel demand models as well as big data analytics could be used to access origin/destination data and estimate the fraction of long-distance trips that end in a certain location. For example, sites can be evaluated by the frequency of trips that surpass a specified daily VMT target. Charging and fueling stations could be recommended at specific sites when at least **40 percent of MD-HD vehicle trips to that location are greater than or equal to 50 miles**. In this example, the locations with the higher number of long-distance trips are likely more suitable for placement of charging and fueling infrastructure.

Dwelling Time

As discussed earlier, even when using high-power chargers, MD-HD BEVs will often require longer stops (>1-2 hours) to fully recharge. Unless vehicles already have long stops, having to wait on hours-long time scales could significantly reduce vehicle utilization. Therefore, understanding the dwelling time is a critical factor when siting charging infrastructure. Big data transportation analytics platforms often provide details on the start and end time of chained trips which could be then used to estimate the average dwelling time of MD-HD vehicles within a certain location. MD-HD vehicles with short dwelling times (e.g., ≤2 hours) typically benefit the most from high power chargers (>150 kW), whereas vehicles with longer dwelling times can maintain high utilization with lower power chargers (≤ 150 kW). With respect to hydrogen fueling infrastructure, the refueling time is similar to those of gasoline and diesel vehicles and therefore, dwelling time may not be a relevant criterion when siting hydrogen fueling infrastructure.

Land

Aside from the utilization, land size and land use conditions could also play a critical factor for successful adoptions of ZEV infrastructure. Here the project team explored some of the land criteria that could be considered when siting ZEV infrastructure.

Land Size

Land size is an important factor to consider when siting a charging infrastructure for several reasons:

- **Space for charging stations**: Depending on the charging technology being used, each charging station will require a certain amount of space to accommodate the charging equipment, cables, and user access.
- **Parking spaces**: Battery electric MD-HD vehicles need to be parked while they are charging, so the charging infrastructure must include adequate parking spaces for the MD-HD BEV. The number of parking spaces required will depend on the expected demand for charging and the charging technology being used.
- **Room for expansion**: As the number of MD-HD BEVs on the road continues to grow, the demand for charging infrastructure is likely to increase. Siting a charging infrastructure on a piece of land that allows for future expansion will help ensure that the charging infrastructure will remain relevant and functional as the demand for charging grows.
- **Power supply**: Charging stations need to be connected to a reliable power supply. A larger piece of land may provide more options for connecting to the power grid, as well as options for installing backup power supplies or DERs, such as solar and battery storage, to ensure continuous operation.
- **Local regulations**: Local zoning and building codes may have requirements for the size of a charging infrastructure and the amount of land that must be set aside for parking and maneuvering. It's important to consider these regulations when selecting a site for a charging infrastructure.

The recommended square footage per vehicle at MD-HD vehicle rest stops can vary depending on the specific needs and requirements of vehicles and operators; criteria that may serve as a starting point for property size include:

- **Parking Space**: A standard parking space for a heavy-duty vehicle is typically 40 to 80 feet in length, and 8 to 10 feet in width, which equates to 320 to 800 square feet per vehicle.
- **Charging Space**: For electric vehicles, an additional space of up to 100 square feet per vehicle might be considered for the charging equipment. However, fitting charging equipment around parking spaces in general requires some pre-planning, as some parking space configurations/geometries afford more flexibility than others.
- **Maintenance Space**: A truck or bus may require additional space for maintenance activities. A recommended minimum of 300 square feet per vehicle may be considered.

Accordingly, an MD-HD vehicle rest stop may require 720 to 1,100 sq. ft. solely per parking spot. In addition to this, land must be allocated for clearance, and maneuvering. To further elaborate on this,

Table 1 provides a summary information for the University of California, Irvine (UCI) EV bus charging site and hydrogen fueling station, of which only the hydrogen fueling station is open to the public.

Table 1. Summary of UCI Campus' ZEV Infrastructure[5]

ZEV Infrastructure	Type	Quantity	Capacity	Accessibility
EV Charging Station	Level 1 and 2	180 ports combined	2 - 19 kW	Semi-public
	DCFC	20 stations	80 kW	Private
Hydrogen	35 MPA, 70 MPa	1 dispenser	180 kg H2/day	Public

The UCI campus shuttle is comprised of 20 battery electric buses, which use the 20 DCFC stations to recharge outside of revenue hours. The battery electric buses park and charge in a separate lot; Figure 4 shows an image of the dedicated bus parking lot at UCI, which is approximately 55,000 sq. ft, or 1.26 acres in size. Although the UCI bus parking lot has 24 parking spots for buses, the campus fleet only uses the 20 battery electric buses to meet its environmental goals. However, this works out to 2,754 sq. ft per battery electric bus, more than double the upper end of the previously suggested range. For the purpose of this exercise, our team is recommending the land sizes for small, medium and large charging facilities assuming a minimum of 3,000 sq. ft. per parking space needed. This is further illustrated in Figure 5.

[5] http://www.apep.uci.edu/PDF/Microgrid_Research_UCI_Microgrid_UCIMG_090921.pdf

Figure 4. Overhead UCI's battery electric bus parking lot (chargers are spaced between parking spots)

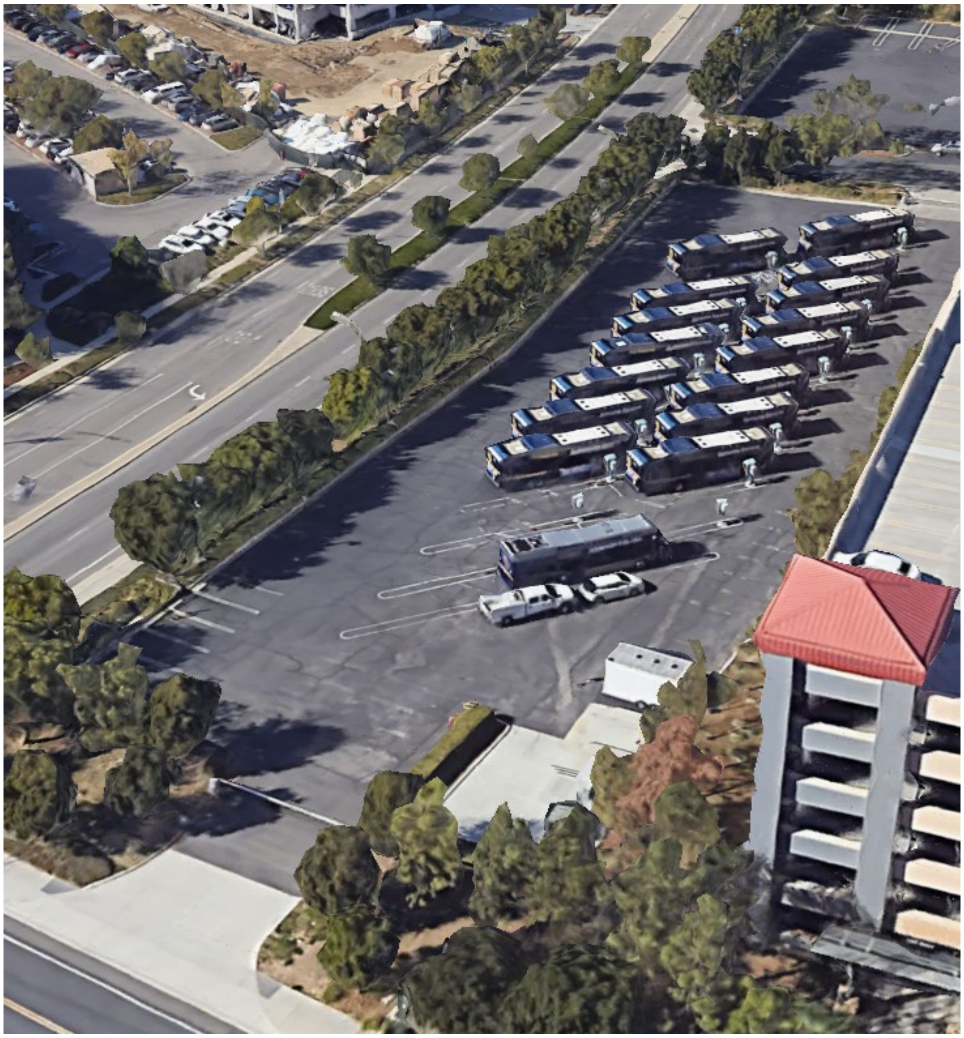
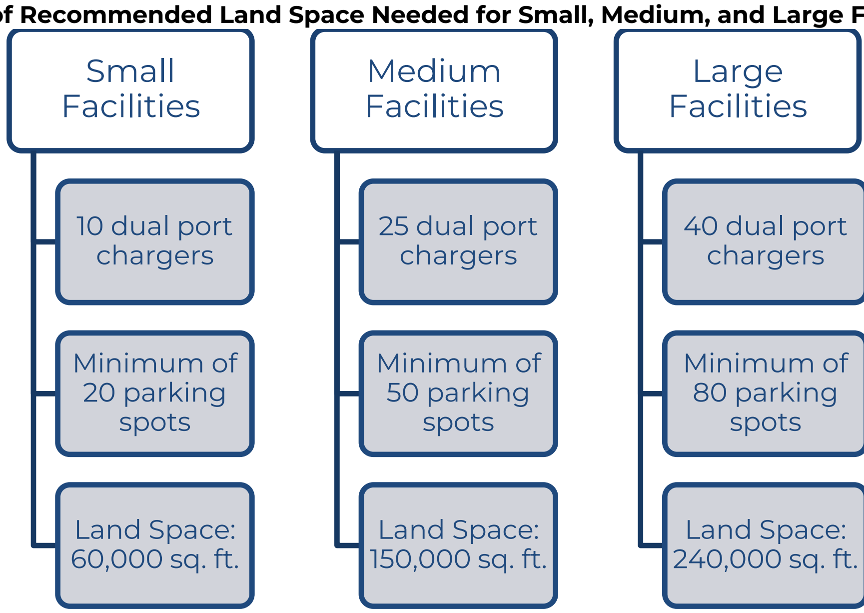


Figure 5. Example of Recommended Land Space Needed for Small, Medium, and Large Facilities



The selection of 3,000 sq. ft. per truck is also corroborated by the average space per stall at the Buckman Springs Rest Area in San Diego County. Measurements made via Google Earth reveal that this facility has a total of 18 stalls covering an approximate area of around 53,000 sq. ft. This translates to approximately 3,000 sq. ft. per truck parking stall.

Figure 6. Square footage of Buckman Springs Rest Area in the San Diego county

Regarding hydrogen fueling infrastructure, we refer to two examples of hydrogen stations in Southern California. The University of California, Irvine (UCI) hydrogen fueling station services vehicles ranging from light-duty to heavy-duty FCEVs, including some of the first fuel cell electric buses operated by the Orange County Transit Authority (OCTA). The station has a capacity of 180 kg/day but dispenses an average of 310 kg/day when factoring in station refills. The UCI hydrogen station is located within a 56,000 sq. ft. parking lot, but the actual footprint of the hydrogen fueling equipment is approximately 11,000 sq. ft, or about 0.25 acres.

Comparatively, Orange County Transportation Authority (OCTA) hydrogen station (built to accommodate its fuel cell electric bus fleet) is the nation's largest hydrogen fueling station, with a capacity of 1,250 kg H2 per day[6]. The OCTA hydrogen fueling station is located within their Santa Ana base (approx. 868,207 sq. ft, approx. 20 acres), can support 40 to 50 fuel cell electric buses, and is scalable to 100 with additional fuel storage and components[7]. Although the total area of the OCTA Santa Ana base is close to 20 acres, the actual footprint of the hydrogen fueling equipment is only slightly larger than that of the UCI hydrogen fueling station.

[6] https://www.octa.net/News/About/OCTA-Debuts-Nation-Largest-Hydrogen-Fueling-Station/
[7] https://www.octa.net/About-OCTA/Environmental-Sustainability/Zero-Emission-Bus-Progress/Fuel-Cell/

In deciding on the dimensions of truck parking areas for building our charging infrastructure, it's crucial to accurately gauge the demand for truck parking. The FHWA published the Truck Parking Development Handbook, a comprehensive resource that considers trucks and land use planning to support mobility and quality of life in communities with industrial uses. The Handbook considers the many factors influencing or generating the demand for truck parking and provides tools for evaluating truck parking demand and how to adequately meet that demand. For example, the Truck Parking Demand Estimation Tool takes a series of inputs including the number of trucks traveling in a specific area, average trip length, and road time. Upon entering this information, the tool calculates truck parking demand based on factors like the number of trucks, hours of service regulations, among others. The outcome is an estimate of the region's truck parking demand, assisting in guiding infrastructure planning and investment decisions, such as determining the requisite number of parking spaces at rest stops to ensure the safe and efficient operation of freight transport.

Existing Parking Facility

The challenges associated with land reservation and acquisition are often understated and can be a bottleneck for deployment of ZEV infrastructure. MD-HD vehicle rest stops, and port facilities are commercial vehicle facilities that presently provide fuel and amenities to vehicle operators. These locations have high traffic, long dwell periods, and can be retrofitted to make charging and hydrogen fueling MD-HD ZEVs easier than vacant sites. In example, California's existing network of approximately 500 publicly accessible truck stops may serve as a proxy for supporting ZE truck fleets. In addition to truck and bus parking locations, developers and planners could also consider truck staging and layover areas.

The California Department of Transportation (Caltrans) recently completed a Statewide Truck Parking Study[8] to identify and prioritize existing truck parking shortages across the State and propose a range of strategies for providing safe places for truck drivers to park to ensure the safe, efficient movement of goods and reflect local requirements, concerns, and goals. As part of this study, Caltrans conducted a comprehensive analysis utilizing proprietary truck GPS data as well as other data sources to provide information about where trucks are parked and for how long. This study could serve as a valuable data source to identify existing truck parking locations that could benefit from deployment of charging infrastructure. In addition to this study, data from Trucker Path, a crowdsourced app that truck drivers use to find and report the availability of truck parking, could be used to identify the number of truck parking spaces and average utilization of truck parking at major truck parking facilities. This data could help to identify where truck parking spaces are located and frequently used, thereby providing insight into where ZEV infrastructure would be highly utilized.

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[8] https://dot.ca.gov/-/media/dot-media/programs/transportation-planning/documents/freight-planning/plan-accordion/catrkpkgstdy-finalreport-a11y.pdf

Land Use & Zoning

It is critical to consider land use and zoning criteria when selecting sites for development of charging and hydrogen fueling infrastructure. Planner and developers may need to identify locations that permit the development of a MD-HD ZEV infrastructure. For example, sites zoned industrial are typically ideal, and while commercial zoning may accommodate charging/hydrogen fueling, it may not allow truck parking.

Another key consideration is Section 111, of Title 23, United States Code, and 23 CFR 752.5 which prohibit over-the-counter sales of merchandise in public facilities located within the Interstate Right of Way (ROW), and at all rest areas.[9] Exception is made for telephones, vending machines, and distribution of travel-related materials. As a result, states cannot generate revenue from truck parking services or sale of goods, including ZEV infrastructure. It will be cost prohibitive to provide ZEV fueling at facilities where public agencies lacks the authority to charge a fee, however facilities that are not designated rest areas and not located within Interstate right of way could be feasible options. To that effect, in April 2021, the Federal Highway Administration (FHWA) issued a guidance[10] to support the use of highway ROW for climate change, equitable communications access, and energy reliability projects, with a focus on electrification and the deployment of connected and autonomous vehicles. The guidance aims to help state departments of transportation (DOTs) maximize the value of existing ROW assets and reduce maintenance costs by creating new revenue opportunities through public-private-partnerships for renewable energy and charging infrastructure projects. The FHWA encouraged division offices to use a "programmatic approach" when considering state DOT requests related to ROW uses. This guidance is expected to support the expansion of charging infrastructure networks and broadband deployment efforts in several states, including California.

Land Price & Economic Viability

Often overlooked in the overall cost of infrastructure deployment is the cost of land acquisition. This is especially important for ZEV infrastructure deployment within urbanized areas, where land costs are much higher. Understanding the cost of land acquisition is critical in determining the economics and cost effectiveness of the ZEV infrastructure. When siting ZEV infrastructure, locations with lower land acquisition costs, or sites which offer potential public-private-partnership (P3) opportunities should be prioritized as they provide a higher ROI opportunity for private investors and developers. Specific to P3 opportunities, planners and developers should consider sites with the following characteristics: (1) flexibility in land use regulations that allow for mixed-use development, (2) streamlined permitting processes, (3) tax incentives for private investment, (4) favorable leasing arrangements for public land,

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[9] Code of Federal Regulations. https://ecfr.federalregister.gov/current/title-23/chapter-I/subchapter-H/part-752/section-752.5

[10] https://www.fhwa.dot.gov/real_estate/right-of-way/corridor_management/alternative_uses_guidance.cfm

and (5) provisions for shared use of public amenities. Having clear and favorable zoning criteria can provide a supportive environment for P3s in the development of MD-HD ZEV infrastructure. Additionally, planners and developers should investigate opportunities for converting existing gas/diesel fueling stations to charging or hydrogen fueling stations.

Access, Congestion & Safety

Easy access to MD-HD charging and fueling infrastructure should be a key consideration. The best locations should not require vehicle operators to significantly detour and increase their overall travel time, mileage, and fuel consumption. Of relevance to this are the requirements established under the Bipartisan Infrastructure Law's (BIL) National Electric Vehicle Infrastructure (NEVI) Formula program which suggests that EV charging infrastructure be located no more than one (1) mile from interstate exits or highway intersections along designated corridors. State governments are responsible for identifying exceptions to this in their NEVI plans, but this starting point emphasizes the importance of siting MD-HD ZEV infrastructure along routes that operators will likely take to access stations.

Traffic should be considered as well. While road reforms are carried out by local and state agencies to reduce traffic congestion in certain areas, it remains a widespread issue. The installation of charging and clean fueling stations for commercial MD-HD ZEVs should not add to congestion. Placing ZEV infrastructure that causes increased traffic on truck and bus routes or near vulnerable communities would defeat the purpose of improving both the environment and local communities. Hence, it is advisable for developers to conduct a traffic analysis, particularly in goods movement corridors, when selecting locations for MD-HD ZEV charging infrastructure. Ideally, the only sites that should be recommended either have no impact on congestion or will improve it. In the absence of any site meeting that criteria, planners and developers should select sites that minimize negative impacts to congestion.

In addition to impacts of MD-HD ZEV infrastructure on congestion, planners and developers shall also consider potential safety impacts. Not only the station itself should provide the needed safety for the vehicle drivers to stop and recharge/refuel, but the placement of ZEV infrastructure in a community should also not be detrimental to the overall community safety. The routing to MD-HD ZE charging/fueling facilities should consider pedestrian and bicycle activity in the area. The ingress/egress to these sites should be designed to avoid conflicts with non-motorized traffic.

Amenities

While charging their vehicles, vehicle drivers typically remain with their vehicles and therefore needs essential amenities such as a paved and striped parking area, restrooms, water, vending machines, lighting, green space, and picnic tables. Also, it is important for the charging and refueling facilities to offer services for the convenience of drivers while they stop for charging/refueling. Examples of services that were found in FHWA's national truck rest stop survey are shown in

Table 2. The average number of existing parking spaces for truck stops in each of the three size categories from this study were: 16.4 spaces for small truck stops, 49.0 spaces for medium truck stops, 166.2 spaces for large truck stops.

Table 2. FHWA Survey Results on Truck Stop Services by Size (from 1996 national survey)[11]

Service	Small Truck Stop (avg. 16.4 spaces)	Medium Truck Stop (avg. 49.0 spaces)	Large Truck Stop (avg. 166.2 spaces)
Open 24 hours	100%	100%	100%
Restaurant/Deli	97%	96%	100%
Convenience Store	100%	94%	99%
Showers	80%	94%	99%
Check Cashing	72%	83%	96%
Scales	44%	64%	93%
Laundry	20%	52%	93%
Truck Repair	11%	43%	84%
Hotel/Motel	14%	33%	45%

The survey results indicated that most truck stops, regardless of size, offered essential services, consisting of convenience stores and showers, however there are more services available at larger, public stops than at smaller, private stops. Hence, when considering the site for development of ZEV infrastructure, it is important to consider the availability of, or ability to provide these amenities. The existing truck parking locations often provide these amenities, and deployment of publicly available ZEV infrastructure in these locations (or adjacent to them) could benefit their owners by bringing additional truckers or bus operators that are in need of using their facilities.

Scalability

As the market for MD-HD ZEVs, including buses, expands and more ZEVs are being deployed by fleets, existing ZEV infrastructure needs to grow and provide charging/refueling services to a higher number of vehicles. Such growth could be translated into both an increasing number of parking spaces with charging stations as well as higher power level chargers that could energize vehicles in a much shorter amount of time, making the chargers available for

[11] https://www.fhwa.dot.gov/publications/research/safety/commercial.pdf

a higher number of vehicles. Therefore, when selecting the site for deployment of ZEV infrastructure, it is critical to keep the scalability in mind. While a certain location might provide the needed space and power levels for today's needs, the lack of scalability could inhibit that location from serving the future needs of the region. Similar to parking availability criteria discussed above, there are various data sources, including data sources used by the Caltrans for the 2022 Statewide Truck Parking Study to evaluate the space constraints within each parking location. Additionally, as discussed further in the document, developers and planners should also evaluate the electrical grid capacity available to that site and assess if there is enough headroom capacity available for the site to scale up in the future. Note that the scalability criteria for a public charging facility apply to both trucks and transit buses. Similar to ZE MD-HD trucks, the increased adoption of electric buses will necessitate the growth of public charging infrastructure for these fleets, both in terms of the number of parking spaces and the power capacity.

Scalability is just as important for hydrogen refueling stations as it is for charging stations. According to the Needs Assessment Report, most hydrogen fueling stations currently have capacities of less than 1,000 kg/day, but as the number of medium- and heavy-duty fuel FCEVs increases, it is expected that these stations will also need to increase their capacities for hydrogen supply and the number of fueling nozzles and stalls. Securing sites with adequate space and the ability to handle larger amounts of hydrogen will be crucial in determining the locations of hydrogen fueling stations.

Proximity to Other Charging/Refueling Infrastructure

Although there are currently limited MD-HD charging/fueling stations in the region, with the projected rapid growth of MD-HD ZEV in California due to various policies and programs, we can expect a significant increase in ZEV infrastructure development throughout the state. As we have highlighted the significance of ZEV infrastructure utilization, it is equally important to assess the distribution and proximity of these charging/fueling stations in the region. If the ZEV infrastructure is overly concentrated in one area, it could lead to decreased utility for each station and a shortage of ZEV infrastructure in other parts of the region. Therefore, it is crucial to consider the locations of other charging/fueling stations when evaluating the suitability of a site for ZEV infrastructure development.

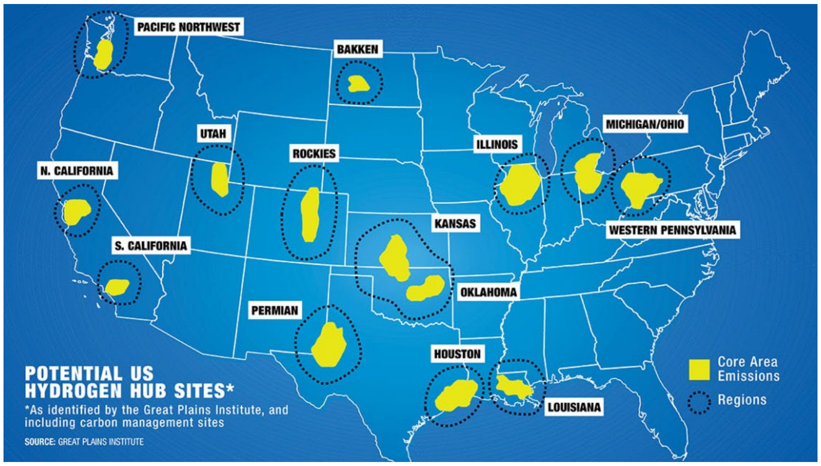
The NEVI program suggests that new EV charging infrastructure locations should be spaced a maximum distance of 50 miles apart along designated corridors (including planned stations and existing stations)[12]. Considering that today most MD-HD BEVs have similar electric ranges as light duty EVs (~100 – 300 miles), the same criteria could be used for MD-HD charging infrastructure deployment. To evaluate this criteria, one can leverage the Alternative Fuel Data

[12] https://www.fhwa.dot.gov/environment/alternative_fuel_corridors/nominations/90d_nevi_formula_program_guidance.pdf

Center (AFDC) Station Locator[13] which provides details on the locations, and type of charging stations deployed across the country. While today the AFDC station locator tool does not distinguish between light duty versus MD-HD charging station, it is expected the tool to provide such capabilities as the MD-HD charging infrastructure become more prevalent. Using this tool, one can assess the proximity of existing public charging stations to the studied site.

With respect to hydrogen, tools such as the AFDC Hydrogen Station Locator and Hydrogen Fuel Cell Partnership Station Map maintain the most up-to-date information on hydrogen stations, including the distribution of renewable vs. non-renewable hydrogen and real-time station capacity for both 35 and 70 MPa fuel pressure options. Similar to charging stations, one could utilize data extracted from these tools to evaluate the proximity of existing fueling stations to the studied locations. Considering MD-HD FCEVs are likely going to have higher ranges, (between 300 to 500 miles of range), a starting point for recommended distance between refueling stations may be 20% of this range, or 60 to 100 miles between refueling stations.

Proximity to Hydrogen Supply Chain



The siting of hydrogen fueling stations requires an understanding of the full supply chain of hydrogen, from both the supply and demand sides. The cost of fuel needs to be confined for hydrogen to be an economically viable solution for transportation. From the supply side, hydrogen production cost depends on the technology used, which determines its physical fuel values, and on the credits and incentives from different programs. Delivery is another key cost component. Hydrogen is mainly distributed from centralized production facilities to fueling stations, primarily though gaseous tube tailers and increasingly through liquid tankers. Due to the low payload of hydrogen trucking, boil-off and leakage, the delivery cost of hydrogen is high and makes a significant contribution to hydrogen prices at the pump. When determining the site for deployment of hydrogen refueling station, one needs to evaluate existing centralized hydrogen production facilities based on publicly available information and overlay forecasts of upcoming hydrogen hubs and facilities. Understanding that some hydrogen fueling stations may rely on onsite hydrogen production via electrolysis, developers

[13] https://afdc.energy.gov/stations/#/find/nearest

and planners could identify regions of the county with persistent low electricity prices now and in the future and with a high likelihood of further renewable build-out, such as solar and wind. Based upon this assessment, one can identify hot zones of hydrogen fueling stations by considering potential suppliers, costs, and delivery distance and use that to prioritize regions in the county that could benefit from lower cost of hydrogen delivery/production, offering better economic for public and private developers.

For example, planners and developers could leverage tools such as U.S. DOE H2 Matchmaker[14], an online information resource to assist hydrogen suppliers and users with self-identifying collaborators and opportunities to expand development toward realizing regional hydrogen Hubs. These types of tools could help identify the proximity of hydrogen suppliers and provide insights on potential cost implications for accessing hydrogen supply when studying a specific site. According to U.S. DOE AFDC, the transportation of compressed hydrogen gas via trucks in high-pressure tube trailers should be primarily utilized for short distances of 200 miles or less[15]. On the other hand, liquid hydrogen could be transported over longer distances. For this purpose of this guideline, we would recommend planners to site locations within 200 miles of hydrogen production facilities.

Other Site Development Considerations

The National Electrical Installation Standards (NEIS) offers practical guidance for the installation of Electric Vehicle Supply Equipment (EVSE) at commercial sites, adhering to NECA 413-201x[16]. This guidance clarifies the range of products and applications available in the electric charging field and provides installation and maintenance guidelines for developers to follow. These guidelines act as a crucial resource for individuals and organizations participating in the installation of EVSE in both residential and commercial environments. Emphasis is given to compliance with local codes and standards enforced by the Authority Having Jurisdiction (AHJ). It is advised to make contact with the local code enforcement office to determine the AHJ, validate the applicable codes and standards, and thoroughly examine the Americans with Disabilities Act (ADA) requirements related to EVSE installations.

For instance, the guideline advises developers to carry out a thorough site survey. This evaluation should take into consideration numerous factors, such as potential risks or hazardous materials, obstructions, lighting conditions, signage, driver accessibility, and the overall safety and security of the site. Moreover, it is recommended to locate the EVSE away from petroleum fueling stations and in low-traffic areas, ensuring convenience and seamless access for fleet operations.

[14] https://www.energy.gov/eere/fuelcells/h2-matchmaker
[15] https://afdc.energy.gov/fuels/hydrogen_production.html
[16] http://www.neca-neis.org/docs/default-source/default-document-library/neca-413-ansi-canvass-draft-20180622.pdf?sfvrsn=0

Prioritizing Equitable Outcomes

Despite broad efforts to improve air quality and public health, large metropolitan areas that are home to people of all income bands and racial/ethnic backgrounds, still suffer from high levels of air pollution. It is often the case that the marginalized and low-income populations shoulder the greatest air pollution and health burdens due to their proximity to industrial complexes and congested traffic zones. Within the nexus of low income/disadvantaged communities and the transportation sector, MD-HD vehicles are some of the worst offenders. At the same time, these vehicles are responsible for much of the goods movement that empowers local economies. The solution to mitigating Environmental Justice[17] (EJ) issues that current MD-HD fleets present is to transition this sector to zero-emission technologies. However, this process is going to take time. One way to speed up the benefits for low-income communities (LIC) and DACs is to strategically locate charging and hydrogen fueling infrastructure, increasing the proportion of MD-HD ZEVs operating in these areas. While charging infrastructure in LICs and DACs can increase ZEV operations, community advocates have expressed concerns about increased truck traffic and safety impacts from these deployments. Thus, planners and developers should weigh the environmental benefits and impacts on congestion and safety when advancing EJ through zero-emission vehicle infrastructure deployment. Therefore, as part of this guideline, we would recommend two criteria to be considered: a) distance to LICs/DACs, and b) en-route to LICs/DACs. These will be further discussed in the following sections.

It is noteworthy to mention that equity is also an important criterion when it comes to available funding for deployment of ZEV infrastructure. At the federal level, the Justice40 Initiative has set a goal to direct 40 percent of the overall benefits of federal investments flow to DACs. Hence when siting ZEV infrastructure, it is important to consider the metrics identified under Justice40 to access the significant amount of funding that being available through various federal programs. Similar requirements also apply to California's government investments. At least 35 percent of California Climate funding (through Cap & Trade proceedings) should be invested in low income and disadvantaged communities.

Distance to LICs/DACs

An important factor when it comes to equity implications of ZEV infrastructure is the proximity of those infrastructures to LICs/DACs. As discussed earlier, community advocates have raised concerns with various planners and developers considering deployment of charging and fueling infrastructure within LICs/DACs. ZEV infrastructure can often serve as a MD-HD vehicle magnet in these communities and while it will increase the operation of ZE

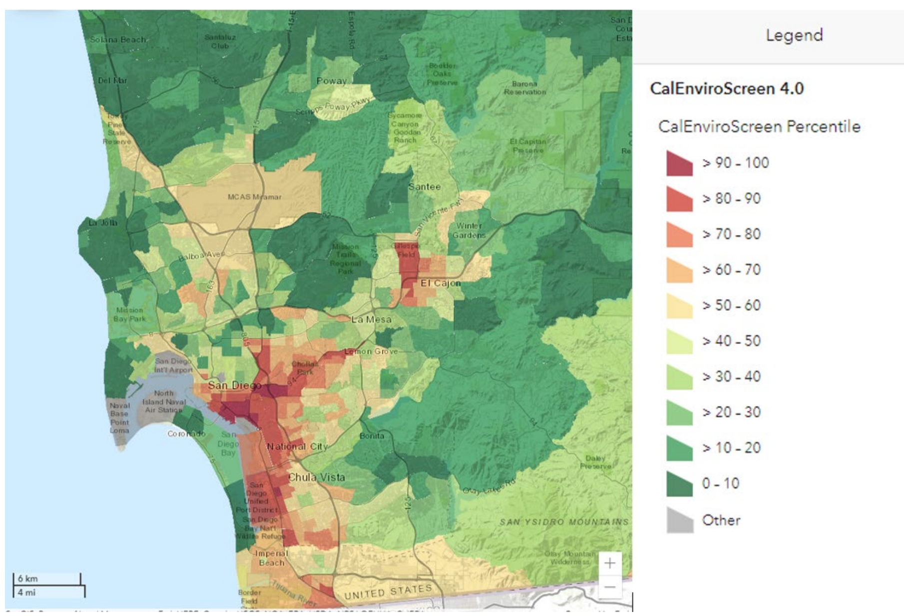
[17] According to the U.S. EPA "EJ is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies."

MD-HD vehicles, it could lead to increased traffic impacting the quality of life as well as safety for community members. Additionally, it is speculated that deployment of ZEV infrastructure within LICs/DACs can also lead to rent speculation and higher housing prices, thereby exacerbating gentrification and displacement.

At the same time, LICs/DACs experience difficulties with frequent truck parking in undesignated areas. Some of this is a result of independent truck owner-operators living in the neighborhood without a safe, close, designated place to park their trucks overnight, some of it occurs because truck drivers have run out of available hours of service during their trip, but most frequently the primary cause is due to a lack of designated truck parking where it is needed. Undesignated truck parking occurs when a driver parks outside of a dedicated truck parking facility. The lack of designated truck parking results in trucks idling in historically disadvantaged neighborhoods near seaports, ports of entry, warehouses, and rail yards. As a result, residents are unduly burdened by noise and air pollution. Truck parking in these neighborhoods also reduces roadway safety within LICs/DACs. Therefore, as public agencies and private developers are exploring sites for deployment of ZEV infrastructure, they may need to consider how deployment of the ZEV infrastructure and parking facility could not only facilitate the adoption of MD-HD ZEVs in those communities, but also help reduce the number of trucks parking in undesignated areas.

To this end, the State has developed several mapping tools that could be used to identify these communities and inform decisions on proper siting of charging and fueling infrastructure. CalEnviroScreen is a mapping tool that identifies California's environmental and social justice communities using indicative EJ scores proportional to pollution burden and population characteristics[18].

Figure 7. San Diego County on CalEnviroScreen 4.0 Data Dashboard



In Figure 7, a map of San Diego County from CalEnviroScreen and its scores are shown to demonstrate the distribution of pollution burden; these maps can be configured to show distributions of specific pollutants as well as identify economic disparities across geographies. The CalEnviroScreen tool offers planners and developers a

[18] https://oehha.ca.gov/calenviroscreen/about-calenviroscreen

starting point for evaluating community proximity to MD-HD vehicle activity. These maps can be cross-examined against fuel corridor and traffic analysis maps to narrow down the best locations for charging and fueling infrastructure.

Additionally, as part of AB 1550[19], CalEPA has developed a mapping tool[20] that identifies low-income communities and households that have a population at or below 80 percent of the statewide median income or at or below the threshold designated as low income by the California Department of Housing and Community Development's (HCD) 2016 State Income Limits[21].

Aside from the CalEnviroScreen and AB 1550 maps, the Caltrans 2022 Statewide Truck Parking Study is another valuable data source for identifying the communities that are currently being impacted by trucks parking in undesignated areas due to lack of truck parking availability. Utilizing the CalEnviroScreen and AB1550 mapping tools combined with the truck parking needs analysis recently completed by Caltrans, one can identify locations that not only could benefit from increased ZE MD-HD operations due to the deployment of ZEV infrastructure, but also could leverage the additional parking spaces available through these ZEV infrastructures to mitigate the parking issues within their nearby communities. Although a more robust data analysis is recommended to determine the ideal location for the ZEV infrastructure, the project team suggests placing these ZEV infrastructure within 5 miles of the community. Such distance will ensure that while MD-HD vehicles travelling to a community can have access to ZEV infrastructure, the placement of the infrastructure does not negatively impact the vehicle traffic and safety within the community.

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[19] Assembly Bill 1550, which was passed in 2016, requires CalEPA to identify DACs and established minimum funding levels allocated from California Climate Investments (i.e., GGRF). At least 25% of funds must be allocated toward DACs, at least 5% must be allocated toward projects in low-income communities or benefiting low-income households, and at least 5% must be allocated toward projects in low-income communities or households located within a half-mile of a DAC but not officially part of it.

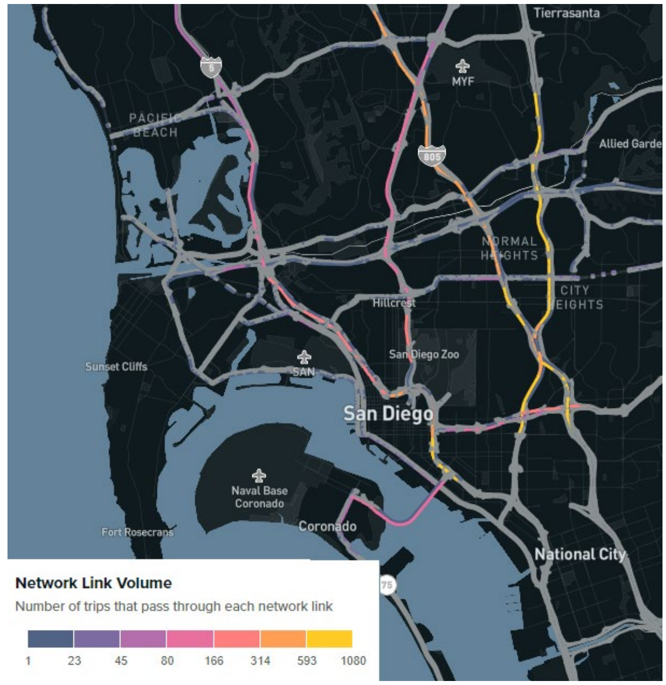
[20] https://webmaps.arb.ca.gov/PriorityPopulations3/

[21] https://www.hcd.ca.gov/grants-funding/income-limits/state-and-federal-income-limits/docs/inc2k16.pdf

Direct Benefit to DACs

Aside from the proximity to DACs, to ensure that deployment of ZEV infrastructure will have direct benefits to DACs, these infrastructures should be strategically placed in locations that are en-route to disadvantaged communities. Trucking companies and possibly transit agencies are more likely to send their zero-emission vehicles to routes where they are confident that there is enough charging infrastructure available. Therefore, the project team suggests focusing on where the MD-HD vehicles are going when deciding where to build the charging stations. This means putting the stations in places that will serve the most MD-HD vehicles with a destination in a DAC. Both travel demand models as well as big data transportation analytics platform (e.g., Replica, Streetlight Insight, Geotab, INRIX) could be used to determine the optimal locations for siting charging and fueling infrastructure and to maximize the benefits in DACs. Figure 8 provides an example of how big data transportation analytics, such as the one from Replica could be leveraged to assess locations that have higher fraction of MD-HD vehicles en-route to DACs. In this example, the project team highlights the volume of commercial vehicles on major highways that are en-route to National City, one of the communities in San Diego that have historically been bearing the burden from air pollution from the port. As shown in the graph, the majority of MD-HD vehicles that are traveling toward National City are often on interstate 15 and highway 805 (highway links with yellow color represent regions with highest volume of commercial vehicles moving toward National City). Using this example, if a ZEV charging or fueling station intends to directly benefit the DACs within the National City, it is recommended that sites are selected in regions with a higher fraction of vehicles travelling toward the city. As a criterion for choosing a site that is not located close to a DAC (more than 5 miles away), it is necessary to ensure that at least 40 percent of the MD-HD vehicles passing through that area have a final destination in a DAC.

Figure 8. Volume of commercial vehicles with destination of National City



To measure the benefits of having charging and hydrogen fueling infrastructure en-route to DACs, one can count the number of trips that go to a certain DAC, similar to how it is illustrated in Figure 8, and estimate the reduction in emissions if a portion of those trips become zero-emission with the new infrastructure. By knowing the number of trips and how far they travel in the community, the overall emissions reductions resulting from infrastructure deployment could be calculated.

Other opportunities to ensure that DACs directly benefit from the deployment of ZEV infrastructure can manifest through public-private partnerships for innovative business solutions to increase the utility of chargers. In some cases, it may be possible to adopt a diurnal charging system at commercial depots, where chargers are public-use during the day and private-use for overnight charging by commercial fleets. Other types of public-private partnership models are possible, and a network of partially public chargers could be incorporated into the AFDC's Electric Vehicle Charging Station Locator map to inform community members where they may access their nearest MD-HD ZEV chargers.

Social and Environmental Justice

As discussed, ZEVs and charging infrastructure have significant public health and workforce benefits for residents of LICs and DACs. These benefits are important because these communities have historically borne the brunt of environmental and economic injustices, often being displaced by roadway/highway projects or suffering adverse health effects as a result of increased exposure to toxic air pollutants. Here, equity should not only consider optimal use of ZEVs and charging/fueling sites, but also other core tenets of social and environmental justice.

Promoting equitable outcomes would include protection and safety of residents while creating the charging/fueling infrastructure in their communities; providing viable alternatives when their livelihood or homes are displaced during the creation or planning for the establishment of charging sites; ensuring that their health and well-being are not compromised; their social history and historical artifacts not lost; their information and technology infrastructure upgraded and become meaningful in their day-to-day living; and their quality of lives improved. These considerations are consistent with the landscape-level approaches taken by federal agencies (i.e., U.S. Dept. of Energy, U.S. Dept. of the Interior), structured and analytical methods than inform resource management decisions at multiple spatial scales, especially when diverse stakeholders seek multiple social, environmental, and economic goals. In essence, these alternative frameworks of social and environmental justice consider not just immediate benefits, like air quality improvement, but also broader, long-term benefits for communities.

One example of long-term benefits are the creation of green job opportunities for residents of disadvantaged communities. By prioritizing the hiring of local residents, the implementation of zero emission truck infrastructure can bring about positive economic change. It is also important to break the cycle of economic codependency between high-polluting industries and the communities in which they reside. This can be achieved through local ownership of green businesses and a shift towards a cleaner transportation economy.

When selecting sites for charging and fueling stations, developers may be more likely to choose low-cost sites in disadvantaged communities. It is important to consider the social and cultural costs of displacement and relocation efforts. Metrics must be developed to provide just and equitable land cost compensation, especially in low-income neighborhoods. It is also necessary to address the potential loss of historical artifacts and the upgrading of information and technology infrastructure.

Grid Interconnection/Capacity

Regardless of which charging strategy (e.g., on-route or depot) MD-HD BEVs use, there are several considerations surrounding the grid's capability to accept charging infrastructure at different sites. One is grid capacity, or the maximum power output available at a given site. Grid capacity is location specific, meaning there is a limit to the quantity and type of electric charging infrastructure that can be installed at sites because power demand cannot exceed supply. Grid system improvements and site readiness measures can increase grid capacity. However, these processes can be very time-consuming and cost prohibitive. The challenges that grid capacity (or lack thereof) poses are significant, so alternative solutions (e.g., distributed energy resources for local generation) will be important to infrastructure build out.

Another factor is grid interconnection, or a site's access to other local networks. Grid interconnection enables the exchange of energy from other grids with surplus power to those having higher demand than what is available at site. It is important to consider grid interconnection because it determines how resilient the grid is to stress events and dictates how well the grid can absorb surplus supply. Thus, an assessment of the San Diego region's grid capacity and interconnection are key to proper siting of charging infrastructure as well as hydrogen fueling station with on-site production. In addition to grid capacity and interconnection, planners and developers may also need to consider the cost of electricity in areas where they plan to deploy the charging stations or hydrogen station with on-site hydrogen generation. These factors are further described in the following sub sections.

Grid Capacity, Upgrades, Scalability

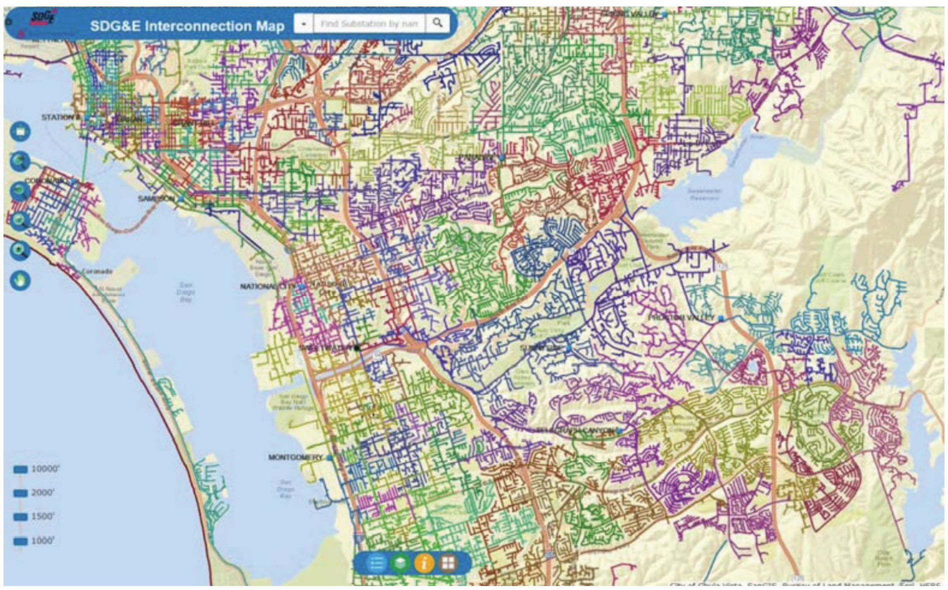
A site's existing grid capacity sets a limit on the type and quantity of charging infrastructure that can be installed. In 2016, the California Public Utilities Commission (CPUC) issued an Assigned Ruling [R. 14-04-103] that established Integration Capacity Analyses (ICA) for the San Diego Gas & Electric (SDG&E), evaluating the Northeast and Ramona distribution planning areas of San Diego. This effort led to the development of ICA distribution system maps, exceptionally useful for visualizing San Diego electricity transmission circuits. An example of the SDG&E Interconnection Map is shown in

Figure 9. The ICA maps are publicly accessible, enabling developers and planners to perform an initial screening of grid capacity and interconnection. Additionally, the ICA map tool is designed to quantify the capability of specific sites to integrate DERs within SDG&E's grid and

enables planners and developers to examine site grid capacity/interconnection and ability to "host" additional DERs, such as solar panel, and battery storage.

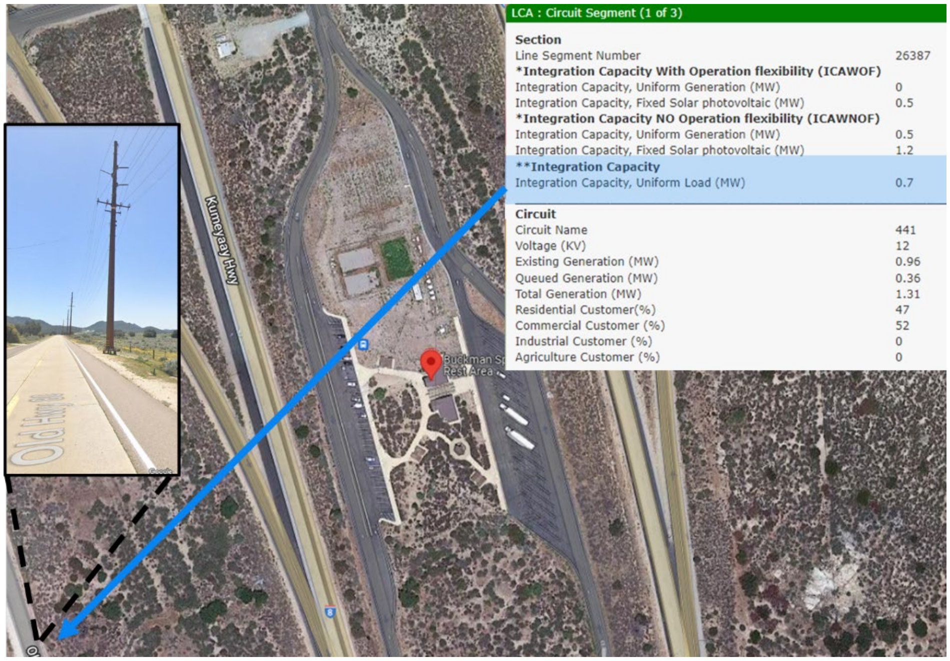
With ICA maps being publicly available, developers and planners can assess the grid capacity of sites by searching them through ICA maps and extract the load capacity analysis (LCA) data that are available at circuit and feeder level. Users can select individual circuits or substations to see key data on load profiles and maximum capacity. Additionally, the ICA map tool can quantify the capability of specific sites to integrate distributed energy resources (DERs) within the grid's network. For example, Figure 10 demonstrates an LCA for circuit line segment 26387 that passes by the Buckman Springs Rest Area along highway 8. This rest area currently has 18 heavy duty parking spots and the SDG&E ICA map illustrates that the circuit passing by this facility has about 700 kW of load capacity. In case a developer plans to install 350 kW chargers at this location, the current ICA analysis suggests that they will be limited to only 2 charging stations.

Figure 9. System View of SDG&E's ICA Maps[22]



[22] Demonstration Projects A & B Final Reports of San Diego Gas & Electric Company (U 902-E)

Figure 10. An example of load capacity analysis for the circuit near Buckman Springs Rest Areas in San Diego region



It is also important to consider grid capacity upgrades and the prospect of scalability. There are different types of make-ready infrastructure, including: upgrades to transformers, concrete work, and electric panels. These types of make-ready infrastructure will precede large electric equipment installations in anticipation of the higher load demand from charging infrastructure. Depending on the type of charging infrastructure planned to be installed, grid capacity upgrades can be configured to handle slow or fast charging loads by time of use. Depending on the type of grid capacity upgrades needed, whether it is upgrading a transformer or purchasing/constructing a new substation, the cost and timeline to complete those upgrades could drastically vary. Therefore, when siting ZEV infrastructure, if the existing grid capacity is not sufficient to meet the demand, one needs to consider the potential cost and timeline for the needed upgrades as a criterion for selecting the proper sites. When deciding where to build charging or hydrogen infrastructure with on-site generation, planners and developers may prioritize locations with excess grid capacity over those that require upgrades. The choice of site will depend on the specific region and the priority of having ZEV infrastructure in that area.

Ability to Integrate Distributed Energy Resources (DER)

Distributed energy resources (DER) refer to a variety of small-scale, decentralized generation and storage technologies. DERs are typically deployed close to the point of energy consumption. Examples of mature DER technologies include solar panels, wind turbines, biofuels, combined heat and power systems, and energy storage solutions like BESS. DERs can be connected to the grid, operated in parallel with the grid, or function as standalone systems. The feasibility of certain DERs, like solar, will depend on where they are installed. Typically, solar installations at commercial depots or private facilities may be larger and managed independently, whereas solar installations at public sites may be smaller and managed by public partnerships. Moreover, different solar installations may have different energy or business requirements that could affect the system's capability to meet excess grid demand. While deploying DERs would increase the upfront cost of infrastructure development compared to a scenario without them, they offer several potential cost and resilience benefits valuable to developers. For example, solar and battery DER installations can power charging infrastructure and store excess energy in the BESS for use when the need arises. However, some coordination may be required between site owners and utilities to assess possible instances of increased demand to plan for inadvertent grid impacts.

As illustrated in the SANDAG MD/HD ZEV Blueprint Needs Assessment Report, public charging stations for MD-HD vehicles are often in the range of 150, 350, and >1,000 kW. These chargers will place a significant burden on the grid, and deployment of them could result in high costs due to potential grid upgrades needed, as well as demand charges that utilities will pose on facilities. These costs, when accumulated, could significantly increase the overall capital and operational expenses (CAPEX and OPEX), and create uncertainties surrounding the ROI that investors and developers are expecting to achieve through these infrastructure deployment projects.

DERs are a viable alternative to some more costly grid capacity upgrades and can help fulfill power demand for locations without grid interconnection to other resources. Additionally, commensurate deployment of DERs across the grid can reduce peak loads, enhancing grid interconnection in the wake of increasing electric MD-HD vehicle adoption. DERs also provide an additional supply of power in a way that could lower operating costs compared to purchasing that electricity from the utility during peak demand, potentially avoiding demand charges and high energy costs. Moreover, DERs can increase the resilience of facilities to enable reliable backup power during emergency response or power outages.

When evaluating sites for the ability to serve DERs, two factors shall be considered: a) integration capacity, and b) space constraints. With respect to integrations capacity, the ICA maps have the added utility of evaluating the amount of DERs a site can accept. Similar to the previous analysis showing the load capacity, the SDG&E ICA maps also provide information on integration capacity with and without operation flexibility. For example, as shown in Figure 10. , the circuit passing by the Beckman Springs Rest Area has an integration capacity between 0.5 – 1.2 MW for fixed solar photovoltaics. Therefore, when selecting sites, planners should prioritize sites that have the needed integration capacity for using DERs (e.g., solar panels) and meeting the excess load from the deployment of charging infrastructure or on-site hydrogen generation system.

With respect to space, planners and developers may want to consider the parking setup and space needed for deployment of DERs such as solar panel or BESS depending on the power generation they are expecting to achieve (or the grid allows them). For example, the space requirements for installing solar panels in truck/bus parking lots can vary depending on a number of factors such as the type of solar panels, the orientation of the panels, and the local climate. In general, a typical commercial solar panel system requires approximately 100 square feet of space per kilowatt of installed capacity. This means that a 10-kilowatt solar panel system would require roughly 1,000 square feet of space. It is also important to take into consideration the shading patterns, the orientation of the panels (for maximum sunlight exposure), and the overall design of the parking lot.

With respect to BESS, the space requirement may vary widely depending on the type and design of the battery technology. Lithium-ion batteries, commonly used in stationary energy storage, have an energy density of 100-200 Wh/kg, so a 1 kWh battery would weigh 5-10 kg and require a certain amount of physical space that depends on the size and shape of the battery cells. Other battery technologies, such as lead-acid or flow batteries, have different energy densities and space requirements. The number of cells, cooling and ventilation needs, and system layout can all affect the amount of space required per kWh of battery storage.

This provides a few examples of how space requirements for DERs could be factored into the site selection.

Cost of Electricity

MD-HD vehicles are often used for commercial or industrial purposes, where their operating costs are a significant consideration. The cost of electricity to charge these vehicles can make up a substantial portion of their operating costs, which is why it is important to consider the cost of electricity when siting charging stations to ensure that the overall operating costs remain reasonable. Additionally, many commercial and industrial electricity tariffs include demand charges, which are based on the highest amount of power used during a specified period. The demand charges can make charging MD-HD BEVs during peak demand periods more expensive.

While SDG&E is the primary electricity provider for most of San Diego County, customers have the option to purchase their electricity from Community Choice Aggregators (CCAs). CCAs are local, not-for-profit entities that procure and supply electricity to customers within their jurisdiction. In California, they are authorized to purchase electricity directly from generators and sell it to customers in their community. They may also offer different rate structures or pricing options than Investor-Owned Utilities (IOUs) such as SDG&E. Therefore, depending on the community where planners/developers are considering deployment of charging infrastructure (or fueling stations with on-site hydrogen generation capability), the cost of electricity could vary. In the San Diego region, both SDG&E and the CCAs provide a Joint Rate Comparison that includes information on typical electricity rates, average monthly charges, and sources of power. These comparisons are accessible at: https://www.sdge.com/customer-choice/community-choice-aggregation/joint-rate-comparison.

Site Specific Environmental Considerations

When siting charging and hydrogen fueling infrastructure, planners and developers shall consider the environmental implications of the ZEV infrastructure deployment. Here in this section, the project team covers several relevant criteria including the flood risk, CEQA/NEPA implications, land cover, soil contamination & brownfields.

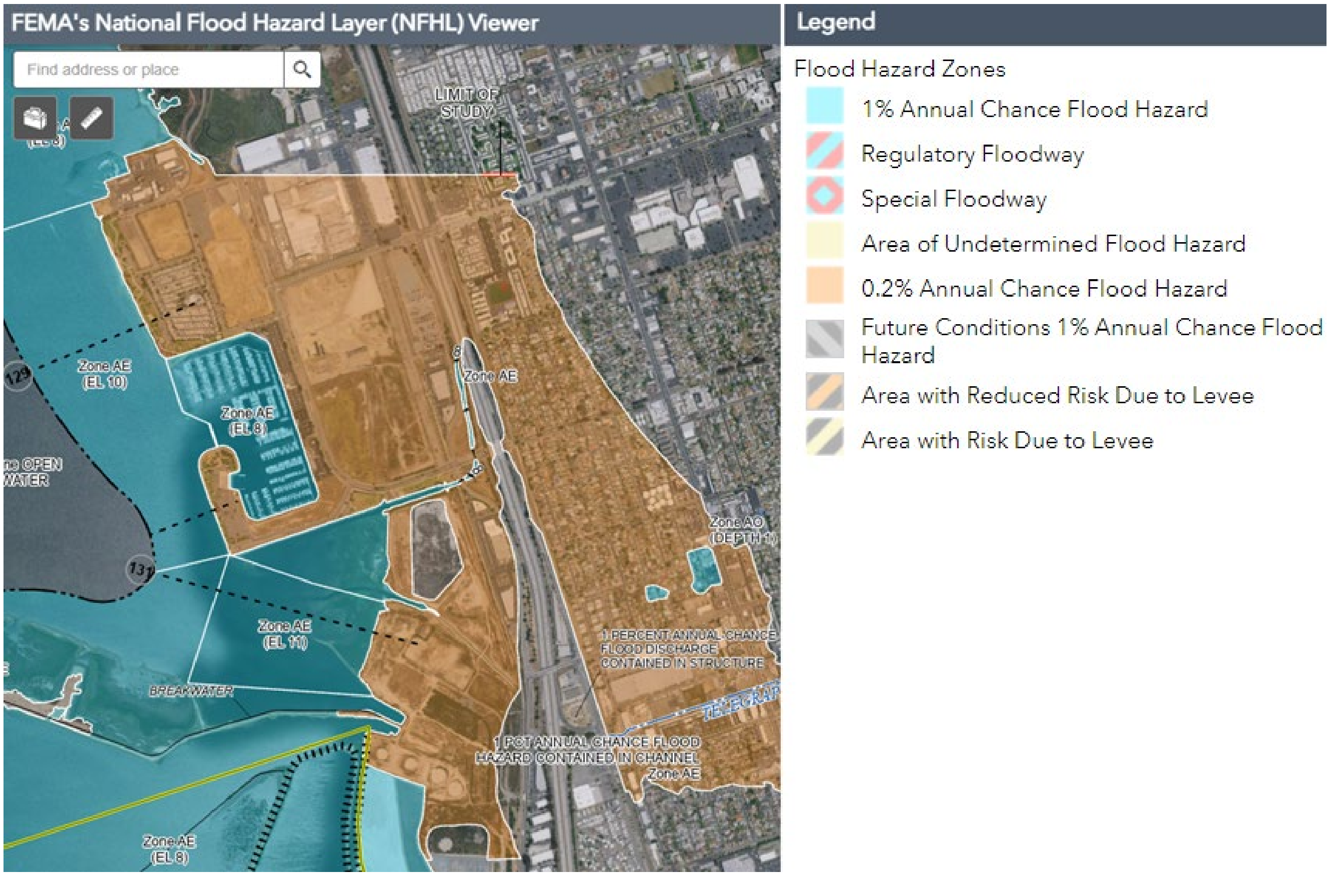
Flood Risk

In California, floods are the second-most widespread natural disaster, which means that flood risk is an important environmental condition to bear in mind when siting charging and fueling infrastructure. Locations for charging and fueling infrastructure should not be so close to the coast, where flooding may be more likely to occur. Siting charging and fueling infrastructure near the coast may induce added environmental burden by increasing the likelihood that electric equipment be washed back into the sea, along with a host of other preventative measures and certifications that increase cost (i.e., NEMA 4x rating for corrosion resistance). Locations that have lower flood risk, but are still susceptible to flood damage, can implement mitigating measures. For example, runoff canals and reservoirs can prevent water from overflowing or redirect water away from critical infrastructure. Wetlands can provide a natural barrier, acting as a giant sponge for floods. However, charging and fueling infrastructure should still be sited cautiously near such areas, so as not to contaminate water plains or runways.

Flood maps[23] are valuable tools that could be used to assess the potential flooding risk in a specific region. An example of such maps are the flood maps provided by the Federal Emergency Management Agency (FEMA) where they could be used to evaluate the flood risks in sites of interest. An example of information that can be extracted from the flood maps is shown in Figure 11. When siting charging and fueling infrastructure, to the extent possible, planners and developers should avoid selecting areas with potential flood risk.

[23] https://www.fema.gov/flood-maps

Figure 11. Flood Risks from FEMA's National Flood Hazard Assessment Map for Communities in Vicinity of San Diego Bay



CEQA/NEPA

CEQA (California Environmental Quality Act) and NEPA (National Environmental Policy Act) are environmental laws that require an assessment of potential environmental impacts before new construction projects can be approved. These laws help ensure that new projects are evaluated for their potential effects on the environment, including air and water quality, wildlife, cultural resources, and other factors. The purpose of CEQA/NEPA is to provide transparency and accountability in the decision-making process, and to ensure that the public can participate in the process and provide input. In the case of charging and fueling infrastructure development, this could include considerations such as the potential impact on nearby habitats, traffic and noise levels, and other environmental concerns. CEQA/NEPA also help to ensure that the public and decision-makers are aware of the environmental impacts of new projects and that appropriate measures are taken to mitigate any negative effects.

CEQA is applicable to projects in California that are proposed or approved by state or local public agencies, including those initiated by private entities but requiring discretionary approval from a government agency. On the other hand, NEPA is a federal law applicable to projects involving federal actions, funding, or permitting. Thus, if a private project necessitates a federal permit or uses federal funds, it is likely that NEPA would apply, necessitating an environmental review. In both instances, the determining factor for triggering CEQA/NEPA is the extent of government involvement. If a private project doesn't involve discretionary approval, permitting, or funding from a government agency (either state, local, or federal), then CEQA or NEPA might not apply.

CEQA requirements can impact the development of charging or fueling infrastructure by requiring environmental impact assessments, mitigation measures, public participation, causing delays, and potentially facing legal challenges. These requirements can add time, cost, and uncertainty to infrastructure development, but they also help ensure that the potential environmental impacts of the projects are fully considered and addressed.

Therefore, when siting MD-HD ZEV infrastructure, planners and developers shall consider the implications of CEQA and NEPA processes on the feasibility and timeline of infrastructure development. It shall be noted that sometimes, the CEQA/NEPA process could be avoided if the proposed ZEV infrastructure falls under the category of exempt projects, or the proposed project does not have a significant impact on the environment. A ZEV infrastructure project could fall under the category of exempt if it meets certain criteria including:

- **Existing facilities**: If the ZEV infrastructure project involves the rehabilitation or expansion of an existing facility, it may be exempt from CEQA review.
- **Emergency projects**: If the ZEV infrastructure project is considered an emergency repair or replacement, it may be exempt from CEQA review.
- **Categorical exemptions**: There are several categorical exemptions listed under CEQA, such as minor alterations to land, small infrastructure projects, and utility line extensions. If the ZEV infrastructure project fits under one of these exemptions, it may be exempt from CEQA review.
- **Statutory exemptions**: Certain projects are statutorily exempt from CEQA review, such as projects that support the implementation of an energy conservation program, or projects that are considered a benefit to the environment.
- **Exemptions for Transit and Alternative Transportation Projects**: In 2020, the California legislature passed Senate Bill 288 (Wiener, Scott) which provides a CEQA exemption through 2023 for various transportation projects, such as pedestrian and bicycle facilities, charging infrastructure for zero-emission buses, and new rapid transit, bus, or light rail service. The exemption only applies to projects constructed in urbanized areas on public right-of-way led by a public agency and constructed by a skilled and trained workforce (unless exempted). Projects must not increase automobile capacity or result in a demolition of affordable housing units (unless exempted).

It is important to note that the determination of exempt categories is made on a case-by-case basis and depends on the specific facts and circumstances of each project. Of course, ZEV infrastructure sites that could streamline the CEQA/NEPA processes (or avoid them through exemptions) may be prioritized as they could significantly reduce the amount of time needed to deploy the infrastructure.

Soil Contamination & Brownfields[24]

Cleaning up and transforming underused and potentially contaminated properties into charging and hydrogen fueling stations is a strategic way to meet the land demand for charging and fueling infrastructure. One of the greatest benefits of using brownfields is the much lower cost of property clean up as compared to redevelopment options. Additionally, there are public grant opportunities available to offset property cleanup and construction costs. EPA has recently released a fact sheet[25] that detail benefits and considerations for redeveloping brownfields into charging and hydrogen fueling stations. When considering brownfields sites for development of ZEV infrastructure, planners and developers may needs to consider the following questions:

- Is a current environmental assessment available?
- Is site cleanup necessary?
- What are the regulatory cleanup requirements?
- Are there environmental enforcement activities on the site?

Answering these questions can aid planners and developers in determining if a site is suitable for the deployment of charging infrastructure.

[24] A brownfield is a property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant.

[25] https://www.epa.gov/system/files/documents/2021-09/revitalizing-brownfield-sites-into-electric-vehicle-charging-stations.pdf

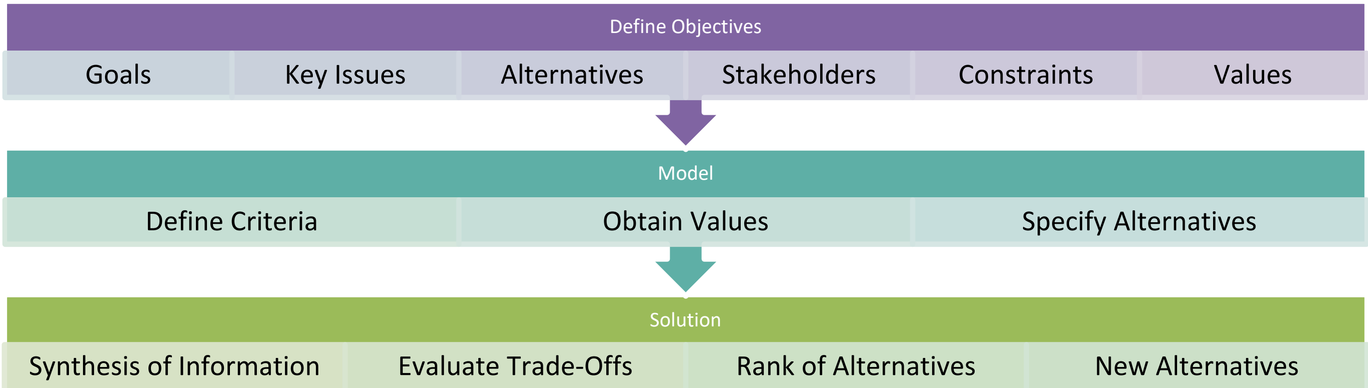
3. INFRASTRUCTURE SITING ANALYSIS FRAMEWORK

Drawing from the research conducted on appropriate siting criteria, the project team proposes a framework for infrastructure siting analysis, designed to pinpoint the best locations for charging and fueling infrastructure. This framework utilizes a multi-criteria decision analysis (MCDA) approach. An illustrative example of the MCDA process can be seen in Figure 12. MCDA is a high-level scoring methodology applied to tackle complex problems typically marked by a selection among alternatives. One of its key benefits is the provision of a structured approach, allowing a diverse group of stakeholders to contribute their insights towards reaching the optimal decision. Recognized for its effectiveness and high utility, MCDA serves as a powerful decision-making instrument routinely employed to determine the best course of action in large-scale projects[26]. Stakeholders assign a numeric weighting to the criteria most important to them, like a standard survey, meaning that no technical proficiency is required to fill out an MCDA survey form. The survey administrator would collect stakeholder responses and can process the results to form a representative outcome of how its constituents prioritize siting criteria. Typically, no technical proficiency is required to interpret the results, since the result is a list of the priorities to consider in siting, ordered by score. The score of siting criteria helps disseminate decision opportunities across different groups (e.g., planners, developers, site owners, utilities, communities). MCDA can be useful in this situation as it allows the various priorities and trade-offs to be quantified and used to optimize the placement of charging and fueling locations. The proposed infrastructure siting analysis framework is illustrated in

[26] Huang, I. B., Keisler, J., & Linkov, I. (2011). Multi-criteria decision analysis in environmental sciences: Ten years of applications and trends. *Science of The Total Environment*, *409*(19), 3578–3594. https://doi.org/10.1016/j.scitotenv.2011.06.022

Figure 13.

Figure 12. An Example of MCDA Process



In the example of infrastructure siting analysis framework shown in

Figure 13, values of the evaluation and ranking of categories are assigned points from a 100-point pool. The more important the criteria, the higher its weight. The sum of the scores for all categories should add up to 100. This illustration depicts an Excel-based MCDA tool, which utilizes the weighted values of siting criteria obtained from survey respondents as input data.

The survey administrator is responsible for defining the criteria and sub-criteria to be weighted. Survey respondents (i.e., developers, and planners) provide each sub-criterion with its own weight. Weights can take on any value between zero and the maximum of the main category (group weight). For example, if a group weight was assigned 20 as the score/value, the sub criteria in that group can range from 0 to 20. This methodology enables respondents to emphasize or dismiss the relevance of that criterion. Next, each sub-criterion will take a score of 0 to 1. For example, if a developer is looking to deploy a small site with ten 150 kW chargers, a site that has at least 1.5 MW load capacity will take a score of 1, and any site below that capacity will get a score of between 0 to 1. Table 3 illustrate what data sources and methodologies can be used to evaluate each sub-criterion.

After the score for each sub-criterion is entered, the overall weighted average score for each site can be calculated and compared against those from other sites. The site with the highest score could be considered for further considerations and evaluations (e.g., coordination with landowner, utility, community stakeholders).

It is important to note that although each criterion is weighted to determine the site's overall score, there are several criteria that must be met as the bare minimum for considering a site for charging and fueling infrastructure deployment. Table 3 highlights these criteria, indicating the minimum requirements. Also, risk analysis within MCDA frameworks for utility investment planning involves identifying, assessing, and mitigating risks specific to the utility sector, so it is important that the administrator incorporate risk assessment and management criteria into prospective MCDA surveys for stakeholders to evaluate potential consequences and uncertainties based on their group's or industry's experience.

Table 3. Methodologies and Tools to Evaluate the Siting Criteria for ZEV Infrastructure

Criteria	Sub-Criteria	Methodology	Potential Tools
Utilization	Vehicle Volume	Count the number of MD-HD vehicle trips that end in the same census block group as the selected site. The scoring methodology varies for small, medium, and large facilities. For small sites (i.e., 10 chargers, 1000 kg/day), the score is determined based on the ratio of the vehicle volume over 1000. For example, if the selected site is located in a census block group that receives at least 1000 trips per day, then a score of 1 is assigned. For any number of trips below that, we will calculate the ratio over 1,000 (e.g., if the area receives 500 vehicle trips, it will get a score of 0.5). For medium size facilities (25 chargers, 2,500 kg/day), we will use a value of 2,500 vehicle trips per day, and for large facilities (40 chargers, 4,000 kg/day), we will use a value of 4,000 vehicle trips per day.	Travel Demand Models / Big Data Analytics (e.g., Replica, Streetlight Data)
	Trip Distance	If at least 40% of MD-HD vehicle trips to that location are greater than or equal to 50 miles, then the location will get a score of 1. Any percentage below 40% will result in a pro-rated score. For example, if 20% of trips to the location have a distance greater than 50 miles, the score will be 0.5.	Travel Demand Models / Big Data Analytics (e.g., Replica, Streetlight Data)
	Dwelling Time	Dwelling time is only relevant for sites intended for charging infrastructure. For on-route charging sites (high power chargers), a score of 1 will be given if the average dwelling time is between 1-2 hours. If the average dwelling time is less than 1 hour, a score of 0 will be given, and a score will be calculated as 2 divided by the average dwelling time for those with average dwelling time above 2 hours (e.g., a site with an average dwelling time of 4 hours will receive a score of 0.5). For overnight charging sites (low power chargers), a score of 1 will be given for average dwelling time above 6 hours, a score of 0 for average dwelling time below 2 hours, and a score between 0-1 for average dwelling time between 2-6 hours.	Big Data Analytics (e.g., Replica, Streetlight Data)
Land Use	Land Size **(Basic Requirement)**	Small facilities should have a minimum of 60,000 square feet of land space. Medium facilities should have a minimum of 150,000 square feet of land space. Large facilities should have a minimum of 240,000 square feet of land space. If a site meets the land size requirement, it will receive a score of 1. If it does not meet the requirement, the score will be zero and the site must be removed from consideration	County parcel data
	Existing Parking Facility	If a site is an existing parking area, it will get a score of 1, otherwise it will be score as zero	Data from Caltrans Truck Parking Study

Criteria	Sub-Criteria	Methodology	Potential Tools
	Land Use/Zoning **(Basic Requirement)**	If the zoning does not allow for the establishment of a truck parking facility with a charging or hydrogen fueling station, the site cannot meet the minimum requirements and should be excluded from consideration. However, if it is an allowable use and the zoning is industrial, it will get a score of 1, otherwise it will get a score of zero.	County parcel data
	Land Price	The score is calculated based on two factors: 1) the land price relative to other candidate sites, and 2) the ability to establish a public-private partnership. When determining the score for land price, the site with the highest price per square foot will receive a score of 0, and the site with the lowest price per square foot will receive a score of 0.5. The scores for all other sites will be calculated relative to these two. If the zoning of a site permits a public-private partnership, it will receive an additional 0.5 points (e.g., if a site has the lowest price compared to other candidates, and allows for public-private-partnership, it will get a score of 1).	Real Estate Market Data (e.g., Zillow, Costar, etc.)
	Access/Congestion/Safety	The score is calculated based on two factors: 1) accessibility and 2) impact on congestion. Sites located within 1 mile of a highway exit will receive a score of 0.5. If the traffic analysis shows that the site has no positive impact on congestion, it will receive an additional 0.5 points.	GIS Analysis, Traffic Modeling,
	Amenities	If the selected site already has one of the essential amenities (such as a restroom, convenience store, or restaurant), it will receive a score of 1. Otherwise, it will receive a score of zero.	Site visit
	Scalability	If the site has the potential to increase charging or fueling capacity by at least 100%, it will receive a score of 1. If the site has no capacity for growth, it will receive a score of zero. Sites with scalability ranging from 0% to 100% will receive a score ranging from 0 to 1 accordingly.	Grid Capacity Analysis, Land Size
	Proximity to other ZEV Infrastructure	If a site is located within 50 miles of another charging infrastructure or 100 miles of another hydrogen fueling infrastructure, it will receive a score of 0. If not, it will receive a score of 1.	AFDC Station Locator + GIS Analysis
	Proximity to Hydrogen Supply/Distribution	If a site is located within 200 miles of a hydrogen production facility, it will receive a score of 1. If not, it will receive a score of zero.	U.S. DOE H2 Matchmaker + GIS Analysis

Criteria	Sub-Criteria	Methodology	Potential Tools
Grid System	Capacity **(Basic Requirement)**	If a site has sufficient load capacity to support the addition of charging infrastructure or on-site hydrogen generation, it will receive a score of 1. If it lacks capacity but grid capacity upgrades can be completed within 6 months, it will receive a score of 0.5. Otherwise, if the grid upgrade takes between 6 – 12 months, it will receive a score of 0. If the grid upgrades take more than 12 months, coordinate with the utility to see what is reasonable before excluding the site from near-term consideration.	SDG&E ICA Maps
	Ability to Integrate DERs	If the site has an integration capacity equal or greater to the additional charging load or load from on-site hydrogen generation, it will receive a score of 1. If it does not have the capacity, it will receive a score between 0 and 1, with a score of 0 given to sites that cannot host any DER.	SDG&E ICA Maps + GIS Analysis
	Electricity Price	The score is determined by comparing the electricity price with that of other potential locations. A score of 0 is assigned to the site with the highest electricity price per kWh, while a score of 1 is given to the site with the lowest price. The remaining sites receive scores between 0 and 1 based on their electricity prices.	SDG&E Joint Rate Comparison
Environmental Condition	Flood Risk	If the site is located within a zone with a flood hazard of 0.2% or higher, it will receive a score of 0. If the site is in a zone with a lower flood hazard, it will receive a score of 1.	FEMA Flood Maps
	CEQA/NEPA	If the site is required to undergo CEQA or NEPA review, it will receive a score of 0. If the site is exempt from such review, it will receive a score of 1.	CEQA/NEPA Analysis
	Brownfields	If a site is a brownfield that can be redeveloped (i.e., the answers to questions in section 3.5.3 are all affirmative), then it will receive a score of 1, otherwise it will be scored as 0.	U.S. EPA Brownfield Map
Equity	Distance to DACs	If a site is located within 5 miles of a DAC boundary, then it will receive a score of 1. If it is located further than 5 miles from a DAC boundary, then it will receive a score of 0.	CalEnvrioScreen,
	Direct Benefit in DACs	The score for a site will be calculated based on the percentage of trips ending up in a DAC. If at least 40% of trips passing the site result in a trip to a DAC, the site will receive a score of 1. If the percentage is lower, the score will be proportional (e.g., a score of 0.5 for 20% of trips ending up in a DAC).	CalEnvrioScreen, Travel Demand Modeling, Big Data Analytics

Figure 13. An example of MCDA framework for siting charging and fueling infrastructure

Infrastructure Siting Analysis Framework

Organization Type: Other

The criteria and subcriteria below are designed to help evaluate each siting criteria. Please fill up the survey following Steps 1, 2, and 3. The "Criteria 1 Example" (yellow section) presents an example of how to fill out the survey. If there is a criteria or subcriteria that you are not familiar with, assign it the lowest possible value.

Step #1: Assign each category a group weight by distributing 100 points among the categories. The more important the criterion, the higher its weight. The sum of the scores for all categories should be 100.

Step #2: Provide to each subcriterion its own weight. Weights can take on any value between 0 and the maximum of the group weight. For example, if you assigned a group weight of 10 to a category, the subcriteria in that group can range from 0 to 10. You can assign all subcriteria in that group a 10, or some a 5, one a 0,

Step 3: Rate each location feature relative to the others in satisfying each subcriteria. For example, if you think battery electric charging is the best infrastructure for truck stops, you would give BE Charging a score of 4 for that subcriteria.

The best location feature for the subcriteria = 4
The worst location feature for the subcriteria = 1

			Location Features		
Criteria Categories and Subcriteria	Group Weight	Subcriteria Weight	Opportunity Charging	Overnight Charging	H2 Fueling
Utilization	20				
Vehicle Volume		10	1		
Trip Distance		5	1		
Dwelling Time		5	0		
Land Use	20				
Land Size		4	1		
Existing Parking Facility		4	1		
Land Use/Zoning		1	1		
Land Price		2	0.5		
Access/Congestion/Safety		2	0		
Amenities		1	0		
Scalability		2	1		
Proximity to other ZEV Infrastructure		4	1		
Proximity to Hydrogen Supply/Distribution		0			
Grid System	25				
Capacity		20	1		
Ability to Integrate DERs		2	0		
Electricity Prices		3	0.8		
Environmental Condition	20				
Flood Risk		5	1		
CEQA/NEPA		10	1		
Brownfields		5	0		
Environmental Justice	15				
Distance to DACs		5	1		
En-route to DAC		10	1		
		Weighted Average Score	**83.4**		

4. VEHICLE TECHNOLOGY CRITERIA FOR FLEETS

As described in the market assessment section of the Needs Assessment Report, the market for MD-HD ZEVs is growing rapidly and there are currently various ZE models across different body type and weight classes that are either available today or are expected to become available in the next few years. Considering, that these vehicles require different fueling infrastructure, and have different type of operational limitations than their ICE counterparts, this section intends to provide a set of criteria that fleets could use to select the proper MD-HD vehicle models when transitioning to ZE technology. These criteria are described in the following sections.

Range

MD-HD ZEV range consistently presents itself as the primary concern fleets have when considering the transition to alternative technologies. However, the market has introduced several battery electric MD-HD vehicle models that have demonstrated short (<50 miles), medium (<100 miles), and long range (100-300 miles) capabilities. These short, medium, and long-range options have incremental costs associated with total energy capacity and charging speed capabilities. Battery electric MD-HD vehicles that can expect to perform local, routine shifts (e.g., 50-100 miles) and return to base may only need a maximum of 150 miles of range to fulfill that role. For interregional vehicle trips greater than 100 miles, higher capacity battery electric MD-HD vehicles coupled with high-power public charging will be needed to facilitate longer vehicle trips without having to return to base. Alternatively, long regional haul may be fulfilled by either high range battery electric or hydrogen fuel cell electric MD-HD vehicles.

Table 4 below shows the minimum, average, and maximum all-electric ranges (AER) associated with commercially available (or soon to be available) battery electric MD-HD vehicles in the market. As shown, for most of the vehicle types, there is a broad range of electric vehicles with various AERs that fleet could select depending on their needs. Of course, the current availability of battery electric MD-HD vehicles is fairly limited for AERs greater than 250 miles. For those applications, fleets may also need to consider FCEVs.

Table 4. Minimum, Maximum, and Average AER for Commercially Available (or soon to be available) Battery Electric MD-HD Vehicles

Vehicle Type	Number of Models	Minimum AER	Average AER	Maximum AER
Van	17	60	133	230
Step Van	22	80	135	250
Medium-Duty Pickup	7	110	263	500
MD Vocational	30	70	132	200
Box Truck	23	66	162	200
Bucket Truck	1	130	130	130
Refuse Truck	5	56	111	170
Street Sweeper	2	200	200	200
Heavy Truck	22	90	199	500
Transit Bus	35	62	189	329
School Bus	33	70	122	180
Shuttle Bus	32	70	128	200
Articulated	2	153	173	193
Coach Bus	7	125	161	195

Access to Charging Infrastructure

When deciding on the proper technology to select in transitioning to ZE MD-HD vehicles, fleet owners should evaluate the availability of charging and fueling options in the areas where their vehicles operate. Fleets that are considering to transition to BEVs have two options: a) depot charging, where charging stations are located at the fleet's base, can provide a secure and reliable source of energy to recharge vehicles overnight, and b) public charging infrastructure, such as fast-charging stations along highways and at truck/bus stops, can provide en-route opportunity charging options for vehicles on long-haul trips (or vehicles that do not return to base). The availability and accessibility of charging options, combined with the duty cycle requirements of the vehicles, will determine the type of charging infrastructure that is necessary for a successful transition to ZE technology. For example, if the vehicles are used for local, routine trips and return to base regularly, depot charging may be sufficient. However, for interregional trips, public charging infrastructure may be required to provide the needed energy to complete the journey without returning to base.

For fleets considering FCEVs, access to hydrogen fueling stations, whether public or private, should be taken into consideration. If the number of FCEV vehicles that the fleet intends to purchase is significant enough (large transit agencies), building a private hydrogen infrastructure may be a viable economic option. Otherwise, relying on publicly available stations is necessary.

Payload Capacity

Compared to their ICE counterparts, the currently available, battery electric MD-HD vehicles have lower payload capacity due to increased weight from their onboard traction battery. The same battery capacity (i.e., kilowatt-hours) can be configured from batteries with different energy densities (i.e., pounds per kilowatt-hour), creating a wide range of potential battery weight on-board electric MD-HD vehicles. This affects the amount of freight (and passengers in the case of buses) that can be carried, since the vehicle tare weight is regulated. According to a study by the NACFE[27] there are multiple factors that impact the weight difference between a diesel MD-HD vehicles as compared to its battery electric counterpart when considering freight transportation. As a hypothetical example, consider a diesel tractor with a tare weight of 16,000 lbs. and a trailer with a tare weight of 14,000 lbs., resulting in a total tare weight of 30,000 lbs. The maximum permissible freight weight in this scenario is 50,000 lbs. In comparison, a BEV with a 200-mile range and a 400-kWh battery pack has a tare weight of 24,000 lbs., with 8,000 pounds attributed to the battery. When mated with the same 14,000 lbs. trailer, the total tractor-trailer tare weight is 38,000 pounds, reducing the maximum permissible freight weight to 44,000 lbs. In this example, the diesel truck can carry 6,000 pounds more freight than the BEV.

For these reasons, the implications of battery weight on payload capacity are part of the vehicle technology criteria that fleet owners should consider. Of course, MD-HD vehicle payloads may vary by vocation, and there may be opportunities to make up for reduced permissible weight through deadheading reduction strategies. Depending on whether the vehicle operators are using the maximum payload of their vehicle or not, BEVs could pose challenges. Of course, another option is to utilize FCEVs which due to higher energy density of hydrogen, do not pose the same payload capacity limitations as BEVs.

Cost of Ownership

The capital and operational cost of vehicles are one of the significant factors that determine the economics of switching to ZE technology. When fleets are evaluating the technology for their next vehicle purchase, total cost of ownership (TCO) could be used as primary factors in determining the business case for one vehicle technology over the other. There are multiple publicly available TCO analysis tools available to fleet owners to compare CAPEX and OPEX of various technologies. An example is the TCO calculator being offered by the Pacific Gas & Electric[28] (PG&E) utility which provides an option to fleet owners to enter various inputs including the type of vehicles that fleets plan to purchase, the ZE make and model they would like to evaluate, their average daily mileage, their charging behavior, potential EV readiness

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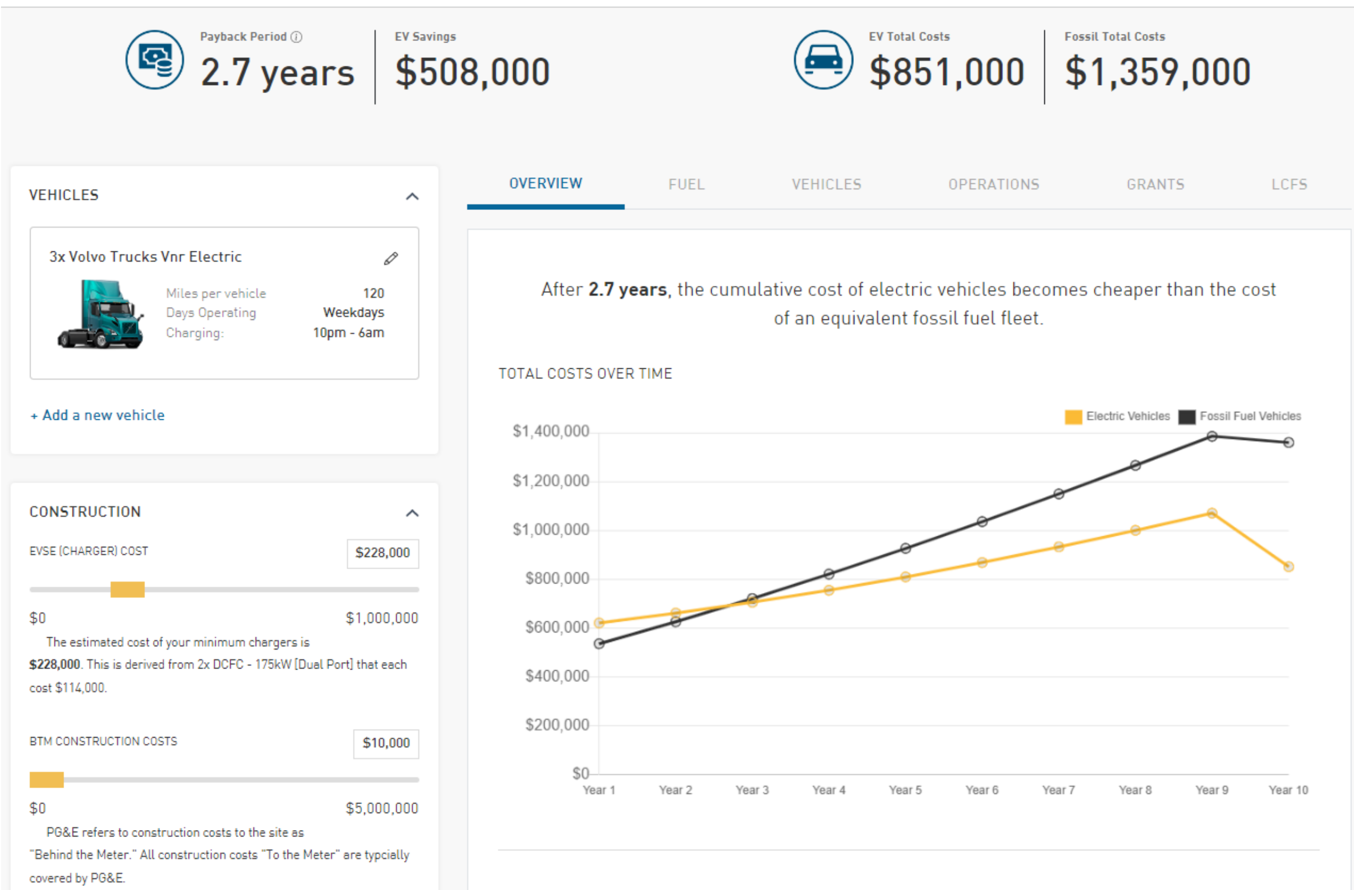
27 North American Council for Freight Efficiency. (2019) Guidance Report: Viable Class 7/8 Electric, Hybrid and Alternative Fuel Tractors. https://nacfe.org/wp-content/uploads/edd/2019/12/Viable-Class-7-8-Alternative-Vehicles-Final-12-10-.pdf

28 https://fleets.pge.com/tco/

costs (e.g., behind the meter construction as well as EVSE installation cost), cost of fuel, and many other factors. The TCO tool can then provide the fleet owners with the estimates of TCO over time for the ZE option as compared to its counterpart ICE. An example of such analysis is shown in Figure 14 which compares the TCO for a Class 8 Volvo VNRe driving 120 miles per day as compared to its counterpart diesel. In this example, the TCO analysis shows that after 2.7 years, the cumulative cost of owning a Volvo VNRe becomes cheaper than the cost of an equivalent diesel vehicle.

Another example of publicly available TCO tools is one provided by CARB's HVIP program[29] is meant to be used as a guide for understanding the direction of vehicle TCO only. Version 1.0 of this tool does not include any capital cost information associated with alternative fueling stations or electric vehicle charging station development, nor does it include other fees commonly associated with near- and zero-emission vehicle deployment such as demand charges.

Figure 14. PG&E TCO Analysis for a Class 8 Volvo VNR Electric driving 120 miles per day.



[29] https://californiahvip.org/tco/

Charging Power Acceptance

As outlined in the Needs Assessment Report, advancements in charging technology have led to the development of Megawatt Charging Systems (MCS), capable of providing a maximum of 3.75 MW of charging power. Despite this innovation, most MD-HD battery electric vehicles currently available have charging rates ranging from 100 kW to 350 kW. For duty cycles that allow for ample charging time, such as an 8-hour charging window, lower charging rates of 50 to 100 kW are sufficient for overnight charging. However, for duty cycles requiring en-route opportunity charging with limited downtime for charging, higher power charging rates will be necessary to not significantly curb revenue generation time.

Consider a ZEV truck with a 250-mile electric range that operates on a duty cycle with an average daily mileage of 500 miles. To complete its duty cycle, the truck would need to rely on en-route opportunity charging. If the truck has one hour of downtime available for charging, it will require a 500-kW charger to recoup the necessary energy to complete its shift. However, if the truck can only accept a maximum power of 150 kW, it will not draw more than that amount, regardless of the charger's power. This scenario could pose a significant challenge to truck drivers, as they would need to significantly increase their downtime, and therefore their shift hours, to complete their duty cycle. For these reasons, fleet owners should carefully consider the maximum charging power acceptance rate when selecting the appropriate technology for transitioning to ZEVs.

Power Take Off (PTO)

Power take-off (PTO) is a device that transfers an engine’s mechanical power to another piece of equipment. A PTO allows the hosting energy source to transmit power to additional equipment that does not have its own engine or motor. For example, a PTO helps to run a cement mixer. There are many MD-HD vehicles that rely on PTOs to fulfill their duties. Examples are bucket trucks, sewer trucks, cement mixers, digger derricks, dump trucks, etc. For ICE vehicles, the PTOs are usually seated on the flywheel housing, which transfers power from the engine to a secondary application. In most cases, this power transfer applies to a secondary shaft that drives a hydraulic pump, generator, air compressor, pneumatic blower, or vacuum pump. For BEV and FCEVs, the electric PTOs (ePTO) are not connected to the electric motor, but they have a separate small electric motor that gets connected to the battery so they could power various mechanical equipment on the truck or the trailer that it is pulling. While there are quite a few MD-HD ZEV manufacturers that are offering ePTO on their vehicles, fleet owners should always consider the availability of PTOs (if needed for their application) when deciding on the type of ZE technology that they are planning to acquire.

Decision Tree For Selecting Proper MD-HD Vehicle Technology

In this section, the project team provides an example decision tree that offers a structured and systematic approach for a fleet to plan on selecting ZE MD-HD. This helps to organize the various factors that need to be considered, such as the types of operations the vehicles will be used for, the charging or fueling infrastructure available, the maximum permissible weight for the vehicles, and many others. By using a decision tree, the fleet can weigh the pros and cons of different vehicle options and make a well-informed decision based on their specific needs and constraints. This results in a more efficient and effective process for selecting the best ZE MD-HD vehicles for the fleet.

A decision tree for selecting ZE MD-HD vehicles for a fleet could involve several steps:

1. Identifying the primary application for the vehicles, including delivery routes, weight of loads, and operating conditions.
2. Evaluating the available vehicle options, including battery electric and fuel cell electric vehicles, and their range, PTO capability, maximum payload capacity, and refueling options.
3. Determining the charging infrastructure requirements, including the availability of charging stations and the maximum charging power acceptance rate for the vehicle.
4. Considering the operational costs, including fuel and maintenance costs, and the overall cost of ownership.
5. Evaluating the financial incentives and regulations in the area, including government subsidies and ZEV requirements.

Figure 15 displays a decision tree example for MD-HD vehicle fleets (trucks and buses) to identify proper and cost effective ZE models that can meet their operational needs. The first step—identifying the primary application of the vehicle—is critical and should be informed by market segmentation, particularly for MD-HD vehicles that operate in commercial fleets. Much of the foundational vehicle market segmentation analysis for MD-HD vehicles has been accelerated by California's progressive electrification rules, such as the Advanced Clean Trucks, Innovative Clean Transit, and Advanced Clean Fleets regulations, which categorize vehicles by occupational characteristics for pollutant mitigation. For example, CalHEAT, a California based non-profit accelerating research, development, and demonstration of cleaner, more efficient MD-HD vehicles, dispels MD-HD vehicle classifications by weight and application, as well as projections of electrified MD-HD vehicle outcomes that will achieve air quality goals required by California rules[30]. These developments, as well as the criteria outlined in this document, serve to inform how to shape future clean MD-HD vehicle fleets.

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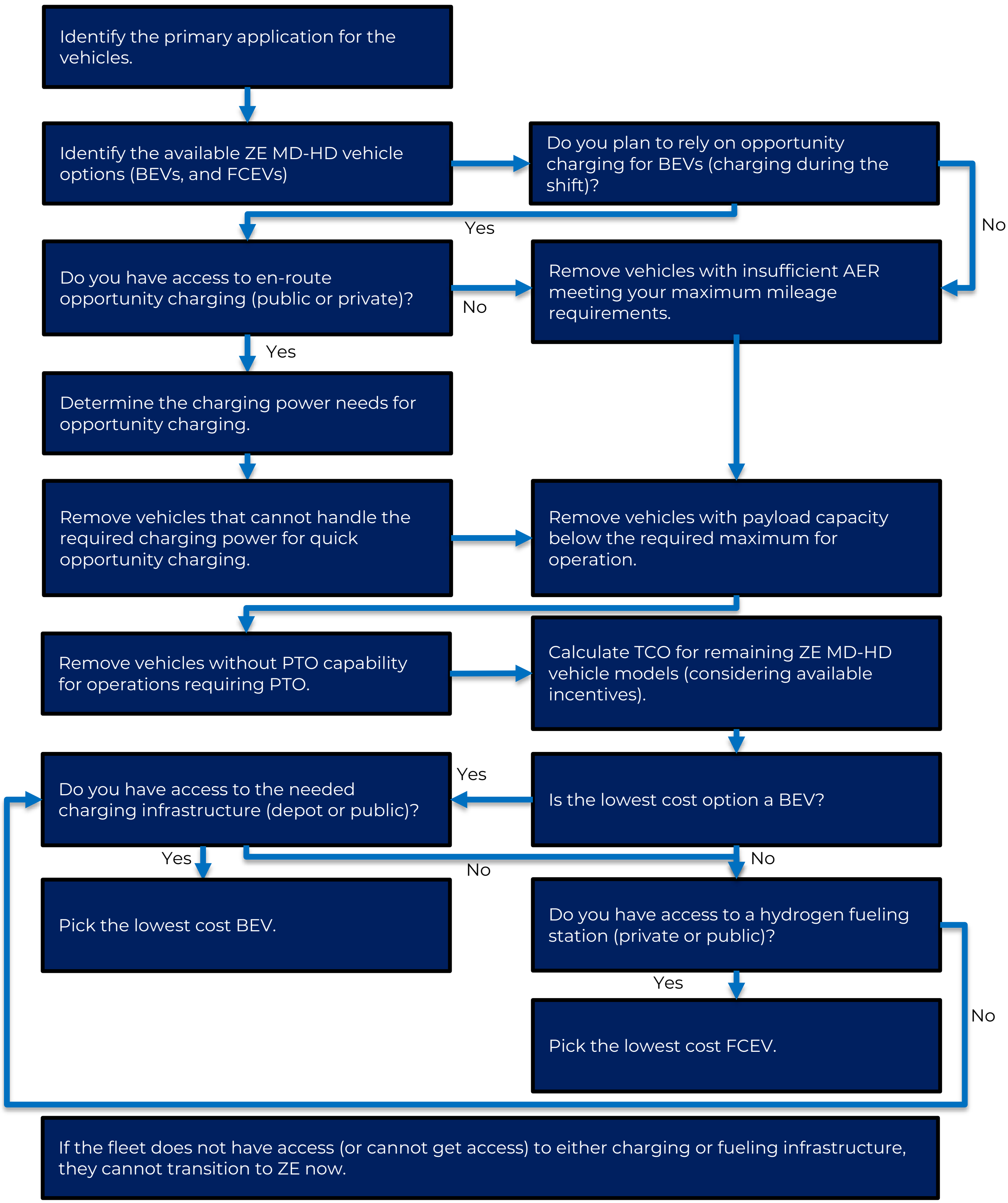
[30] https://calstart.org/wp-content/uploads/2018/10/CalHEAT-Roadmap.pdf

Figure 15. An example decision tree for vehicle technology selection



5. SUMMARY & NEXT STEPS

The goal of this report is to identify technology and infrastructure siting criteria that can be used to support the transition of MD-HD fleets in the San Diego region to zero emission technologies. The report is divided into two parts: siting criteria for charging and hydrogen fueling infrastructure and technology criteria for fleets.

The first part of the report provides details on the siting criteria for charging and hydrogen fueling infrastructure, highlighting the key criteria that regional planners and infrastructure developers should consider. The five broad groups of criteria include utilization, land, equity, grid capacity and environmental conditions. Utilization refers to the demand for charging or hydrogen fueling, while land encompasses the availability of suitable sites and compatibility with land use. Equity involves ensuring that deployment of infrastructure does not negatively impact disadvantaged communities and that they receive direct benefits. Grid capacity considers the availability of high-power charging stations and power availability from the utility provider. Environmental criteria consider potential environmental conditions that could impact construction or operations of a station, as well as the potential environmental impact that the station could pose on the community. The project team also proposed a framework for infrastructure siting analysis, which utilizes a multi criteria decision analysis (MCDA) framework to determine the best locations for charging and fueling infrastructure. The MCDA approach involves assigning weights to the different siting criteria based on their significance, then computing the overall weighted average score for each potential site. This methodology gives respondents the ability to adjust the importance of each criterion by assigning it a weight, allowing them to emphasize or de-emphasize its relevance. Moreover, the administrator of the MCDA survey can regularly solicit input from diverse stakeholders to reflect the latest terminological considerations and advances in clean MD-HD vehicles.

The second part of the report provides criteria for fleet owners/operators to consider prior to investing in new MD-HD ZEVs. The vehicle technology criteria include range, payload capacity, cost of ownership, charging acceptance rate, charging/fueling frequency, power take off (PTO), and access to charging and fueling infrastructure. Fleets need to consider the availability of both depot and public charging/fueling infrastructure to ensure they can fully charge/fuel their vehicles to meet the demands of their duty cycles. The report also provides a decision tree that can help fleets to determine the proper ZE MD-HD vehicle model when transitioning to ZE technologies.

Following the completion of the SANDAG MD/HD ZEV Technology & Siting Criteria Report, the project team will move forward with developing an extensive inventory of strategies that will aid the region to transition its MD-HD fleets to zero-emission technology. These strategies will be based on effective methods for accelerating deployment, take into account the economic considerations of the fleets in the region, and will prioritize equity. The strategies will also be tailored to align with the region's MD-HD goals for the next two decades.