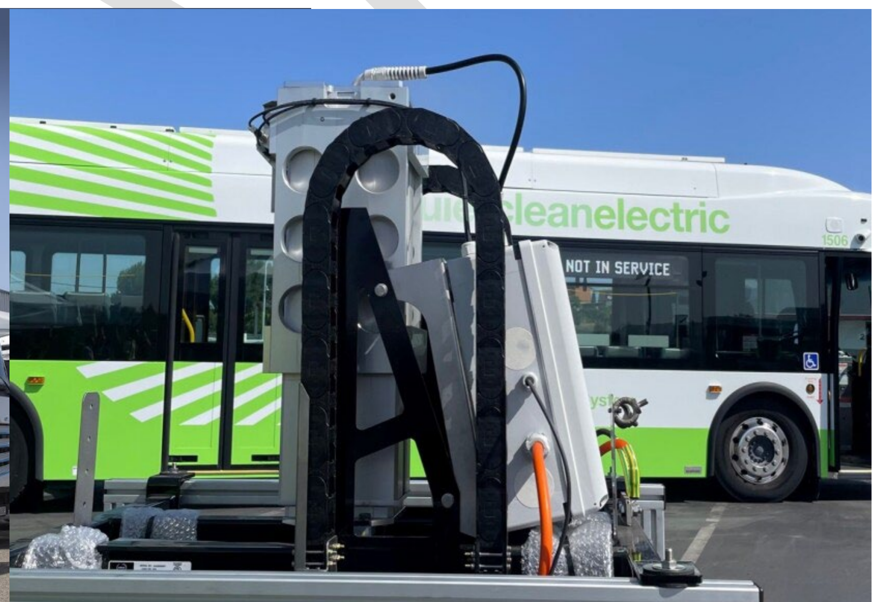
Draft San Diego Regional Medium & Heavy-Duty Zero Emission Vehicle Blueprint

October 2023


ABSTRACT

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- Imperial County Transportation Commission
- Nikola
- Pacific Environment
- Port of San Diego
- Prologis
- San Diego Air Pollution Control District
- San Diego County Regional Airport Authority
- Sutra Research
- USC/Metrans

EXECUTIVE SUMMARY

The San Diego Association of Governments (SANDAG) has secured funding through GFO-20-601, titled "Blueprints for Medium- and Heavy-Duty Zero-Emission Vehicle Infrastructure," under the California Energy Commission's (CEC) Clean Transportation Program to guide the transition of Medium- and Heavy-Duty (MD-HD) freight and transit vehicles to zero-emission technology while addressing challenges related to technology readiness, infrastructure availability, and cost. The Blueprint integrates policy landscape research, vehicle fleet and emissions modeling, and a projected energy and infrastructure needs assessment to provide a comprehensive overview of the transition path for MD-HD vehicles in the region towards zero-emission technology. Additionally, this Blueprint pinpoints both short- and long-term strategies designed to accelerate the adoption of MD-HD Zero Emission Vehicles (ZEVs) in the San Diego region, with an emphasis on maximizing air pollution and GHG emissions reductions in low-income and disadvantaged communities.

Given the current consumer confidence and awareness regarding MD-HD ZEVs and their associated infrastructure, this Blueprint begins with a detailed assessment of the current state of ZEV technologies and their supporting infrastructure. Presently, the ZEV market is segmented into three primary technology platforms: battery-electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), and fuel cell electric vehicles (FCEV). In this Blueprint, as corroborated by other reputable studies conducted by state agencies and market experts, BEVs are projected to have a notably successful adoption rate compared to PHEVs and FCEVs. This is largely attributed to the extensive availability of BEV models from manufacturers. At this time, there are over 200 MD-HD BEV models tailored to nearly every MD-HD vehicle segment. In contrast, a diversified range of MD-HD PHEV models seems less probable. The MD-HD FCEV market segment, however, does show potential for growth, especially in areas such as long-haul trucking. This is because FCEVs offer quick refueling times comparable to conventional diesel trucks, a longer driving range than many battery-electric options and can maintain consistent performance even under heavier loads. Additionally, as hydrogen refueling infrastructure expands and becomes more accessible, and access to clean hydrogen becomes more widespread (due to investment from Federal Bipartisan Infrastructure Law – BIL), the fuel cell electric powered technology will become increasingly viable for long haul truck that cross vast distances without frequent charging or refueling stations. However, there are currently a limited number of MD-HD FCEV models available, and further advancements in the technology may be required for it to gain traction over MD-HD internal combustion engine vehicles (ICEVs).

On the other hand, there are stronger prospects for expanding electric vehicle charging networks and the reach of hydrogen fueling stations in parallel and proportion to the projected influx of MD-HD BEVs and FCEVs in the region. Both electric vehicle charging and hydrogen fueling stations have exceeded the commercialization stage, particularly in California. Agencies tracking zero-emission infrastructure deployed to date, such as the CEC and U.S. Department of Energy's (DOE) Alternative Fuels and Data Center (AFDC), estimate that the San Diego region currently hosts 428 direct current fast charging (DCFC) stations ports, 9,633 Level 2 chargers, and one hydrogen fueling station, almost all serving light-duty vehicles, with the exception of one public charging station in Otay Mesa serving MD-HD vehicles.

With the emergence of MD-HD ZEVs and the notable disparity in their supporting infrastructure, the necessity for expanded charging and hydrogen fueling networks is evident. As part of this Blueprint, SANDAG reviewed fleet technology, emission, and energy consumption projections to determine the regional needs for charging and fueling infrastructure. With the implementation of California's Advanced Clean Truck (ACT) and Advanced Clean Fleet (ACF) regulations over the coming two decades, there is an anticipated surge in electricity and hydrogen fuel demand to sustain MD-HD ZEV operations in the region. The Blueprint highlights this aspect, underscoring the urgency for planning and investing in both charging and hydrogen infrastructure.

The energy and fuel consumption projections formulated in this analysis served as foundational data for the modeling of charging and fueling infrastructure needs. For 2024, to accommodate the projected electricity demand of 534 MWh per day, 1,380 new charging ports for MD-HD BEVs will be required, with capacities ranging from 19.2 kW up to megawatt-scale systems. The assessment also categorizes chargers as either "public" or "private-access." Although the majority of chargers are anticipated to be for private use at depot locations, there will be an urgent need to establish a robust network of public chargers catering to those without access to depot chargers and those requiring opportunity charging. Concurrently, 11 hydrogen stations should be operational by 2024 to meet the projected daily hydrogen demand of 3,342 kg. Predictably, the number of charging and fueling stations is anticipated to steadily rise between 2024 and 2040, with a projected annual increase of over 1,300 charging stations and 8 fueling stations per year. By 2040, the region should possess 22,860 chargers for MD-HD BEVs and 83 hydrogen stations for MD-HD FCEVs geared to accommodate the daily demands of 6,479 MWh and 62,160 kg of H2, respectively.

According to the project team's estimates, the construction of the necessary charging and fueling infrastructure to support the anticipated transition to MD-HD ZEVs is a significant endeavor. The financial forecast suggests that by 2040, a substantial investment of nearly $2.54 billion will be required for the development of charging infrastructure alone. In parallel, the establishment of hydrogen fueling infrastructure will demand an additional outlay of around $140 million. These figures underline the magnitude of commitment and resources needed to propel the region towards a sustainable transportation future.

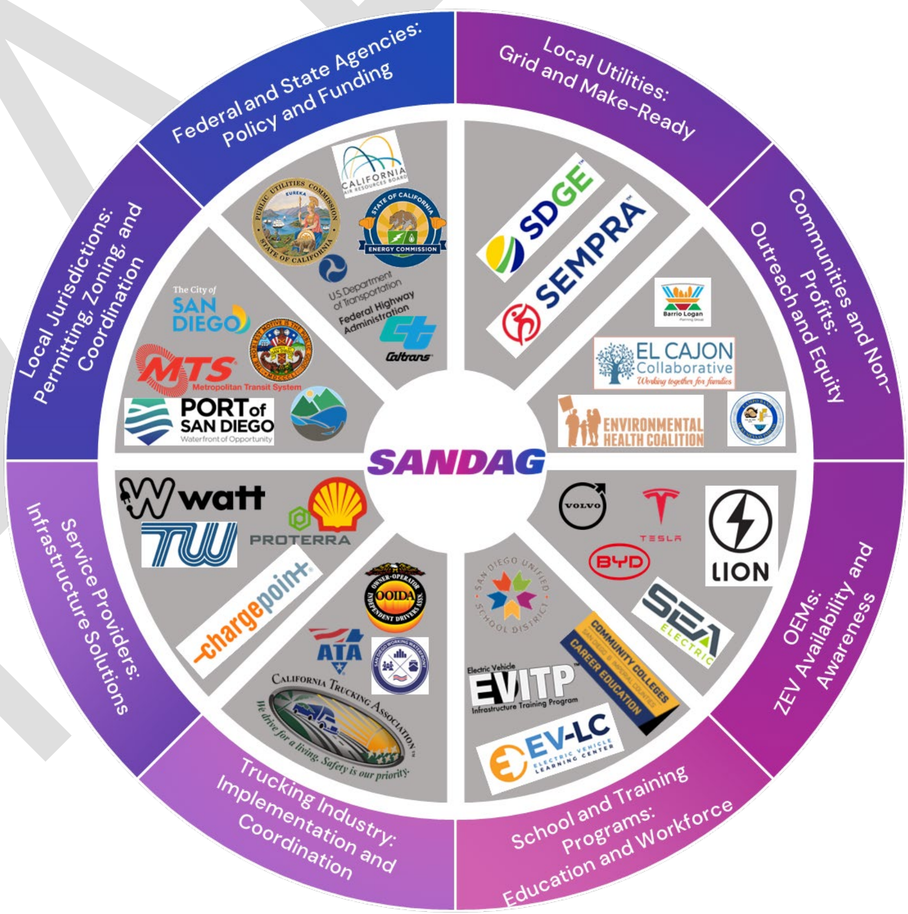
Significant Investment Needed

$2.7 billion investment will be needed by 2040 to install approximately 23,000 depot and public charging ports as well as 83 hydrogen fueling stations dedicated to medium and heavy duty vehicles across the San Diego Region.

Since the region is projected to steadily deploy charging and fueling infrastructure between 2024 through 2040 to meet MD-HD ZEV energy demand, SANDAG also made available in this Blueprint a series of resources to ensure optimal infrastructure deployment. The Blueprint provides siting criteria and technology criteria for developers and fleet owners to consider the best path towards seamless MD-HD ZEV adoption. For siting criteria, the Blueprint recommends the planners and developers to consider technical facets, such as utilization of the charging and fueling infrastructure as well as the grid capacity. Additionally, land and site-specific environmental conditions are recommended for inclusion in planning efforts, as the challenges associated with these areas from a permitting perspective are often understated. Equally, if not more crucial as a siting criterion, is the commitment to equity and environmental justice (EJ). This emphasis stems from the goal of MD-HD ZEV adoption, which is to alleviate public health challenges historically imposed by diesel and gasoline MD-HD vehicles in the region. Aside from the siting criteria for EV charging and hydrogen fueling infrastructure deployment, the Blueprint also elaborates on technology criteria that fleet owners can consider when deciding what kind of MD-HD ZEV will fulfill the duty cycles performed by their current fleets.

While the Blueprint's technical analysis and resources are vital for expediting the deployment of MD-HD ZEVs in the region, an integral component of this Blueprint focuses on the near-term and long-term implementation strategies. Specifically designed to address current adoption barriers of MD-HD ZEV technologies, they leverage existing programs and resources from federal, state, and local agencies, offering practical, cost-effective, and equitable solutions that align with regulatory mandates. These strategies, intended for SANDAG and its regional partners, advocate for simplifying the guidelines for site selection, land use, zoning, and entitlements processing. They also delineate potential funding sources, highlighting the synergy of public funds and public-private collaborations for the advancement of ZEV infrastructure. Additionally, they emphasize the critical importance of workforce development, training, and education, ensuring residents, businesses, and entire communities are well-equipped for the upcoming shift to ZEV technologies. In addition to strategies, the Blueprint also highlights specific roles and responsibilities for SANDAG and its regional partners, as illustrated in Figure ES.1. In collaboration with these partners, SANDAG can offer regional policy and funding support, complementing the contributions of state and federal agencies.

Figure 1. Roles of SANDAG and Regional Partners in the MD/HD ZEV Deployment Paradigm (*Please be aware that this chart serves as an illustrative example of a set of stakeholders and does not present an exhaustive list of all regional partners and stakeholders*)



1. THE SHIFT TO ZERO EMISSION MD-HD VEHICLES

What is the San Diego Regional MD-HD ZEV Blueprint?

In light of the growing demand for sustainable and innovative transportation solutions, SANDAG has pioneered the development of a regional blueprint to chart the path for MD-HD ZEV integration within the region. It is intended to guide the San Diego region through a pivotal shift towards zero-emission technology. Emerging from this initiative are foundational documents including the ZEV Needs Assessment Report[1], the ZEV Siting and Technology Criteria Report[2], and most recently the ZEV Implementation Strategies Report[3]. Collectively, these in-depth studies culminate in the San Diego Regional Medium-Duty and Heavy-Duty Zero-Emission Vehicle Blueprint (Blueprint). This Blueprint emphasizes the urgency of transitioning to environmentally conscious transportation modalities and offers a comprehensive roadmap for achieving this paradigm shift in the region.

Needs for Emission Reductions

The San Diego region is burdened by high levels of criterial pollutants from major freight facilities and truck corridors. As of 2022, MD-HD vehicles contributed one fifth of NOx and DPM emissions in the San Diego region, both of which cause adverse health effects to residents burdened by proximity to MD-HD vehicle traffic. In the same year, the San Diego region's MD-HD vehicle fleet produced 2.5 million metric tons (MMT) of GHG emissions. These significant emission impacts serve as compelling evidence for the growing consensus that transitioning the San Diego region's MD-HD vehicle fleet to ZEVs is critical.

ZEVs represent the technological solution to these air quality, climate, and public health issues. Transitioning from internal combustion engine (ICE) vehicles to ZEVs reflects a paradigm shift in transportation by eliminating tailpipe emissions. Electric powertrains also have superior fuel efficiency compared to conventional fossil fueled vehicles, taking less energy in the form of grid electricity. While there are also several other benefits, such as lower total cost of ownership, reduced noise pollution, improved driver experience, the air quality, climate, and health benefits associated with ZEVs alone are sufficient to command regional fleet transition. For these reasons, most recently, federal, state, and regional agencies have developed various regulatory requirements and funding policies to support the transition of MD-HD vehicles to ZEV.

Executive Orders

At the state level, California's Governor Gavin Newsom signed Executive Order No. 79-20 in September 2020, mandating that all new passenger vehicles sold in the state and all drayage fleets be zero-emission by 2035. The directive also sets targets for non-port MD-HD vehicles to

[1] Available online: https://www.sandag.org/-/media/SANDAG/Documents/PDF/projects-and-programs/innovative-mobility/clean-transportation/regional-medium-duty-heavy-duty/md-hd-zev-needs-assessment-report-2023-01-01.pdf
[2] Available online: https://www.sandag.org/-/media/SANDAG/Documents/PDF/projects-and-programs/innovative-mobility/clean-transportation/regional-medium-duty-heavy-duty/md-hd-zev-draft-blueprint-2023-04-01.pdf
[3] Available online: https://www.sandag.org/-/media/SANDAG/Documents/PDF/projects-and-programs/innovative-mobility/clean-transportation/regional-medium-duty-heavy-duty/md-hd-zev-blueprint-draft-implementation-strategies.pdf

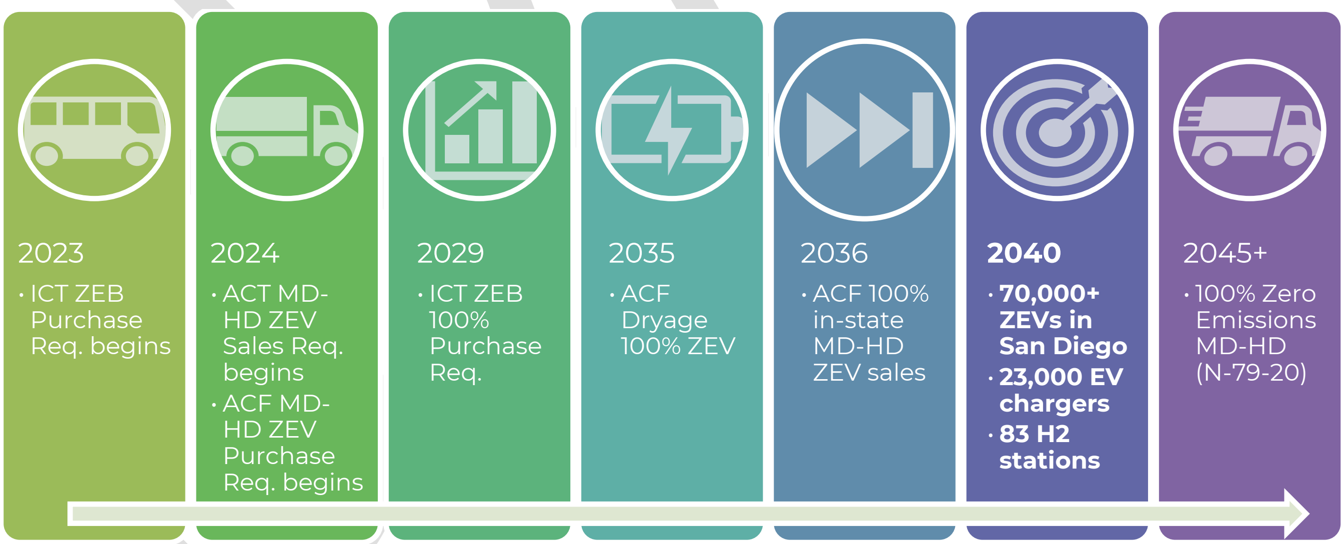
be 100 percent zero-emission by 2045. Following the order, the California Air Resources Board (CARB) developed regulations to help the State achieve these electrification targets, such as the Advanced Clean Trucks (ACT) and most recently the adoption of the Advanced Clean Fleets (ACF) regulation.

At the federal level, President Biden signed Executive Order 14037 in August 2021, ordering a comprehensive plan to accelerate the adoption of ZEVs in the United States[4]. This plan sets the goal to make half of all new light duty vehicles sold in 2030 to be ZEVs, including: BEV, PHEV, and FCEV. The White House has also created a goal that 100 percent of federal fleet procurement be light-duty ZEVs by 2027. For MHDVs, the goal is to have 30 percent of new vehicle sales be ZEV by 2030 and reach 100 percent by 2040, and also have the federal fleet procurement be 100 percent ZEVs by 2035.[5] A related EPA proceeding proposes Phase 3 GHG standards for MD-HD vehicles, which would require more stringent emission standards beginning model year 2027. These initiatives are expected to advance the United States as a leader in electric vehicle manufacturing, infrastructure, and innovation while improving the workforce.

Regulatory Orders

Aside from the executive orders, there also has been a suite of regulatory actions at the State and Federal levels with the goal of boosting the adoption of clean MD-HD vehicles. **Figure 2** provides a summary of the regulations and MD-HD ZEV milestones establish under each regulation. In California, several adopted CARB regulations have established MD-HD ZEV milestones. For example, the ICT regulation requires all public transit agencies to gradually transition to 100 percent zero-emission buses (ZEB) by 2029, with a goal for full fleet transition by 2040. **Figure 2** also presents an estimated count of zero-emission MD-HD vehicles anticipated for deployment in the San Diego region by 2040 due to these regulations.

Figure 2. Summary of State Regulatory Milestones for MD-HD ZEVs



[4] Available online: https://www.federalregister.gov/documents/2021/08/10/2021-17121/strengthening-american-leadership-in-clean-cars-and-trucks

[5] https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/08/fact-sheet-president-biden-signs-executive-order-catalyzing-americas-clean-energy-economy-through-federal-sustainability/

Following the adoption of the ICT regulation in 2018, the scope of MD-HD ZEV transition was significantly expanded through the ACT regulation. Approved in March 2021, the ACT regulation mandates that manufacturers who certify Class 2b-8 chassis or complete vehicles with combustion engines will be required to sell zero-emission trucks as an increasing percentage of their annual California sales from 2024 to 2035. The goal is to achieve NOx and GHG emission reductions and to increase MD-HD ZEV penetration into current MD-HD ICEV operations.

Arguably, the ACF regulation has captured the most attention in the MD-HD ZEV regulatory landscape. Approved in April 2023, the ACF regulation is an MD-HD zero-emission fleet regulation with the goal of achieving significant adoption of zero emission technologies by 2045 everywhere feasible and significantly earlier for certain market segments, such as last mile delivery and drayage applications. In summary, the ACF regulation will require all drayage trucks to be zero-emission by 2035 and federal and high priority fleets to be zero-emission by 2042. The ACF regulation is one of the most anticipated regulatory advances, with many fleets expecting to begin following the ZEV purchasing requirements as soon as 2024. According to CARB's estimates, by 2050, almost two-thirds of trucks operating in California are expected to be zero-emission. Together, the ACT and ACF regulations will drastically change the mix of MD-HD vehicle technologies in the San Diego region.

Incentive Programs

Regulatory programs play an indispensable role in accelerating the deployment of MD-HD ZEVs. However, alongside these regulatory frameworks, there is an imminent need for incentive programs. The primary objective of these incentives is to alleviate the substantial upfront costs associated with these advanced vehicles, thus making them more financially accessible. Equally important is the establishment of robust charging and fueling infrastructure. Given the initial capital-intensive nature of setting up such infrastructure, incentives can significantly lower the financial barriers for businesses and municipalities, encouraging faster and wider deployment. This approach is especially vital in promoting adoption within low-income and disadvantaged communities, where the financial barrier can be particularly prohibitive.

In recent years, the Federal government, California's state and local governments, as well as local utilities such as San Diego Gas & Electric (SDG&E) have established various incentive programs (or market based programs that incentivize clean transportation such as LCFS), which have played a pivotal role in promoting MD-HD ZEV adoption. Most of these incentive programs offer additional benefits for specific technology applications, as well as additional funding for Disadvantaged Communities (DACs). A complete list of these incentive programs is shown below in **Table 1**.

Table 1. Summary of Incentive Programs for Class 2b through 8 Vehicles

Program	Eligible for Funding	Funding Amount
HVIP	• Class 2b-8 ZEVs • ZEV Voucher Modifiers for DAC[6] • ePTO Vouchers[7]	$7,500 - $120,000 (Base unmodified)
Inflation Reduction Act	• Class 4-8 ZEVs	30% of the vehicle purchase price up to $40,000
Carl Moyer	• Class 4-8 clean combustion and ZEVs • Requires scrappage	$20,000-$410,000 for new ZE truck replacement
Carl Moyer VIP	• Fleets of ≤10 vehicles with at least 75% of miles driven in California during the previous 24 months	$20,000-$410,000 for new ZE truck replacement
VW Mitigation Trust	• Class 8 Freight Trucks (including drayage trucks, waste haulers, dump trucks, and concrete mixers) – Public and private	Up to $200,000 for zero-emission trucks
Truck Loan Assistance	• Trucking fleets with ≤10 heavy-duty vehicles for small businesses	Varies
Clean Transportation Program	• Public and private fleets of Class 2b-8 • Public charging and hydrogen fueling station developers	Between 50 – 75 percent of the project cost
LCFS	• Non-residential EV charging and H2 fueling stations	Number of credits earned x Credit price
San Diego Gas & Electric Power Your Drive for Fleets	• Commitment to procure a minimum of 2 electric fleet vehicles • Long-term electrification growth plan and schedule of load increase • Provide data related to charger usage for a minimum of 5 years • Own or lease the property where chargers are installed within SDG&E's service area and operate and maintain vehicles and chargers for a minimum of 10 years	Provide low-to no-cost electrical system upgrades. Rebates up to 80% of the cost of customer-side infrastructure.

Existing State of Technology & Infrastructure

Understanding the current availability and readiness of MD-HD ZEVs is an important starting point. It helps inform decision-making for organizations transitioning to cleaner fuel alternatives, facilitates realistic policy formulation by policymakers, and offers insights for economic considerations and strategic planning for stakeholders. Furthermore, it is essential for prioritizing infrastructure development, ensuring that as vehicles are adopted, the necessary support systems are concurrently developed.

The MD-HD ZEV market is largely segmented into BEV and FCEV technologies. As part of this Blueprint, SANDAG explored MD-HD ZEV technology readiness and availability,

[6] For vehicles domiciled in a disadvantaged community that are purchased or leased by any public or private small fleet with 10 or fewer trucks or buses, and less than $50 million in annual revenue for private fleets, or for any purchase or lease by a California Native American tribal government. There is no revenue provision for public fleets.

[7] ePTO funding amounts may cover up to 65 percent of the incremental cost of the ePTO vehicle, not to exceed: $20,000 for 3-10kWh, $30,000 >10-15kWh, $40,000 for >15-25kWh, and $50,000 for >25kWh.

including a recent market assessment by CARB and ICF. The project team found that there are between 70 to 250 electric MD-HD ZEV models that are available today or planned to be available within the next two years. There are several resources available to review MD-HD ZEV options on the market today: **Table 2** summarizes available vehicle catalogs and **Figure 3** illustrates the current model availability across various MD-HD ZEV platforms.

Table 2. Summary of MD-HD ZEV Market Resources

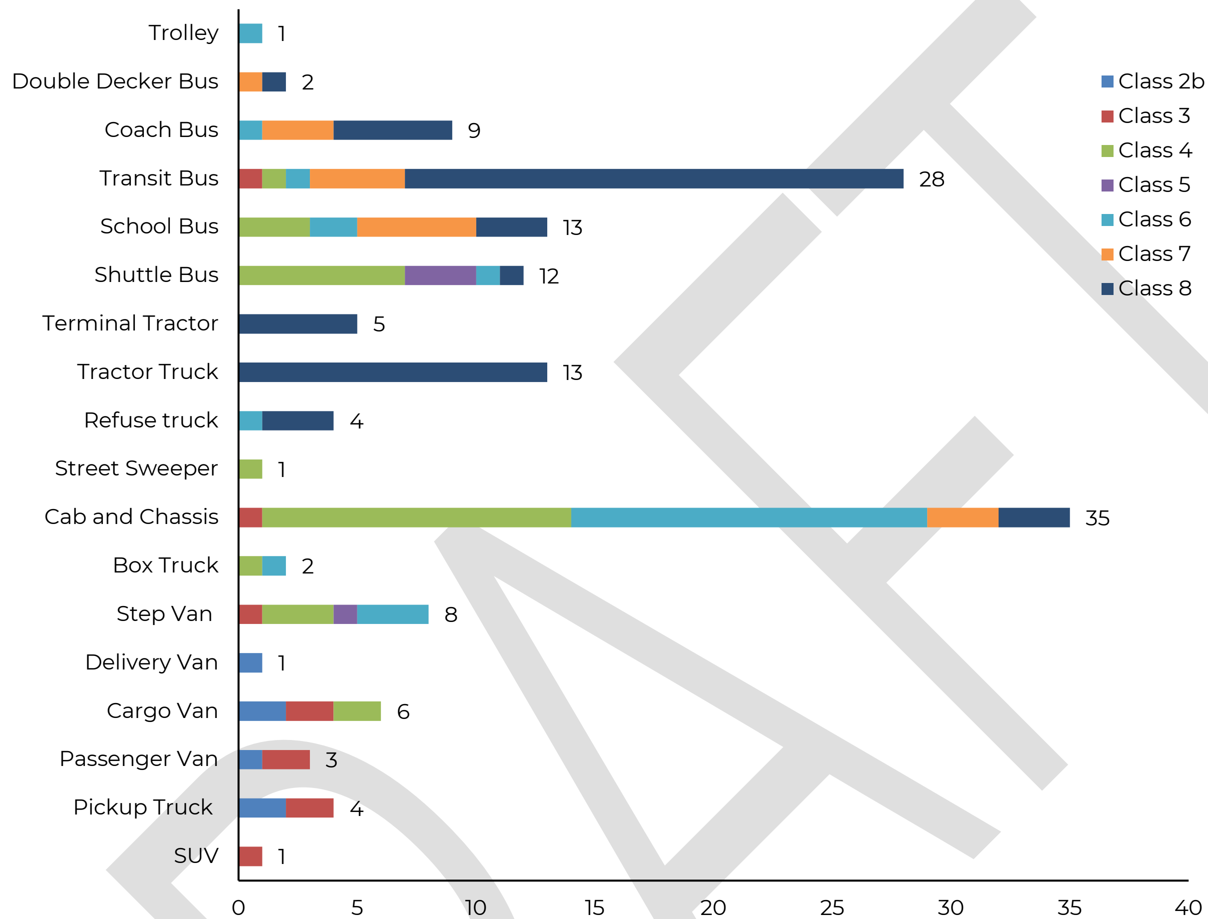
Resource	Description

CALSTART Zero-Emission Technology Inventory (ZETI) Tool	• Part of CALSTART's Drive to ZERO Program
	  • Tracks worldwide commercially available offerings of zero-emission medium- and heavy-duty vehicles
	  • Includes brands available by region for purchase today and timelines for future rollouts

SDG&E Electric Vehicle Availability Guide	• Published in 2021 by San Diego Gas and Electric • Summary of currently available battery-electric vehicles for medium- and heavy-duty electric fleets
HVIP Vehicle Catalog	• The Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project's (HVIP) Vehicle Catalog • 144 medium- and heavy-duty vehicles in database as of mid-2021
US. DOE Alternative Fuel Vehicle Database	• The U.S. DOE Alternative Fuels Data Center's online heavy-duty vehicle database • 97 Medium- and heavy-duty vehicles in database as of mid-2021
ICF EV Library	• A comprehensive proprietary library of more than 500 EVs available today or over the next three years along with detailed specification associated with each vehicle

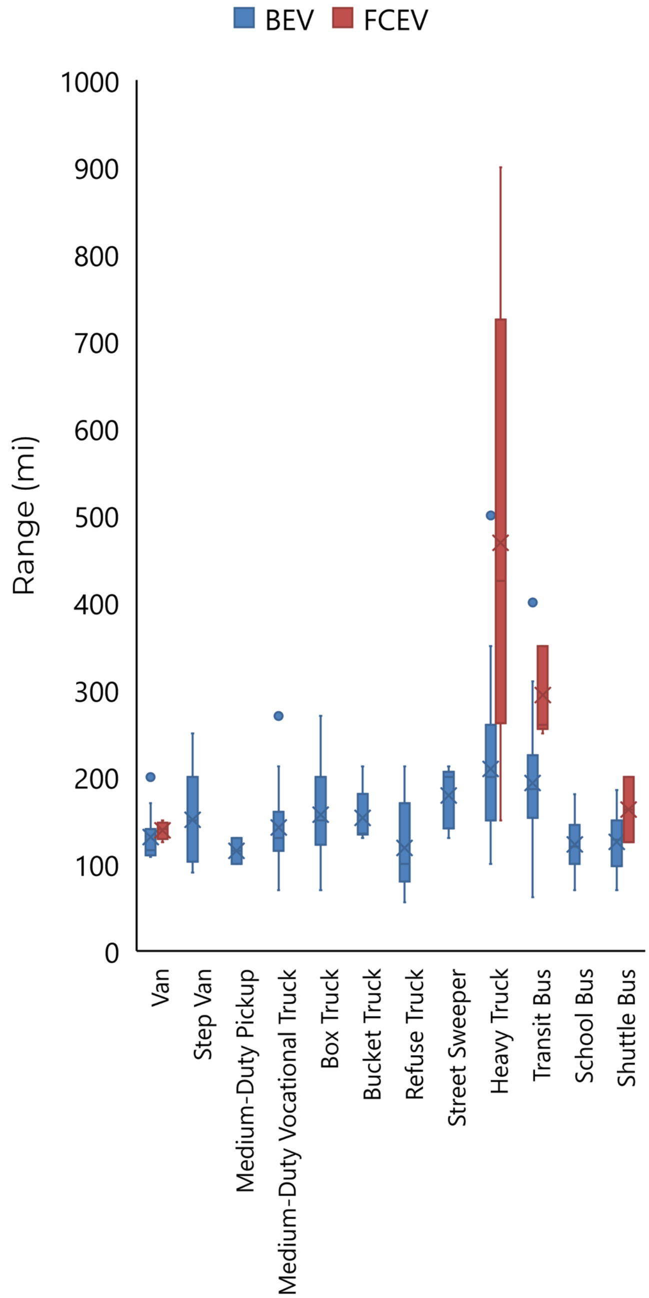
The project team conducted a literature review of the MD-HD ZEV market using inventories and resources published by CARB, CALSTART, and other agencies, as well as ICF's proprietary EV Model Library. Overall, battery-electric technology reflects the most mature and diverse share of the MD-HD ZEV market, and manufacturers are likely continuing to provide more BEV offerings than FCEV due to the significantly lower operational cost – given higher cost of hydrogen as compared to electricity – as well as consumer confidence in the platform. On the other hand, FCEVs have demonstrated success in California's public transportation sector and are competitive solutions for zero-emission long-haul trucking applications. Within the next twenty years, rapid deployment of charging and fueling infrastructure is expected across the region. As illustrated in **Figure 3**, currently there exists a suite of zero emission models across various MD-HD vehicle platforms with 35 of them being Cab and Chassis, 13 being Class 8 tractor trucks, and 28 transit buses.

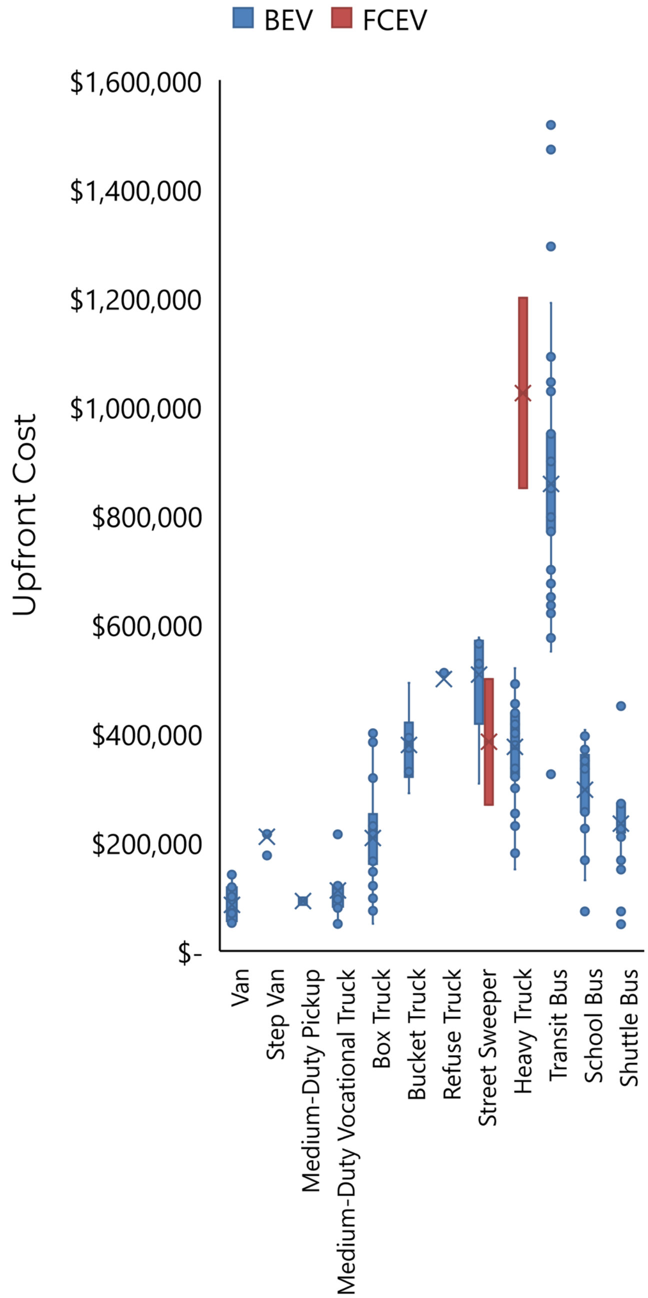
Figure 3. ZEV Model Availability Across Different MD-HD Vehicle Categories (CARB 2023)



Despite the increasing availability of ZEVs spanning a variety of MD-HD platforms, the electric range of many of these models remains a key concern. As illustrated in **Figure 4**, the majority of BEVs on the market offer electric ranges of around 200 miles. Though there are select FCEV models that have ranges comparable to their diesel counterparts, their accessibility is hindered due to their elevated initial costs and the limited availability of necessary fueling infrastructure. Beyond range considerations, the significant upfront cost of zero-emission vehicles is a crucial barrier for many potential adopters. As illustrated in **Figure 4**, currently, a typical zero-emissions class 8 heavy-duty tractor carries a price tag of roughly $400,000, over 2.5 times the cost of a standard diesel Class 8 tractor.

Figure 4. MD-HD ZEV Range (left), Actual/Projected Vehicle Price (right) [ICF EV Library]





When considering the transition to zero-emission technology, it is important to recognize that it is not just about the vehicles themselves. Equally crucial is the development and availability of the infrastructure to power and support these vehicles, ensuring their seamless and widespread adoption. Today, the San Diego region's charging and fueling infrastructure largely serves light-duty vehicles. These electric vehicle charging stations are from different service providers, such as ChargePoint and Electrify America. The singular hydrogen fueling station has two hydrogen fuel dispensers and is a part of the TrueZero hydrogen fueling network, which provides liquid hydrogen delivery to the San Diego site.

Figure 5. Current Light-Duty ZEV Infrastructure in San Diego0

Typically, Level 2 chargers are public- or private-access chargers with power levels between 2.5 and 19.2 kW, whereas direct current fast chargers (DCFC) are public-access chargers with power levels above 20 kW, up to 350 kW in some cases. It should be noted that although higher-power chargers enable faster BEV recharging, most commercially available BEVs have an upper limit on the amount of power their battery can accept, due to hardware and software limitations. To date, charging infrastructure has been subject to significant hardware and installation cost variability. For example, according to data from CALeVIP program in California, Level 2 charger deployment costs can vary between $2,700 and $24,000 per charger; the difference is greater for DCFCs, where total deployment costs vary between $70,000 and $130,000 per charger.

According to the AFDC Station Locator, there are a total of 57 publicly accessible hydrogen stations in the United States; California hosts 56 hydrogen stations and Hawaii hosts 1 hydrogen station. Unlike BEV chargers, which draw electricity from the grid to recharge batteries, hydrogen stations require a delivery pathway to transport gaseous or liquid hydrogen fuel from the site of production to the site of dispensary. Hydrogen stations share a similarity to combustible fuel stations, in that each stores a finite amount of fuel in storage tanks, meaning that the limited number of hydrogen stations currently open may require multiple fuel deliveries per day to meet current demand. Expanding the number and capacity of hydrogen stations is a shared interest, however, hydrogen station development continues to require significant amounts of capital investment and permitting considerations. Hydrogen station development cost data are sparse, and high-level estimates suggest that the average 1,400 kg hydrogen station can have a capital cost between $4 million through $9.8 million.

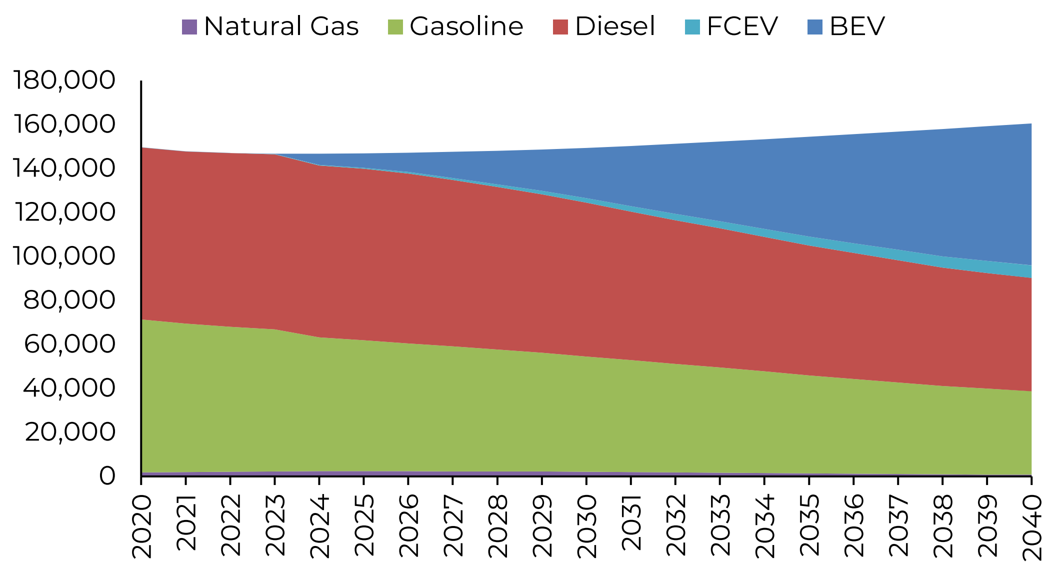
2. THE NEEDS FOR INFRASTRUCTURE BUILDOUT

As the San Diego region anticipates an increased penetration of ZEV MD-HD vehicles starting in 2024, it is essential to develop a comprehensive understanding of the projected fleet mix and technology composition of the region. This foresight is instrumental in ensuring the region's readiness for the logistical and infrastructural challenges. This led to the project team conducting a vehicle and infrastructure needs assessment, reflecting the policies and technology options, as discussed in Chapter 1. For the fleet technology projection, the project team leveraged CARB's EMFAC2021 model to estimate the quantity and type of MD-HD ZEVs, accounting for the ACT and ACF regulation requirements. For the infrastructure needs projection, the project team utilized energy-based methodologies to translate projected electric charging and hydrogen fueling demand into distributions of charger and fueling infrastructure by type. The following sections provide a summary of results from this analysis. More details can be found in Medium & Heavy-Duty Zero Emission Vehicle Blueprint Needs Assessment Report[8]

San Diego MD-HD Fleet Technology Projection

The regional MD-HD fleet technology projection, accounting for the ACT and ACF regulations, is shown in **Figure 6**. In 2024, as many as 5,282 new zero-emission MD-HD vehicles are expected to be added to the San Diego region as a result of the regulatory requirements. By 2040, the distribution of San Diego's MD-HD vehicle fleet is expected to be 40 percent BEV, 32 percent diesel, 23 percent gasoline, 5 percent FCEV, and less than 1 percent natural gas.

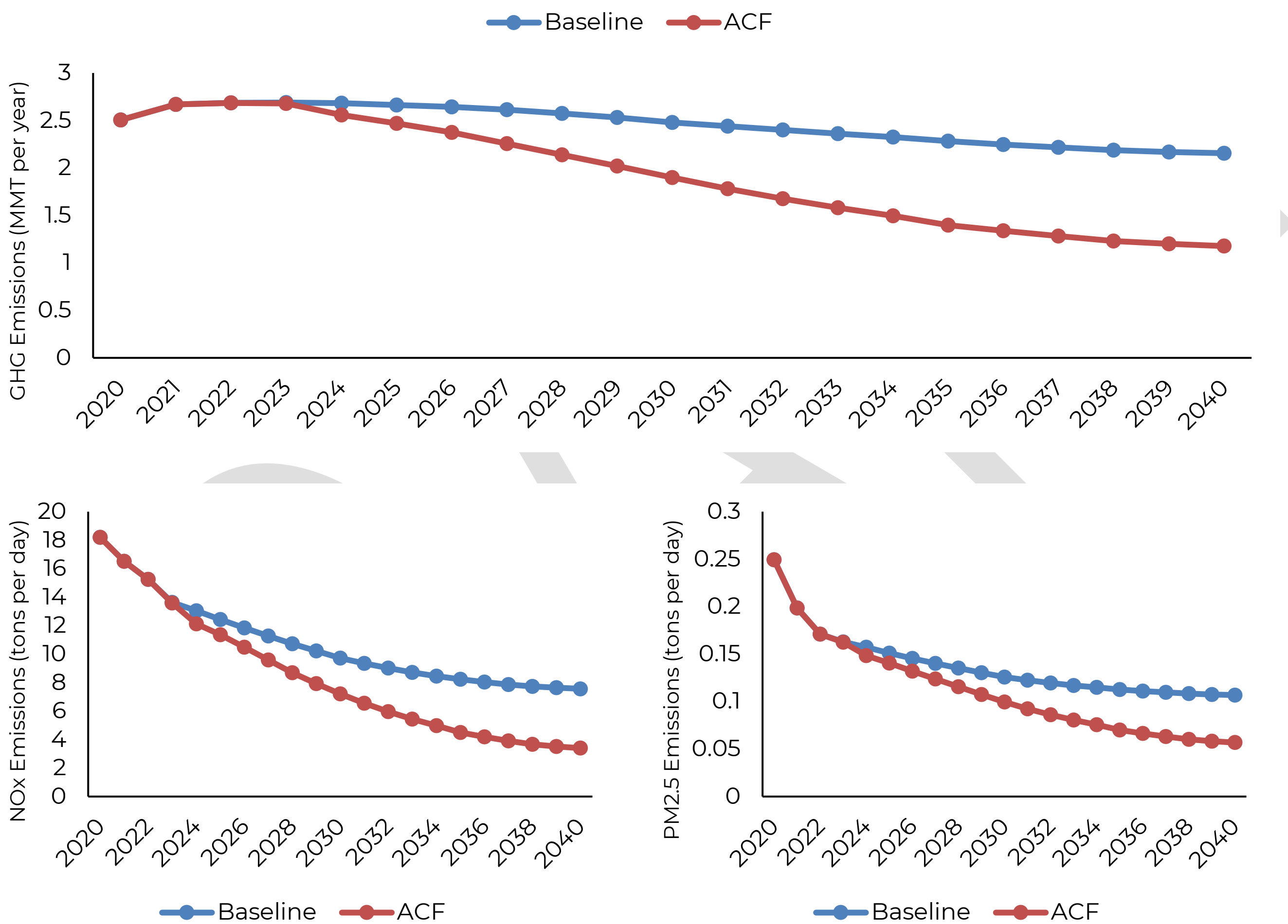
Figure 6. San Diego Region's MD-HD Vehicle Population by Fuel Type



[8] https://www.sandag.org/-/media/SANDAG/Documents/PDF/projects-and-programs/innovative-mobility/clean-transportation/regional-medium-duty-heavy-duty/md-hd-zev-needs-assessment-report-2023-01-01.pdf

Following the MD-HD fleet technology projection, the project team also estimated the potential NOx, particulate matter (PM), and GHG emission reductions, assuming tailpipe emission reductions proportional to decreases in the ICEV fleet size (**Figure 7**). Note that although criteria pollutant and GHG emissions are projected to decrease in the baseline scenario (due to existing regulations), significant emission reductions will be achieved through the ACF regulation. By 2040, emissions are expected to be reduced to nearly half from the baseline level for all three emission categories.

Figure 7. Comparison of Baseline and Projected Emission Reductions for San Diego Region[9]



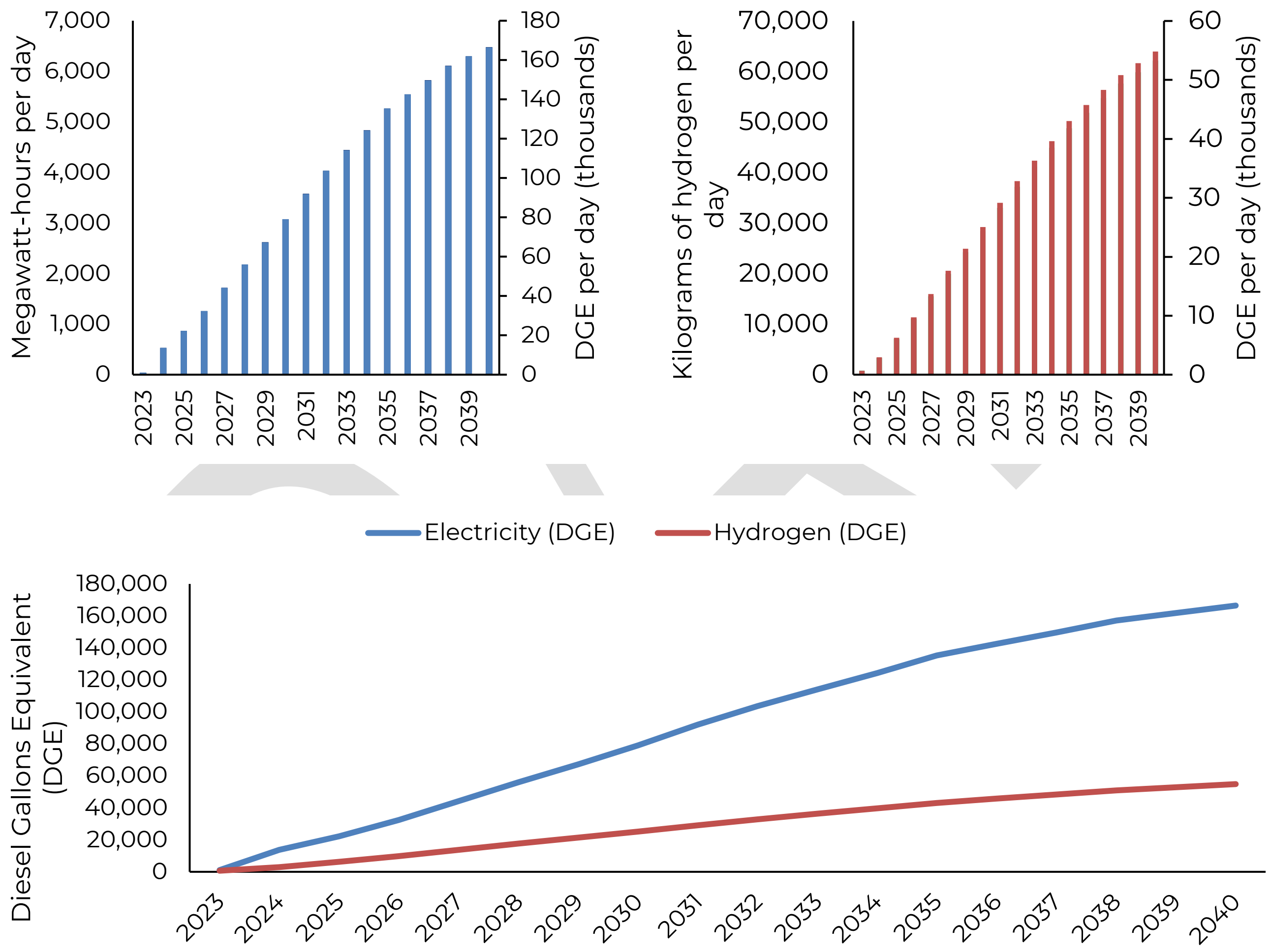
San Diego Region Charging and Fueling Infrastructure Projection

To determine regional infrastructure needs by type, the project team estimated the energy consumption of the projected MD-HD fleet. The project team utilized methods consistent with the Assembly Bill (AB) 2127 assessment[10] and CARB Hydrogen Self Sufficiency Report[11] to transform energy consumption estimates into electricity and hydrogen fuel infrastructure

[9] Note that while the scenario is called ACF, it does include the impact of both ACT and ACF. EMFAC2021 model already reflects the impact of ACT.
[10] https://www.energy.ca.gov/data-reports/reports/electric-vehicle-charging-infrastructure-assessment-ab-2127
[11] https://ww2.arb.ca.gov/sites/default/files/2021-10/hydrogen_self_sufficiency_report.pdf

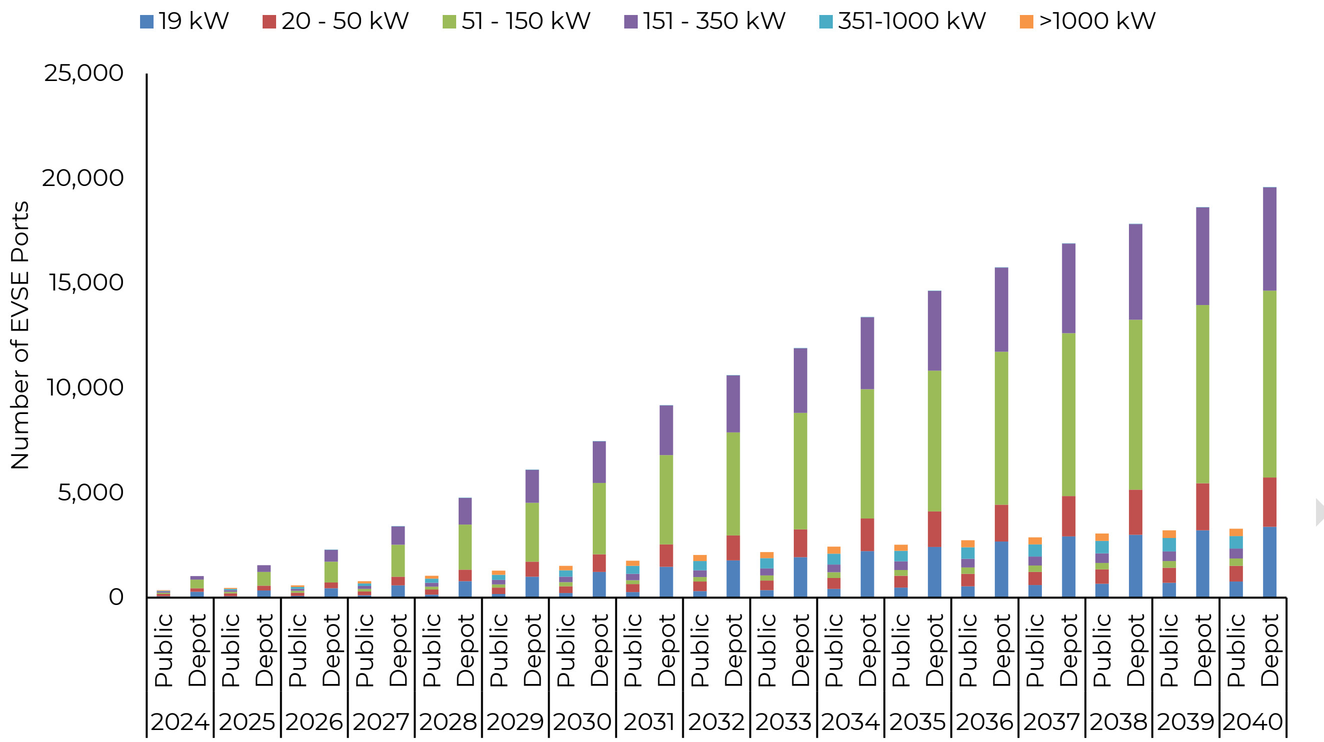
recommendations. The project team's analysis conducted with EMFAC2021 provided the region's electricity and hydrogen fuel MD-HD consumption, as shown in **Figure 8**. In 2024, electricity demand is projected to peak at 534 MWh per day, whereas hydrogen fuel demand is projected to peak at 3,342 kilograms of hydrogen per day. On average, the daily electricity demand and hydrogen fuel demand are expected to increase by 377 MWh per day (9,729 DGE per day) and 3,576 kg of hydrogen per day (3,186 DGE per day), respectively. Between 2025 and 2040, electricity and hydrogen fuel consumption by the MD-HD vehicle sector is expected to grow 650% and 780% respectively.

Figure 8. Projected San Diego Region's MD-HD Vehicle Daily Electricity and Hydrogen Fuel Consumption



To determine the charging infrastructure needs for MD-HD BEVs, the project team leveraged Lawrence Berkeley National Laboratory (LBNL) HEVI-LOAD tool to determine the number and types of charger deployments based on power levels and MD-HD duty cycles. HEVI-LOAD was the primary tool that California used in development of its MD-HD charging infrastructure plan (AB 2127 Report). The charging infrastructure needs are illustrated by application (i.e., public or depot use) and power level in **Figure 9**.

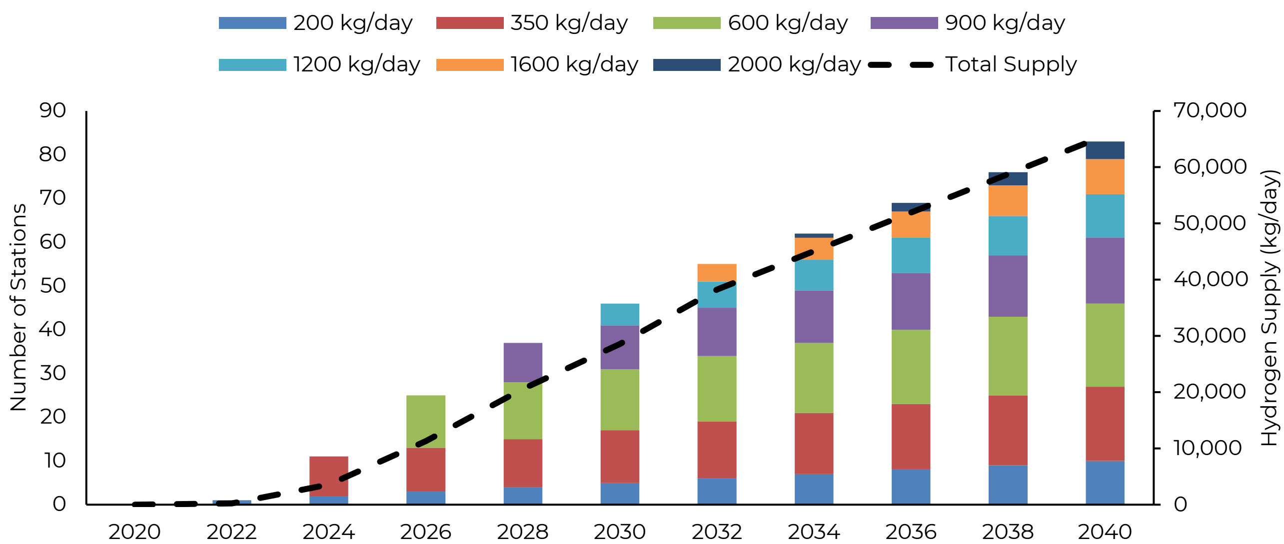
Figure 9. Number of MD-HD Public and Depot Chargers by Power Level



The HEVI-LOAD results demonstrate the projected public and depot charging solutions expected in the San Diego region based on the fleet modeling results presented earlier in this chapter. First, it is evident that most MD-HD BEV chargers are projected to be private- or depot-access chargers, with charging power levels ranging between 19.2 kW through 1 MW. The results also show that in early years, chargers with lower power capacities will be deployed in greater quantities than chargers with higher power capacities. For example, between the years 2024 through 2027, 80 percent of MD-HD BEV chargers in the region will have power levels ≤ 150 kW, whereas post-2030, that share is reduced to 70 percent as the number of ≥ 150 kW chargers rapidly increases. By 2040, approximately 23,000 chargers (~3,200 public and ~19,600 depot chargers) will be required to meet MD-HD BEV charging demand.

The results for the number of hydrogens fueling stations by station capacity between 2020 through 2040, as well as the total hydrogen supply by station capacity are shown in **Figure 10**. Hydrogen supply is also expected to increase as developers transition from lower capacity stations in early years to higher capacity stations in later years. By 2040, a total of 83 hydrogen fueling stations provide 65,650 kilograms of hydrogen per day for FCEVs in the region.

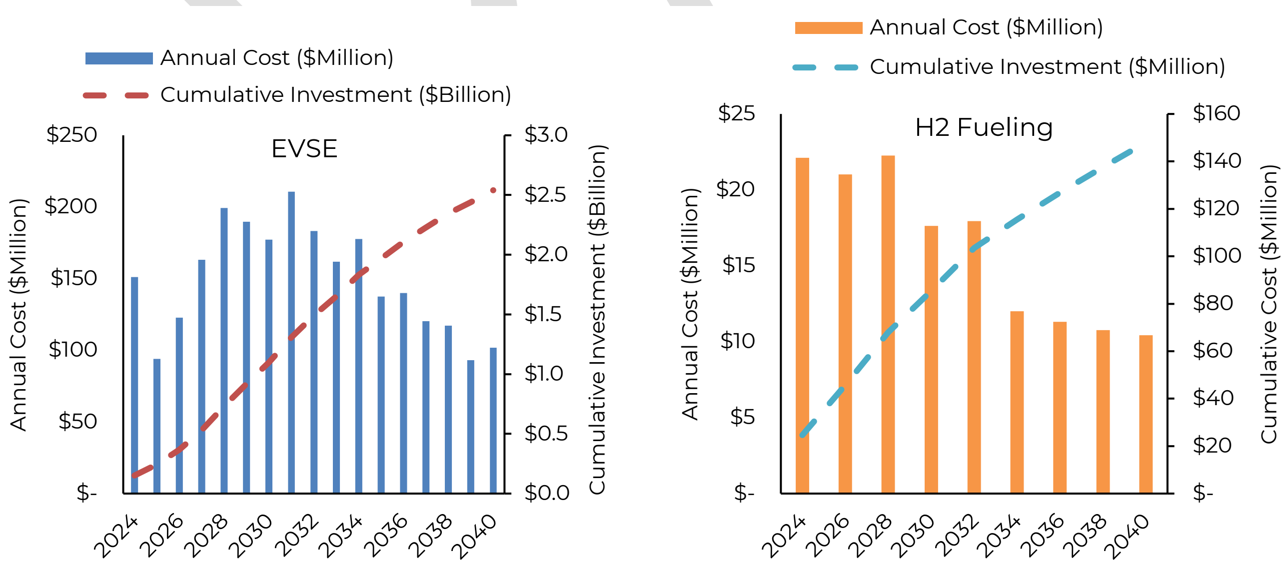
Figure 10. Hydrogen Station Deployment Schedule by Daily Capacity



San Diego Region Charging and Fueling Infrastructure Cost Estimate

Subsequent to the gap analysis presented earlier, the project team provided detailed financial estimates, both on an annual basis and cumulatively over the projected timeline. Our methodology was rooted in a comprehensive literature review, with particular emphasis on the cost per port and cost per station metrics. More details on these figures were derived from the Medium & Heavy-Duty Zero Emission Vehicle Blueprint Needs Assessment Report[12]. The results for the projected charging and fueling infrastructure costs per year are illustrated in **Figure 11**.

Figure 11. (Left to Right) Estimated Total MD-HD EVSE Costs, Estimated Total MD-HD H2 Station Costs



[12] https://www.sandag.org/-/media/SANDAG/Documents/PDF/projects-and-programs/innovative-mobility/clean-transportation/regional-medium-duty-heavy-duty/md-hd-zev-needs-assessment-report-2023-01-01.pdf

For chargers, the project team assumes per port costs consistent with those found across the studies reviewed in the ZEV Needs Assessment Report[1], as well as a 3 percent hardware and installation cost reduction per year until 2030, in alignment with research from Atlas Policy on discounted charging hardware and installation costs[13].

For hydrogen stations, the project team adopted CARB's truncated cost model, which states that capital expenses of fully installed hydrogen stations can be approximated with a power law function. In essence, the cost model estimates the total station cost (in dollars per kilogram per day) as a function of station capacity (in kilograms per day), and data from CEC's Clean Transportation Program suggest that on average a MDHD hydrogen fueling station with a capacity of over 1000 kg per day would initially cost around $4,978 per kg/day, consistent with CARB's analysis for the AB 8 program. In order to reflect potential equipment capital cost reduction due to technology progression or economies of scale, similar to what has been observed for other emerging technologies like solar and wind electricity generation and BEV battery manufacturing, Moore's Law with 12 percent reduction per doubling of installed capacity is applied to the initial cost model. While a 12 percent cost reduction rate might appear slow and conservative compared to other clean energy technologies, it aligns with trends observed for specific technologies related to fuel cells and hydrogen, such as those reported in CARB's hydrogen self-sufficiency report and industry's estimate of hydrogen production cost[14]. For this analysis, a roughly 70 percent cost reduction from the 2020 baseline level is expected by 2035.

Based on these results, the project team estimates cumulative costs of nearly $2.5 billion for charging infrastructure and $140 million for hydrogen fueling infrastructure by 2040. It is important to note that the projected charging infrastructure costs only include hardware and installation costs, no make-readiness or grid upgrade costs are considered in this estimate.

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[13] Atlas Public Policy, "U.S. Medium- and Heavy-Duty Truck Electrification Infrastructure Assessment," November 2021. [Online]. Available: https://atlaspolicy.com/u-s-medium-and-heavy-duty-truck-electrification-infrastructure-assessment/.
[14] ICF, "Examining the current and future economics of hydrogen energy," 13 August 2021. [Online]. Available: https://www.icf.com/insights/energy/economics-hydrogen-energy. [Accessed 29 September 2023]

3. THE SIGNIFICANCE OF PROPER INFRASTRUCTURE SITING

While quantifying the necessary charging and fueling infrastructure is undoubtedly vital, what is even more crucial is the strategic placement of these facilities. Ensuring their optimal siting goes beyond merely maximizing utilization and return on investment. It is about enhancing equity across the board, ensuring that the benefits of cleaner transportation are reaped by all, especially within low-income communities (LICs) and DACs. In this Blueprint the project team identified five broad groups of siting criteria to be considered by planner and developers of charging and hydrogen fueling infrastructure: utilization, land, equity, grid capacity and environmental conditions (**Figure 12**). For more details on the siting and technology criteria, refer to ZEV Siting Criteria and Technology Report[15].

Utilization denotes the demand for charging or hydrogen fueling and serves as an indicator of station usage, reflecting the station's financial viability. Considering utilization is important, as the initial success of capital-intensive projects sets the trajectory for continued investment and robust infrastructure deployment. Consequently, grasping MD-HD vehicle travel patterns, encompassing origins, destinations, rest locations, and refueling patterns, is essential to optimize charging and fueling site locations.

Land, and being strategic about the availability of land for charging and fueling stations, often goes unconsidered despite being one of the most challenging permitting obstacles. Key factors in this evaluation include land value, ownership, demand, and potential community impacts, such as safety and congestion. In 2020, the California Governor's Office of Business and Economic Development (GO-BIZ) has developed a permitting guidebook designed to assist local jurisdictions, as well as hydrogen[16] and EV charging[17] station developers, in simplifying and streamlining the station development process. Given their comprehensive content and practical guidelines, it is recommended that local jurisdictions consult these guidebooks when addressing permitting challenges.

Equity is another criterion that the project team recommended to ensure that the deployment of charging and fueling infrastructure does not adversely impact low income communities and 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.

Grid capacity is crucial when considering MD-HD vehicle charging, given their high energy needs requiring stations often above 150 kW. Development challenges arise due to grid limitations and interconnection issues. Additionally, on-site hydrogen production is power-intensive. Coordination with utility providers, especially SDG&E in San Diego, is key to ensure power availability and address infrastructure investments.

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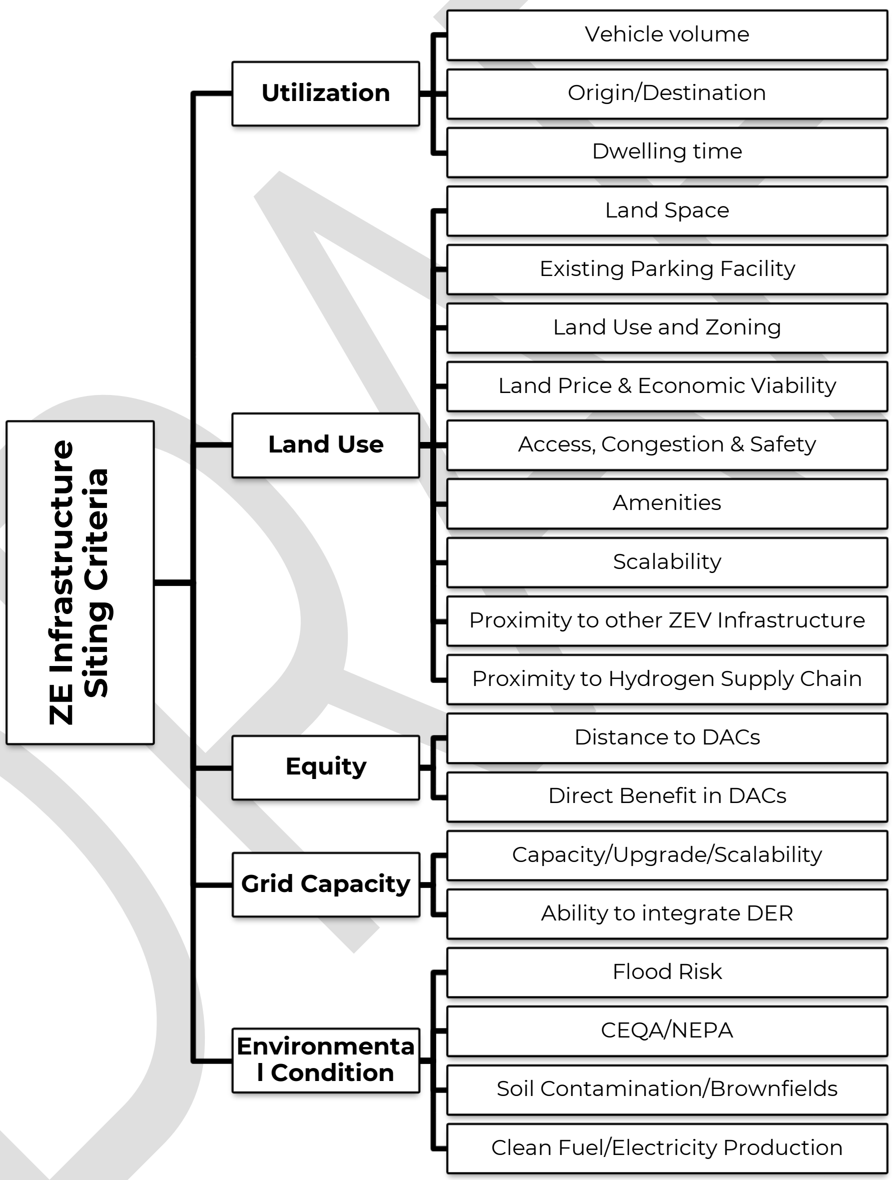
[15] Available online at: https://www.sandag.org/-/media/SANDAG/Documents/PDF/projects-and-programs/innovative-mobility/clean-transportation/regional-medium-duty-heavy-duty/md-hd-zev-draft-blueprint-2023-04-01.pdf
[16] Available online at: https://business.ca.gov/wp-content/uploads/2019/12/GO-Biz_Hydrogen-Station-Permitting-Guidebook_Sept-2020.pdf
[17] Available online at: https://business.ca.gov/wp-content/uploads/2019/12/GoBIZ-EVCharging-Guidebook.pdf

Environmental 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. Similarly, the grid generation mix (types of fuels used to generate electricity) and hydrogen fuel production pathways (e.g., renewable hydrogen versus hydrogen produced using fossil natural gas) pose environmental impacts that should be considered on a site-level basis. For example, according to CARB[18], compressed hydrogen's carbon intensity ranges from 82 to 152 g/MJ. At the high end, it equals diesel emissions, challenging its classification as a zero-emission fuel when produced from fossil fuels.

Figure 12. Summary of ZEV Infrastructure Siting Criteria

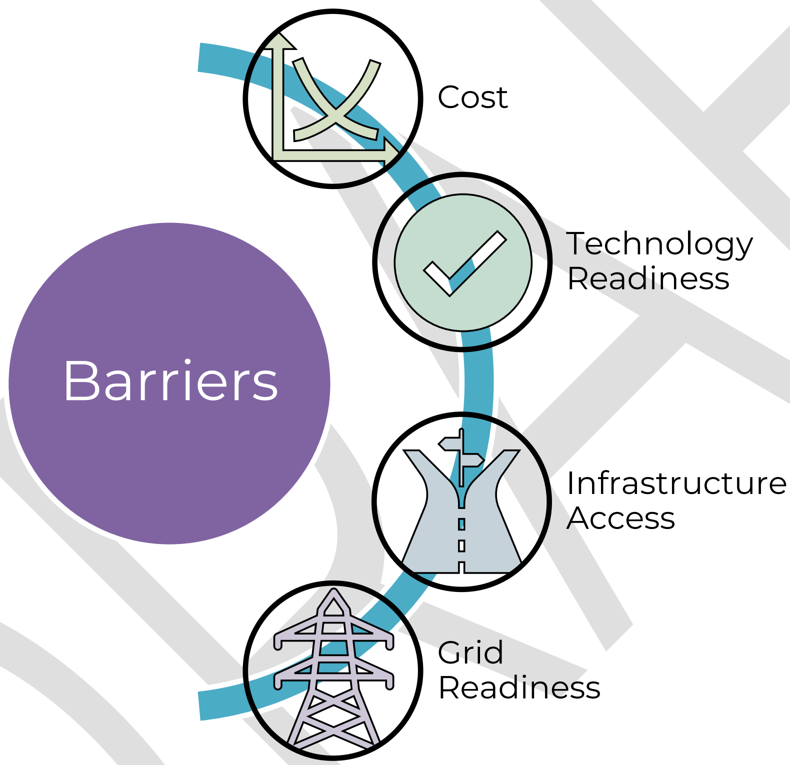


[18] California Air Resources Board (CARB) (2015). Staff Report: Calculating Life Cycle Carbon Intensity Values of Transportation Fuels in California.

4. FROM ROADBLOCKS TO INNOVATIONS

In the coming transition to MD-HD ZEVs and deployment of supporting infrastructure, there are several barriers that slow progress that can be made in early years. These barriers span from cost considerations, technological readiness, and lack grid readiness or conflicting regulations (**Figure 13**). To effectively address these barriers, this Blueprint offers a comprehensive list of six pivotal recommendations for SANDAG and its regional partners. These guidelines have been carefully formulated, in collaboration with stakeholders, to provide actionable insights and strategic direction and help SANDAG and its collaborators to navigate the challenges more adeptly, ensuring a cohesive and efficient approach towards regional ZEV infrastructure and development goals.

Figure 13. Examples of Regional Barriers to MD-HD ZEV and Infrastructure



- High upfront costs and limited time to meet competing priorities.
- MD-HD ZEV range and ability to fulfill current transportation demands met by ICEVs
- Lack of public MD-HD infrastructure; land use and permitting challenges
- Limited ZEV options equate to high upfront costs
- Grid capacity and fuel delivery pathways.

Barriers to Adoption

High Upfront Cost: Perhaps the most frequently referenced barriers to adoption are capital costs of MD-HD ZEVs and infrastructure. As delineated in the ZEV Needs Assessment Report[1], when comparing only initial purchase costs, the data show that MD-HD ZEVs are priced higher than their ICEV counterparts. Although the purchase price of ZEVs is expected to decrease over time due to battery pack and fuel cell stack price reductions in the short-term MD-HD ZEV options can cost between thousands and tens of thousands of dollars more than ICEV options.

Comparatively, battery-electric technologies have been cheaper to implement and faster to adopt than fuel cell electric technologies. MD-HD BEVs in nearly every vocation (e.g., short-haul delivery, long-haul trucking, public transportation) have reached commercialization within the market, signifying the highest technology readiness level prior to market transformation. FCEVs are largely still in demonstration and pilot project phases, with some commercialization achieved in the public transportation sector.

Technology Readiness: One of the significant barriers to the widespread adoption of zero-emission MD-HD vehicles is technology readiness. There are concerns regarding the range and weight of MD-HD zero-emission trucks; the current technology may not support the extensive range required for some operations, and the addition of batteries can increase vehicle weight, impacting payload capacity. Secondly, the availability of models from Original Equipment Manufacturers (OEMs) is limited, restricting choices for fleet operators. Additionally, the availability of specialty trucks tailored for specific operational needs is scarce, further complicating the transition. Lastly, the maximum charging acceptance rate for these vehicles might not align with the rapid charging infrastructures available, potentially leading to extended charging durations and operational inefficiencies.

Lack of Charging & Fueling Infrastructure: Another barrier to MD-HD ZEV adoption is the disparity in infrastructure accessibility and how it dissuades—or in exceptional cases, prevents—fleet owners and operators from vehicle procurement. It is not uncommon for prospective ZEV owners to consider "waiting" for more infrastructure to be deployed prior to investing resources and adapting behavioral patterns. Although charging and fueling infrastructure should be developed to anticipate some excess demand, most infrastructure that gets designed, permitted and deployed intends to meet current demand. In other words, ZEVs and infrastructure need to integrate into the transportation sector in parallel, not as competing priorities. Infrastructure has its own unique set of challenges, particularly because location, permissions, and lead times on projects can vary widely and limit the extent of deployable infrastructure.

Grid Readiness: An unprepared electric grid can pose a significant barrier to the widespread adoption of MD-HD ZEVs. Especially since MD-HD BEVs are projected to have high daily electricity demand in the region, leaving inadequate grid infrastructure could lead to power outages, increased charging times, and overall grid instability. It may also lead to costly upgrades in the future to accommodate the increased load from ZEV charging, as opposed to slightly lower grid upgrade costs in the short-term. In essence, planning for grid capacity upgrades is vital, particularly in terms of scalability. Although make-ready infrastructure costs incur more high upfront costs, starting the process as a preparative measure helps transform the prospect of the electric grid as the limiting factor into a network that can handle varying charging loads.

Lack of Awareness: Although there is data to describe market trends in MD-HD ZEV options, prices, and operating capabilities, the existence of these tools or inventories is often not pushed into public perception. Only a limited number of tools publicly available are able to create TCO comparison summaries between ZEV and ICEV options, and those estimates often cannot reflect actual fleet operating costs and unique needs. Another challenge with raising the lack of awareness surrounding MD-HD ZEVs is time and resources required to train or retrain the workforce to be acquainted with ZEV technologies. Many ZEVs come with manufacturer warranties that do not require fleets to perform their own maintenance, but this makes understanding maintenance requirements for ZEVs opaque, especially information related to parts and labor costs. The auto and truck mechanic industry has many decades of experience in the ICEV industry, but there is a shortage of technicians certified to work on high-voltage and advanced powertrain technologies found in MD-HD ZEVs. As a result, fleet owners may encounter difficulties self-servicing their MD-HD ZEVs after warranty coverages and technician support expire and could potentially be left without a way to fulfill transportation demands.

Regulatory Hurdles: Lastly, there may be regulatory hurdles or formalities that can slow MD-HD ZEV and infrastructure deployment. In some instances, there may be special exemptions that should be exercised to avoid penalizing fleets acting in good faith but with limited options. In other cases, some regulations may need additional reinforcement or incentives to meet regional needs. These kinds of regulatory hurdles can pose significant challenges to the deployment of MD-HD ZEVs and associated infrastructure. For example, fleets may find an overwhelming amount of information online regarding federal, state, and local regulations, which can vary widely and sometimes conflict with one another. Obtaining the necessary permits and approvals for infrastructure installation, especially in densely populated or environmentally sensitive areas, can be a time-consuming process that delays deployment. Additionally, regulatory frameworks may not always be well-suited to emerging ZEV technologies, creating uncertainty for fleet operators and developers. Compliance with safety standards and emissions regulations can also impact the design and deployment of MD-HD ZEVs.

The ZEV Implementation Strategies Report[3] presents an array of strategies, developed in collaboration with various agencies, industry stakeholders, and advocacy groups, to guide SANDAG and its regional partners in deploying MD-HD ZEVs and the requisite infrastructure within the San Diego region. Subsequent sections revisit strategies concerning site selection, land use compatibility, zoning, funding avenues, and workforce development, all curated to equip communities and businesses for this transition.

Strategies to Accelerate

Regional Policy and Funding Support

The federal and California state governments have established frameworks to promote ZEV technology adoption among manufacturers and service providers. SANDAG and its regional partners must bolster these measures and address unique regional needs. **Figure 14** provides a list of strategies to this effect. The tracking metrics (**Figure 15**) associated with these strategies focus on quantitatively measuring the increase in clean fuels, emission reductions, operational savings from ZEV-forward policies, and making equity impacts more transparent for the region.

Figure 14. Summary of Regional Policy and Funding Support Opportunities

- Collaborate with SDG&E to enhance the Power Your Drive for Fleets program, making more fleets eligible for benefits and helping them manage Low Carbon Fuel Standard (LCFS) credits.
- Explore solutions to address weight limitations for battery-electric trucks (BETs) through short-term weight allowances on specific routes and long-term technological innovations.
- Establish a Vehicle-Grid Integration (VGI) Working Group to plan for VGI infrastructure and foster grid resiliency, ensuring EVs contribute to emissions reduction.
- Promote clean hydrogen production through a strategic plan and safety protocols, collaborating with stakeholders to expedite hydrogen infrastructure deployment.
- Advocate for consistent ZE policies across state and national borders, focusing on binational coordination for cross-border trucking and addressing regulations prohibiting charging infrastructure at rest areas.
- Develop targeted incentives programs to reduce upfront costs of MD-HD ZEV equipment and prioritize equity, including incentives for disadvantaged communities and small businesses.

Figure 15. Tracking Metrics for Regional Policy and Funding Support Strategies

Infrastructure Deployment Metrics:	Fleet Adoption Metrics:	Grid Integration and Resiliency Metrics:	Hydrogen Production and Safety Metrics:	Policy and Advocacy Metrics:	Incentives Program Metrics:
• **LCFS Credits Generated**: Monitor the quantity of LCFS credits generated from infrastructure installations, indicating emissions reductions.	• **Fleet Transition Rate**: Track the rate at which MD-HD fleets transition to ZEVs, considering both new purchases and conversions. • **Weight-Allowance Impact**: Measure the impact of weight allowances on BETs, including changes in cargo capacity and operational costs.	• **VGI Infrastructure Growth**: Monitor the expansion of Vehicle-Grid Integration infrastructure, including V2G and V2H capabilities. • **Grid Resiliency Enhancements**: Assess improvements in grid resiliency achieved through VGI and microgrid initiatives.	• **Clean Hydrogen Production**: Track the increase in clean hydrogen production capacity and the share of hydrogen produced from renewable sources. • **Safety Protocol Adherence**: Evaluate the adherence of fleet operators and service providers to safety protocols for hydrogen handling.	• **Policy Alignment**: Measure progress in aligning regional ZE policies with state and national policies, particularly for cross-border trucking.	• **Incentive Program Effectiveness**: Assess the effectiveness of targeted incentives programs by evaluating the number of ZEV deployments they facilitate. • **Equity Impact**: Measure the impact of incentives on disadvantaged communities and small businesses, ensuring that equity goals are met.

Siting, Land Use, Zoning, and Permitting

The Infrastructure Siting and Technology Criteria report assessed best practices for placing charging and fueling infrastructure to aid the MD-HD ZEVs transition, considering various factors like travel patterns and grid capacity. SANDAG and its partners can support this by helping with subsidies, development approvals, and guiding fleet owners on ZEV purchases based on multiple vehicle characteristics. **Figure 16** provides a summary of these strategies. The tracking metrics (**Figure 17**) associated with these strategies focus on quantitatively measuring the geo locational distribution of infrastructure, capacity-growth for improving demand forecasting, and greater transparency in project timelines.

Figure 16. Summary of Siting, Land Use, Zoning, and Permitting Strategies

Leverage Existing Resources for Public Infrastructure Planning, identify areas where charging infrastructure is needed based on MD-HD travel patterns and land use data, collaborate with the trucking and freight industries to disseminate these resources through SANDAG's GIS portal.

Identify Grid and Hydrogen Availability and Enhance Grid Capacity in Advance, participate in Freight Infrastructure Planning by the CPUC to plan long-lead-time utility-side electrical infrastructure upgrades, facilitate connections between hydrogen equipment providers, MD-HD fleet owners, and site operators to assess energy demand and grid updates., consider infrastructure sharing and leasing.

Streamline Infrastructure Development, work with local jurisdictions to streamline the MD-HD ZEV infrastructure development process, including permitting, safety standards, zoning, and building codes, support efforts to shorten the energization process for projects requiring distribution line extensions and substation upgrades.

Leverage Available Permitting Tools
Utilizing the DOE Hydrogen Program's codes and standards sub-program, local officials can efficiently navigate proposals for hydrogen projects. The DOE offers permitting tools that highlight relevant model codes and standards, simplifying the approval process for initiatives like hydrogen fueling stations and fuel cell applications.

Codes and Standards | Hydrogen Program

Figure 17. Tracking Metrics for Siting, Land Use, Zoning, and Permitting Strategies

Public Infrastructure Metrics

- **Charging Infrastructure Coverage:** Measure the increase in the number of MD-HD charging/fueling infrastructure sites in areas identified based on MD-HD travel patterns and land use data.
- **GIS Portal Usage**: Assuming development of a GIS portal, monitor the usage and engagement metrics through the portal among trucking and freight industry stakeholders to gauge the dissemination of resources..

Availability Metrics

- **Grid and Hydrogen Capacity Increase**: Track the increase in grid and hydrogen capacity in regions where advance planning and upgrades were initiated.

Deployment Time Metrics

- **Permitting Process Time Reduction**: Calculate the average time reduction in the permitting process for MD-HD ZEV infrastructure projects, such as charging stations.
- **Safety Compliance**: Monitor compliance rates with federal and state safety standards throughout the MD-HD ZEV infrastructure development process.
- **Energization Time Reduction**: Measure the average reduction in the time taken for MD-HD ZEV infrastructure projects to receive power, especially for projects requiring distribution line extensions and substation upgrades.

Promote Public-Private-Partnership Models

Leveraging Public-Private Partnerships (P3) models is effective in expanding ZEV infrastructure by combining public and private sector strengths, offering benefits like faster deployment and diversified business models. Besides traditional P3 models, emerging concepts like Charging-as-a-Service (CaaS) are seen as viable for SANDAG's infrastructure deployment, with private entities also considering options like Truck-as-a-Service (TaaS) to mitigate initial costs and incorporate new technologies. **Figure 18** provides a summary of the P3 model strategies. The tracking metrics (**Figure 19)** associated with these strategies focus on quantifying funding pools and charging network growth because of innovative partnerships.

Figure 18. Summary of Public-Private-Partnership Model Strategies

Leveraging P3 models for funding, speed up deployment, ensuring long-term sustainability, explore Charging-as-a-Service (CaaS) and Truck-as-a-Service (TaaS) business models.

Streamlining Public Procurement Processes, RFPs backed by public and private partners, circumvent inefficient processes, develop Request for Information (RFI) to refine scope.

Exploring New Charging Business Models, shared charging networks, charging with reservations.

Streamlining Revenue Sharing, distribute charging fees to incentivize investment, explore utility revenue sharing mechanisms, leverage LCFS credits for incentives.

Figure 19. Tracking Metrics for Public-Private-Partnership Strategies

PPP Metrics

- **Funding Generation:** Track the amount of funding secured through P3 models and private sector partnerships to assess their contribution to infrastructure deployment.
- **Deployment Speed:** Measure the time it takes to initiate and complete infrastructure projects under P3 models compared to traditional approaches.
- **Infrastructure Network Expansion:** Monitor the growth of MD-HD ZEV charging and fueling infrastructure within the region as a result of P3 models.
- **CaaS and TaaS Adoption:** Keep track of the adoption rates of Charging-as-a-Service (CaaS) and Truck-as-a-Service (TaaS) models among private fleets and businesses.

Procurement Process Metrics

- **Process Efficiency:** Measure the time reduction achieved in the procurement process by using pre-qualified private sector partners.
- **Budget Optimization:** Assess whether circumventing inefficient procurement processes leads to cost savings in infrastructure development.
- **RFI Utilization:** Track the efficacy of RFIs by the number of projects approved after clarifying requirements.

Business Metrics

- **Model Adoption:** Monitor the adoption of innovative charging business models, such as shared charging networks and charging with reservations, within the region.
- **Charging Network Growth:** Measure the expansion of charging infrastructure resulting from the adoption of these new business models.
- **User Experience:** Collect user feedback to evaluate the effectiveness of new models in enhancing the charging experience for MD-HD ZEV operators.

Cost Metrics

- **Investment Incentive:** Track the level of investment in charging infrastructure driven by streamlined revenue sharing processes.
- **Utility Collaboration:** Measure the extent to which utilities collaborate with charging infrastructure providers to implement revenue sharing mechanisms.
- **LCFS Credit Utilization:** Monitor the utilization of Low Carbon Fuel Standard (LCFS) credits as incentives for infrastructure development.

Public Education and Community Outreach

Communities and the public need to be equipped to tap into the benefits of MD-HD ZEV deployment in the region. **Figure 20** illustrates key outreach and engagement strategies to address concerns and barriers related to this regional ZEV initiative. The tracking metrics (**Figure 21**) associated with these strategies focus on quantifying the frequency of public relation or community input events, public health highlights for community members to interpret, and keep better public record of what the community looks forward to versus what the community does not want from expansion of MD-HD ZEVs and infrastructure.

Figure 20. Summary of Public Education and Community Outreach Strategies

Showcase Proof of Concept, demo ZE MD-HD trucks, highlight availability, TCO estimates, emissions and public health benefits.

Raise Awareness of Regulations and Incentives, ensure compliance, offer financial support, optimize resource allocation, collaborate with state and local agencies for educational campaigns and outreach initiatives.

Facilitate Bidirectional Communications, community dialogue about infrastructure and ZEV technology concerns, establish channels for addressing green gentrification and ZEV technology readiness, prioritize accessibility and inclusivity by disseminating information in multiple languages.

Figure 21. Tracking Metrics for Public Education and Community Outreach Strategies

Awareness Metrics

- **Number of Demonstrations:** Measure the number of MD-HD ZEV truck demonstrations conducted to showcase proof of concept.
- **Participation and Engagement:** Track the level of participation and engagement from fleet operators, technology developers, funding agencies, and local communities in these demonstrations.
- **Technology Deployment:** Track the growth in the deployment of clean technologies within communities that had focused education and outreach programs.

Policy Impact Metrics

- **Regulatory Compliance:** Track the level of compliance among MD-HD fleet operators and businesses with relevant regulations related to ZEV adoption.
- **Financial Uptake:** Measure the utilization of financial incentives by MD-HD ZEV adopters and assess the impact of incentives on adoption rates.
- **Resource Allocation:** Evaluate the optimization of resources in funding, incentives, and support for MD-HD ZEV deployment.
- **Collaboration Effectiveness:** Assess the success of collaboration with state and local agencies in developing educational campaigns and outreach initiatives.
- **Stakeholder Engagement:** Measure the level of stakeholder engagement in workshops, webinars, and informational sessions organized to raise awareness.

Communication Metrics

- **Community Dialogue:** Quantify the number and frequency of community dialogues conducted to address infrastructure and ZEV technology concerns.
- **Community Feedback:** Gather and analyze feedback from community members, residents, and businesses to gauge their perspectives and concerns.
- **Channels for Concerns:** Track the utilization of established channels for addressing common community concerns, such as green gentrification and ZEV technology readiness.
- **Accessibility and Inclusivity:** Assess the effectiveness of multilingual information dissemination in reaching diverse stakeholders and ensuring accessibility and inclusivity.

Workforce Development

Transitioning to ZEVs will change the skills needed in the freight and trucking industry compared to traditional diesel fleets. SANDAG and its partners should ensure training and workforce recruitment evolve with ZEV deployment, working with educational entities and stakeholders to develop pertinent training programs. **Figure 22** provides a summary of the workforce development strategies. The tracking metrics (**Figure 23**) associated with these strategies focus on quantifying, in some cases at the local level, the progression in workforce skills and accreditations, positive impacts in DACs, and integration of ZEV career pathways in public schools.

Figure 22. Summary of Workforce Development Strategies

Workforce Training for ZEV Transition, collaborate with regional partners to identify necessary skills and competencies for the evolving freight industry due to ZEV adoption, develop comprehensive training programs in coordination with educational institutions and industry stakeholders, include training for automotive technicians, first responders, charger and fueling infrastructure crews, truck drivers, and more, prioritize training programs in DACs, partner with OEMs and labor unions like IBEW 569 for specialized training programs, encourage OEMs to donate ZEV models to training programs.

Integrate ZEV Career Pathways, integrate ZEV career pathways into the educational system, create a continuum of educational opportunities from K-12 and university, develop curriculum and programs that nurture skills relevant to ZEV-related careers, equip students with knowledge and expertise for careers in ZEV scientific research, design, and development.

Figure 23. Tracking Metrics for Workforce Development Strategies

Workforce Metrics

- **Skills Gap Assessment:** Measure the gap between the skills and competencies identified for the evolving freight industry and the existing workforce's skills.
- **Training Program Participation:** Track the number of individuals participating in the comprehensive training programs, categorizing them by job roles (e.g., automotive technicians, first responders, etc.).
- **Completion Rates:** Measure the percentage of participants who successfully complete the training programs.
- **Employment Placement:** Monitor the employment placement rate of individuals who completed the training, especially in the ZEV-related job sectors.
- **DAC Program Success:** Assess the success and impact of prioritized training programs in Disadvantaged Communities (DACs), including employment outcomes.
- **OEM Partnerships:** Track the number of partnerships established with OEMs and the number of ZEV models donated for training purposes.

Educational Metrics

- **Curriculum Integration:** Evaluate the extent to which ZEV career pathways are integrated into the educational system, including the number of schools and universities adopting these pathways.
- **Student Participation:** Monitor the enrollment of students in ZEV-related educational programs and courses.
- **Graduation Rates:** Measure the percentage of students who successfully complete ZEV-related educational pathways.
- **Industry Engagement:** Assess the level of engagement and collaboration with industry stakeholders to ensure curriculum relevance.
- **Research and Development Careers:** Track the number of students who pursue careers in ZEV scientific research, design, and development after completing the educational pathways.

Lead by Example

SANDAG, in collaboration with regional partners, should integrate MD-HD ZEV goals into future planning, assist local areas in setting ZEV targets, develop infrastructure on public lands, and prioritize converting their fleets to zero emissions. By converting public fleets, SANDAG and its regional partners can foster an early market for new technology, showcase its effectiveness, and share experiences and insights from the transition, promoting a better understanding of the advantages and challenges of zero-emission vehicles. **Figure 24** provides a summary of these leadership strategies. The tracking metrics (**Figure 25**) associated with these leadership strategies focus on quantifying MD-HD ZEV and infrastructure and the realized benefits moving forward.

Figure 24. Summary of Leadership Strategies

Integration of MD-HD ZEV Deployment Goals, consider integrating regional MD-HD ZEV deployment goals and targets into future planning efforts, provide assistance to local jurisdictions to set and update ZEV adoption targets through EV Roadmap or CAPs, build out some of the first public infrastructure.

Conversion of Public Fleets to Zero Emission, develop a ZEV transition plan for public fleets, proactively convert public fleets to zero emission vehicles on expedited timelines, share lessons learned from public fleet transitions with the public to promote understanding.

Collaboration for Air Quality Monitoring, collaborate with SDAPCD, the Port of San Diego, and other local jurisdictions to monitor the impact of ZEV deployment on local air quality, consider adopting ZEV targets through EV Roadmap, CAPs, and Regional Plan.

Figure 25. Tracking Metrics for Leadership Strategies

MD-HD ZEV Goals Metrics

- **Number of Jurisdictions Setting ZEV Adoption Targets:** Track how many local jurisdictions set and update ZEV adoption targets through EV Roadmaps or CAPs.
- **Infrastructure Expansion:** Measure the progress in building out the first public infrastructure for MD-HD ZEVs, including the number of charging/fueling stations and their locations.

Fleet Conversion Metrics

- **Public Fleet Transition Plan Implementation:** Monitor the development and implementation of the ZEV transition plan for public fleets.
- **Public Fleet Conversion Rate:** Track the rate at which public fleets are being converted to zero emission vehicles compared to the set timelines.
- **Lessons Learned Sharing:** Assess the effectiveness of sharing lessons learned from public fleet transitions with the public by gathering feedback and understanding their perspectives.

Air Quality Metrics

- **Air Quality Improvement Metrics:** Measure changes in local air quality over time as ZEV deployment progresses, considering factors such as reduced emissions.
- **Collaborative Partnerships:** Evaluate the extent of collaboration with SDAPCD, the Port of San Diego, and other local jurisdictions in monitoring air quality and achieving ZEV targets.

Monitoring and Evaluation

As the region embarks on the journey towards widespread adoption of MD-HD ZEVs and supporting infrastructure, SANDAG and its stakeholders may consider establishing a monitoring and evaluation framework. This proposed framework considers the results of the research and analysis conducted in the previous reports, distilling key metrics recommended to track across the following categories:

- Status of vehicle fleet mix, emissions
- Status of infrastructure deployment
- Infrastructure utilization
- Benefits to LICs and DACs
- Public surveys on MD-HD ZEV awareness
- Number of P3 Models for MD-HD ZEVs

The project team selected these indicators to prompt SANDAG and its stakeholders to track real-world vehicle fleet, energy consumption, and infrastructure capacity data as the region shifts towards MD-HD ZEVs. These metrics can offer decision-makers insights into regional needs and areas where the region either excels or faces challenges with MD-HD ZEV and infrastructure deployment. As time progresses, forecast adjustments become more precise, challenges are addressed, and milestones are eventually celebrated.

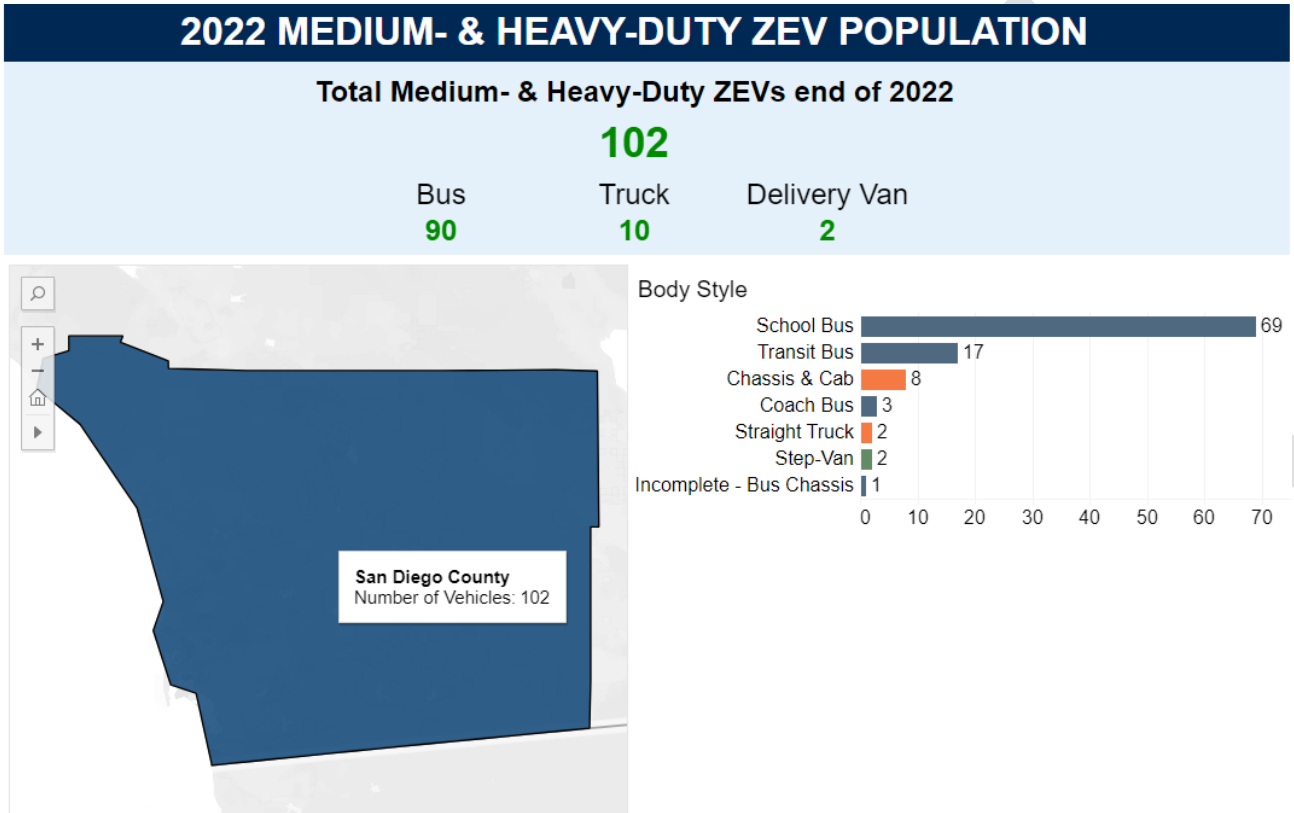
This section addresses what monitoring and evaluation of MD-HD ZEVs and infrastructure can encompass. The indicators reflect the same kinds of metrics explored by the project team, including: the number of MD-HD vehicles by type, the number of charging and fueling stations by type, criteria and GHG emission reductions, and public health benefits. Other indicators, such as measuring the positive socioeconomic impacts for communities and public awareness of MD-HD ZEV fleet transition, provide SANDAG, its stakeholders, and the public with greater fidelity to the imperative shift to zero-emission MD-HD vehicles over the next two decades.

Regional Vehicle Adoption

SANDAG can capitalize on the Zero Emission Vehicle and Infrastructure Statistics[19] developed by the CEC in partnership with the Department of Motor Vehicles (DMV). These statistics are vital in monitoring the sales and population of MD-HD ZEV population and sales within California. An example of data extracted from the CEC's Zero Emission Vehicle and Infrastructure Statistics is illustrated in Figure 26. It is critical for SANDAG to tap into these resources, utilizing this information to closely monitor the adoption rates of zero emission MD-HD vehicles within the region.

[19] https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics/medium-and-heavy

Figure 26. An Example of MD-HD ZEV Population Reported by the CEC Zero Emission Vehicle and Infrastructure Statistics Platform



Regional Criteria and GHG Emissions

The project team utilized the CARB EMFAC2021 model to conduct the MD-HD vehicle technology fleet projection and emissions modeling. It's anticipated that CARB will release an update to the EMFAC2021 modeling suite to automatically account for the impacts of the ACF regulation. This will make it easier for SANDAG and its stakeholders to access updated technology mix projections and their potential criteria and GHG emissions reductions over time. Additionally, SANDAG might leverage the EMFAC model to simulate different scenarios of MD-HD ZEV adoption. This could be based on real-world adoption data sourced from CEC's Zero Emission Vehicle and Infrastructure Statistics, helping evaluate the actual emissions reductions arising not just from regulations but also from regional actions. Such comparisons can further assist SANDAG in assessing the effectiveness of its initiatives in surpassing the emissions reductions anticipated from the ACF regulation alone.

Infrastructure Deployment

Several resources are available to monitor the number of public- and private-access charging and fueling stations across the region. Perhaps the most comprehensive mapping tool that is publicly available is the US DOE's

AFDC Station Locator Map[20], the largest North American map of electric charging and hydrogen fueling stations that features total number of stations by type and state. Proposed infrastructure projects submitted to the various incentive programs available may also provide greater context behind the types of charging and fueling station sites that developers are trying to secure the funds for. Similar information can also be extracted from the CEC's Zero Emission Vehicle and Infrastructure Statistics.[21]

Infrastructure Utilization

As delineated in the ZEV Siting Criteria and Technology Report, utilization is a major decision pivot for the release of investment funds towards infrastructure projects. Developers and investors have good reason to look at utilization in return on investment (ROI) calculations and risk assessments, especially since every site has unique characteristics that need to be considered. Utilization can be measured in several ways, either through traffic flow in proximity to the site or based on the amount of time that the station is online and can properly dispense fuel. Another option to measure infrastructure utilization is to consider partnering with fleet owners/operators to obtain telematics data recorded by MD-HD vehicles to determine the amount of actual dwelling time during charging periods. Collaborating closely with SDG&E and SDCP is also critical for effectively tracking the utilization of charging infrastructure in the San Diego region. Both entities play pivotal roles in energy distribution and sustainable power initiatives within the area. Their insights, data, and on-the-ground experiences can provide invaluable granularity regarding infrastructure usage patterns, potential challenges, and growth opportunities. The Clean Energy Alliance may also have a large role in the formation and facilitation of CCA programs.

Benefits to LICs and DACs

ZEV infrastructure deployment in low-income communities (LICs) and disadvantaged communities (DAC) will need to strike a balance between providing greater public charging and fueling resources with mitigating negative impacts to residents of those communities. Some practical measurements, like the physical proximity of traffic and infrastructure sites to LICs/DACs, can be gathered from field surveys and station locator tools. Additionally, there can be changes in cost-of-living trends as a result of charging and fueling stations acting as "vehicle magnets". Some metrics may be more difficult to measure, such as the number of undesignated truck parking infractions in LICs and DACs. Moreover, neighborhood changes, environmental issues, noise pollution, air quality, traffic congestion, and community outlook are some facets that data analytics cannot always provide a clear answer for.

Nonetheless, there are a number of acceptable methods to measure the impacts of strategies that successfully facilitate MD-HD ZEV fleet transition. These include health impact studies to assess changes in air quality and public health, noise pollution monitoring, traffic congestion analysis, economic impact studies measuring job creation and local business growth, continuous community feedback through surveys, tracking electricity consumption, analyzing traffic safety data, environmental monitoring, and assessing community development indicators. Additionally, documenting successful case studies and best

[20] https://afdc.energy.gov/stations/#/find/nearest
[21] https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics

practices, monitoring public awareness, and evaluating equity impacts will provide other regions with invaluable research to engage in their own EJ measures.

Public MD-HD ZEV Awareness Surveys

To conduct research on public awareness regarding MD-HD ZEVs in LICs and DACs, a baseline survey can be administered to residents and stakeholders in these communities to gauge their existing awareness levels, perceptions, and knowledge of MD-HD ZEVs. Note that it may be necessary to prepare multiple copies of material if the region is multilingual or make access to a dynamic online survey easy. Following this, ongoing surveys and focus group discussions could be conducted at regular intervals to track changes in attitudes and knowledge as ZEV adoption and infrastructure deployment progress.

It may also prove successful to share MD-HD ZEV and infrastructure benefit "highlights" through social media. Well conducted research that aims to shed a positive outlook on progress made towards sustainability and reducing consumption can gain significant traction on social media. Monitoring social media trends, community outreach programs, and public engagement events could provide real-time insights into public sentiment and awareness.

Number of P3 Models

Public-private partnerships (PPPs) offer a collaborative approach to charging infrastructure development, involving private partners who finance initial costs in exchange for returns over time. This model entails a partnership between government and private companies, with the private sector leading the design, financing, construction, and operation of charging infrastructure, while the government provides funding and resources. Various PPP models are available, including Build-Operate-Transfer (BOT), Design-Build-Finance-Operate-Maintain (DBFOM), Concession, and Joint Venture models, each suited to specific goals and needs. PPPs have been employed successfully in the deployment of MD-HD electric vehicles, with examples like CARB and SCAQMD partnering to fund EV deployment and infrastructure construction and the Port of Los Angeles collaborating with the private sector to test electric delivery trucks, aiming to reduce emissions and demonstrate feasibility. Tracking the frequency and success of PPPs allows us to gauge the level of collaboration and innovation in the transition to MD-HD ZEVs, providing valuable insights into the effectiveness of these partnerships in driving technological advancements and adoption.

5. CHARTING THE COURSE AHEAD

The San Diego Regional MD-HD ZEV Blueprint emerges as a crucial guiding document for the future of sustainable transportation in the region. At its core, the Blueprint offers projections concerning the number of MD-HD ZEVs anticipated to be on the roads, and correspondingly, the infrastructure necessary to support them. The Blueprint does not merely stop at presenting data, but it strategically details how SANDAG, in tandem with its regional partners, can come together to streamline this massive transition.

The magnitude of investment required to develop the supporting infrastructure as proposed is exceptionally large. Yet, the Blueprint recognizes that the financial burden should not be shouldered by public entities alone. In advocating for robust public-private partnerships, the Blueprint champions a collaborative approach to funding. By integrating regional incentive programs and offering clear guidance on infrastructure siting criteria, the Blueprint aims to build a compelling financial narrative for the private sector's involvement. The ultimate goal is to encourage both public and private enterprises to invest in and establish an expansive network of charging and fueling infrastructure. Such a collaborative infrastructure is envisioned not just as a support system for ZE vehicles but as a catalyst that enhances the regional economy and significantly benefits the environment. Through its well-laid strategies, the Blueprint hopes to drive the region towards a sustainable, economically vibrant, and environmentally responsible future.

Sharing Lessons Learned

Projects in the MD-HD ZEV and infrastructure landscape that demonstrate early success and long-term promise should be publicized. In example, Indian Energy LLC, a private microgrid developer and systems integrator, recently commenced construction of the Viejas Enterprise Microgrid, funded partially by the CEC and a 3rd-party financier on behalf of Indian Energy. The project is expected to support the tribal-state-federal partnerships that currently exist between Indian Energy, the Viejas Nation, CEC, the United States Navy/Marine Corps and the US Department of Energy. The microgrid project is expected to expand upon the power generation and battery energy storage system to provide 100 percent energy resiliency from grid disturbances.

Other regional efforts that have demonstrated early success include SDG&E's Hydrogen Innovations, which explores the potential of clean hydrogen to help the State achieve net zero GHG emissions by 2045. Earlier this year, the North County Transit District (NCTD) was granted more than $29 million from the FTA to purchase 23 fuel cell electric buses, which SANDAG will actively monitor to consider the lessons learned from the project. Currently, SDG&E monitors hydrogen fuel production at its Palomar Energy Center, reserving it for its initial FCEVs and as a cooling gas for combined cycle processes at power plants. SDG&E is also testing long-duration hydrogen storage at its Borrego Springs Microgrid, which makes hydrogen available for dispatch when grid energy demand is high. The most recent project SDG&E has been pursuing approval of is its hydrogen blending project at the University of California San Diego campus. If approved by the CPUC, the project will study the impact of hydrogen blended natural gas (up to 20%) in infrastructure materials common to the natural gas distribution system — addressing the need to fill knowledge gaps to inform a hydrogen blending injection standard. Pending approval by the CPUC, development and design activities are planned to start in Q2 2023, construction in Q2 2024, and hydrogen blending would occur between Q4 2024 and Q1 2026. The site would be fully restored to its original conditions by Q3 2026.

One other notable regional effort is the SANDAG Zero Emission Vehicle Incentive Project (ZEVIP), a light-duty vehicle rebate program. The goal of the program is to accelerate light-duty ZEV adoption, with the goal to introduce 100,000 new light-duty ZEVs between 2025 through 2035. The SANDAG ZEVIP is currently in development, soliciting lessons learned from other incentive programs and CBOs committed to equitable distribution of light-duty ZEVs and infrastructure. Through ZEVIP, SANDAG anticipates offering a streamlined and effective incentive program to meet regional and State electrification goals. Lessons learned from this incentive program shall be used to inform potential future regional incentive programs for MD-HD vehicles.

Supporting BEV/FCEV Demonstrations at the Port of SD and beyond

As previously discussed, the adopted ACF regulation is positioned to mandate the most stringent fleet electrification requirements for fleets especially those operating at the ports and intermodal railyards. Specifically, the adopted ACF regulation calls for 100 percent zero-emission drayage truck sales starting in 2024, and eventually require that 100 percent of drayage trucks be zero emission by 2035. The Blueprint can serve as a starting point for recommending demonstration battery electric and fuel cell electric drayage truck projects at the Port of San Diego as well as other freight facilities throughout the region.

Pilot Projects to Consider

Pilot programs are instrumental in the adoption of MD-HD ZEVs as they offer a controlled environment to test and refine these new technologies. By allowing for real-world data collection, they help stakeholders understand actual performance and infrastructure needs, while mitigating risks associated with full-scale rollouts. These programs build confidence among fleet operators, policymakers, and the public, shaping positive perceptions and fostering collaborations. Additionally, they provide invaluable insights into cost dynamics, training requirements, and potential regulatory frameworks, making them essential bridges between conceptual promise and large-scale practical implementation.

Table 3 illustrates five recommended pilot programs designed to test emerging MD-HD ZEV technologies. These pilots aim to assess feasibility, uncover logistical issues, and incentivize technology adoption. Some may involve temporary incentives, such as toll discounts, contingent upon meeting financial requirements, with long-term alignment of toll policies with other agencies. More details are available in the Near- and Long-Term Implementation Strategies Report[3].

Table 3. List of Recommended Pilot Programs for Regional MD-HD ZEV Deployment

Program Category	Detailed Proposed Projects
Innovative technology demonstrations	Charging depot using renewable grid or photovoltaic (PV) technologies with energy storage
	Ultra-fast charging techniques
	V2X demonstration
	Wireless and dynamic charging application
	Onsite clean, renewable hydrogen production
ZEV infrastructure business models	Depot charging facilities with equipment and/or vehicle lease options
	Multi-use charging site/MD-HD charging plaza
	Valet EV charging program
	Universal payment method for infrastructure usage
Port technology feasibility assessments	Short-haul BET/FCET application
Border-crossing goods movement	Binational fleets ZEVs application
	Wireless charging for border-crossing BETs during wait time
	Toll discounts for MD-HD ZEVs at POEs
	Dedicated lane for MD-HD ZEVs at POEs
ZEV Lanes	Exemptions or dedicated lane for MD-HD ZEVs
	Toll discounts for MD-HD ZEVs on highways

Conclusion

In conclusion, the Blueprint proposes MD-HD ZEVs as a crucial component of the San Diego region's solution to address the adverse environmental and climate impacts of MD-HD vehicles, ultimately aiding the region in achieving its ambitious sustainability goals. Developed by SANDAG in coordination with its regional partners, the core objective of this Blueprint is to guide the transition of MD-HD vehicles to zero-emission technology, addressing challenges related to technology readiness, infrastructure availability, and cost. The Blueprint also outlines short- and long-term strategies to accelerate the adoption of MD-HD ZEVs in the San Diego region, with an emphasis on reducing air pollution and GHG in disadvantaged communities.

Much of the impetus for MD-HD ZEVs stems from State-level regulations, such as the ACT and ACF regulations, that aim to transition MD-HD vehicles to ZEVs. The advent of regional MD-HD vehicle fleet electrification will yield emissions benefits for vulnerable communities along major goods movement corridors. The Blueprint provides a detailed assessment of ZEV technologies and their supporting infrastructure, with BEVs expected to serve as a strong base of support for operations currently fulfilled by ICEVs. It should be noted, however, that the need for expanded electric charging and hydrogen fueling networks is evident, with projections for yearly infrastructure requirements through 2040. The associated financial investment required to bring the infrastructure needs to fruition are substantial, surpassing a cumulative $2.5 billion by 2040. Achieving this goal necessitates an all-hands-on-deck approach, bringing together regional partners, as well as public and private capital, to make it possible.