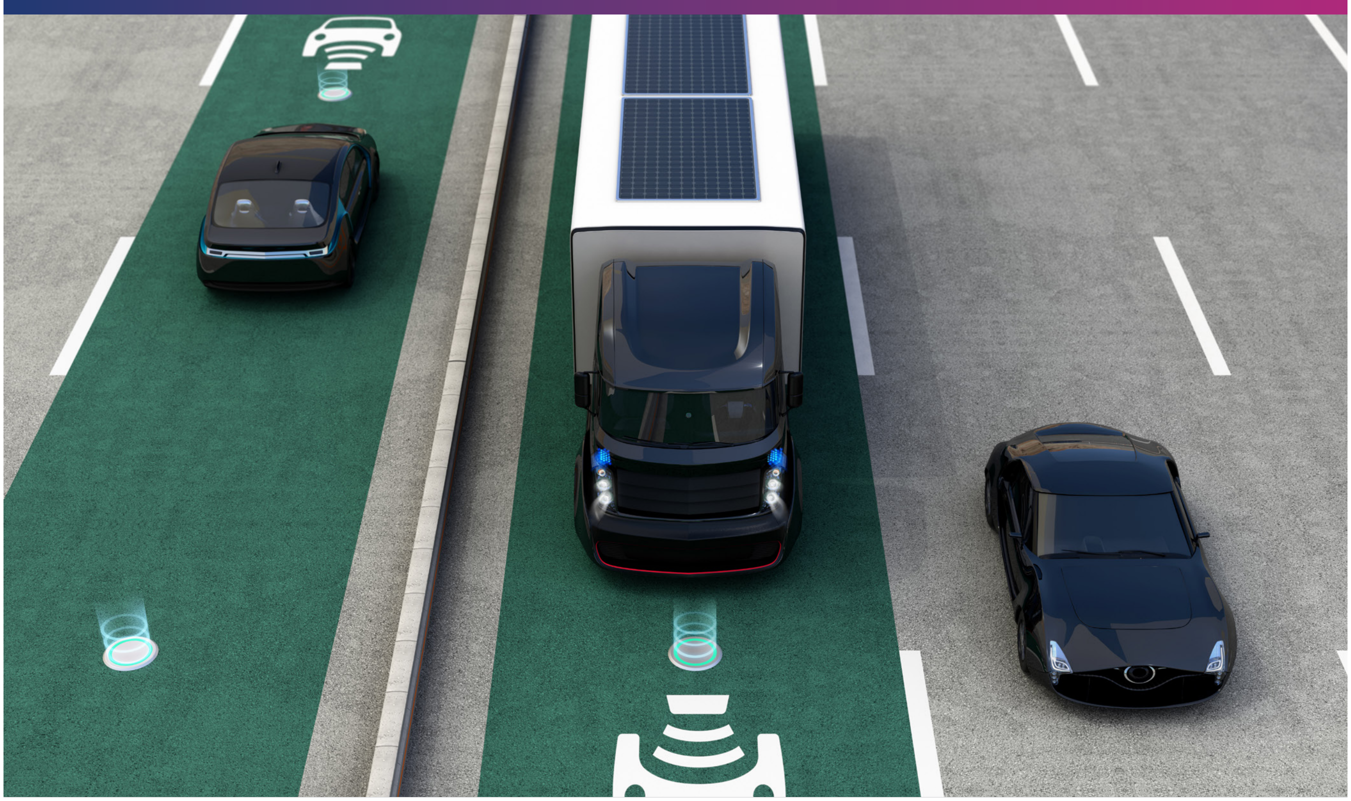
San Diego Regional

Medium-Duty and Heavy-Duty Zero Emission Vehicle Blueprint

January 2024



Free Language Assistance | Ayuda gratuita con el idioma | Libreng Tulong sa Wika | Hỗ trợ ngôn ngữ miễn phí 免費語言協助 | 免费语言协助 | مساعدة ترجمة مجانية | 무료 언어 지원 | کمک زبان رایگان | 無料の言語支援 | Бесплатная языковая помощь | Assistência linguística gratuita | मुफ़्त भाषा सहायता | Assistance linguistique gratuite | ជំនួយភាសាឥតគិតថ្លៃ ఉచిత భాషా సహాయం | ການຊ່ວຍເຫຼືອດ້ານພາສາຟຣີ | Kaalmada Luqadda ee Bilaashka ah | Безкоштовна мовна допомога

SANDAG.org/LanguageAssistance | 619.699.1900

ABSTRACT

TITLE:	San Diego Regional Medium-Duty and Heavy-Duty Zero Emission Vehicle Blueprint
AUTHORS:	ICF Incorporated, L.L.C., and Fehr & Peers
DATE:	January 2024
SOURCE OF COPIES:	San Diego Association of Governments 401 B Street, Suite 800 San Diego, CA 92101 619.699.1900
NUMBER OF PAGES:	50
CEC AGREEMENT NUMBER:	ARV-21-028

LEGAL NOTICE

This document was prepared as a result of work sponsored by the California Energy Commission. It does not necessarily represent the views of the Energy Commission, its employees, or the State of California. The Energy Commission, the State of California, its employees, contractors, and subcontractors make no warranty, express or implied, and assume no legal liability for the information in this document, nor does any party represent that the use of this information will not infringe upon privately owned rights.

TABLE OF CONTENTS

Acknowledgments 5
Executive Summary 6
1. The Shift to Zero Emission MD-HD Vehicles 12
What is the San Diego Regional MD-HD ZEV Blueprint? 12
Need for Emission Reductions 12
Executive Orders 13
Regulatory Orders 13
Incentive Programs 14
Existing State of Technology & Infrastructure 14
2. The Need for Infrastructure Buildout 19
San Diego MD-HD Fleet Technology Projection 19
San Diego Region Charging and Fueling Infrastructure Projection 20
San Diego Region Charging and Fueling Infrastructure Cost Estimate 23
3. The Significance of Proper Infrastructure Siting 25
4. From Roadblock to Innovations 27
Barriers to Adoption 28
Strategies to Accelerate 30
Regional Policy and Funding Support 30
Siting, Land Use, Zoning, and Permitting 32
Promote Public-Private Partnership Models 34
Public Education and Community Outreach 36
Workforce Development 38
Lead by Example 40
Monitoring and Evaluation 42
Regional Vehicle Adoption 42
Regional Criteria and GHG Emissions 43
Infrastructure Deployment 44
Infrastructure Utilization 44
Benefits to LICs and DACs 44
Public MD-HD ZEV Awareness Surveys 45
Number of P3 Models 45
5. Charting the Course Ahead 46
Sharing Lessons Learned 46
Supporting BEV/FCEV Demonstrations at the Port of San Diego and Beyond 48
Pilot Projects to Consider 48
Conclusion 50

ACKNOWLEDGMENTS

The project team extends its sincere appreciation to the individuals and organizations that generously provided their support, expertise, and contributions to the development of the San Diego Regional Medium- and Heavy-Duty (MD-HD) Zero Emission Vehicle (ZEV) Blueprint.

Special thanks to the Port of San Diego and the Environmental Health Coalition for their unwavering support and constructive feedback through the development of the MD-HD ZEV Blueprint (Blueprint). Their involvement allowed the project team to engage with and gather invaluable insights from a diverse group of industry experts, infrastructure supporters, and community stakeholders. These insights spanned various domains, including regulatory frameworks, technological advancements, and strategies for transitioning the region's fleet of MD-HD vehicles to zero emission technology.

Furthermore, the project team extends its gratitude to the Freight Stakeholders Taskforce. Their active participation and input were instrumental for the Blueprint's successful completion.

Key members of the SANDAG Freight Stakeholders Taskforce included:

- BNSF Railway
- Caltrans
- City of Chula Vista
- County of San Diego
- California Public Utilities Commission
- Governor’s Office of Business and Economic Development
- 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
- University of Southern California/METRANS

EXECUTIVE SUMMARY

The San Diego Association of Governments (SANDAG) secured funding from the California Energy Commission's (CEC) Clean Transportation Program grant titled "Blueprints for Medium- and Heavy-Duty Zero-Emission Vehicle Infrastructure," (GFO-20-601) to guide the transition of Medium-Duty 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 prepare the regional shift toward zero-emission MD-HD vehicles. This Blueprint also outlines short- and long-term strategies to accelerate the adoption of MD-HD Zero Emission Vehicles (ZEVs) in the San Diego region. These strategies emphasize improving air quality and reducing GHG emissions, especially within low-income and disadvantaged communities.

Current State of ZEV Technology

This Blueprint opens with an assessment of the current state of ZEV technologies and required infrastructure to establish a public educational resource regarding the transition to MD-HD ZEVs. Currently, the ZEV market is segmented into three primary technology BEVs platforms: battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell electric vehicles (FCEVs). In this Blueprint, as corroborated by other reputable studies conducted by state agencies and market experts, BEVs are projected to be widely adopted compared with PHEVs and FCEVs. This is largely because of the high number of BEV models to be made or are already available from manufacturers. At the time that this Blueprint is published, there are more than 200 MD-HD BEV models tailored to nearly every MD-HD vehicle segment. In contrast, it is unlikely that there will be many MD-HD PHEV models available over time. The MD-HD FCEV market segment, however, does show potential for growth, especially in areas such as long-haul trucking. MD-HD 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. 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).

Current State of ZEV Infrastructure

Both electric vehicle charging and hydrogen fueling stations have surpassed the commercialization stage, especially in California. Agencies tracking ZEV infrastructure deployed to date, such as the CEC and U.S. Department of Energy's (DOE) Alternative Fuels and Data Center (AFDC), estimate that at the time this Blueprint is published, the San Diego region will currently host 428 direct current fast charging (DCFC) station 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. Despite only one station being available, hydrogen fueling infrastructure and clean hydrogen fuel production (i.e., green hydrogen produced through electrolysis using renewable electricity) are projected to become more widely available. This expansion is anticipated due to significant funding provided through Federal Bipartisan Infrastructure Law also known as hydrogen hubs, and tax credits offered through the Inflation Reduction Act, which will greatly help the industry transition away from hydrogen produced by fossil fuels (e.g., steam methane reformation).

Need for Infrastructure Development

With the emergence of MD-HD ZEVs and the notable disparity in their supporting infrastructure, the time to expand charging and clean hydrogen fueling networks is now. As part of this Blueprint, SANDAG reviewed fleet technology, emission, and energy consumption projections to determine the regional need 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 clean 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. According to this assessment, 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 hydrogen (H_2), respectively. 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.

SIGNIFICANT INVESTMENT NEEDED

A **$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.

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 toward to propel the region towards a sustainable transportation future.

Optimal Siting of Charging and Hydrogen Fueling Infrastructure is Key

Since the region is projected to steadily deploy charging and fueling infrastructure from 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 toward seamless MD-HD ZEV adoption. For siting criteria, the Blueprint recommends that the planners and developers consider technical facets, such as:

- Utilization of charging and fueling infrastructure,
- Grid capacity,
- Equity,
- Environmental justice, and
- Land use.

Near- and Long-Term Implementation Strategies

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 a series of near- and long-term implementation strategies. This Blueprint has identified six critical strategy pillars for advancement and accelerated adoption of MD-HD ZEVs in the region. These include:

Regional Policy and Funding Support

Despite policies and programs established by the federal and California state governments to encourage ZEV technology deployment, much remains to be done at the regional and local levels to reinforce these regulatory measures and provide the necessary support. This strategy presents six opportunities for SANDAG and its regional partners to consider:

- Expanding and enhancing "make-ready" infrastructure programs
- Exploring solutions for the increased weight of battery-electric trucks (BETs)
- Supporting vehicle-grid integration
- Prioritizing clean (i.e., green) and safe hydrogen production
- Advocating for consistent ZE policies across state and national borders
- Developing targeted incentive programs to reduce ZEV deployment costs, especially in disadvantaged communities

Siting, Land Use, Zoning, and Permitting

SANDAG and its regional partners can assist with infrastructure siting and technology criteria. This involves detailed regional planning and data analysis to identify optimal locations for charging and fueling stations based on MD-HD travel patterns, grid capacity, land use, environmental conditions, and equity. The strategy also includes streamlining infrastructure development processes, as well as enhancing grid and clean hydrogen availability. Furthermore, the strategy calls for coordination with industry stakeholders, government agencies, and utility providers to align with broader electrification goals, while ensuring compliance with safety and performance standards for efficient and effective ZEV deployment in the region.

Promote Public-Private Partnership (P3) Models

Public-Private Partnerships (P3) are crucial for the successful deployment of ZEV infrastructure because they effectively combine public goals with private sector efficiency and innovation. The strategy involves utilizing P3 models to enhance funding, accelerate deployment, diversify business models, and ensure the sustainability of the infrastructure service market. The strategy calls for streamlining the procurement process and supporting innovative partnership models. Additionally, the strategy includes streamlining revenue sharing in the EV charging industry, necessitating collaboration across

various sectors to create transparent and equitable revenue distribution models.

Public Outreach and Community Engagement

This strategy involves showcasing the benefits and feasibility of MD-HD BET and FCET models to enhance technology awareness and foster consumer confidence. Key opportunities include developing a Technology Advancement Program for demonstrating these technologies, and raising public awareness about relevant regulations and incentive programs through educational campaigns, workshops, and technical assistance programs. This approach prioritizes inclusivity and accessibility, ensuring that resources and information are available in multiple languages and that community needs and concerns are integrated into regional planning efforts.

Workforce Development

The transition to ZEVs necessitates a significant shift in the skills and knowledge required in the freight and trucking industry, highlighting the need for specialized workforce development strategies. This strategy includes identifying the specific skills and competencies required for the evolving ZEV industry and working with educational institutions, training centers, and industry stakeholders to create comprehensive training programs. Essential to this strategy is the development of training programs that prepare a 6 diverse range of professionals, including EV technicians, first responders, dealership staff, and maintenance crews, with a focus on incorporating ZEV-comprehensive career pathways into the educational system.

Lead by Example

The Blueprint also calls for regional partners and local jurisdictions to lead by example. This not only sets a precedent for adoption but also demonstrates the practicality and effectiveness of these technologies. This strategy entails integrating regional MD-HD ZEV deployment goals into future planning efforts and assisting local jurisdictions in updating their ZEV adoption targets through tools such as Climate Action Plans (CAPs). This proactive transition can serve as a tangible demonstration of commitment to sustainability and provides a real-world example of the benefits and operational implications of ZEVs. By sharing experiences and lessons learned from these fleet transitions and infrastructure deployment, regional partners can provide insights into the adoption process, fostering wider understanding and acceptance of ZEVs.

Roles & Responsibilities

In addition to strategies, the Blueprint also highlights specific roles and responsibilities for SANDAG and its regional partners, as illustrated in Figure ES1. Federal and state agencies are integral for providing policy direction and funding, which lay the groundwork for infrastructure and vehicle incentives. Local utilities are tasked with ensuring that the electricity grid can support increased demands from ZEV charging and are also involved in creating "make-ready" programs for charging infrastructure. Community organizations and non-profits can help conducting outreach and education, ensuring equitable access to information and benefits of ZEV adoption, especially in disadvantaged communities. Local jurisdictions, including city governments and transit authorities, may focus on planning, zoning, and coordinating the development of ZEV infrastructure within their regions. They shall also work closely with service providers and infrastructure solution companies to integrate charging and fueling stations into their urban landscape effectively. Trucking industry representatives and associations can help align industry practices with new technologies, advocating for their members' needs and facilitating the transition to ZEVs. Original Equipment Manufacturers (OEMs) and infrastructure companies are on the frontline of technology provision, bringing the latest innovations in electric and hydrogen-fueled vehicles to the market. Schools and training programs are essential for workforce development, ensuring that the current and future workforce is equipped with the skills needed for a ZEV-centric transportation sector.

Figure ES1. 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. This Blueprint is intended to guide the San Diego region through a pivotal shift toward zero-emission (ZE) technology. Foundational documents that guided the development of this effort include 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 the transition to environmentally conscious transportation modalities and offers a comprehensive roadmap for achieving this paradigm shift in the region.

Need 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 on residents burdened by their 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 of greenhouse gas (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 for improving regional air quality and public health.

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 with conventional fossil-fueled vehicles, taking less energy in the form of grid electricity. While there are also several other benefits, such as the lower total cost of ownership, reduced noise pollution, and improved driver experience, the air quality, climate, and health benefits associated with ZEVs alone are sufficient to command regional fleet transition. For these reasons, federal, state, and regional agencies have recently developed several regulatory requirements and funding opportunities to support the transition of MD-HD vehicles to ZEV.

Locally, there are also various strategies and pledges, notably the Maritime Clean Air Strategy (MCAS) and Portside Community Emissions Reduction Plan (CERP). The MCAS identifies future projects and initiatives that the Port can take on to the reduce emissions and improve public health of portside communities. The MCAS sets ambitious electrification goals for port-calling vehicles, with a goal of 100 percent of cargo trucks calling on the Port of San Diego cargo maritime terminals being ZEVs by 2030. The Portside CERP also sets ambitious goals to transition MD-HD vehicles to ZE, which reflect unique and important plans for the San Diego region. These strategies, as well as the North County Transit District (NCTD) and San Diego Metropolitan Transit System rollout plans, seek to achieve similar electrification goals within different vocations.

1. Available online: https://www.sandag.org/-/media/SANDAG/Documents/PDF/projects-and-programs/innovativemobility/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/innovativemobility/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/innovativemobility/clean-transportation/regional-medium-duty-heavy-duty/md-hd-zev-blueprint-draft-implementation-strategies.pdf

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[4] fleets be zero-emission by 2035. The directive also sets targets for non-port MD-HD vehicles to 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 Advanced Clean Trucks (ACT) and most recently the adoption of the Advanced Clean Fleets (ACF) regulation.

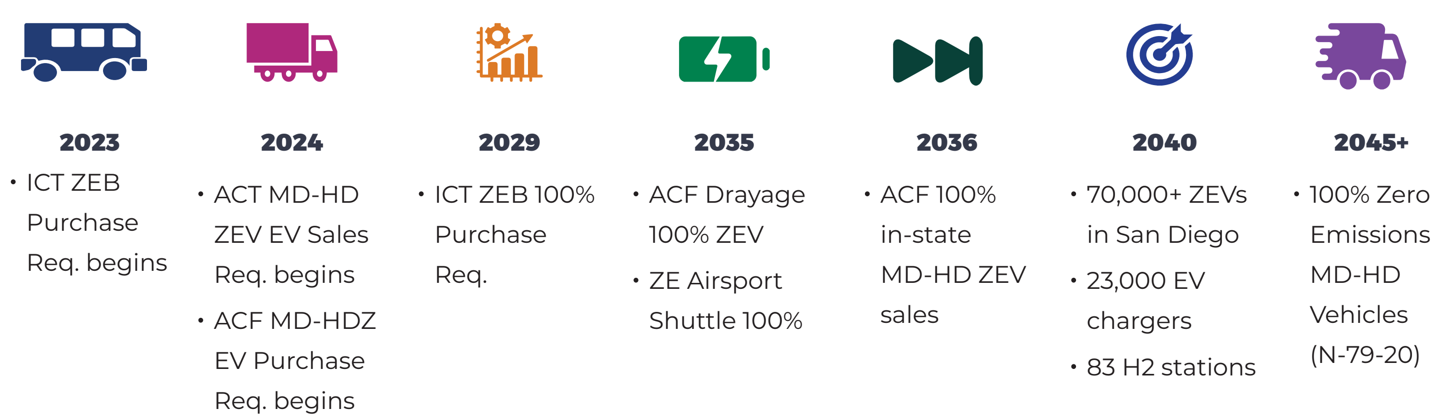
At the federal level, President Biden signed Executive Order 14037 in August 2021, ordering a comprehensive plan to accelerate the adoption of ZEVs in the United States.[5] This plan sets the goal of making half of all new light-duty vehicles sold in 2030 ZEVs, including: BEV, PHEV, and FCEV. The White House has also created a goal that 100 percent of federal light-duty fleet procurements are ZEVs by 2027. For MD-HD vehicles, the goal is to have 30 percent of new vehicle sales be ZEVs by 2030 and reach 100 percent by 2040.[6] A related U.S. Environmental Protection Agency 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 1** provides a summary of the regulations and MD-HD ZEV milestones established under each regulation. In California, several adopted CARB regulations have established MD-HD ZEV milestones. For example, the Innovative Clean Transit (ICT) regulation requires all public transit agencies to gradually transition to 100 percent zero-emission buses (ZEB) by 2029, with a goal of full fleet transition by 2040. **Figure 1** 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.

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 reduce NOx and GHG emissions and to increase MD-HD ZEV penetration into current

Figure 1. Summary of State Regulatory Milestones for MD-HD ZEVs



4. Drayage is the transportation of shipping containers, typically by heavy-duty trucks and from seaports or intermodal terminals.

5. Available online: https://www.federalregister.gov/documents/2021/08/10/2021-17121/strengthening-american-leadership-inclean-cars-and-trucks

6. 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/

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 zeroemission by 2042. 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 barriers can be particularly prohibitive.

In recent years, the federal government and 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 the Low Carbon Fuel Standard), 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**; these incentive programs are listed based on their applicability in 2023 and are subject to change based on legislative direction and agency budgetary considerations.

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

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. This is due to the significantly lower operational cost—given the higher cost of hydrogen as compared with electricity—as well as consumer confidence in the platform. On the other hand,

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

PROGRAM	ELIGIBLE FOR FUNDING	FUNDING AMOUNT
Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)	• Classes 2b through 8 ZEVs • Zero Emission Vehicle (ZEV) Voucher Modifiers for DAC[7] • ePTO Vouchers[8]	$7,500 – $120,000 (Base unmodified)
Inflation Reduction Act	• Classes 4 through 8 ZEVs	30% of the vehicle purchase price up to $40,000
Community Air Protection Program	• Classes 2b through 8 ZEVs • Pilot and demonstration projects	Varies by subprogram
Zero Emission Truck Pilot	• Classes 4 through 8 ZEVs • Requires DAC proximity	Up to 90% or $250,000 of eligible purchase cost
Volkswagen 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 Classes 2b through 8 • Public charging and hydrogen fueling station developers	Between 50% and 75% of the project cost
Low Carbon Fuel Standard (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 two 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

FCEVs have demonstrated success in California's public transportation sector and are competitive solutions for zero-emission long-haul trucking applications. Within the next 20 years, rapid deployment of charging and fueling infrastructure is expected across the region. As illustrated in **Figure 2**, 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. 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 3**, the majority of BEVs on the market offer electric ranges of around 200 miles. Although 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

7. 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.

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

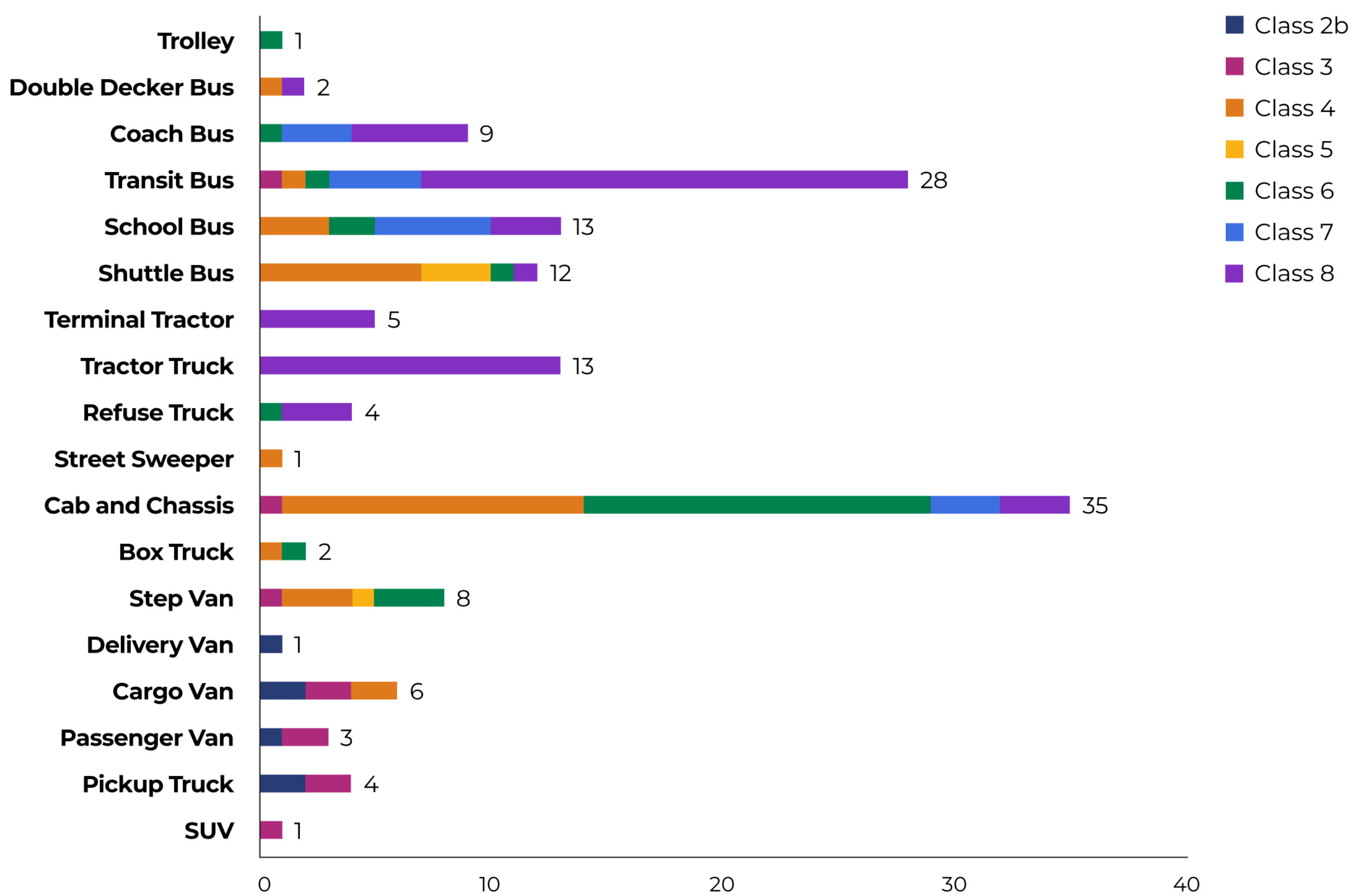
Table 2. Summary of MD-HD ZEV Market Resources

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 2022 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
U.S. 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 3 years along with detailed specifications associated with each vehicle

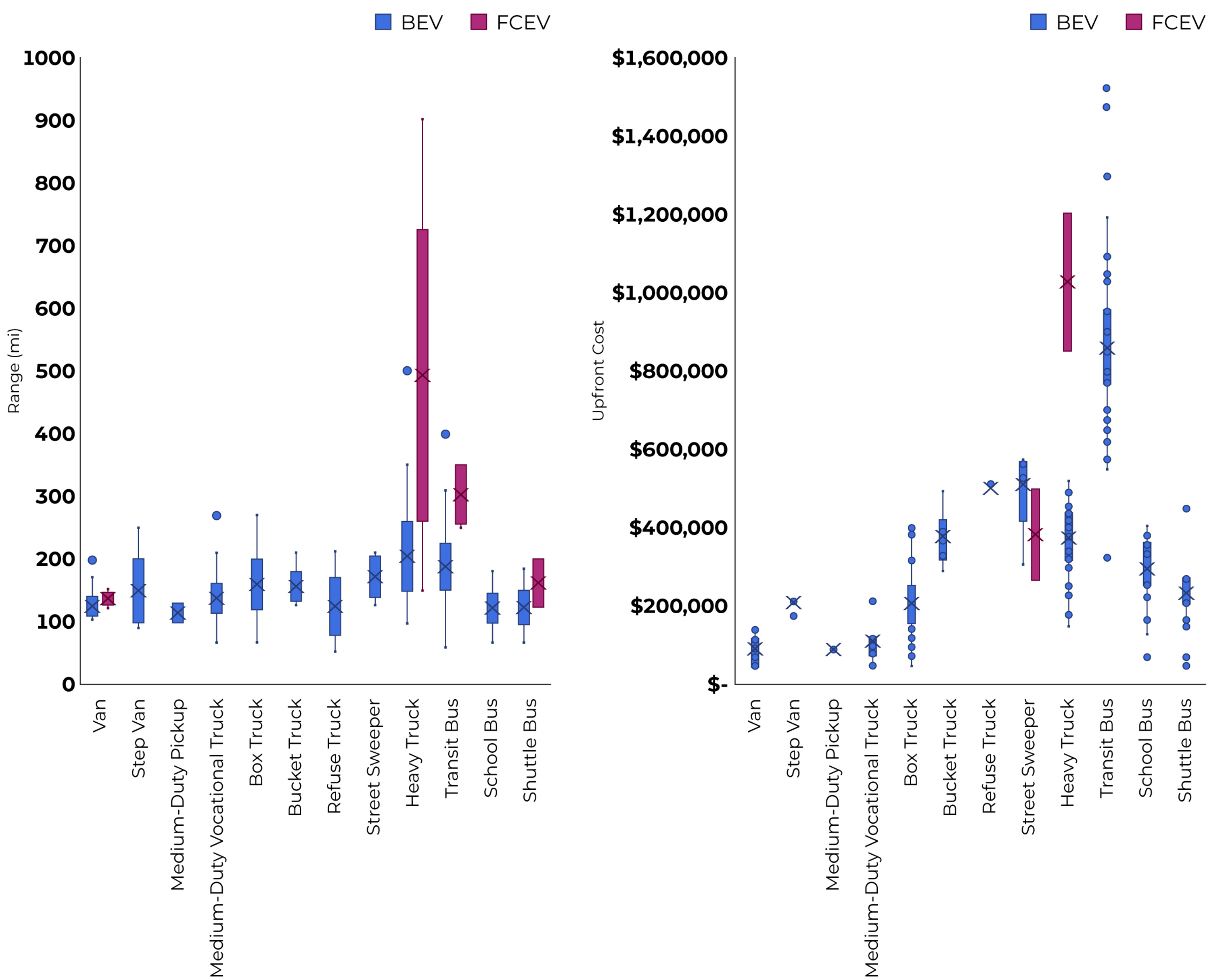
Figure 2. ZEV Model Availability Across Different MD-HD Vehicle Categories (CARB 2023)



vehicles is a large barrier for many potential adopters. As illustrated in **Figure 3**, currently, a typical zero-emissions class 8 heavy-duty tractor truck carries a price tag of roughly $400,000, over 2.5 times the cost of a standard diesel Class 8 tractor truck. The safety of battery electric and fuel cell electric MD-HD vehicles continues to be discussed at length as well. Reporting bodies, such as the Federal Transit Administration[9] and North American Council for Freight Efficiency[10] have published best safety practices for both BEVs and FCEVs, emphasizing the importance of incorporating these learnings in workforce training and in the detection features of EV charging and H2 dispenser hardware faults.

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.

Figure 3. MD-HD ZEV Range (left), Actual/Projected Vehicle Price (right) (ICF EV Library, October 2022)



9. https://www.transit.dot.gov/sites/fta.dot.gov/files/2023-08/FTA0252-Research-Report-Summary.pdf
10. Reports available for download with an account at: https://nacfe.org/research/electric-trucks/

Figure 4. Current Light-Duty ZEV Infrastructure in San Diego

The singular hydrogen fueling station has two H2 dispensers and is part of the TrueZero hydrogen fueling network, which provides liquid hydrogen delivery to the San Diego site.

Typically, Level 2 chargers are public or private access chargers with power levels between 2.5 kW 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 the 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. Expanding the number and capacity of hydrogen stations is a shared interest. However, hydrogen station development continues to require significant 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 and $9.8 million.

Additionally, 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 production site to the station. Certainly, the GHG emissions benefits of adopting hydrogen fuel vehicles would be undercut if the hydrogen is delivered by diesel trucks. This underscores the necessity for employing zero-emission trucks, utilizing pipeline systems, or on-site hydrogen generation systems to reduce the carbon footprint of the hydrogen delivered to consumers.

2. THE NEED FOR INFRASTRUCTURE BUILDOUT

As the San Diego region anticipates increased adoption of ZEV MD-HD vehicles, it is essential to develop a comprehensive understanding of the projected fleet mix and technology composition of the region. This led to the project team conducting a vehicle and infrastructure needs assessment, reflecting the policies and technology options, as discussed in Chapter 1. This foresight is instrumental for ensuring the region's readiness for the logistical and infrastructure challenges. For the fleet technology projection, the project team leveraged CARB's EMFAC2021 model to estimate the projected quantity and type of MD-HD ZEVs accounting for the ACT and ACF regulation requirements.

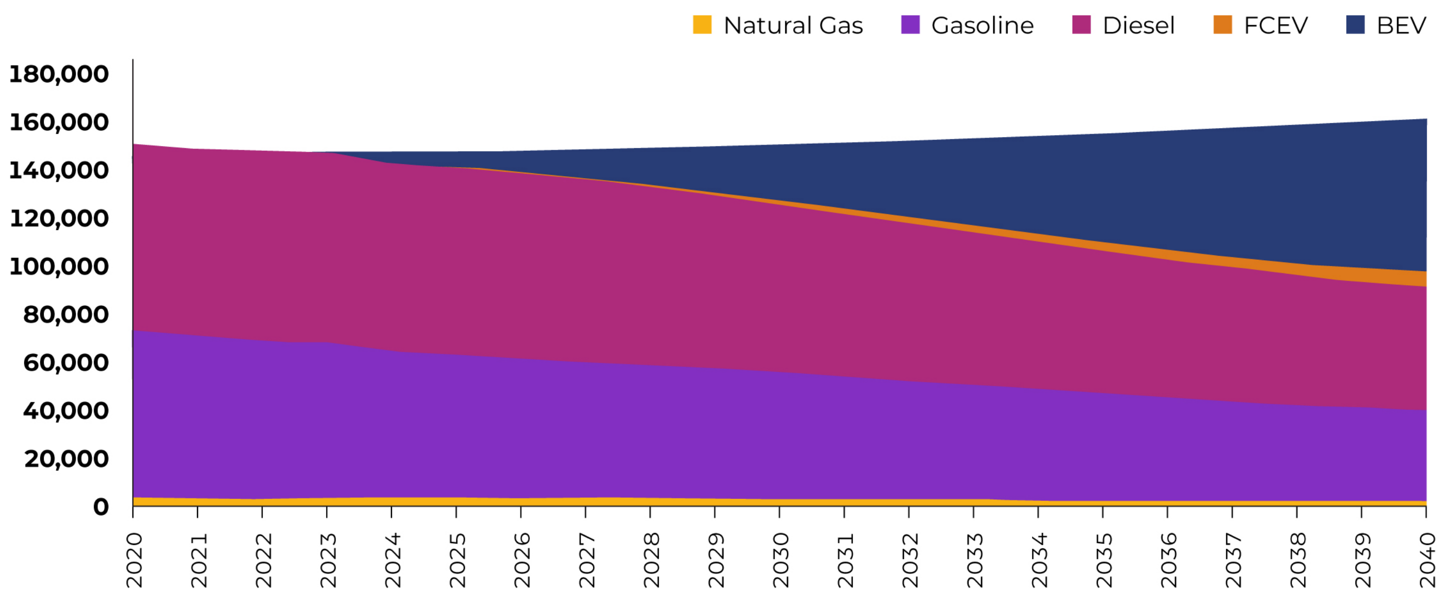
For the infrastructure needs projection, the project team utilized energy-based methodologies to translate projected electric charging and hydrogen fueling demand into distributions of charger and fueling infrastructure by type. The following sections provide a summary of results from this analysis. More details can be found in the Medium & Heavy-Duty Zero Emission Vehicle Blueprint Needs Assessment Report.[11]

San Diego MD-HD Fleet Technology Projection

The regional MD-HD fleet technology projection, accounting for ACT and ACF regulations, is shown in **Figure 5**. In 2024, 5,282 zero-emission MD-HD vehicles are expected to replace ICE MD-HD vehicles in the San Diego region due to the requirements imposed by these regulations. 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; the overall MD-HD vehicle population is projected to increase by 9 percent between 2023 and 2040.

Following the MD-HD fleet technology projection, the project team also estimated the potential NOx, particulate matter, and GHG emission reductions, assuming tailpipe emission reductions proportional to decreases in the ICEV

Figure 5. San Diego Region's MD-HD Vehicle Population by Fuel Type



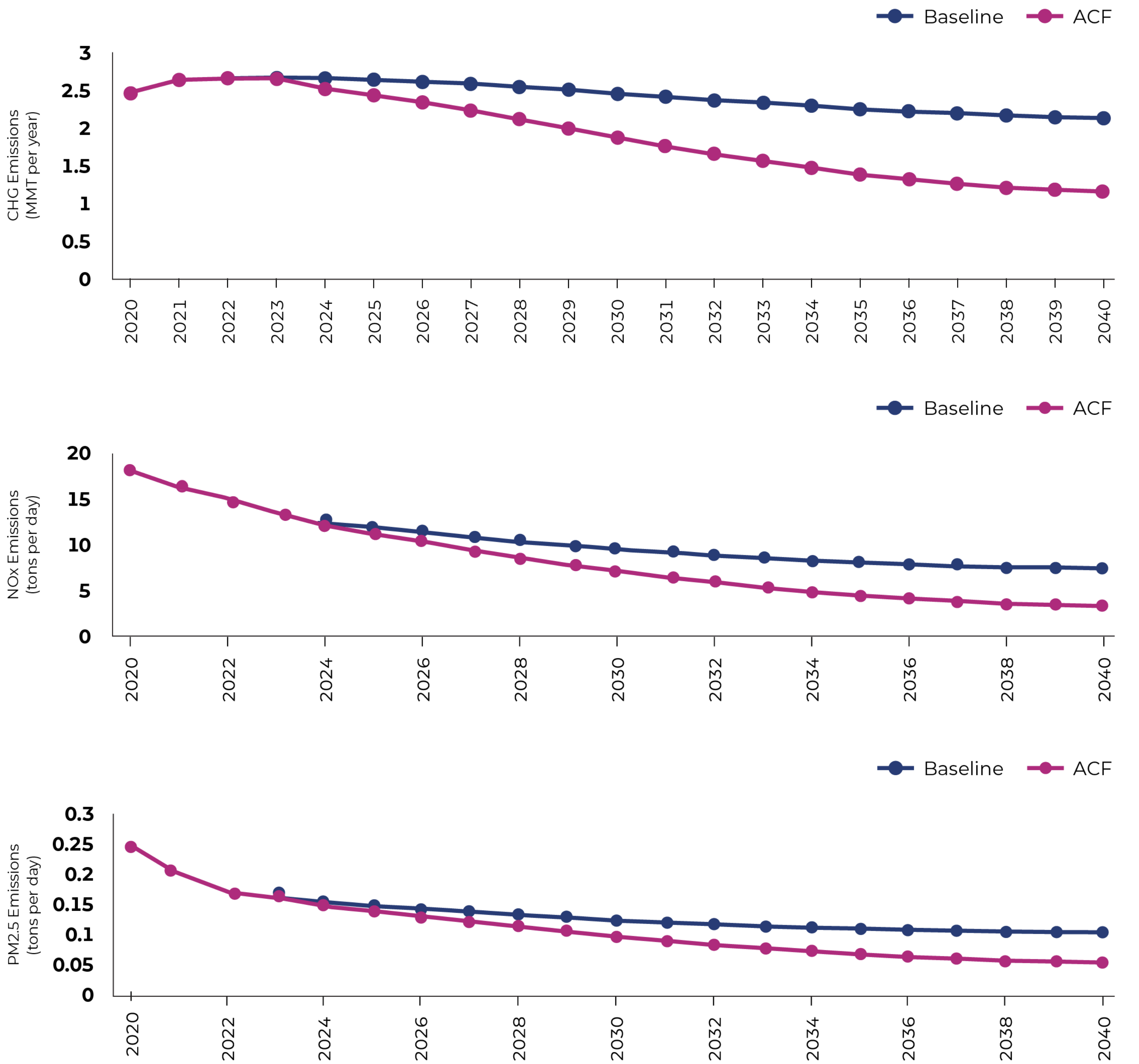
11. https://www.sandag.org/-/media/SANDAG/Documents/PDF/projects-and-programs/innovative-mobility/cleantransportation/regional-medium-duty-heavy-duty/md-hd-zev-needs-assessment-report-2023-01-01.pdf

fleet size (**Figure 6**). Here the baseline represents a scenario without the adoption of the ACF regulation where the reduction in emissions is mainly driven by the regulation reflected in the EMFAC2021 model (i.e., ACT, ICT, Heavy-Duty Omnibus, and Phase 2 GHG standards). With the adoption of ACF, emissions are expected to be further reduced by almost 50 percent from the baseline scenario in 2040 for all three emission categories.

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

Figure 6. Comparison of Baseline and Projected Emission Reductions for the San Diego Region[12]



12. Note that while the scenario is called ACF, it does include the impact of both ACT and ACF. The EMFAC2021 model already reflects the impact of ACT.

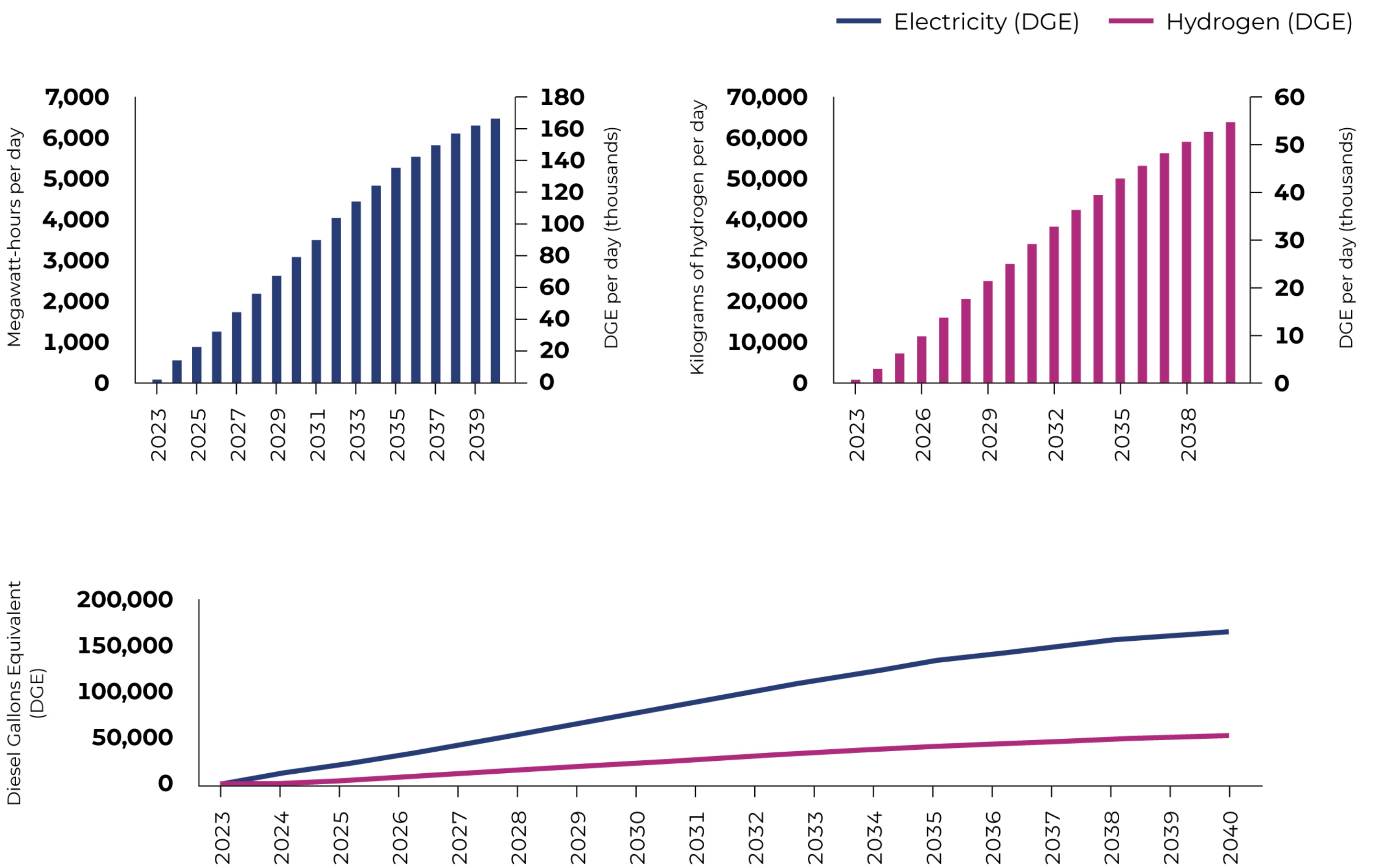
project team utilized methods consistent with the Assembly Bill (AB) 2127 assessment[13] and the CARB Hydrogen Self-Sufficiency Report[14] to transform energy consumption estimates into electricity and H2 infrastructure recommendations. The project team's analysis conducted with EMFAC2021 provided the region's electricity and H2 MD-HD consumption, as shown in **Figure 7.**

In 2024, electricity demand is projected to peak at 534 MWh per day, whereas H2 demand is projected to peak at 3,342 kilograms of hydrogen per day. On average, the daily electricity demand and H2 demand are expected to increase by 377 MWh per day and 3,576 kg of hydrogen per day—equivalent to 9,729 diesel gallon equivalents (DGE) per day and 3,186 DGE per day—respectively.

Between 2025 and 2040, electricity and H2 consumption by the MD-HD vehicle sector is expected to grow 650 percent to 780 percent, respectively.

To determine the charging infrastructure needs for MD-HD BEVs, the project team leveraged the Lawrence Berkeley National Laboratory HEVI-LOAD tool to determine the number and types of charger deployments based on

Figure 7. Projected San Diego Region's MD-HD Vehicle Daily Electricity and Hydrogen Fuel Consumption

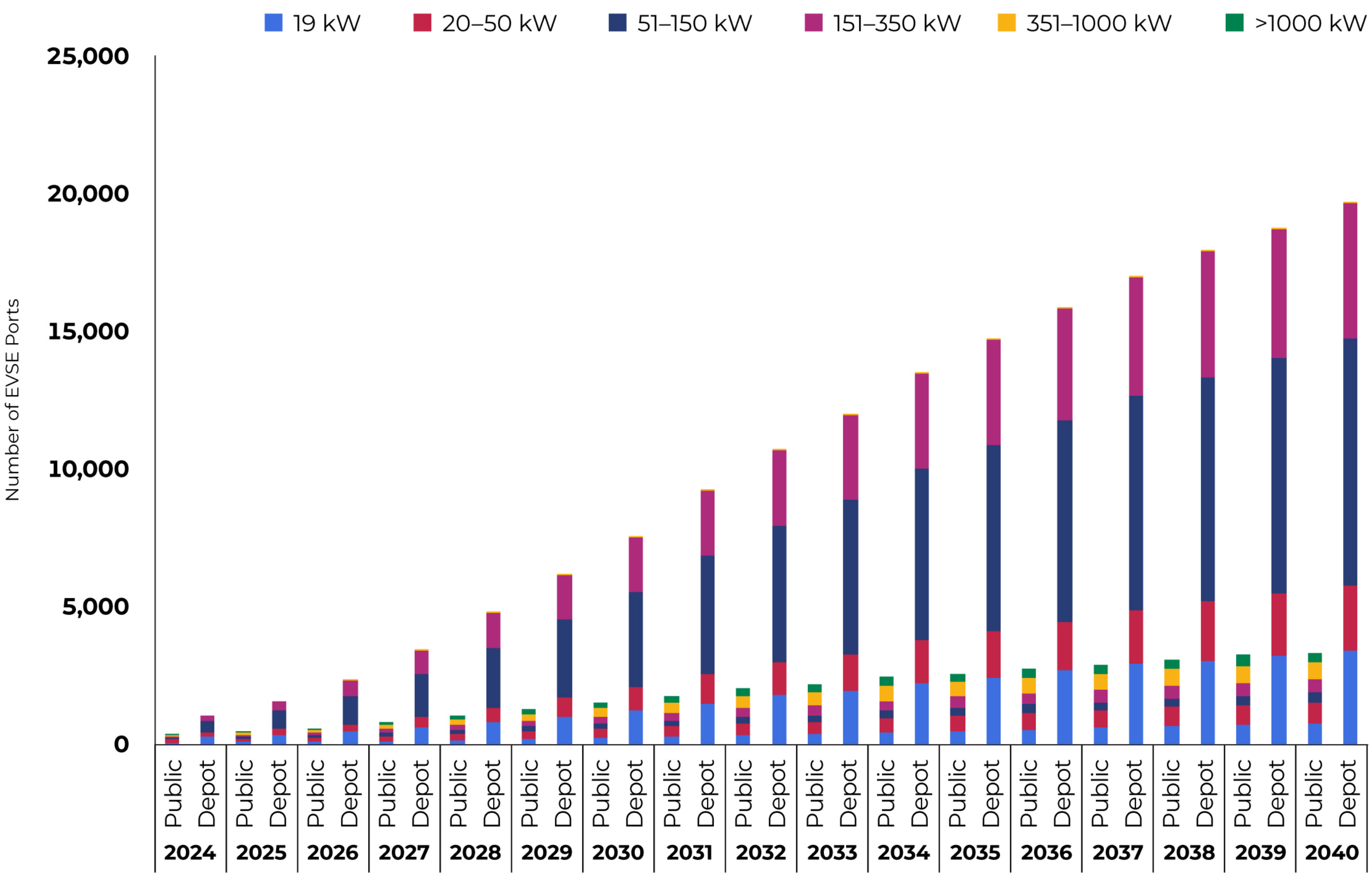


13. https://www.energy.ca.gov/data-reports/reports/electric-vehicle-charging-infrastructure-assessment-ab-2127
14. https://ww2.arb.ca.gov/sites/default/files/2021-10/hydrogen_self_sufficiency_report.pdf

power levels and MD-HD duty cycles. The tool calculates the charging requirements for for MD-HD vehicles by simulating their journeys, employing origin-destination data from the Caltrans California Statewide Travel Demand Model. The simulation tracks vehicles as they navigate the shortest routes across the transport network to their specified destinations. Charging takes place at public stations en route when a vehicle's battery lacks sufficient energy to complete its journey or at depot chargers in between trips. In this context, "depots" encompass both the vehicles' final destinations and their home bases. Vehicles may not charge after every trip to the depot; however, they typically recharge at a depot at least once within every 1 to 3 days. Depot charging is prompted when vehicles are parked, typically overnight, or when their battery state of charge drops below 50 percent. HEVI-LOAD was the primary tool that California used in the 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 8**.

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

Figure 8. Number of MD-HD Public and Depot Chargers by Power Level



projected to be private- or depot-access chargers, with charging power levels ranging from 19.2 kW through 1 MW. The results also show that in the early years, chargers with lower power capacities will be deployed in greater quantities than chargers with higher power capacities. For example, from 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.

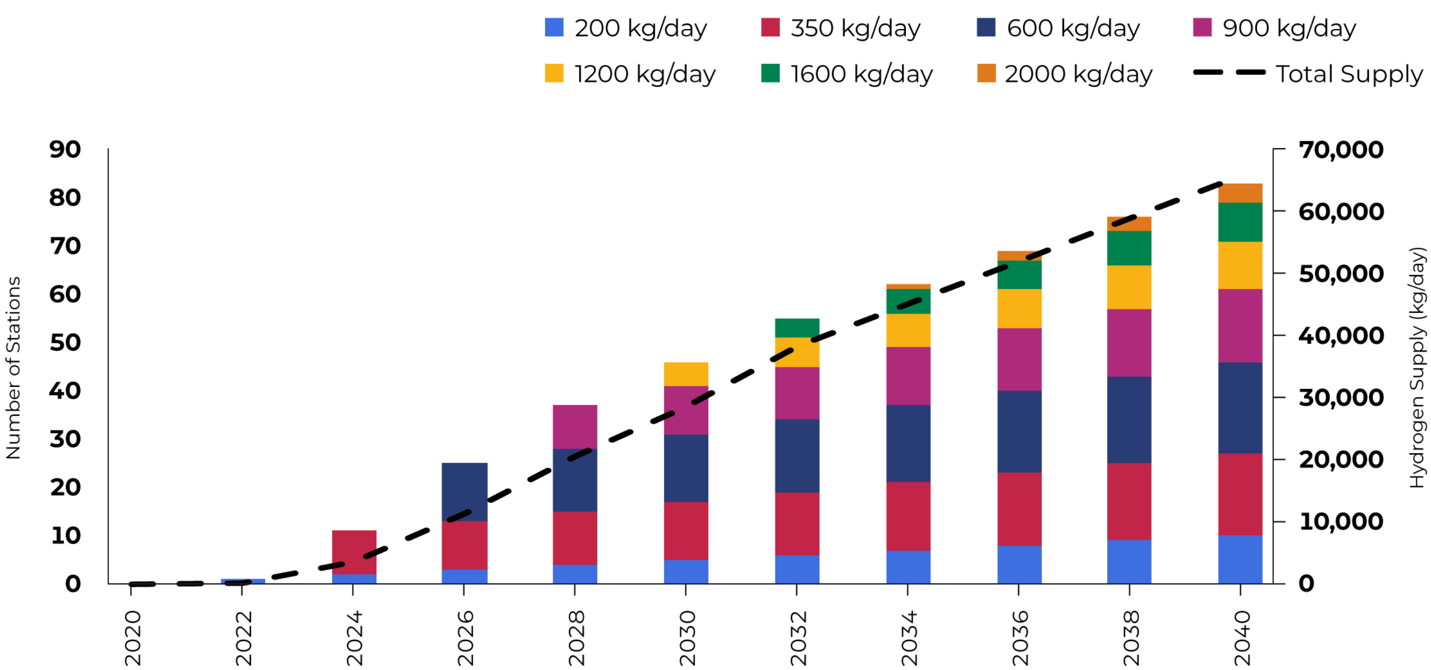
In addition to charging infrastrcture, SANDAG also estimated the number of hydrogen fueling stations needed to support the FCEVs in the region. To do so, SANDAG leveraged a similar methodology to the CARB Hydrogen Self-Sufficiency Report.[15] The results for the number of hydrogen fueling stations by station capacity from 2020 through 2040, as well as the total hydrogen supply by station capacity, are shown in **Figure 9**. Hydrogen supply is also expected to increase as developers transition from lower capacity stations in the early years to higher capacity stations in the later years. By 2040, a total of 83 hydrogen fueling stations that provide 65,650 kilograms of hydrogen per day for FCEVs is anticipated in the region.

San Diego Region Charging and Fueling Infrastructure Cost Estimate

Following the gap analysis presented in the San Diego Region Charging and Fueling Infrastructure Projection section, the project team estimated costs—annual and cumulative—over the projected timeline.

The methodology is based on 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.[16] The results for the projected charging and fueling infrastructure costs per year (in constant dollars) are illustrated in **Figure 10**.

Figure 9. Hydrogen Station Deployment Schedule by Daily Capacity

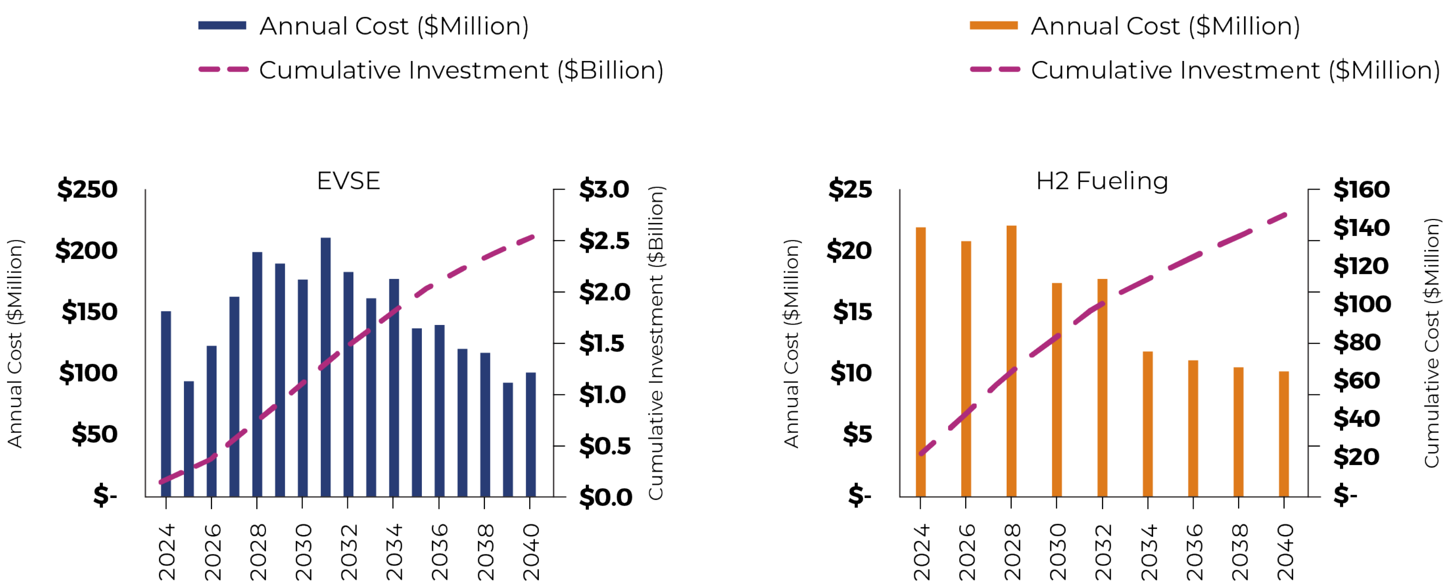


15. https://ww2.arb.ca.gov/sites/default/files/2021-10/hydrogen_self_sufficiency_report.pdf

16 https://www.sandag.org/projects-and-programs/innovative-mobility/clean-transportation/regional-medium-duty-and-heavy-duty-ZEV-blueprint

For electric vehicle supply equipment (EVSE), the project team assumes per port costs consistent with those found across the studies reviewed in the ZEV Needs Assessment Report,[17] as well as a 3 percent hardware and installation cost reduction per year until 2030, in alignment with research from Atlas Public Policy on discounted charging hardware and installation costs[18]. 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, an MD-HD hydrogen fueling station with a capacity of over 1,000 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

Figure 10. (Left to Right) Estimated Total MD-HD EVSE[18] Costs, Estimated Total MD-HD H2 Station Costs



due to technology progression or economies of scale, similar to what has been observed for other emerging technologies such as 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 with 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 the industry's estimate of hydrogen production cost.[19] 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-ready or grid upgrade costs are considered in this estimate.

17. Available online: https://www.sandag.org/-/media/SANDAG/Documents/PDF/projects-and-programs/innovativemobility/clean-transportation/regional-medium-duty-heavy-duty/md-hd-zev-needs-assessment-report-2023-01-01.pdf

18. 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/

19. 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 planners and developers of charging and hydrogen fueling infrastructure: utilization, land, equity, grid capacity, and environmental conditions (**Figure 11**). For more details on the siting and technology criteria, refer to the ZEV Siting Criteria and Technology Report.[20]

Utilization denotes the demand for charging or hydrogen fueling and serves as an indicator of station usage, reflecting the station's financial viability. Considering the utilization rate is important because 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, site distance to major traffic corridors, and refueling patterns are essential for optimizing 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) developed a permitting guidebook designed to assist local jurisdictions, as well as hydrogen[21] and EV charging[22] station developers, with 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 affect LICs 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 of quality of life and environmental justice due to the adoption of ZEVs.

Grid capacity is crucial when considering MD-HD vehicle charging, given the infrastructure's high energy needs, often requiring EVSEs with power levels 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, such as SDG&E in San Diego, is key to ensuring power availability and addressing infrastructure investments.

Environmental criterion considers potential environmental conditions that could affect the construction or operations of a charging/hydrogen fueling station. It also considers potential environmental impacts that the station could pose for the community. On the station development side, the conditions of the site, such as flood risk, land cover, and soil contamination, should be considered. Similarly, the grid

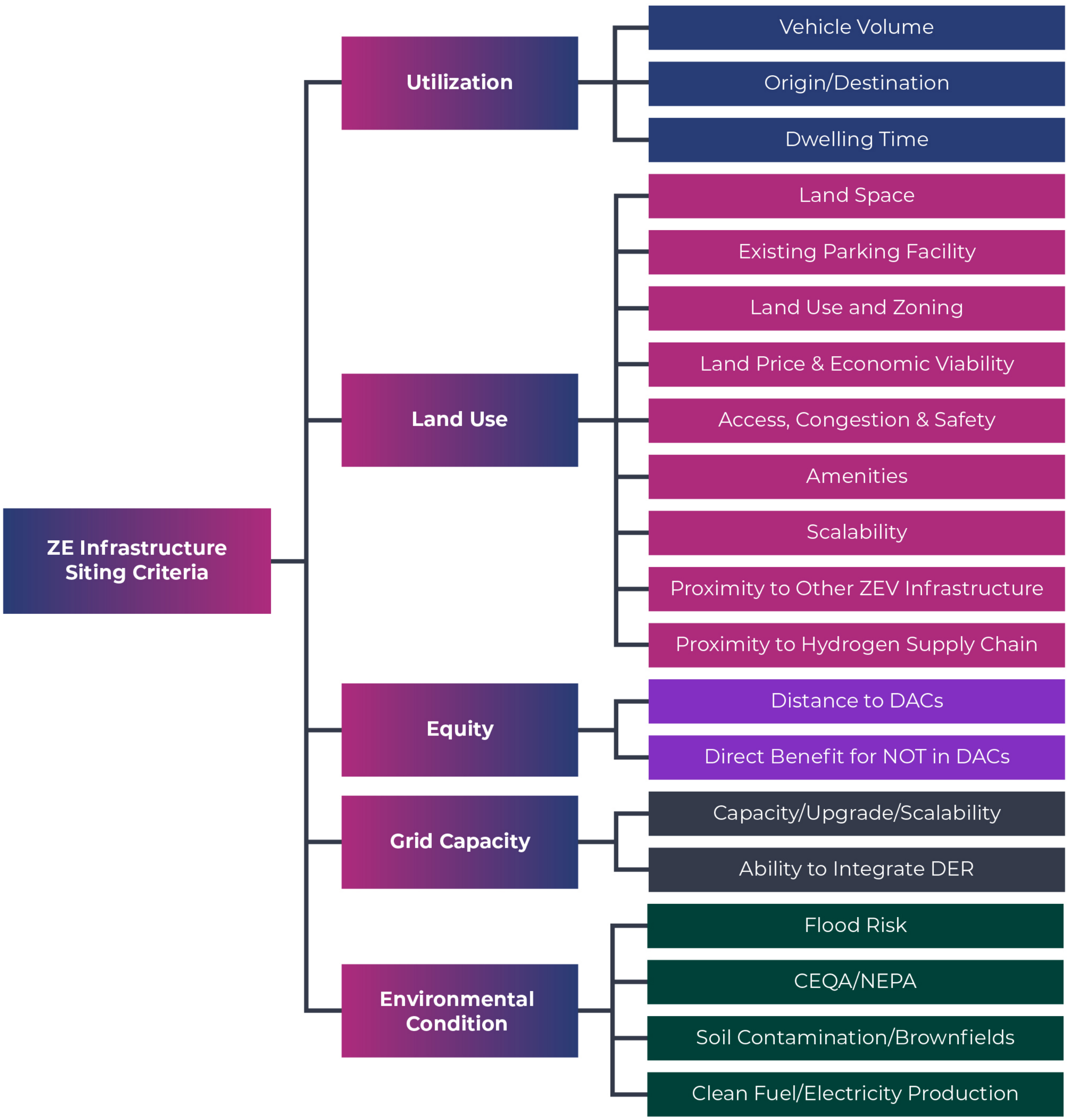
20. Available online at: https://www.sandag.org/-/media/SANDAG/Documents/PDF/projects-and-programs/innovativemobility/clean-transportation/regional-medium-duty-heavy-duty/md-hd-zev-draft-blueprint-2023-04-01.pdf

21. Available online at: https://business.ca.gov/wp-content/uploads/2019/12/GO-Biz_Hydrogen-Station-PermittingGuidebook_Sept-2020.pdf

22. Available online at: https://business.ca.gov/wp-content/uploads/2019/12/GoBIZ-EVCharging-Guidebook.pdf

generation mix (types of fuels used to generate electricity) and hydrogen fuel production pathways (e.g., green electrolytic 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,[23] 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 11. Summary of ZEV Infrastructure Siting Criteria

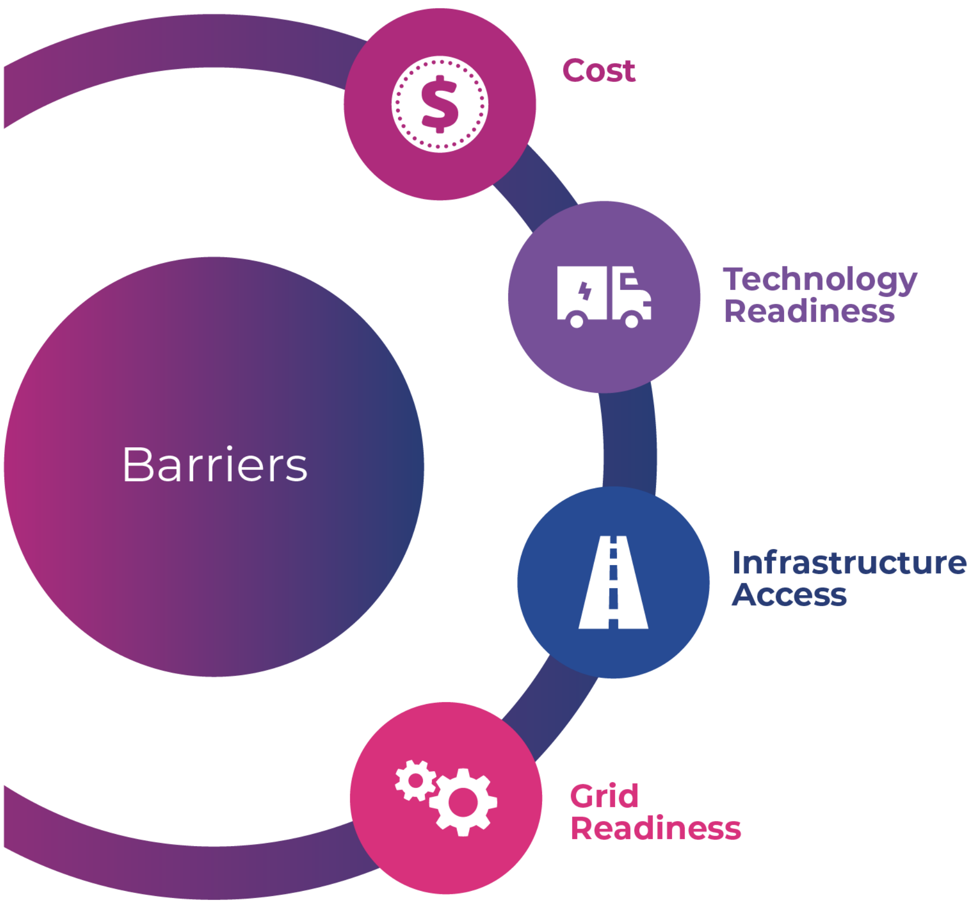


23. California Air Resources Board (CARB). (2015). Staff Report: Calculating Life Cycle Carbon Intensity Values of Transportation Fuels in California.

4. FROM ROADBLOCKS TO INNOVATIONS

There are several barriers that will slow the initial progress in the transition to MD-HD ZEVs and deployment of supporting infrastructure. These barriers include cost considerations, technological readiness, access to infrastructure, grid readiness, and conflicting regulations (**Figure 12**). 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 insight and strategic direction to help SANDAG and its collaborators navigate the challenges more adeptly, ensuring a cohesive and efficient approach toward regional ZEV infrastructure and development goals.

Figure 12. 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 barrier to adoption is the capital cost of MD-HD ZEVs and infrastructure. As delineated in the ZEV Needs Assessment Report,[24] 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. ZEV infrastructure development costs also factor in significant costs as well, between thousands and tens of thousands of dollars per vehicle in a fleet. 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 the 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, affecting the 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 because MD-HD BEVs are projected to have high daily electricity demand in the region, inadequate grid infrastructure could lead to power outages, increased charging times, and overall grid instability. It is recommended to plan for more timely, cost-effective upgrades to adequately prepare for future load demand from ZEV charging. 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 are 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 publicly available tools are able to create total

24. https://www.sandag.org/projects-and-programs/innovative-mobility/clean-transportation/regional-medium-duty-and-heavy-duty-ZEV-blueprint

cost of ownership (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 awareness surrounding MD-HD ZEVs is the 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 mechanics industry has many decades of experience in the ICEV industry, but there may be gaps in the number of technicians certified to work on the high-voltage and advanced powertrain technologies found in MD-HD ZEVs.[25] 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 affect the design and deployment of MD-HD ZEVs.

The ZEV Implementation Strategies Report[26] 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.

25. https://www.fleetequipmentmag.com/electric-truck-service-what-your-technicians-need-to-know/

26. Available online: https://www.sandag.org/-/media/SANDAG/Documents/PDF/projects-and-programs/innovativemobility/clean-transportation/regional-medium-duty-heavy-duty/md-hd-zev-blueprint-draft-implementation-strategies.pdf

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. Regional leadership must bolster these measures and address unique regional needs. **Figure 13** provides a list of strategies to this effect. The tracking metrics (**Figure 14**) 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 13. 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.

Support Vehicle-Grid Integration (VGI) through coordination with local utilities, governments, and fleets.

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 incentive programs to reduce the upfront costs of MD-HD ZEV equipment and prioritize equity, including incentives for disadvantaged communities and small businesses.

Figure 14. Tracking Metrics for Regional Policy and Funding Support Strategies

Infrastructure Deployment Metrics

LCFS Credits Generated: Monitor the quantity of LCFS credits generated from infrastructure installations, indicating emissions reductions.

Fleet Adoption Metrics

- **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.

Grid Integration and Resiliency Metrics

- **VGI Infrastructure Growth:** Monitor the expansion of Vehicle-Grid Integration infrastructure, including Vehicle to Grid and Vehicle to Home capabilities.
- **Grid Resiliency Enhancements:** Assess improvements in grid resiliency achieved through VGI and microgrid initiatives.

Hydrogen Production and Safety Metrics

- **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 and Advocacy Metrics

- **Policy Alignment:** Measure progress in aligning regional ZE policies with state and national policies, particularly for cross-border trucking.
- **Regional Equity Impact:** Measure progress in the implementation of regional Community Emissions Reduction Plan (CERP) goals and actions.

Incentive Program Metrics

- **Incentive Program Effectiveness:** Assess the effectiveness of targeted incentive 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 ZEV transition, considering various factors such as travel patterns and grid capacity. SANDAG and its partners can support this by helping with the development of ZEV infrastrcture siting tools, identifying areas with available grid capacity, streamlining project approvals, and guiding fleet owners on ZEV purchases based on multiple vehicle characteristics. **Figure 15** provides a summary of these strategies. The tracking metrics (**Figure 16**) 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 15. Summary of Siting, Land Use, Zoning, and Permitting Strategies

Leveraging 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, participate in Freight Infrastructure Planning by the CPUC to plan long lead time, utility-side electrical infrastructure upgrades, facilitate connections among hydrogen equipment providers, MD-HD fleet owners, and site operators to assess energy demand and grid updates, consider infrastucture sharing and leasing.

Streamline Infrastructure Development work with local jurisdictions to streamline the MD-HD ZEV infrastucture 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.

Leveraging Available Permitting Tools by utilizing the federal and state permitting guidelines, local officials can efficiently navigate proposals for hydrogen and EV charging infrastructure projects. California GO-Biz and and U.S. DOE offer permitting tools and guidelines that highlight best practices, simplifying the approval process for initiatives such as hydrogen fueling stations and EV charging infrastructure deployment.

Figure 16. 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.
- **GIS Portal Usage:** Assuming the 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 Capacity Increase:** Track the increase in grid capacity in regions where advance planning and upgrades were initiated.
- **Budget Optimization:** Track the increase in 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.

Additional Resources

Consider reviewing these resources for further learning:

- EV Charging Station Permitting Guidebook
- H2 Permitting Guidebook
- DOE Hydrogen Code & Standards

Promote Public-Private Partnership Models

Leveraging Public-Private Partnership (P3) models is effective in expanding ZEV infrastructure by combining public and private sector strengths, offering benefits such as faster deployment and diversified business models. In addition to traditional P3 models, emerging concepts such as Charging-as-a-Service (CaaS) are seen as viable for SANDAG's infrastructure deployment, with private entities also considering options such as Truck-as-a-Service (TaaS) to mitigate initial costs and incorporate new technologies. **Figure 17** provides a summary of the P3 model strategies. The tracking metrics (**Figure 18**) associated with these strategies focus on quantifying funding pools and charging network growth because of innovative partnerships.

Figure 17. Summary of Public-Private Partnership Model Strategies

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

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

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

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

Figure 18. Tracking Metrics for Public-Private Partnership Strategies

P3 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 with 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 prequalified 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 the 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

The benefits of the transition to MD-HD ZEV deployment in the region must be shared with the community. **Figure 19** illustrates key outreach and engagement strategies to address concerns and barriers related to this regional ZEV initiative. The tracking metrics (**Figure 20**) associated with these strategies focus on quantifying the frequency of public relations or community input events, highlighting public health benefits and impacts, and keeping better public records on community desires and concerns from transition to MD-HD ZEVs.

Figure 19. Summary of Public Education and Community Outreach Strategies

Showcase Proof of Concept, demonstrate 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 20. 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.

Business 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.

Cost 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 efficacy of multilingual information dissemination in reaching diverse stakeholders, and committing to community engagement that keeps people well informed about ZEVs and infrastructure.

Workforce Development

Transitioning to ZEVs will change the skills needed in the freight and trucking industry compared with traditional diesel fleets. SANDAG and its partners should ensure that training and workforce recruitment evolve with ZEV deployment, working with educational entities and stakeholders to develop pertinent training programs. Moreover, a just-transition that addresses structural economic justice issues is centerfield to the transition to ZEVs. **Figure 21** provides a summary of the workforce development strategies.

The tracking metrics (**Figure 22**) 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 21. Summary of Workforce Development Strategies

Workforce Training for ZEV Transition, collaborate with regional partners to identify the 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 such as 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 to 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 22. 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).
- **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, and assist local jurisdictions in setting ZEV targets. A key focus should be on the development of infrastructure on public lands and spearheading the shift of the local municipality fleets towards zero emission technology. This proactive transition can set a benchmark for others and catalyze the early adoption of emerging technologies, serving as a live demonstration of their efficacy. Through this process, they will not only lead by example but also compile and share insights gained from their experiences. This knowledge transfer could then cultivate best practices and broaden the understanding of the practical challenges associated with ZEVs. **Figure 23** provides a summary of these leadership strategies. The tracking metrics (**Figure 24**) associated with these leadership strategies focus on quantifying MD-HD ZEV and infrastructure and the realized benefits moving forward.

Figure 23. 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 CAPs, build out some of the first public infrastructure.

Conversion of Public Fleets to Zero Emission
Assist a local jurisdiction to develop a ZEV transition plan for their fleets, proactively convert public fleets to ZEV on expedited timelines, share lessons learned from such transitions with the general 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.

Figure 24. 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 CAPs.
- **Infrastructure Expansion:** Measure the progress in building out 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 with 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 public perception on the progress made.

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:** Track the number of public agency collaborations and partnerships monitoring air quality improvement.

Monitoring and Evaluation

As the region embarks on the journey toward 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
- Impact of weight-based policies (exemption and/or weight fees)

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 toward 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.

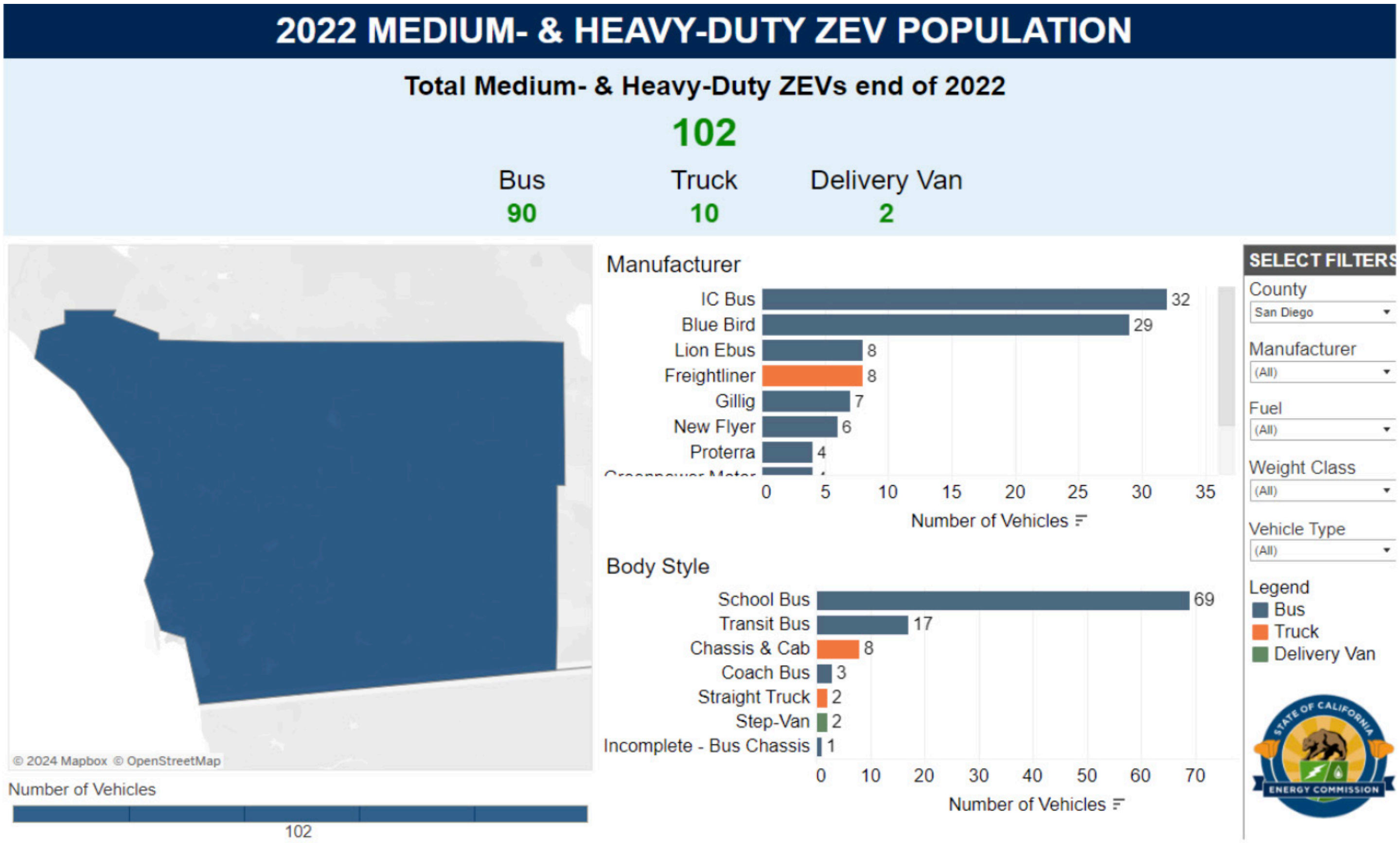
Regional Vehicle Adoption

CALIFORNIA ENERGY COMMISSION

SANDAG can capitalize on the Zero Emission Vehicle and Infrastructure Statistics[27] developed by the CEC in partnership with the Department of Motor Vehicles. These statistics are vital for monitoring the 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 25**. 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.

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

Figure 25. An Example of MD-HD ZEV Population Reported by the CEC Zero Emission Vehicle and Infrastructure Statistics Platform



Regional Criteria and GHG Emissions

CALIFORNIA AIR RESOURCES BOARD

The project team utilized the CARB EMFAC2021 model to conduct the MD-HD vehicle technology fleet projection and emissions modeling. It is 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 air pollutant 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 U.S. DOE's AFDC Station Locator Map,[28] 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 for which developers are trying to secure funds. Similar information can also be extracted from the CEC's Zero Emission Vehicle and Infrastructure Statistics.[29]

Infrastructure Utilization

As delineated in the ZEV Siting Criteria and Technology Report, utilization is a major decision pivot for the release of investment funds for infrastructure projects. Developers and investors have good reason to look at utilization in return on investment calculations and risk assessments, especially because 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 for measuring 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 (DACs) will need to strike a balance between providing greater public charging and fueling resources and mitigating negative impacts on the residents of those communities. Some practical measurements, such as 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 for which data analytics cannot always provide a clear answer.

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

28. https://afdc.energy.gov/stations/#/find/nearest

29. https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics

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 toward 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 (P3) 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 P3 models are available, including Build-Operate-Transfer, Design-Build-Finance-Operate-Maintain, Concession, and Joint Venture models, each suited to specific goals and needs. P3 have been employed successfully in the deployment of MD-HD electric vehicles, with examples such as CARB and the South Coast Air Quality Management District 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 P3 allow us to gauge the level of collaboration and innovation in the transition to MD-HD ZEVs, providing valuable insight to the effectiveness of these partnerships in driving technological advancements and adoption.

5. CHARTING THE COURSE AHEAD

The San Diego Regional MD-HD ZEV Blueprint has been developed to serve as a 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 presents data and details a suite of strategies on how SANDAG, in collaboration with its regional partners, can come together to streamline this massive transition.

The magnitude of the investment required to develop the supporting infrastructure as proposed is exceptionally large. The Blueprint recognizes that the financial investment to electrify transportation must rely on both public and private investment. In advocating for robust public-private partnerships, the Blueprint aims to construct a persuasive financial narrative that encourages private sector participation by providing definitive guidance on infrastructure siting criteria and integrating regional incentive programs. In doing so, the Blueprint seeks to reduce the uncertainty and risk often associated with private investments in emerging technologies. This clarity and coordination are intended to catalyze private sector engagement and investment, thereby accelerating the deployment of necessary infrastructure and fostering a more robust marketplace for ZEV technologies in the region.

The following explores a range of near-term actions that stakeholders can undertake following the development of the Blueprint, utilizing its findings to inform and guide their development strategies.

Sharing Lessons Learned

Projects in the MD-HD ZEV and infrastructure landscape that demonstrate early success and long-term promise should be publicized. Highlighting these projects serves multiple purposes: it recognizes and validates the efforts of those involved, provides tangible case studies for stakeholders considering similar ventures, and fosters public awareness and support for ZEV initiatives. Successful projects can be showcased through various channels such as industry conferences, social media platforms, press releases, and case studies. By publicizing these achievements, it becomes possible to illustrate the practical viability and environmental benefits of MD-HD ZEVs, thereby encouraging further investment and adoption in the sector. Additionally, sharing the lessons learned, challenges overcome, and strategies employed in these successful projects can provide valuable insight to other regions and entities looking to embark on similar initiatives.

For example, the collaboration between Indian Energy LLC, a private microgrid developer and systems integrator, and the Viejas Enterprise Microgrid project stands as a prime example of how the region can explore building a resilient and

integrated energy and charging infrastructure system for MD-HD ZEVs. Funded partially by the CEC and a third-party financier, this initiative marks a significant stride in supporting tribal-state-federal partnerships, involving entities such as Indian Energy, the Viejas Nation, CEC, the United States Navy/Marine Corps, and the U.S. Department of Energy. The project aims to enhance power generation and battery energy storage systems, achieving 100 percent energy resiliency against grid disturbances. This model of public-private partnership paves the way for future development, particularly in supporting truck charging needs in rural and tribal areas. It demonstrates how leveraging diverse partnerships and innovative energy solutions can create robust infrastructure capable of accommodating the specific needs of truck charging.

In another example, the recent inauguration of a high-power DC fast charging station near the U.S.-Mexico border by San Diego Gas & Electric (SDG&E) marks a significant advancement in zero-emission transportation infrastructure. Located at the TruckNet truck stop near the Otay Mesa border crossing, this station features four charging points, each capable of delivering about 250 kw of power, allowing medium- and heavy-duty trucks to gain up to 250 miles of range in approximately an hour. This development is crucial, given that over a million commercial trucks and 5 million passenger vehicles cross this busiest commercial border in California annually. As the first public high-capacity chargers in the region specifically designed for medium- and heavy-duty trucks, this initiative is pivotal in advancing the region's adoption of zero emission MD-HD vehicles. This transition is particularly important for border and portside communities such as Barrio Logan, National City, and San Ysidro, which have historically suffered from diesel pollution. The project, funded in part by a $200,000 grant from the California Energy Commission, exemplifies a successful public-private partnership and is part of a broader effort to connect fleet owners with resources and incentives for installing charging infrastructure.

Another notable regional effort that has demonstrated early success is SDG&E's Hydrogen Innovations, which explores the potential of clean hydrogen to help the state achieve net zero GHG emissions by 2045. At its Palomar Energy Center in Escondido, SDG&E is installing an onsite electrolyzer and solar panels. This installation is aimed at producing hydrogen, which will be utilized in a dual capacity: firstly, as a blend with natural gas for generating electricity, and secondly, as fuel for the inaugural hydrogen vehicles in their fleet. Additionally, this hydrogen will play a crucial role in the combined cycle process, being used as a cooling gas. In line with this effort in producing local green hydrogen, in June 2023, the NCTD received over $29 million from the Federal Transit Administration as part of the Low or No Emission Vehicle grant program. This funding is allocated for the purchase of 23 zero-emission hydrogen fuel cell electric buses. This initiative exemplifies how partnerships across a transit agency, local utility, and the federal government can lead to the adoption of zero-emission solutions powered by renewable fuels within the region.

Supporting BEV/FCEV Demonstrations at the Port of San Diego and Beyond

As previously discussed, the adopted ACF regulation will impose stringent fleet electrification requirements on drayage trucks. Specifically, the ACF regulation mandates that 100 percent of new drayage trucks being registered at the port be ZEV starting in 2024, with the goal of having 100 percent zero-emission drayage trucks by 2035. Locally, the port's MCAS also advocates for port electrification, setting targets to fully electrify cargo trucks by 2030. Given these ambitious goals and targets, this Blueprint serves as a crucial tool for laying out a roadmap for enhancing the infrastructure needed to meet these challenging goals and to support and enhance both ongoing and future demonstration projects. This includes pilot initiatives for battery electric and fuel cell electric drayage trucks and their corresponding infrastrcture at the Port of San Diego and at 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 collaboration. 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.[30]

30. Available online: https://www.sandag.org/-/media/SANDAG/Documents/PDF/projects-and-programs/innovativemobility/clean-transportation/regional-medium-duty-heavy-duty/md-hd-zev-blueprint-draft-implementation-strategies.pdf

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

PROGRAM CATEGORY	PROPOSED PROJECTS
Innovative technology demonstrations	Charging depot using renewable grid or photovoltaic (PV) technologies with energy storage
	Ultra-fast charging techniques
	"Vehicle-to-Everything" (V2X) demonstrations
	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
	Charging reservation programs for MD-HD vehicles
	Universal payment method for infrastructure usage
Port technology feasibility assessment	Short-haul BEV/FCEV application
Border-crossing goods movement	ZEVs application for fleets operating across the U.S./Mexico border
	Wireless charging for border-crossing BETs during wait time
	Toll discounts for MD-HD ZEVs at Ports of Entry (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

The Blueprint identifies MD-HD ZEVs as a crucial component of the San Diego region's way to reduce the adverse environmental and climate impacts of MD-HD vehicles, helping 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.

Much of the momentum for MD-HD ZEVs is driven by state-level regulations, such as the ACT and ACF regulations, which are set to expedite the transition from ICEVs to ZEVs. However, the successful implementation of these programs heavily relies on the development and implementation of expanded EV charging and hydrogen fueling networks across the region. The technical assessment in this Blueprint highlights that the financial investment required to meet these infrastructure needs is significant, anticipated to exceed a cumulative $2.5 billion by 2040. Achieving these ambitious goals necessitates a collaborative effort, uniting regional partners, and harnessing both public and private capital. The short- and long-term strategies outlined in the Blueprint are designed to foster such collaboration and position the region at the forefront of sustainable transportation, setting a standard for ZEV adoption and infrastructure development that can serve as a model for others to follow.