# MEDIUM- AND HEAVY-DUTY CHARGING INFRASTRUCTURE IN THE STATE OF COLORADO

## Market Overview, Charging Needs Assessment, and Incentive Program Design Strategy

James Di Filippo, Lucy McKenzie, Zachary Strauss

May 2023

ATLAS PUBLIC POLICY

# Contents

# Acknowledgements

Atlas would like to thank the generous individuals and organizations who offered their time, expertise, and insight to the development of this report. Those who kindly agreed to share their knowledge and perspectives on the medium- and heavy-duty (M/HD) charging market and/or M/HD charging incentive program design and implementation include:

- Aaron Moseley – *Colorado Department of Public Health & Environment*
- Alyssa Haerle – *CALSTART*
- Andrea Pratt - *Volvo Group North America*
- Anthony Harrison – *TeraWatt Infrastructure*
- Diego Lopez – *FleetPros Colorado*
- Elizabeth John – *California Energy Commission*
- Emil Youssefzadeh – *WattEV*
- Erik Lundeen – *Black Hills Energy*
- Heidi Sickler – *BP Pulse Fleet*
- Lianna Rios – *San Diego Gas & Electric*
- Niki Okuk – *CALSTART*

- Ning Wigraisakda – *Colorado Department of Public Health & Environment*
- Tim Coleman – *Colorado Rural Electric Association*
- *Colorado Clean Energy Fund*
- *FedEx Corporation*
- *Southern California Edison*

We also thank the Colorado Energy Office for their support of this work, especially Matt Lerman, Matt Mines, and Kelly Blynn.

# Disclaimer

This report was funded by the Colorado Energy Office. However, the analysis presented is that of the authors' and does not necessarily reflect the views of the State of Colorado or the Colorado Energy Office. The authors are grateful for the input of Colorado Energy Office staff and the contributors named above. However, those contributions do not imply any endorsement of this report's content or conclusions. Any mistakes or errors in this report are solely attributable to the authors. Furthermore, any mention of commercial products, their source, or their use in connection with material reported herein should not be construed as actual or implied endorsement of such products.

# 1. Introduction

As the energy transition accelerates, transportation electrification will continue to be a critical component of economy-wide decarbonization. Looking beyond light-duty vehicle electrification, the need for greenhouse gas (GHG) and air pollution emission reductions from the medium- and heavy-duty (M/HD) vehicle sector must be met with both government and private sector action.

States across the country have already begun committing to increasing the sale of zero-emission M/HD vehicles and phasing out their internal combustion engine counterparts over time. This is demonstrated by both the *Multi-State Medium- and Heavy-Duty Zero-Emission Vehicle Memorandum of Understanding* [1], signed by Colorado, 15 other states, and the District of Columbia, as well as the Advanced Clean Trucks (ACT) rule[1] [2], now adopted by 7 states in addition to California, with ACT recently adopted by Colorado.

To facilitate the statewide transition to zero-emission M/HD vehicles, the Colorado State Government developed and released its *Clean Truck Strategy* in 2022. The *Colorado Clean Truck Strategy* serves as the foundation for the state's M/HD electrification initiatives and the underlying impetus for this report [3]. To address funding gaps for M/HD vehicle charging infrastructure in Colorado and to spur growth in the nascent M/HD charging market towards the state's goals of 35,000 M/HD zero-emission vehicles (ZEVs) on the road by 2030, 30% new M/HD ZEV sales by 2030, and 100% new M/HD ZEV sales by 2050, the Colorado Energy Office (CEO) will be developing an incentive program to defray the costs of charging infrastructure for M/HD electric vehicles. Once launched, Colorado will be one of the only states in the country to offer such a program, cementing its position as a leader in the zero-emission medium- and heavy-duty vehicle space.

Three research tasks are combined in this report:

1) A Colorado-focused analysis of the M/HD charging market,
2) A M/HD charging needs analysis for Colorado, and
3) A strategic analysis to inform the development of Colorado's forthcoming M/HD charging incentive program

This research is meant to inform the State of Colorado's near- and mid-term planning and programming to support the deployment of electric M/HD vehicle charging infrastructure required to fulfill the state's broader zero-emission M/HD vehicle adoption goals.

[1] The Advanced Clean Trucks (ACT) rule is a California regulation that requires automakers to produce increasing percentages of zero-emission M/HD (Class 2b-8) vehicles.

# M/HD Vehicle Impacts

The transportation sector is the single-largest contributor to climate change across both the State of Colorado and the United States' economies, generating 28% of national greenhouse gas emissions in 2021, a greater share than both the power and industrial sectors [4]. M/HD vehicles represent a subset of the transportation sector populated with trucks, buses, and vans often used in commercial or public service. In this report, M/HD vehicles are defined as those with a gross vehicle weight rating (GVWR) over 8,500 pounds, including Class 2b through Class 8 vehicles ranging from full size pickup trucks to heavy-duty tractors. While M/HD vehicles comprise less than 10% of all on-road vehicles in Colorado, they disproportionately contribute to climate change, air pollution, and environmental degradation. According to the *Colorado Clean Truck Strategy*, M/HD vehicles generate an estimated 22% of on-road GHGs, 30% of on-road nitrogen oxides (NOx), and 40% of on-road particulate matter (PM) emissions in the state and are a major contributor to a large area of Colorado being classified as a severe ozone nonattainment area by the U.S. Environmental Protection Agency (EPA) [3] [5]. In addition, this vehicle-borne pollution most negatively impacts frontline environmental justice communities, who through discriminatory housing and zoning policies often find themselves adjacent to freight corridors, warehouses, and other M/HD transportation infrastructure. M/HD vehicle electrification thus would have a substantially positive, outsized impact on air quality, public health, and environmental justice in the State of Colorado.

To mitigate the negative impacts of M/HD emissions and to advance its overall climate goals, the Colorado State Government has taken several legislative and executive actions. Per a law enacted in 2019, *HB 19-1261 Climate Action Plan to Reduce Pollution*, Colorado committed to reducing statewide greenhouse gas emissions 50% by 2030 and 90% by 2050, based on 2005 levels [6]. Going further, Colorado is now in the process of formally committing to reaching net-zero-emissions by 2050 [7]. As transportation comprises the largest share of emissions in Colorado, 25% of all statewide GHG emissions as identified in the state's *Greenhouse Gas Pollution Reduction Roadmap*, which established a sector-based approach to reaching these statutory targets - assertive climate policy, particularly around M/HD vehicles, will be required to achieve the state's climate goals [8].

# Colorado Policy Context

In 2019, Governor Jared Polis issued *Executive Order B 2019 002 Supporting a Transition to Zero-Emission Vehicles*, which mandated the creation of a new Transportation Electrification Workgroup, the development of a rule to establish a Colorado zero-emission vehicle program, allocation of all remaining Volkswagen funds to transportation electrification, and development of a state clean transportation plan [9]. Additionally, in

2020, Colorado, along with 15 other states and Washington, D.C., then signed a Memorandum of Understanding to accelerate the electrification of trucks and buses, with the goal of achieving 100% zero-emission M/HD vehicle sales by 2050 [10]. Colorado has since passed *Senate Bill 21-260 Sustainability Of The Transportation System*, establishing new state enterprises to collect over $730 million in estimated revenue to consistently fund transportation decarbonization over the next decade [11]. Following which, in 2022, Colorado finalized an interagency *Clean Truck Strategy* with several ambitious M/HD zero-emission vehicle goals and over 35 planned actions, including signaling its intent to adopt the Advanced Clean Trucks rule, which now requires M/HD vehicle manufacturers to make an increasing percentage of zero-emission trucks and buses available in the state starting in model year 2027 [12]. Documentation published by the Colorado Department of Public Health and Environment (CDPHE) affirmed that Colorado's recent adoption of the Advanced Clean Trucks rule will increase the sale of zero-emission medium- and heavy-duty vehicles and substantially reduce GHG, NOx, and PM emissions in the state [13]. In addition to the ACT rule, the Colorado State Legislature also recently adopted *House Bill 23-1272 Tax Policy that Advances Decarbonization*, which extends and increases the availability of state tax credits for M/HD ZEVs and provides a discount on the specific ownership tax for zero-emission trucks, amongst other climate-related tax credits [14].

Beyond planning and policy, the Colorado Energy Office has offered electric vehicle (EV) charging infrastructure incentive programs primarily designed for light-duty vehicles for several years. Now, with funding support from the Community Access Enterprise, CEO is working to design a statewide incentive program dedicated solely to fleet and M/HD vehicle charging infrastructure. CDPHE, with funding support from the Clean Fleet Enterprise, is also working in parallel to design a sister incentive program for the purchase of zero-emission fleet vehicles, trucks, and buses. These incentive programs, although separate and distinct, will complement one another as Colorado fleets and M/HD industry stakeholders move from initial planning and procurement, to infrastructure installation, and M/HD electric vehicle deployment.

Prior to the work on this M/HD charging infrastructure study, the State of Colorado commissioned other research reports to chart the transition to zero-emission M/HD vehicles. For example, MJ Bradley & Associates conducted the *Colorado Medium- and Heavy-Duty Vehicle Study*, in which they 1) detailed the national and Colorado M/HD vehicle markets, 2) evaluated potential M/HD electrification policy levers, 3) collected perspectives from relevant stakeholders, and 4) provided a cost-benefit analysis of policy options with regards to their impact on society and electricity rates [15]. In looking beyond electrification, Colorado has also conducted studies on the prospect for the deployment of M/HD hydrogen vehicles and fueling infrastructure across the state, including E3's *Opportunities for Low-Carbon Hydrogen in Colorado: A Roadmap*, released in 2021 [16].

## Report Roadmap

This M/HD charging infrastructure report supplements prior work commissioned by the State of Colorado. The report is broken out into three substantive chapters that each cover one of the study's primary research tasks, along with a concluding chapter.

*Chapter 2: State of the Market*, provides an analysis of the M/HD charging infrastructure sector in Colorado that details the relevant actors and stakeholders, and their respective relationships to one another. For this analysis, the report synthesizes both existing research and draws upon primary sources, such as interviews with market participants, informational materials from market actors, implementation guides, and others.

In *Chapter 3: Charging Needs Analysis,* the study summarizes the results of an evaluation of needed M/HD charging infrastructure and its related costs in Colorado from 2023 through 2030. This analysis employs Atlas' Investment Needs of State Infrastructure for Transportation Electrification (INSITE)-M/HD tool, a technoeconomic model of charging investment needs, as well as a geospatial-based analysis to strategically plan for electrifying priority freight corridors throughout Colorado.

*Chapter 4: Strategies for M/HD Charging Incentive Program Design*, outlines findings of research and analysis conducted on M/HD charging incentive program design. In this examination, the study relies on information learned in the prior two chapters, along with qualitative analysis of the few existing M/HD charging incentive programs in the United States drawn from interviews of key program implementers, managers, and program documentation. The chapter provides a summary landscape of M/HD charging incentive programs, an overview of the programmatic elements of M/HD charging incentive design, and a high-level set of program design recommendations for Colorado.

*Chapter 5: Conclusion*, contains a broad discussion and summary of key findings from each research task and suggestions for future research.

## Existing Literature

As electric M/HD vehicles have transitioned from the theoretical to practical commercial products, there has been a substantial increase in research focus on the M/HD EV market. Likewise, as governments have begun to adopt regulations requiring increased electric M/HD vehicle deployment, there has been a related increase in interest for understanding the infrastructure needs associated with these requirements. However, while there is considerable literature available on the state of the M/HD charging market and emerging literature on M/HD charging infrastructure needs analysis, we are unaware of any prominent examples of economic or policy analysis of M/HD charging infrastructure incentive programs.

This section summarizes the state of the literature most relevant to this report, while identifying important gaps that remain. While this section is meant only as a survey of extant scholarship related to the topic of this report, we also use the market literature summarized here to inform and augment primary sources analyzed in *Chapter 2*.

## M/HD Market Literature

In the 2021 *Colorado Medium- and Heavy-Duty (M/HD) Vehicle Study,* Moynihan et al. conducted an in-depth analysis of M/HD zero-emission vehicle adoption in Colorado, which found that adoption of M/HD ZEVs would have a substantial positive impact on GHG emission reductions and air quality benefits in Colorado and would offer significant savings. Specifically, the study found that "if the State of Colorado pursues strategies that support an accelerated transition to M/HD ZEVs" it could result in reductions of statewide greenhouse gas emissions of 3.3 to 4.4 million metric tons (45 to 59% of M/HD GHGs), nitrogen oxide emissions of 7,000 to 12,100 metric tons (54 to 93% of M/HD NOx), and particulate matter emissions of 111 to 140 metric tons (53 to 68% of M/HD PM) annually by 2050 from the baseline. Additionally, the study stated that "all scenarios will result in a net societal benefit ranging from $20.2 billion to $26.6 billion," including annual fuel and maintenance cost savings per vehicle of between $1,643 and $2,327 in 2050. However, the study also reported that meeting state M/HD ZEV deployment goals would require substantial policy support beyond existing measures, including finding that supporting charging infrastructure buildout would accelerate the M/HD ZEV deployment process and that the State of Colorado has a critical role to play in planning for and funding M/HD charging infrastructure development [15].

### Battery Electric Truck Operational Viability

Assessing the viability of battery electric truck usage across vehicle types and use-cases is a major focus of prior literature on M/HD truck electrification. In *Transitioning to Zero-Emission Heavy-Duty Freight Vehicles*, Moultak et al. (2017) described the near-term likely opportunities for electric M/HD trucks as limited to uses where vehicles travel relatively short distances around a central base location (such as urban delivery, vocational fleets, etc.) because those use-cases minimize technology limitations of early electric trucks, such as a more constrained battery range and minimal access to en-route charging infrastructure [17]. *Electric Trucks—Where They Make Sense*, by Mihelic et al. (2018), came to similar conclusions, finding that electric trucks will initially be limited to operations with short, predictable daily miles traveled and where vehicles will return to the same location to charge each day [18]. Later studies have echoed the finding that shorter urban routes based at a single depot are ideal electrification use-cases. In *Making Zero Emissions Trucking Possible,* Farrag-Thibault et al. (2022) add that urban operations with longer idle times and stop-and-go driving also favor electric drivetrains, such as in standard delivery vehicle operations [19].

While the key enabling factors for electrification identified in early literature have remained similar, more recent studies, drawing on rapid advances in technology, have updated expectations on how rapidly various truck segments could successfully electrify. In a series of reports that drew on real world experience, Roeth et al., found that medium-duty vehicles (such as step vans and box trucks), along with terminal tractors, are 100% operationally electrifiable in the near- to medium-term, although some applications, depending on the duty cycle, will be easier to electrify than others [20] [21] [22]. Moreover, they found that as many as 50% of harder-to-electrify regional Class 7 and 8 tractors could be electrified with current technology [23]. In a broad-based study using telematics data from trucks in California and New York, *Charting the Course for Early Truck Electrification* further found that about 65% of medium-duty and 49% of heavy-duty trucks in these states are regularly driving routes that are already electrifiable with trucks on the market today, meaning that these use-cases could immediately be replaced with M/HD electric vehicles as their diesel vehicle counterparts are retired [24] .

While much of the existing literature remains focused on vehicles that operate out of a depot and return to charge every night, focus has also shifted to the use of electric trucks in long-haul operations. *Why Regional and Long-Haul Trucks are Primed For Electrification Now*, by Phadke et al. (2021), finds that viable long-haul battery electric trucks are on the horizon, but stresses the need for policy support, such as binding zero-emission vehicle sales requirements and targeted subsidies to encourage technology developments, increase vehicle supply, reduce costs, and incentivize the accelerated deployment of charging infrastructure to support the needs of these trucks [25].

## Charging Infrastructure for Electric Trucks

While most published literature focuses on the electric trucks themselves, charging infrastructure to support these trucks is a key factor in the research on M/HD electrification. *Amping Up: Charging Infrastructure for Electric Trucks* offers a deep dive on available charging options for electric M/HD vehicles, which examines both standard cord and connector (plug-based) options, along with alternatives such as catenary electric or wireless charging. Like vehicle-focused studies, the report concludes that an outsized amount of charging infrastructure will be deployed at depots, particularly in the near-term. Moreover, the report notes that much of the demand for electric charging for M/HD can be met by existing charging technologies widely used by light-duty vehicles (Level 2 and DC Fast-Charging) [26]. However, the report also acknowledges the need for megawatt-level charging as the market matures, particularly for long-haul electric trucking on major freight corridors, a finding that is echoed by Walkowicz et al. (2019) in *R&D Insights for Extreme Fast Charging of Medium- and Heavy-Duty Vehicles* when reporting out from a workshop on the research needs for extreme fast-charging, and by Bourlaug et al. (2022) in *Charging Needs for Electric Semi-Trailer Trucks*, finding that megawatt-level charging will be critical for mid-shift charging of heavy-duty long-haul trucks [27] [28]. Additionally, there is general agreement across these reports that charging management strategies enabled by software and/or onsite energy resources will be crucial for managing energy costs in some higher-powered M/HD charging applications.

The existing literature on M/HD charging does provide some insight on the barriers inherent in deploying charging infrastructure. However, research here is more limited than on vehicles. Generally, the literature identifies common themes in infrastructure deployment barriers. For example, both *Road Freight Zero: Pathways to Faster Adoption of Zero-Emission Trucks* and *Medium- and Heavy-Duty Electrification: Weighing the Opportunities and Barriers to Zero Emission Fleets* cite capital cost, depot space availability, ownership models, and grid capacity as substantial barriers to deployment of depot-based chargers [29] [30]. In addition, both reports also identify utilization risks — that not enough trucks will materialize to justify investment — as an additional barrier to the deployment of public opportunity or en-route charging.

## M/HD Charging Needs Analysis

Charging needs analysis for electric M/HD vehicles is a very new area of research with few published papers or reports. Atlas' modeling tool (INSITE) and methods employed in this study are based on prior work by Atlas estimating nationwide infrastructure needs for M/HD vehicles conducted as part of a broader effort to estimate infrastructure requirements and costs for both light- and M/HD EVs. In one such study, titled *U.S. Vehicle Electrification Infrastructure Assessment: Medium- and Heavy-Duty Truck Charging*, McKenzie et al. (2021) found that nationwide infrastructure needed to meet a 100% electric M/HD sales target in 2040 would require between $100 and $166 billion in investments by 2030 [31].

Additionally, in an analysis specific to the State of Colorado's charging infrastructure needs that focused primarily on light-duty vehicles, and for which this report builds on, Hsu et al. (2021) in *Colorado Charging Infrastructure Needs to Reach Electric Vehicle Goals*, conducted a simplified analysis of required investments for supporting M/HD electric vehicles in the state (prior to the completion of the *Colorado Clean Truck Strategy* and adoption of the ACT rule). This research covered Class 4-8 trucks and was limited to 50 kW and 350 kW charging stations. The analysis found that by 2030, 85 public 350 kW chargers and 1,570 50 kW depot chargers would be needed to support 2,021 Class 4 through 6 trucks in the state. An additional 598 public and 2,350 depot chargers would be needed to support 2,480 Class 7 and 8 trucks in the state. The authors estimated the total cost for this infrastructure would be $363.6 million [32].

The California Energy Commission's *Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment* offers a similar analysis for charging needs in California. The report authors used NREL's recently developed HEVI-LOAD tool for its M/HD EV analysis. The HEVI-LOAD model takes aggregated estimates of energy needs and disaggregates energy recovery needs to time and location using vehicle travel pattern data across several vehicle types. Location and time of use for charging load is used to compute required numbers of 50 kW or 350 kW chargers to satisfy load requirements. When applied to California energy needs and travel pattern data, the HEVI-LOAD tool projected 141,000 50 kW chargers and 16,000 350 kW chargers would be necessary to charge 180,000 M/HD electric vehicles. The analysis did not estimate costs [33].

## Lessons and Gaps

As detailed above, there is substantial agreement in the literature about how and where electric trucks are likely to deploy first and emerging evidence on the opportunities for deep transitions in the medium-term, even in harder to electrify segments. Moreover, except for novel "future" charging modes, such as catenary charging or wireless charging, M/HD charging technology is relatively well understood, as it generally carries over technology from the light-duty EV market. The barriers to charging infrastructure deployment are less well explored, but the literature does lay out a common set of likely barriers that M/HD charging deployment will face. While there has been some study of the market landscape for charging provider business models, the industry is changing so rapidly that much of it is already either out of date or lacking in depth. Lastly, given the recency of electric truck developments, there is little research that looks at the M/HD charging market from a Colorado perspective, meaning that research thus far may not perfectly represent state-specific conditions as Colorado M/HD vehicles electrify.

M/HD charging infrastructure needs analysis is a developing area of study, though several different methods have been employed in different geographic contexts. While methods do differ in implementation and source data, extant methods all rely on estimated energy consumption of M/HD vehicles as the basis for establishing infrastructure needs. While prior studies have estimated M/HD charging needs in Colorado, they are either based on differing assumptions of electric M/HD vehicle adoption than envisioned by Colorado's Clean Truck Strategy goals or lack sufficient depth to inform a Colorado M/HD charging incentive program.

# 2. State of the Market

M/HD fleet electrification will be challenging to navigate, and the markets, business models, and financing structures for electric trucks, buses, vans, and tractors are still maturing. An understanding of the various interconnected actors in this space, from fleet operators, to charging providers, to electric utilities, is vital to establishing a well-designed M/HD EV infrastructure funding program. Likewise, knowledge of the numerous enabling factors, as well as barriers to electrification for M/HD vehicles, is crucial to ensuring widespread adoption and deployment.

M/HD fleets across Colorado are diverse in their operations, vehicle mixes, and business models, much like the state's varied utility and charging vendor ecosystem. This chapter, *State of the Market*, provides a comprehensive analysis of the sector state of play, detailing the M/HD fleet landscape across Colorado, the stakeholders engaged in the market, and both the enabling factors and key barriers to the electrification of this segment. Furthermore, we break down the M/HD charging modes, power requirements, operational use-cases, and charging business models that currently apply to the medium- and heavy-duty sector. And, in looking toward program development, this section takes a deep dive into what is holding the M/HD fleet market back in its electrification journey and details the key factors and changemakers that have the potential to move it forward.

## Methods & Data

For this analysis, we employed a mixture of synthesis research of existing academic and grey[2] literature, as well as original qualitative research of primary sources. We employed several search methods to identify relevant secondary research material, including keyword and exact phrase searches of general search engines and academic journal databases, along with citation mining of identified sources. The bulk of existing literature comes from non-academic sources. Along with these secondary sources, we conducted similar searches for primary documents, such as marketing materials, guides, and other relevant information. We also gathered considerable qualitative data from interviews of small Colorado fleets and dealerships conducted by Drive Clean Colorado and CALSTART as part of a CEO project leading up to the initiation of this study, as well as through semi-structured interviews completed during the course of the study with select stakeholders and market actors working in the M/HD sector both in Colorado and across the country. Interviewees included charging- and fleet-as-a-service providers, fleet owners and

[2] Grey literature includes reports from governments, trade associations, research institutes, and other authoritative but non-academic sources.

operators, financial entities, state agencies, program managers, manufacturers, dealers, freight trade associations, advocacy organizations, real estate owners and developers, as well as investor-owned, cooperative, and municipal electric utilities. Finally, we conducted two case studies with organizations with operations in Colorado that have or are in the process of deploying charging infrastructure for M/HD vehicles. We weave together data from these varied sources to provide a robust picture of the M/HD vehicle and charging market as it is developing on the ground in Colorado and how it will likely continue to develop in the near future.

# M/HD Charging Market Overview

The M/HD charging market is a submarket of the overall EV charging market, which until recently, has been focused primarily on serving light-duty EVs. There is substantial overlap in technology use and the supplier side of the market. However, the M/HD charging market is differentiated from the light-duty charging market both by the generally higher energy and power demand of M/HD vehicles and their typical commercial or public service usage.

Conceptually, the M/HD charging market can be broken down into three broad participant categories:

1) Electric M/HD vehicle owners and operators
2) Charging equipment and infrastructure supply ecosystem
3) Utilities or other electricity suppliers

Electric M/HD vehicle operators are the buyers in the market who need access to charging (either onsite or elsewhere) to fuel their vehicles. Thus far, the consumers of these products are mostly larger fleets, with heavy representation from the transit bus segment. Other public and municipal fleets are also early adopters of electric M/HD vehicles (and thus are buyers of charging equipment). Deployment has been limited in the private sector, with early grant-funded pilots mostly confined to middle-mile logistics or last-mile delivery. However, governmental mandates and funding, environmental social governance priorities, and economic factors are expected to substantially increase the number of vehicle operators (across industries and fleet sizes) that will pursue fleet electrification.

The charging equipment and infrastructure supply ecosystem encompasses the diverse set of sellers involved in the manufacture, distribution, planning, sale, deployment, operations, and maintenance of M/HD charging solutions. Market actors in this ecosystem may focus on one aspect of supplying charging equipment or be vertically or horizontally integrated. Many M/HD charging providers are companies that started in the light-duty sector and are now expanding their offerings to M/HD charging, while other companies have emerged in the last few years to specifically provide solutions in the M/HD space. Dealers and vehicle original equipment manufacturers (OEMs) have also stepped into the role of charging provider (often through third-party agreements) in an effort to ensure that charging infrastructure is available to vehicle buyers. This supply ecosystem includes vendors that offer charging equipment and installation coupled with alternative financing, such as charging- and truck-as-a-service offerings.

Electricity suppliers sell the power that fuels M/HD EVs. The major actor in this space is the electric utility, which plays a vital role in the successful deployment of M/HD charging infrastructure and equipment. While not typically involved in the direct supply of charging equipment, utilities are directly involved in the M/HD charging market. Most importantly, utilities are responsible for providing the power and energy needed to charge M/HD vehicles, which can prove complicated, costly, and time consuming. Moreover, in part because transportation electrification represents an opportunity for utilities to increase the amount of electricity they sell and (in some cases) to utilize grid assets more efficiently, some have become key partners in developing charging infrastructure and providing funding for make-ready infrastructure, charging equipment, and valuable advisory services. While most M/HD EVs will be supplied with energy from utility grids, some charging equipment suppliers have integrated electricity supply into their service models using onsite renewable generation and battery storage.

## Other Involved Parties

Though not necessarily traditional market participants, funding providers are key players in the early M/HD charging market. In this developing market where costs and uncertainty are high, funding and financing providers, including incentive programs, grant-making agencies, and utility programs, are key enablers of project success. The ability to access funding from one or more funding providers is very frequently a make-or-break factor in M/HD charging deployment.

In addition to the direct market participants and funders, there are a number of additional actors who are often involved in the development of M/HD charging projects, including:

- Property Owners and Managers — many logistics facilities are leased by the fleet operator, meaning that landlords must be involved in project development
- Public Site Hosts — in the case of public, en-route, or other opportunity charging, chargers must be hosted. Where charging providers and vehicle operators do not secure their own locations, suitable hosts, such as existing truck stops or parking facilities must be contracted
- Truck and Bus Dealerships — Dealers are often the entity with the closest and most direct relationship with the fleet operator and often sell charging equipment bundled with vehicles
- Original Equipment Manufacturers (OEMs) — Like dealers, OEMs have relationships with fleets and have expertise in the charging infrastructure needs for their vehicles

- Green Banks and Sustainable Finance Lenders — Can provide financing and loan guarantees for M/HD projects
- Electricians and Contractors — Perform the actual electrical and construction work necessary to deploy chargers. Includes both specialized and non-specialized providers
- Technical Assistance Providers — Provide third-party planning support and facilitation

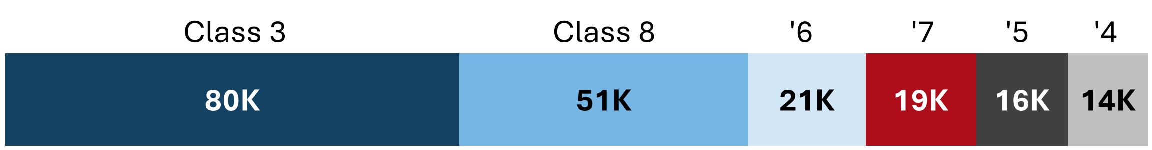
# Colorado M/HD Fleets and Electrification

By the Advanced Clean Trucks rule definition, M/HD vehicles include all vehicles over 8,500 lbs. gross vehicle weight rating — encompassing Class 2b to Class 8 — everything from a Ford Transit van to a Freightliner Cascadia tractor truck [34]. Across the M/HD classification are heavy-duty pickup trucks, cargo and step vans, box trucks, vocational vehicles, buses, construction trucks, and tractors, among others. The diversity of M/HD vehicle types is exceeded by the fleet operator landscape, which is rife with complexity in services rendered, operation types, and structures.

## M/HD Vehicles in Colorado

Analysis of S&P Global vehicle registration data shows there were just over 200,000 Class 3-8 vehicles[3] registered in Colorado in 2019, the most recent year for which we have data. Figure 1 shows the breakdown of registrations by Class in Colorado. Among Class 3-8 vehicles, about 4 in 10 are Class 3. The next largest category is at the other end of the weight spectrum, with Class 8 vehicles accounting for about 1 in 4 Class 3-8 vehicles. Middle vehicle Classes 4-6 are substantially less common. While we do not have direct data on the number of Class 2b vehicles, MJ Bradley estimated that there are approximately 300,000 Class 2b vehicles on the road in the state, making them by far the largest weight Class category of M/HD vehicles on the road in Colorado [15].

Figure 1. M/HD Vehicle Registrations by Class in Colorado (excluding Class 2b)




Class 2b and 3 are the largest overall weight Class categories of M/HD vehicles because they are the most likely to be non-commercial pickup trucks used as personal vehicles. While there is no source for a precise estimate of the number of total vehicles in these

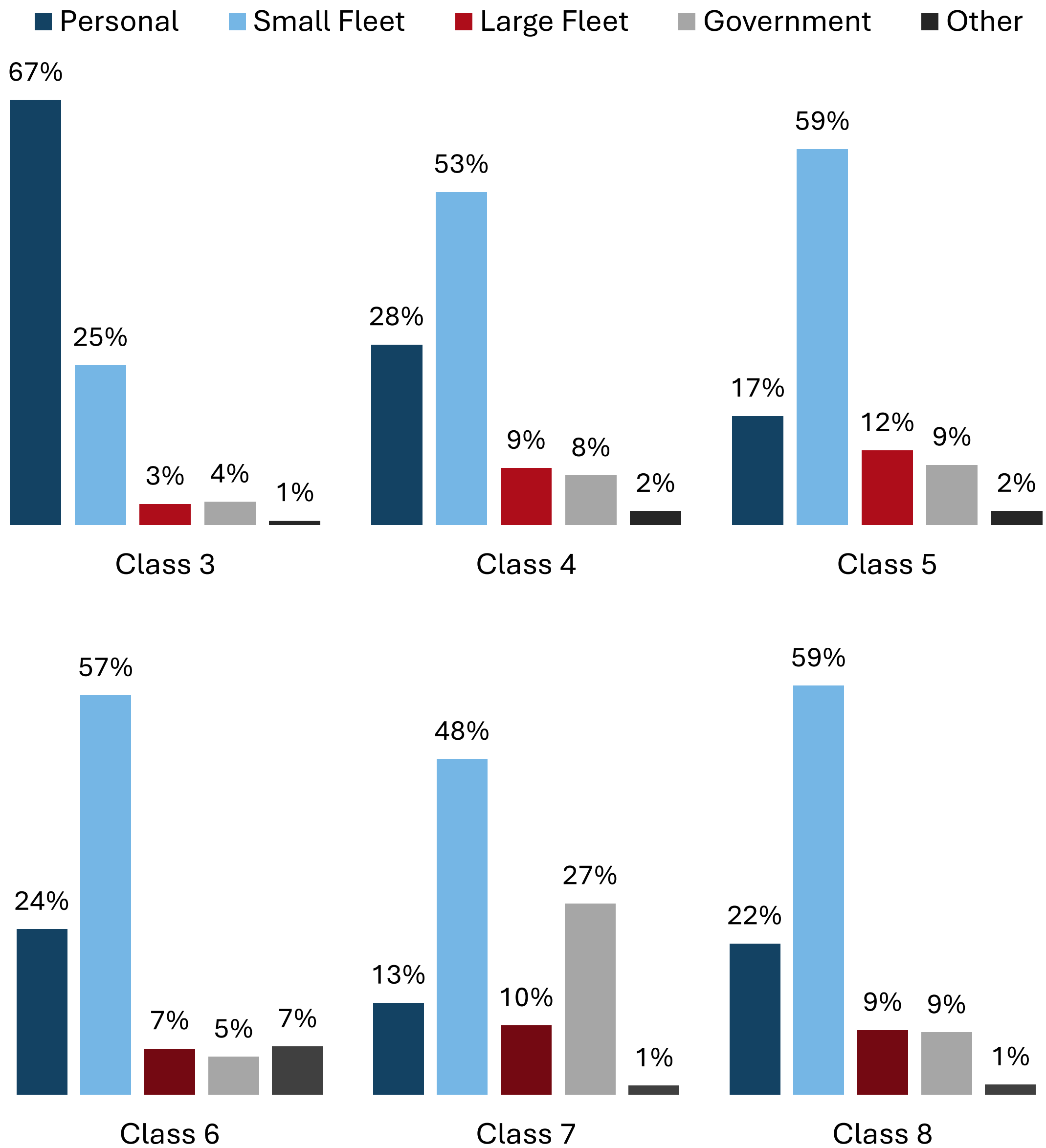
[3] Because this data does not distinguish between Class 2a and 2b vehicles, Class 2 vehicle figures are not included in this particular analysis.

Classes that are not used for commercial purposes, the percentage is undoubtedly high, particularly for Class 2b pickup trucks, which are popular personal and recreational vehicles. For Class 3 vehicles (for which we have data), 67% (see Figure 2) are classified as personal vehicles. Though because this “personal vehicle” classification only indicates that the vehicle is registered to an individual, it is likely that some percentage of these “personal vehicles” are used for a small commercial enterprise.

## M/HD Fleets in Colorado

The S&P Global registration dataset includes an indicator of ownership type that includes *personal (individual)*, *small fleet (<10)*, *large fleet (>10)*, *government*, and *other (rental, dealer, etc.)*, which is visualized in Figure 2. Except for Class 3 (where personal registrations are likely to be non-commercial vehicles), *small fleet* dominates each vehicle Class and *large fleet* makes up only around 10% of Class 4-8 vehicles. This breakdown reveals a private M/HD fleet industry that is dominated by small fleets. Individually owned vehicles make up the second-highest category in Class 4-6 and Class 8 vehicles, though these are more likely to be used for commercial purposes than Class 3 vehicles. Class 7 vehicles are more represented by *government* because a large fraction of buses are Class 7. While the S&P data shows that 59% of Class 8 vehicles in Colorado are owned by a small fleet, it is likely that a substantial portion of these vehicles are fleets of one, registered to an incorporated independent owner-operator.

Figure 2. Class 3-8 Vehicles by Ownership




When considering the market for charging M/HD vehicles, the distinction between a personal vehicle and one that is used for commercial purposes is an important one. Non-commercial medium-duty pickup trucks dominate the M/HD fleet in Colorado, but they are more akin to light-duty vehicles in that many are used for personal transportation and recreation rather than a business purpose. Like light-duty vehicles, these trucks will mostly charge at home and will use public charging that is geared towards light-duty use-cases. However, because Class 2b and 3 pickup trucks are marketed as towing vehicles, in these instances, they will need pull-through charging that can accommodate a truck and trailer (more so than Class 2a pickup trucks).

Overall, the makeup of fleets in Colorado looks similar to that in other states. Urban-based fleets in Denver or Boulder fulfill similar functions with comparable duty cycles to those in other metropolitan contexts. Likewise, rural fleets in Colorado operate comparably to those in other rural communities across the country. This means that lessons learned from across the country will generally apply relatively well to fleets in Colorado; however, Colorado's topographical, geographical, and meteorological conditions do present some distinct challenges for electrification that, while not solely unique to Colorado, do differ substantially from areas not in the Mountain West. These conditions can pose additional challenges, such as longer than typical driving distances, steep grades, colder weather, heavy snowfall, and changing weather conditions.

In summary, M/HD fleets are substantially diverse, serving functions in nearly every industry and governmental activity. The diversity of fleet activities and industry structure defies easy classification, but at a high-level, M/HD fleets can generally be grouped into three broad categories:

Table 1. High-Level Fleet Categories

| Category | Example Fleet Types | Example Fleets |
|---|---|---|
| Goods Movement (Logistics) | Freight Trucking<br>Retail / Food Service<br>Distribution<br>Delivery | Old Dominion Freight Line<br>Sysco<br>DHL |
| People Movement | Transit<br>Shuttles<br>Motorcoaches | Regional Transportation District<br>Ace Express Coaches<br>Kiowa County School District |
| Other Services | Utility Vehicles<br>Construction<br>Refuse Collection<br>Rental | Colorado Springs Utilities<br>Waste Management<br>Ryder Trucks<br>Xcel Energy |

Moreover, fleets can also be classified by their ownership and structure, such as:

- Public — Government owned and operated vehicles
- Private — Vehicles owned and operated by the business they serve
- Contract — Independent fleets contracted to a single or small collection of businesses or government
- For-Hire and Delivery — Fleets (or often owner-operators) hired on a per-load or less-than-load basis rather than on a long-term contract
- Rental and As-a-Service — Fleets of vehicles that can be hired out short-term for use by other companies or individuals

## Fleet Factors that Affect Charging Needs

While fleets are diverse in their operations, considerations for charging needs are comparatively simple. The number and power level of chargers, as well as required onsite electrical capacity, come down to just four factors that may differ from fleet to fleet.

**Vehicle Efficiency:** Generally, M/HD vehicles use more energy than light-duty vehicles. However, there is substantially more diversity in energy use per mile among M/HD vehicles than light-duty. For example, a Class 3 delivery van may require as much as 70 kWh to travel 100 miles, whereas a Class 8 tractor trailer may require 300 kWh to travel the same distance. All things equal, fleets that run smaller, more efficient vehicles will require less charging capacity than those that run larger, less efficient vehicles.

Other conditions that affect vehicle efficiency and that may differ between fleets include:

- Load weight (heavier cargo can impact efficiency)
- Typical operational speeds (higher speeds are less efficient)
- Route topography (climbing hills takes more energy)
- Power take-off needs (some vehicles use traction battery power to operate equipment, such as loaders and pickers)
- Average climate (colder temperatures reduce powertrain efficiency)

**Operating Parameters:** Energy use is generally a function of both efficiency and operating distance. All things equal, vehicles that travel shorter distances between charging events will require less charging capacity than those that travel further. Operating distances are generally related to the type of work the fleet performs. For example, a regional-haul tractor may travel several hundred miles on a single shift, hauling a full truckload of goods between cities, whereas a construction truck may travel at most 50 miles to a job site. For some fleets, operating distances will also vary by service area. Delivery and service fleets will generally travel shorter distances in dense urbanized areas, whereas these fleets will travel longer distances in suburbs and rural areas due to distance between route stops.

**Dwell Duration:** Charging capacity needs are a function of the required energy recovery (based on distance and efficiency) and the amount of time the vehicle can remain stationary while charging (known as dwell time). Recovering the same amount of energy in a shorter period requires more power, and thus electrical capacity. Fleet vehicles with long operating hours, particularly those in *slip seat* operations (where drivers alternate shifts on a single vehicle within the same day) may have short windows of time when they are able to stay plugged in. Other fleet vehicles may be used in much shorter operations, with as much as 14 hours of dwell time between each shift. Recovering 100 kWh of energy in 10 hours can be accomplished with a basic 11 kW level 2 charger, but recovering 100 kWh of energy in one hour requires a 100 kW+ DC fast-charger (DCFC). Longer dwell times also enable greater optimization of charging by utilizing energy management software, which can substantially decrease needed onsite energy capacity.

A special case of dwell duration are vehicles that do not operate out of a homebase or are otherwise not regularly domiciled at a location with charging access. This is the default mode for long-haul trucking, but is also common among owner-operator vehicles. As these vehicles often must charge at third-party locations, charging time cannot necessarily be matched with long periods of vehicle dwell time. Because minimizing downtime is key, very high-power levels are desirable.

**Operational Predictability:** This factor does not directly affect energy recovery needs, but can have substantial impact on the number and power of necessary charging equipment. Fleets with very predictable routes and dwell durations, and that operate vehicles with ranges capable of managing more than one day of operations at a time, will be able to better share charging equipment between vehicles by alternating or otherwise scheduling charging. Fleets that can share charging equipment and infrastructure will be able to support the same average daily energy recovery needs with a smaller charger deployment.

## Enabling Factors for Electrification

The enabling (and motivating) factors for electrification can be broadly described as technical, economic, and organizational. These factors intersect with fleet types, operations, and use-cases, rendering some fleets easier to electrify early than others.

Technical factors are a make-or-break category, which include:

- Vehicle fit for purpose — Are there electric vehicles on the market that can handle the daily duty cycles required by the fleet’s business case? Vehicle technology is advancing rapidly, meaning many fleets already have electric options suitable for their operations. Notable exceptions are for long-mileage and very heavy-duty applications, such as long-haul trucking.
- Charging equipment availability — Does charging equipment exist that can sufficiently charge the vehicle based on its energy needs and dwell time? Like vehicle technology, charging technology is advancing, with equipment capable of charging at greater than megawatt speeds coming to the market in the near-term.
- Compatible operations — Are fleet operations conducive to the use of available vehicles and charging equipment? As a corollary to the prior two bullets, fleet operations that are compatible with existing technology are critical enablers of electrification. In the near-term, this means return-to-base operations and duty cycles that are within the battery range of the vehicle in worst case conditions.

Economic factors are also important considerations for identifying early-to-electrify fleets, as they determine whether a given project is likely to be viable:

- Well-capitalized fleets — Fleets that have access to low-cost capital are best positioned to benefit from electrification because returns on fleet electrification rely on operational savings outweighing higher initial capital cost. This is easier to achieve when the average costs of upfront capital are low. Well-capitalized fleets are also usually better positioned to absorb the risk of switching to an emerging technology.
- Favorable operations — While technical vehicle range constraints place a cap on the operational distances that are easily electrifiable, project economics for electric M/HD vehicles improve as average usage increases. This is because the return from electric vehicles comes from operational cost savings in fuel and maintenance costs, which add up faster the more miles a vehicle is driven and the higher the utilization. All things equal, higher usage applications (within daily range constraints) or applications where vehicles spend substantial time idling, will present a more favorable case for electrification. Economics become even more favorable if a fleet were to factor in the externality costs of reduced emissions. Additionally, operations that allow for fleets to avoid high utility demand charges and to take advantage of lower-cost time-of-use electricity rates will also increase economic viability.
- Incentive program availability — Access to government and utility incentives can impact project economics and attract investment. If and where availability of incentives targets specific fleets and vehicles (such as incentives for school buses) those fleets will be more likely to electrify earlier.

Technical and economic factors are not the only important considerations for early M/HD electrification. In most cases, the impetus for early electrification will come from organizational drivers:

- Governmental commitments — The State and numerous jurisdictions in Colorado have instituted or are considering zero-emissions targets specifically for public fleet operations (i.e., GoEV Cities). While technical constraints will still steer these transitions and focus will be put on economics, these governmental commitments make public fleets (or private fleets contracted to public agencies) more likely candidates for early electrification.
- Private commitments and environmental, social, and governance (ESG) — Most large publicly traded companies that operate fleets have ESG goals (driven increasingly by requirements from institutional investors) that include reducing vehicle emissions. In addition, public facing companies whose brand will be associated with vehicles they operate are increasingly conscious of the impact that electric vehicles can have on their brand image. Public perception, as well as

institutional commitments and requirements for these companies serves as a strong motivation to electrify vehicles where possible.

These factors combine to create a profile of likely first mover fleets, most of which have already taken action towards electrification in locations inside and outside of Colorado:

Table 2. Example First Mover Fleet Types

| Category | Example Fleet Types |
|---|---|
| Public Fleets | Transit Buses<br>School Buses<br>Refuse and Solid Waste Trucks<br>Heavy-Duty Work Pickup Trucks<br>Service Vehicles |
| Private Fleets — (operated or contracted by large companies) | Medium-Duty Vans for Parcel & E-Commerce Delivery<br>Investor-Owned Utility Service Vehicles<br>Food Service M/HD Fleet Trucks<br>Rental M/HD Fleet Trucks<br>Food and Beverage Distribution M/HD Fleet Trucks<br>Refuse M/HD Fleet Trucks<br>Local Service M/HD Fleet Trucks |

# Charging Infrastructure and Equipment

The basic technology for charging M/HD vehicles does not differ substantially from that used for light-duty vehicles. Level 2 (< 19.2 kW) alternating current (AC) charging uses the same J1772 standard as light-duty vehicles. High-power direct current (DC) charging has to-date primarily employed the CCS connector standard used for fast-charging by most non-Tesla vehicles. The recently publicized Megawatt Charging System (MCS), which is specified to provide up to 3.75 MW of power, is poised to take market share, at least among vehicles that require heavy charging loads [35]. New megawatt charging technology will, however, continue to coexist with the CCS standard for DC charging of M/HD vehicles.

The key differences between M/HD charging and those of typical light-duty vehicles come down to power level and configuration. Higher-power level 2 chargers (11 kW+) are much more common for M/HD vehicles than light-duty vehicles. Moreover, while a DC charger is considered a “fast-charger” for light-duty vehicles, a M/HD vehicle might require charging with a high-power DC charger for long periods of time just to cover a single day of driving. In addition to higher power requirements, M/HD chargers require more space, longer cords, and increased planning to accommodate larger vehicles. Also, due to space constraints at depots, chargers may be installed in overhead configurations uncommon for light-duty charging or may be designed to be better shared between multiple vehicles.

In addition, due to the higher power needs, predictable charging patterns, and reliability requirements of fleet charging, M/HD charging solutions are more likely to incorporate integrated power management, renewable generation, and energy storage. These additions increase the upfront capital cost of the system itself, but can avoid substantial grid upgrade costs and delays. In addition, managed charging and onsite energy resources can also be employed to reduce the impact of utility rates and demand charges, reducing ongoing electricity costs. Energy storage can also offer resiliency for fleet operations.

Because the basic technology is similar, infrastructure and equipment providers for M/HD charging are primarily the same firms that supply the light-duty charging market. Charging system equipment providers are a mixed industry, with some suppliers vertically integrated with downstream charging services,[4] and others equipment-only suppliers that may be solely focused on charging equipment or a part of a larger company with diversified offerings. A growing number of companies are focused on full M/HD charging system solutions and technical assistance, incorporating smart energy management, microgrid controllers, and distributed energy resources.

## M/HD Charging Service Provider Business Models

Like on the equipment side, EV charging service providers that started in the light-duty sector have begun to stand up fleet charging divisions that offer services for M/HD charging. However, as the market ramps up, there are new entrants offering novel services or specializing in niches, such as corridor truck charging and charging- / truck-as-a-service, or logistics industry-focused charging deployments.

To-date, nearly all deployed M/HD charging has occurred at a depot or other M/HD facility. Deploying charging infrastructure and equipment at any location requires engineering, design, construction, electrical work, permitting, equipment procurement, utility coordination, and more — generally, everything necessary for any major construction project that adds substantial energy load to a site. While fleets may manage this process themselves through a traditional construction process, integrated solutions from charging providers have become more common in recent years. In addition to managing the infrastructure deployment, providers generally also offer ongoing software, maintenance, and repair contracts for the equipment they provide. In many cases, charging providers will manage funding and incentive applications as well, and even help fleets with route planning, capacity assessments, and charging strategies, such as equipment right-sizing and future proofing in alignment with longer-term fleet electrification plans.

[4] Downstream charging services may include additional services offered by EV charging providers beyond installation and ongoing operation of the charging hardware itself.

Limited evidence from direct discussions with fleet owners and operators indicates that the decision to contract with a full-service charging provider, [5] rather than managing the process in-house, appears to be dependent on the size and capacity of the fleet deploying the chargers. Larger fleets with many facilities are more likely to build internal capacity to deploy and manage their own charging. On the other hand, smaller fleets with few locations may not find it profitable to build capacity to manage a more limited deployment, making a full-service option more attractive. However, integrated charging solutions can be attractive even to larger fleets, with early-adopter electric transit bus operators indicating a desire for more integrated solutions than were available at the time of their conversion [36].

## Charging-as-a-Service (CaaS)

Most charging service providers have adopted charging-as-a-service products that operate alongside their more traditional operator-owned offerings. These services bundle the integrated charger deployment services, ongoing service / maintenance, and software fees with an equipment lease. These services reduce or eliminate the upfront cost of charger deployment in exchange for a monthly per-stall cost or a per-kWh fee. While most of these products are offered by established charging service providers, in at least one instance, an industrial logistics real estate company has started offering charging-as-a-service as an add-on for tenants. Additionally, while most charging-as-a-service solutions are predicated on the customer having space where chargers may be installed, several service providers also install charging offsite for use by one or multiple fleet customers.

Charging-as-a-service for M/HD fleets is a young industry and there is very little data on uptake of this service model. However, as-a-service offerings have proven popular in other industries, notably technology and software. Moreover, the fact that a substantial proportion of charging service providers have adopted the model speaks to industry confidence in the viability of the business model. As-a-service models are attractive to fleets that prefer to outsource fueling their vehicles with electricity, so they can focus on their traditional operations without having to navigate installing, operating, or maintaining charging infrastructure. Multiple industry sources interviewed for this report indicated that charging-as-a-service is an important and lasting part of the charging infrastructure and equipment supply ecosystem, and that it may also be particularly attractive for smaller fleets who lease property and may wish to avoid the risk of long-term infrastructure investments in locations they do not own or may not occupy over the long-term.

[5] Charging provider that offers end-to-end services from planning to execution, operations, and maintenance.

## Truck-as-a-Service (TaaS)

In addition to charging-as-a-service models, some companies are standing up electric truck-as-a-service offerings. The business models represented in this space are diverse, but common bundled features include truck leasing, charging-as-a-service, maintenance, and other fleet management services. In some cases, truck-as-a-service models resemble traditional full-service leases with the addition of electric fueling infrastructure solutions. OEMs selling electric M/HD vehicles, such as Mack Trucks, Lion Electric, and OrangeEV, along with major truck leasing companies, have started to adopt this model.

In a departure from traditional truck leasing, a number of startup companies are experimenting with truck-as-a-service models that move beyond full-service leases to include features, such as access to centralized high-power charging depots and even truck yards where vehicles can be both stored and receive a charge. Two notable companies experimenting with this model are WattEV and Zeem Solutions — both of which are currently operating in Southern California. Currently, the business models of these companies are strongly tied to the drayage truck[6] industry for Southern California ports (which have aggressive zero-emission truck requirements). However, they may prove a sustainable model for the electrification of smaller truck fleets and trucks run by independent owner-operators, which may have difficulty funding and securing a location in addition to charging infrastructure to fuel their trucks.

## En-route Charging

While depot-based or nearby centralized charging locations can serve trucks on shorter distance regional or local routes, they cannot support long distance interstate trucking, nor can they support local trucking operations for vehicles that do not have access to depot charging options.

While the electric truck technology necessary to operate on long routes is limited and demand for en-route M/HD charging is currently low, there has been some movement to begin building the high-power charging outposts needed to electrify truck transport on longer distance routes and where depot charging is otherwise unavailable.

Early efforts are fragmented and mostly confined to the West Coast. In one example, TeraWatt, a well-funded charging-as-a-service startup, is building charging depots in California with plans to expand along Western freight corridors. TeraWatt will provide a combination of subscription-based and one-off semi-public charging, but will limit its sites solely to commercial vehicles. Another example is Portland General Electric (PGE)'s pilot, a

[6] Drayage trucks move containerized freight to and from ports and other intermodal facilities such as rail yards.

high-power, modular M/HD charging site in Portland, Oregon known as Electric Island, which was developed in partnership with vehicle manufacturer Daimler Truck North America [37]. This pilot site is fully public and is not limited to truck traffic. PGE also plans to install additional sites in its service territory as part of the West Coast Clean Transit Corridor Initiative (WCCTCI).[7] A final example is a partnership between Volvo, California truck dealers, and a charging service provider, that is building a network of charging locations along freight corridors in California to encourage sales of Volvo's electric trucks.

# Electric Utilities

The electric utility landscape in Colorado is diverse. Two investor-owned utilities, Xcel Energy and Black Hills Energy, cover roughly 10% of the state's land area. However, because they serve densely populated areas, they account for about 60% of utility customers in the state. The remaining 40% of customers are split between 22 rural electric cooperatives and 29 municipal utility territories over the remaining 90% of the state's land area. According to the Southwest Energy Efficiency Project, municipal utilities provide 16% of the state's electricity, with rural electric cooperatives providing 28% [38]. With so many electric utilities in Colorado, there is significant range in the size, structure, funding, and capacity of utilities that may serve a fleet or charging provider looking to deploy M/HD vehicle charging in the state. The large number of electric utilities serving Colorado therefore introduces complexity in the charger installation planning process and can create inconsistencies in customer experience across the state.

[7] The WCCTCI is a multi-utility partnership to support the electric vehicle charging infrastructure development along the Interstate 5 corridor. https://westcoastcleantransit.com/

Figure 3. Colorado Electric Utility Service Territories

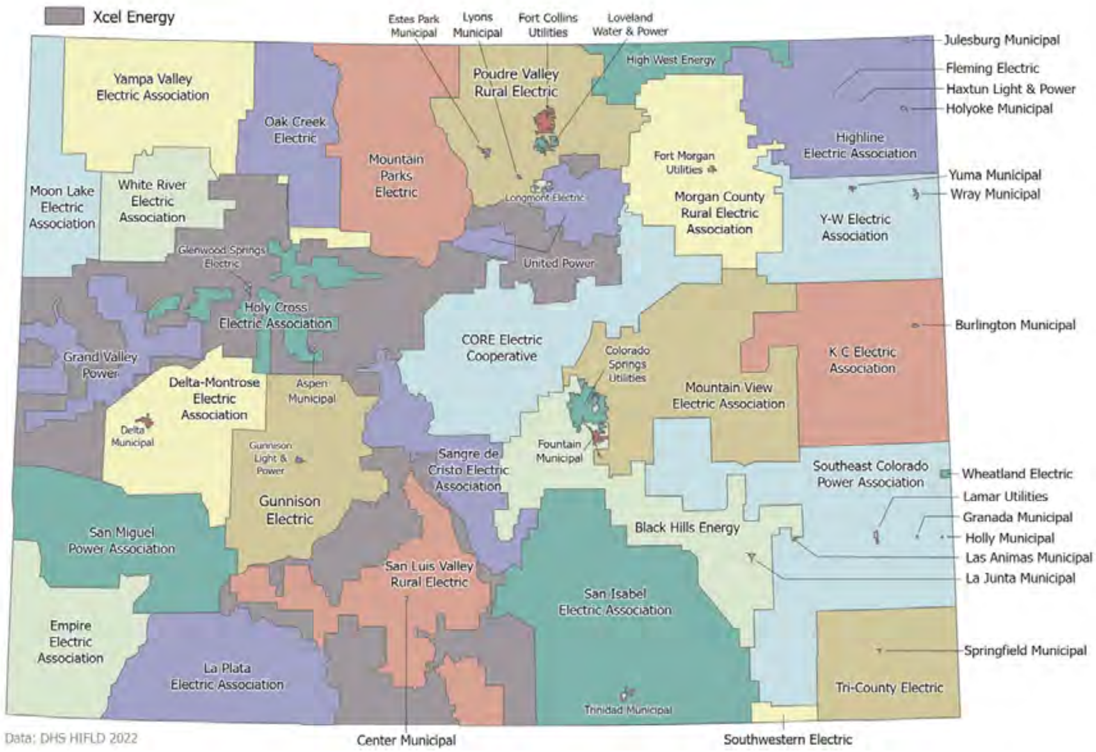



Image courtesy of the Colorado Energy Office

## Xcel Energy Colorado

Xcel Energy is Colorado's largest investor-owned utility serving a total number of 1.5 million customers. As part of their first approved Transportation Electrification Plan (TEP) from 2021 to 2023, Xcel has developed a fleet electrification advisory services program (FEAP), as well as an electric vehicle supply infrastructure (EVSI) incentive program (new service to the facility, plus electric infrastructure on the customer's side of the meter up to, but not including the charging station), which could provide service at little to no expense to eligible customers. In addition to these offerings, Xcel also offers utility-owned, installed, and operated level 2 chargers for a monthly fee through a 10-year program, as well as a bring-your-own charger program, and equity rebates for charging equipment for low-income and high emissions communities.

Participants in the fleet advisory service offering receive detailed information on vehicle operations and charging needs, followed by a rebate based on costs incurred in the planning process. Additionally, if a customer is eligible, costs for EV supply infrastructure upgrades through the EVSI program are then fully covered and costs associated with line extensions are fully or majority paid for through a utility construction allowance of about $350 per kW of connected load, provided the customer installs a minimum of four (4) charging ports or 50 kW of load. Likewise, the utility requires participants to select charging equipment from a preapproved hardware and vendor list. Xcel Energy maintains a full-time transportation electrification team and provides each participant in the infrastructure installation program a specified project manager to help guide them through the four-stage process: design, build, implement, and optimize. Xcel also works directly with dealerships and OEMs to ensure they are well informed on their incentive offerings and can pass along accurate information to vehicle buyers. Xcel Energy is now in the process of preparing the next version of their TEP spanning 2024 to 2026 that will potentially revise and expand on these currently available offerings.

## Black Hills Energy

Black Hills Energy is Colorado's second investor-owned utility, serving a total number of approximately 98,000 customers. Like Xcel, Black Hills Energy has also implemented their first transportation electrification plan. The utility offers a charger rebate program (Ready EV) based on use-case and power level, in addition to EV time-of-day rates. While they do not yet have a M/HD electrification strategy, Black Hills Energy is working to educate fleet owners and community members around the value and benefits of electrification and the role of the utility in that process. Like Xcel, Black Hills Energy is an investor-owned utility, and therefore has some flexibility to rate base upgrades to its distribution grid to support M/HD charging. Additionally, Black Hills Energy is also now in the process of preparing the next version of its TEP as well.

## Electric Cooperatives and Municipal Utilities

Beyond the two investor-owned utilities, there are 22 electric cooperatives across the state that serve a large swath of rural Colorado. Every electric cooperative is a unique entity, each in a different stage of the transportation electrification journey. However, every Colorado co-op has at least one EV charging station in its territory, and some have even developed electric school bus and transit bus programs, with others experimenting with residential time-of-use (TOU) rates. Notably, the generation and transmission cooperative, Tri-State, is investing millions of dollars to support offtake members with installing EV charging infrastructure. To-date however, electric cooperatives in Colorado have not established specific electric M/HD vehicle initiatives, and the inability to raise funds to conduct upstream grid upgrades due to their differentiated business models from investor-owned utilities serves as a major barrier to fleet electrification in these mostly rural areas. Likewise, electric cooperatives tend to have lean staffing resources and less capacity to manage specific transportation electrification projects.

Colorado also has an ecosystem of 29 not-for-profit municipal utilities regulated by local boards, such as those in Fort Collins, Estes Park, and Colorado Springs. These entities range in size from hundreds of thousands of customers to a few hundred across a wide range of topographies (flat eastern plains to mountainous western slope). Given the diversity across municipal utilities, each is in a different situation regarding EV charger installation across its service territory. Those with greater financial and staffing resources, like Colorado Springs Utilities, are moving to electrify light-duty and small truck fleets, but many of these municipal utilities are resource-constrained with just a handful of lineworkers across the company.

# Common Barriers to M/HD Charging Project Development

The higher cost of electric M/HD vehicles, limited vehicle and model availability, utility rate structures, maintenance training, and workforce development needs are all cited as barriers to M/HD electrification among reports, news articles, trade publications, and interviews with industry leaders. In parallel to these concerns are the barriers to deploying the more expensive, higher-power charging infrastructure and equipment needed to supply these vehicles with a charge.

## Powering Chargers

The importance of early and ongoing engagement with utilities is a common theme in M/HD charging procurement guides, research reports, and interviews with charging providers, fleets, and utilities themselves. Charging equipment of course needs power to operate, and freight facilities or other truck depots, yards, and parking facilities are usually not outfitted with sufficient electrical capacity to handle the additional electrical load necessitated by M/HD charging. Fleets that do not engage with utilities early in the process may find themselves with EVs that they cannot charge, and thus, cannot operate. However, the process of securing additional power to charge electric vehicles is not necessarily simple, and capacity upgrades can come with substantial costs and long lead times.

The first key barrier to powering chargers is the availability of electrical capacity at the site and on the local distribution grid. A truck yard may only have enough existing capacity to support a small office or maintenance facility. Warehouse-adjacent facilities may have substantial electrical capacity, but that will be sized to meet building loads and not EV charging requirements. While a few low-power L2 chargers may fit within a facility's existing capacity footprint, larger, or higher-power installations generally do not.

If there is sufficient capacity on the local feeder circuits that supply the facility and nearby electricity users, upgraded or new service may only require a new transformer for interconnection. If the facility is not already served by an appropriately sized distribution line, a line extension may also be necessary. In the case that a facility requires substantial additional power, or when the local distribution grid is already congested, charger installation can even require substation upgrades or new substation construction.

Each of these issues adds increasing cost and time to M/HD charger deployment. Utility industry sources note that lead times for utility interconnection, where no substantial upgrades are required, can take from six months to two years. Meanwhile, lead times for delivery and installation of new transformers (depending on size) could be ten months (for pole-mounted systems) to two to five years out (for primary transformers if a new substation or significant substation upgrade is needed) given current supply chain constraints. Often, such timelines are out of sync with fleet vehicle purchases and procurement. Uncertainty around utility interconnection and upgrades adds risk to fleet electrification timelines and makes it difficult for fleet operators to move through the electrification process.

While a fleet operator or charging provider can expect at least a minimum amount of lead time to interconnect and power new M/HD chargers, there is little geographic information available on electrical capacity, nor estimated timelines for grid upgrades. This means that a capacity barrier that may be fatal to near-term charger deployment will remain unknown until the utility has assessed the site. Multiple industry sources, including fleet operators and charging providers, expressed need for more transparent capacity maps for use in high-level planning and site selection processes.

Capacity limitations are a heavily binding constraint on M/HD charging deployment. In the near-term, fleets will likely defer electrification where capacity limits impose long timelines on charging infrastructure and equipment deployment. Fleets with multiple locations will prioritize electrification in places where grid capacity is more robust. Highly motivated fleets may opt to deploy onsite renewables and battery energy storage to enable operations ahead of or instead of utility capacity buildout, however this will come at considerable upfront expense. This self-generation and storage strategy is currently being embraced by charging service providers building high-power en-route charging.

In addition to the time constraints that can derail electric M/HD deployment projects, capacity upgrades come at an additional cost to the already high cost of onsite electrical equipment, charging stations, construction, and the electric vehicles themselves. Investor-owned utilities Xcel and Black Hills Energy have flexibility to rate base some of these costs, which can reduce or eliminate the upfront costs of these upgrades to customers and allow the utility to earn a rate of return on their investments. However, this is not true for the other 51 municipal utilities and electric cooperatives across the state. Not-for-profit municipal and cooperative utilities are limited in their ability to use ratepayer funds to pay for electrical system upgrades for single beneficiaries. For customers in these territories, adding substantial capacity upgrade costs to project budgets, along with increased timelines, can render many projects uneconomic, even with grant and incentive funding.

Outside of investor-owned utility strategies of rate basing grid capacity expansion costs, there are few, if any, meaningful proposals that address the cost issue of grid enhancements to support transportation electrification in non-profit utility territories. This is an unsolved problem that deserves further research and attention both in Colorado and nationally as the M/HD electrification transition takes hold.

## Funding Chargers

Cost is of course a major barrier to the deployment of M/HD charging, especially for smaller fleets with fewer resources. Unlike liquid fuel, where using public infrastructure is common, particularly for smaller fleets and owner-operators, public M/HD charging infrastructure is not yet available outside of very limited markets on the West Coast. Moreover, due to longer charging times, higher-power needs, and uncertain public charger availability, many fleets are unable to rely upon public charging if they are to meet their duty cycle obligations and return to base within a specified, narrow timetable. Meanwhile, without incentives or other rebate programs, installing the necessary utility upgrades, wiring, conduit, panels, and charging hardware can be prohibitively expensive. And, as certain projects could require hundreds of kilowatts, or even megawatts of power, these upfront costs may be out of reach for many fleets or site developers, making incentive offerings vital to accelerating the M/HD EV market, particularly in the near-term.

Tax credits, grants, rebates, and other incentive programs and policies are specifically intended to help overcome these cost barriers. However, as designed, some funding programs can be inaccessible or infeasible for many fleets or M/HD charging developers. For instance, in most cases, funding providers require program participants to provide a vehicle purchase order before project approval. If poorly implemented, this model can thus fully exclude charging-as-a-service providers, which may have otherwise enabled a fleet to electrify by financing infrastructure at a cost the fleet operator could not otherwise afford. Likewise, given the asynchronous timelines for vehicle purchase and delivery compared with infrastructure development and site interconnection, purchase order requirements may leave fleets with idle vehicles languishing in depots without power. Other incentive requirements have also hampered fleets from accessing funds, such as ten-year “in-the-ground” infrastructure requirements from some utilities. Fleets on a typical five-to-seven year commercial site lease may not be able to commit to such obligations.

There are generally good public or ratepayer interest reasons for these funding program design features, but many are maladapted for effective deep electrification of the M/HD vehicle sector. New or reauthorized programs that relax these requirements, or that offer funding lanes to cover use-cases that might otherwise be excluded from these program requirements, could have a substantial impact in improving access to available funding.

## Installing Charging Infrastructure

Space is a substantial constraint for many fleet depots and other M/HD facilities. Electrical equipment and charging equipment can have large footprints, particularly for high-power applications, and fleet depots are not configured to have the additional space necessary to accommodate them while still maintaining space to park and maneuver large trucks. Business models are predicated on the number of vehicles currently on site, and revenue or operational efficiency can suffer if fewer vehicles can park at the same depot. The construction related to the installation of chargers at existing depots may also result in interruptions to business operations and hindrances to fleet productivity. While solutions are available to elevate charging equipment above vehicle storage, such structures increase the cost of deploying charging infrastructure and may be impractical.

Land ownership is an additional barrier to deploying charging infrastructure. Leasing property is common in commercial fleet applications. Unlike those that own the land where their vehicles are domiciled, fleets on leased land will need to engage with depot property owners and managers to secure support and buy-in for any electrification project to succeed. As such, required property easements or modification may deter landlords from moving forward with electrification and can deny a tenant’s request to install chargers. Moreover, much of the cost of deploying infrastructure is unrecoverable in the case where a tenant may not occupy a space in the long-term, leaving many fleets hesitant to make these improvements to properties they do not own. Finally, in some cases, utilities may balk at the prospect of investing in service upgrades at a property where there is a risk the tenant will leave and anticipated revenues from charging will leave with them.

While the landlord-tenant relationship issue is recognized in both literature and by industry sources, there is little data on how hard or durable a barrier this issue is. One source interviewed for this report noted that negotiating with property owners has been a challenge for deploying infrastructure, particularly when it came to return of premises conditions that would require removal of newly installed electrical infrastructure. However, it is possible these concerns will temper as the market matures and it becomes clear that future tenants will also desire charging for their vehicles. Landlord reticence may also be mitigated by “right to charge” laws, such as those in California and as recently adopted in Colorado that require landlords to allow tenants to install charging [39] [40].

The more challenging aspect of this barrier may stem from fleets' reticence to invest heavily in improvements for property they do not own. Charging-as-a-service may prove to be a solution to this problem by enabling chargers to stay with the property instead of the fleet upon lease termination. At least one major property manager of industrial logistics assets is pursuing this model directly through the creation of an internal charging-as-a-service division. Understanding of this barrier will evolve as the market matures and more fleets and charging providers come in contact with more landlords and property managers, making this an important topic for future study and ongoing monitoring.

### Dealer Engagement

Vehicle manufacturers, and in particular, dealerships, often serve as the initial gateways for operators into the electrification process. However, if dealerships are not well informed about charging infrastructure needs and incentives, information gaps in this initial contact can cause problems down the line for charger and electric vehicle deployment. If not initially informed by a dealer, these operators and managers may not know to contact their utilities early on, nor about the infrastructure installation and preliminary timelines necessary to energize vehicles, in addition to not fully understanding the next steps in the electrification process. At the same time, a poorly informed dealer may sell a fleet operator charging hardware that is incompatible with or unnecessary for their chosen electric M/HD vehicle, as well as lack knowledge regarding available funding or incentive programs, or otherwise dissuade prospective owners from purchasing an EV altogether.

### Permitting Charging Installation

Often considered a "soft cost," permitting, along with fees and regulations, is an integral component of the fleet electrification process that must not be overlooked. Fleets must be sure to engage with the relevant permitting authorities and secure the appropriate permits before beginning any construction or installation work. Sites slated for DC charger deployment must undergo a zoning review conducted by the local authority, often cited as the lengthiest part of the permitting timeline, in addition to a building and electrical permitting and inspection process. In some cases, permitting processes can take up to a year, particularly if utility upgrades and buy-in are required, and fleets must build those considerations into the planning process. In terms of best practices, Authorities Having Jurisdiction (AHJs) could update zoning ordinances to define EV charging stations as accessories to existing sites in order to mitigate any zoning review requirements, as well as clarify in law that EV charging stations are full parking spaces as they relate to parking minimums. Likewise, AHJs could encourage and allow concurrent reviews and inspections for all required permits to streamline the process and avoid duplicative efforts. To best support permit applicants, AHJs could engage in pre-permitting meetings with prospective DCFC installers, ensure all qualifications and requirements are clear and transparent, and make all documents and applications readily available and submittable online [41] [42].

# Conclusion

The market for M/HD charging infrastructure is continuing to develop, and much uncertainty exists on how it will evolve as demand for M/HD charging increases. Several M/HD market segments, particularly those that are depot-based with predictable operations that lend themselves well to early electric M/HD vehicle deployments, are primed to electrify, especially with access to governmental or utility incentives. Other use-cases, without such favorable operations or access to upfront capital, could potentially electrify in the near-term, but face more difficult project economics and may require more substantial subsidies. Moreover, the higher-power needs of electric truck charging can prove a challenge if there is not suitable electrical capacity where trucks need to recharge.

While the basics of charging M/HD electric vehicles does not differ substantially from light-duty vehicles, the sheer variety of M/HD vehicle use-cases adds complexity to the market. This complexity, along with other challenges more particular to M/HD charging, leave much room for innovation around charging service business models and financing arrangements. Corridor and en-route charging for vehicles that do not have a homebase (such as long-haul trucks) is the least currently developed market for M/HD charging. Several companies have already begun to develop business models to fill this need, but given the high costs and uncertain road to profitability at this time, this sector of the M/HD charging market will also require substantial policy and incentive support.

# 3. Charging Needs Analysis

To develop a well-designed funding program for M/HD vehicle charging in Colorado, it is important to understand not just the current state of the market as examined in the previous chapter, but also to look ahead to understand Colorado's future M/HD charging needs in the context of the state's broader electric M/HD vehicle adoption goals. This chapter details the results of the M/HD charging needs analysis conducted using the Atlas INSITE-M/HD model, an energy-need based technoeconomic framework of M/HD charging deployment, along with a spatial analysis and temporal phasing of long-haul-focused freight corridor charging investment needs across the state through 2030.

## The INSITE Tool

Atlas Public Policy's Investment Needs of State Infrastructure for Transportation Electrification (INSITE) tool is a technoeconomic[8] model designed to provide high-level estimates of annual charger investment needs for widespread M/HD electrification. The INSITE model integrates a high-level analysis of the number and power level of chargers needed to support a given fleet of electric M/HD vehicles, along with a cost model that estimates the associated capital (equipment, infrastructure, and installation) costs.

For this analysis, the tool uses as an input modeled zero-emission M/HD vehicle sales (Classes 2b – 8, excluding transit buses) supplied by the State of Colorado. This input is consistent with Colorado's policy goals established in the Clean Truck Strategy to reach 35,000 M/HD zero-emission vehicles on the road in the state by 2030. The INSITE tool assigns these inputs to one of ten vehicle segments (Table 3) based on Class and use-case and then estimates the energy recovery needs of those vehicles based on operational and mileage parameters. The model then classifies M/HD vehicle segments based on home, depot, public (or a combination of home, depot, and public) charging and estimates the number and power level of chargers necessary to recover energy needs for successful daily route operations, accounting for a significant slowdown in charging rate above 80% state of charge. Finally, the model translates these charging station requirements for each vehicle Class, use-case, and segment, into investment needs by applying installation cost models of charging types and power level to the number of each charging type needed. Further information about the methods, data sources, and assumptions embedded in the INSITE-M/HD model, and its application to this report can be found in Appendix A.

[8] Technoeconomic modeling combines a technological model (in this case a model of infrastructure needs) with an economic model (in this case a cost model that estimates infrastructure cost).

Table 3. INSITE Vehicle Categories†

| Vehicle Use-Case | Description |
|---|---|
| **Cargo Van** | Mid-sized van designed for goods movement. Typically used for delivery service or other commercial applications |
| **Motor Coach** | Intercity or tour bus |
| **Pickup Truck** | Heavy-duty pickup truck marketed for hauling or towing heavy loads |
| **Refuse Truck** | Vocational truck used for waste collection |
| **Regional Truck** | Catch-all category for middle- and last-mile freight trucks used for goods movement |
| **School Bus** | Buses used to transport K-12 students |
| **Shuttle Bus** | Short-distance passenger bus such as those used at airports or to connect to transit |
| **Step Van** | Large van built for easy driver ingress / egress. Typically used for delivery services |
| **SUV** | Large heavy-duty sport utility vehicle used for passenger transport |
| **Terminal Tractor** | Specially configured tractor built to move dry vans or other trailers around cargo terminals and other warehouses |

† Tractor trucks used for long-haul operations are not modeled in INSITE

The results of the INSITE model are the number of needed charging ports and associated investment needs for each charging category to achieve Colorado's 2030 Clean Truck Strategy goals. To simplify this analysis, the INSITE-M/HD tool models a limited number of charger power levels compared to the universe of available charging equipment. Therefore, the result categories should be interpreted as representative rather than exact. High-level charging categories included in the model are listed and described in Table 4.

Table 4. INSITE Charging Categories

| Category Name | Description |
|---|---|
| **Home Level 2 (L2) Class 2b – 3 vehicles** | L2 chargers installed at a residence to support charging of personally owned Class 2b and 3 vehicles. |
| **Depot L2 (48 & 80 amp) Class 2b – 3 vehicles & Class 4 – 8 vehicles** | L2 chargers installed at depots configured to support Class 2b – Class 8 vehicles with relatively low energy needs. Subcategorized into 48 and 80 amp equipment variants |

| Category Name | Description |
|---|---|
| | depending on power recovery needs. INSITE assumes no sharing for L2 chargers (one charger per vehicle). |
| **Depot DC (50 kW & 150 kW) Class 4 – 8 vehicles** | DC chargers installed at depots configured to support Class 4 – 8 vehicles. INSITE allows a single DC charger to be shared using load management up to 80% utilization during a 9 hour overnight charging window [2]. This results in no more than two vehicles sharing a charging port. |
| **En-route 350 kW Class 2b – 3 vehicles & Class 4 – 8 vehicles** | Very high-power DC chargers that support away-from-base charging needs for vehicles that need supplemental charging or have no onsite charging. Because the footprint of Class 2b and 3 vehicles is similar to light-duty vehicles, en-route charging is modeled sufficient to meet the incremental energy demand from Class 2b and 3 vehicles in high-utilization areas that is not already accounted for from existing light-duty charging. Class 4 – 8 vehicles require more space to accommodate their larger footprint and are therefore assumed to require purpose-built charging locations, with lower utilization during the study horizon. |

## Cost model

The INSITE tool's cost model captures the following capital expenditures required to deploy M/HD charging:

- Charging equipment
- Electrical equipment (e.g., panels, switchgear, conductors)
- Grid upgrades at DCFC sites (assumed to not be needed for L2 sites)
- Related construction costs (e.g., bollards, supporting structures)
- Labor
- Project management, design, and permitting costs

The model excludes capital costs for land acquisition, greenfield site development, distributed energy systems, and any ancillary construction costs for structures not directly related to charging equipment (e.g., canopies, restrooms, lighting). Because the INSITE tool models upfront capital investment needs only, the cost model also excludes all operating costs, such as rent, energy bills, networking fees, warranties, maintenance, and repairs. Costs are in undiscounted 2022 dollars.

Table 5. Summary of Costs by Charging Type[9]

| Charging Type | Per Port Cost |
|---|---|
| **Home L2 Charging** | $2,600 – $6,300 depending on home type† |
| **Depot L2 Charging** | $6,600 – $25,000 depending on power level and configuration†† |
| **Depot DC Charging** | $86,900 – $193,300 depending on power level |
| **En-route Charging** | $254,900 – $381,000 depending on configuration†† |

† *Costs differ between detached, attached, and multifamily housing*

†† *Larger vehicles require costlier charging site configurations*

Due to the long lead times necessary for utility upgrades, funding for high-power depot and en-route charging must be committed well in advance of the need for charging. Cost modeling accounts for this lag between committed investment and charging deployment by modeling depot charging and en-route charging needs two (2) and three (3) years in advance, respectively. In other words, the investment for those two categories in year one reflects energy recovery needs in years three and four.

## Cases

There is considerable uncertainty inherent in predicting the number, type, and cost of charging infrastructure needed to satisfy the charging needs of an increasingly electrified M/HD fleet. While the INSITE model is not equipped to capture uncertainty around dimensions, such as infrastructure cost and vehicle adoption patterns, the analysis does address uncertainty in how M/HD operators might size their depot infrastructure builds. To capture this uncertainty, we present results in two cases:

- **Average Case**: This case bases energy needs (and thus required charging infrastructure) on the average daily mileage and dwell time for each vehicle class-segment. This scenario assumes that fleet operators will optimize their charging infrastructure deployment to closely match their average usage and charge time and/or share charging infrastructure efficiently and optimized across their fleet.
- **Conservative Case**: This case increases energy recovery needs by 30% for each vehicle class-segment to build in additional operational reserves within charging infrastructure installations in order to account for fluctuations in a fleet's average daily usage and dwell time. The case assumes that fleet operators will be more

[9] For a full description of costs, cost model assumptions, and data sources, see Appendix A.

conservative in their charging infrastructure sizing to accommodate more energy recovery than their average daily usage would require. For instance, building out charging infrastructure to account for fleet operations where a vehicle at times travels further than its average daily mileage and/or charges for a shorter time period than its average daily dwell time, thus requiring higher-power charging than in a purely average and optimized scenario.

While it is unclear how conservative or aggressive fleet operators will be when making infrastructure investment decisions (especially as the market matures and fleets become more comfortable with EV technology), we expect the true buildout case is likely to reside between these two bounds. Note that both cases assume a substantial operating margin in both home and public charging, and so the two cases do not introduce any differences for those charging modes. Both cases also assume that depot charging vehicles are charged to full, including a significant slowdown above 80% state of charge.

## Long-Haul Trucking

The INSITE model estimates electric M/HD vehicle charging needs based on the energy requirements of an inventory of vehicles registered within the geographic domain under study. This approach works for long-haul trucking when the geographic domain is national or a large multi-state region. However, it is not an appropriate method for estimating the charging needs of long-haul electric trucking in Colorado because a substantial portion of long-haul electric trucks that will operate and require charging in the state are not actually registered in Colorado.

For this analysis, we instead model long-haul truck charging needs using a secondary spatial model that is described in the Electrifying Freight Corridors section.

## Hydrogen Vehicles

The INSITE model does not support analyzing investment needs required for hydrogen fuel cell vehicles, which also is out of the scope of this study. Any assumption of hydrogen fuel cell vehicle adoption in this study would only reduce the number of EV chargers required without accounting for the cost of hydrogen fueling infrastructure that would take their place. Therefore, in the absence of a separate hydrogen fuel cell infrastructure study, the results presented in this analysis reflect the total investment needs for M/HD electric vehicle charging infrastructure in a scenario where all zero-emission M/HD vehicles deployed, in alignment with Colorado's Clean Truck Strategy objective of 35,000 zero-emission M/HD vehicles on the road by 2030, are electric. To the extent that hydrogen fuel cell vehicles will make up any portion of zero-emission M/HD vehicle deployments in Colorado by 2030, as suggested by the state's *Opportunities for Low-Carbon Hydrogen in Colorado: A Roadmap* [16] report, Colorado will require proportionately fewer chargers, but will require hydrogen fueling infrastructure in their place, resulting in this study providing a likely more conservative estimate of M/HD charging infrastructure needed by 2030.

# INSITE M/HD Results

The study finds that Colorado will require between approximately $790 million and $1 billion in cumulative investment in M/HD charging through 2030 to support local and regional operations[10] of electric M/HD vehicles in line with achieving the goals of the Colorado Clean Truck Strategy and accounting for future investment needed by 2030 consistent with assumed M/HD EV adoption rates and project installation timelines. These figures represent the average and conservative case for investment required to construct the approximately 30,000 estimated M/HD vehicle charging ports needed to be operational by 2030 and includes committed funding to deploy an additional approximately 12,000 depot and 560 en-route charging ports installed between 2031 and 2033.[11]

Breaking these categories down further, the largest cumulative cost by charger type is for DC depot charging with $274 million in investment by 2030 in the average scenario and $448 million in investment in the conservative scenario for 1,116 and 1,869 charging ports built by 2030 (plus an additional 1,058 and 1,771 charging ports commissioned by 2032), respectively. The next largest investment need is for L2 depot charging totaling $233 million and $277 million by 2030 in the average and conservative cases for 11,775 and 11,020 charging ports built by 2030 (plus an additional 10,843 and 10,128 charging ports commissioned by 2032). En-route public / semi-public charging then falls close behind in overall cost, accounting for an estimated $223 million in investment for 385 350 kW charging ports built by 2030 (plus an additional 562 en-route charging ports commissioned by 2033) in both scenarios. The least costly category, although the largest number of total charging ports at 17,352 (both invested in and commissioned by 2030), then consists of home L2 charging costing only $59 million comparatively in either scenario due to the much lower capital cost per home L2 charging port.

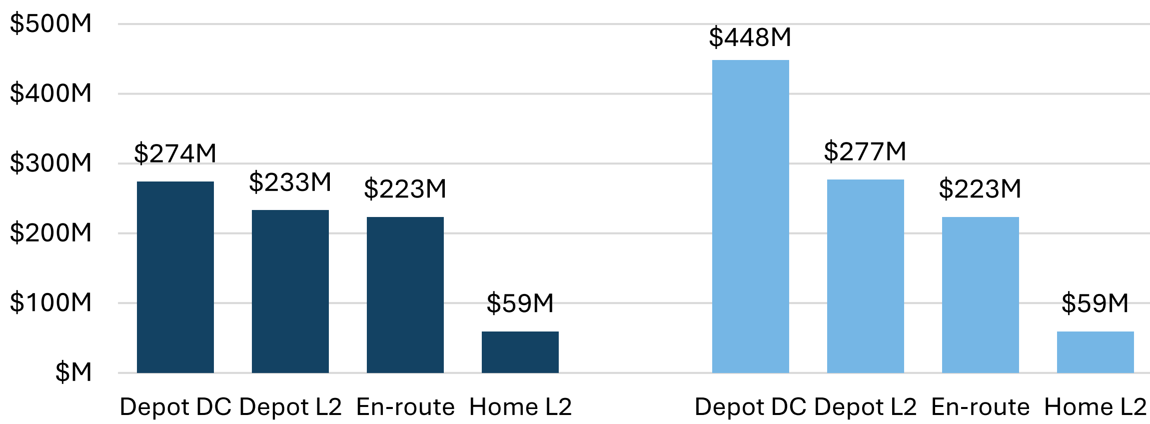
---

[10] This figure does not include the costs to electrify Colorado freight corridors for long-haul electric truck traffic. For an accounting of those costs, see Electrifying Freight Corridors.

[11] Investments account for same-year home, two-year depot, and three-year en-route installation lead times.

Figure 4. Summary INSITE Cumulative Cost and Charging Port Estimates by 2030

a. Total Cumulative Cost


c. Total Cumulative Cost by Year

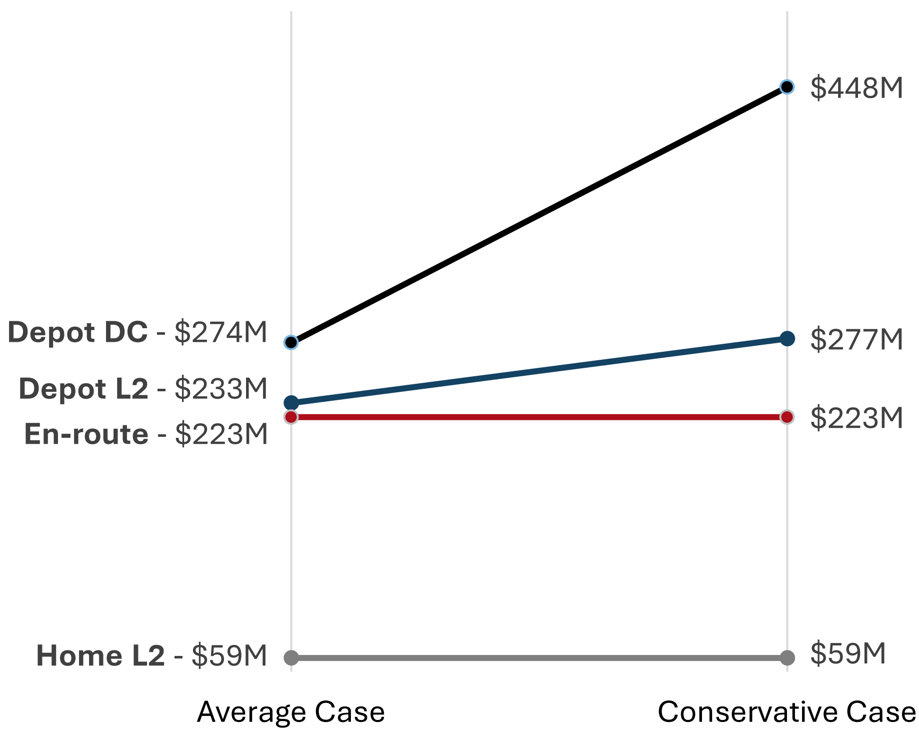
| | 2024 | 2026 | 2028 | 2030 |
|---|---|---|---|---|
| *Average Scenario* | $50.5M | $169.8M | $423.5M | $789.8M |
| *Conservative Scenario* | $62.8M | $213.7M | $538.8M | $1,007.9M |

## d. Cumulative Charging Ports Per Year by Type

| | **2024** *Average Scenario* | **2024** *Conservative Scenario* | **2026** *Average Scenario* | **2026** *Conservative Scenario* | **2028** *Average Scenario* | **2028** *Conservative Scenario* | **2030** *Average Scenario* | **2030** *Conservative Scenario* |
|---|---|---|---|---|---|---|---|---|
| Home L2: Class 2b-3 | 508 | 508 | 1,969 | 1,969 | 6,675 | 6,675 | 17,352 | 17,352 |
| Depot 48a L2: Class 2b-3 | 265 | 11 | 1,028 | 42 | 3,486 | 144 | 9,063 | 374 |
| Depot 80a L2: Class 2b-3 | 8 | 262 | 32 | 1,018 | 108 | 3,450 | 280 | 8,970 |
| Depot 48a L2: Class 4-8 | 15 | 12 | 70 | 56 | 266 | 214 | 729 | 587 |
| Depot 80a L2: Class 4-8 | 34 | 22 | 163 | 104 | 620 | 397 | 1,702 | 1,090 |
| Depot 50 kW: Class 4-8 | 11 | 19 | 51 | 91 | 195 | 348 | 535 | 955 |
| Depot 150 kW: Class 7-8 | 12 | 19 | 56 | 87 | 212 | 333 | 581 | 914 |
| En-route 350 kW: Class 2b-3 | 9 | 9 | 34 | 34 | 114 | 114 | 297 | 297 |
| En-route 350 kW: Class 4-8 | 2 | 2 | 8 | 8 | 32 | 32 | 88 | 88 |
| Total | 864 | 864 | 3,411 | 3,409 | 11,708 | 11,707 | 30,627 | 30,627 |

Figure 4 shows results of the study presented in various formats across the two scenarios, including: a) Total cumulative investment needed by 2030, b) cumulative cost by charging category, c) cumulative cost by year, and d) cumulative charging ports distributed by charging type and year commissioned. Both en-route and home L2 charging ports and costs do not change between the average and conservative scenarios. Meanwhile, depot charging costs for both DC and L2 charging ports increase in the conservative scenario to reflect the impact more conservative charging infrastructure sizing has on the power level and cost of required depot chargers. Although total cumulative investment increases over $200 million between scenarios due to higher-power charging needs in the conservative case, the total number of charging ports required to be built by 2030 remain the same.

Figure 5. Comparison of Cumulative Costs Between Scenarios in 2030



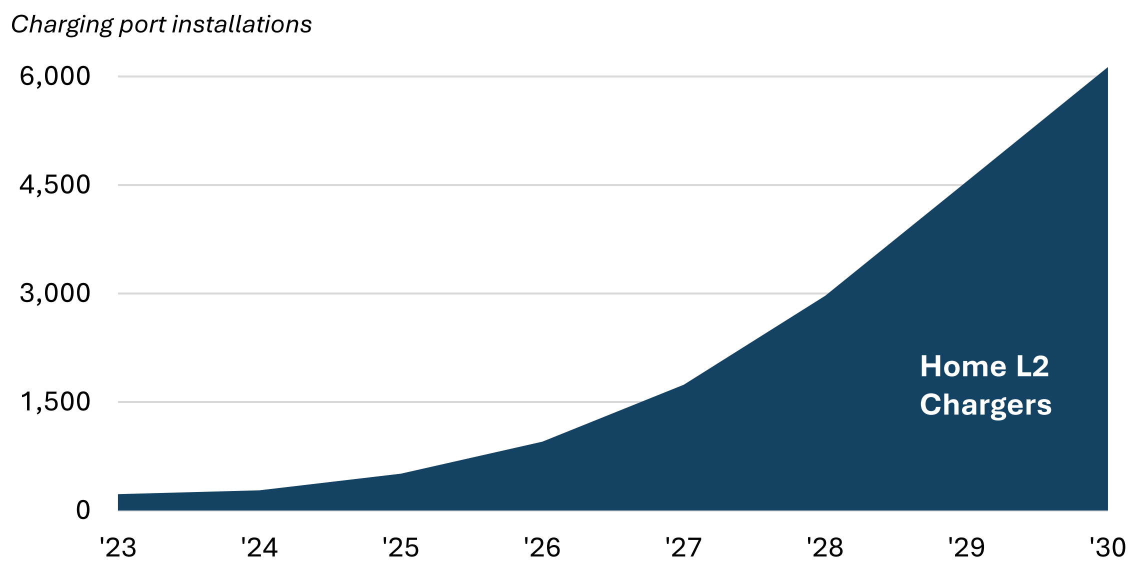

Overall, depot L2 charging costs see less of an increase between scenarios ($44 million) than depot DC charging ($174 million). The larger energy recovery needs in the conservative scenario push many vehicles from cheaper, lower-power 48 amp L2 chargers to higher-power (and more expensive) 80 amp L2 chargers. However, the cost difference between these two L2 charger types (48 amp versus 80 amp) is not very large. Additionally, some vehicle segments for which L2 charging was previously sufficient in the average case, in the conservative case, require DC depot charging instead, somewhat moderating the overall cost increase for higher-power L2 charging being needed in the conservative case due to this scenario also having a lower total overall L2 port count than in the average case.

A similar larger energy recovery need pattern in DC depot charging pushes a number of required chargers from 50 kW to 150 kW in the conservative scenario. However, in the case of DC chargers, the difference in cost between these two power levels (50 kW versus 150 kW) is high, leading to a steeper increase in overall costs between scenarios. Moreover, the vehicles that transition from L2 to DC charging also result in an increase in the number of DC depot charging ports overall, further elevating these costs in the conservative scenario.

## Home L2 Charging

Home L2 charging needs are estimated from the number of Class 2b and 3 vehicles (primarily heavy-duty pickup trucks) registered for personal use.[12] The INSITE tool assumes the vehicles in this category that are electrified are parked at residences and obtain most of their required energy at these locations. Since Class 2b and 3 vehicles (particularly pickup trucks) registered for personal use are by far the largest category of M/HD vehicles in Colorado as informed by the *Colorado Medium- and Heavy-Duty Vehicle Study*, home L2 charging has the highest requirement by total number of charging ports, growing to more than 6,000 per year by 2030 (Figure 6). However, because the average per port cost of installing home L2 charging is relatively low compared to other charging installations, home L2 charging is also the least costly category in terms of M/HD charging investment needed. Cumulatively, Colorado will need almost 17,400 home M/HD L2 chargers by 2030.

Figure 6. Annual Home L2 Charging Port Deployments (2023 – 2030)




---

[12] Identified by registration to an individual rather than a corporation or other organization.

## Depot L2 Charging

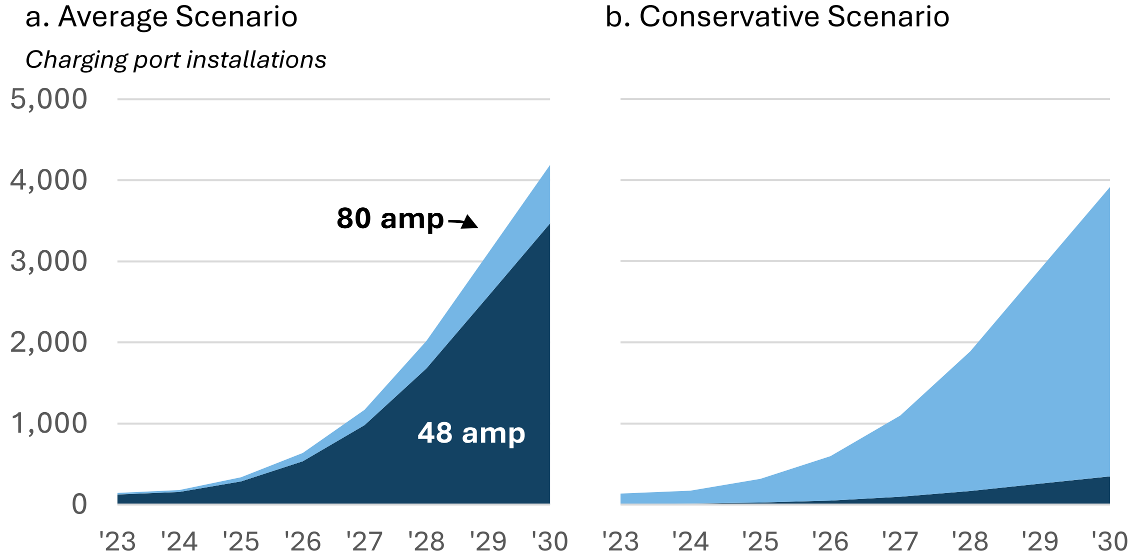
Depot L2 charging supports vehicles with relatively light daily energy needs, either because they do not travel too far between charging opportunities, are smaller and therefore require less energy overall, or both (when factoring in the assumed 9 hour overnight dwell time).[13] M/HD vehicle categories that can be supported by L2 charging at a depot are mostly lighter Class 2b and 3 fleet vehicles, but also include heavier Class 4-8 vehicles that have less intense operating duties or longer dwell times. Examples of vehicles that fall into this segment include cargo vans, step vans, and school buses.

Overall, depot L2 charging is the second-largest charging category by both investment needs and cumulative port count in both scenarios. Figure 7 shows that annual needs for depot L2 chargers will grow from just a few chargers in 2023 to between 3,900 and 4,200 in 2030. Though a fewer number of charging ports are needed for depot L2 than for home L2, the higher average cost of depot L2 charging installations results in them costing substantially more than home L2 chargers. Cumulatively, Colorado needs between around 11,000 and 11,800 depot L2 charging ports by 2030 for M/HD EV deployments.

Within the depot L2 category, vehicles are subclassified into 48 amp (10-11.5 kW) and 80 amp (16.6-19.2 kW) charger power levels, depending on their assumed energy requirements. In the average case, a large majority of the vehicles in this charging category can sufficiently operate as required with lower-powered 48 amp chargers. Figure 7b however shows that this scenario is inverted in the conservative case, indicating that most vehicles utilizing 48 amp L2 charging are close to the threshold of needing higher-powered 80 amp L2 chargers. In addition to alternating to higher-powered L2 power levels, a few vehicle categories in the conservative case — certain Classes of step vans, refuse trucks, and school buses — also move from requiring L2 charging to needing 50 kW DC charging. However, the difference in the total number of L2 chargers between both scenarios is relatively small, amounting to a fewer than 300 charging-ports-per-year difference by 2030.

[13] For a full description of model assumptions and data sources, see Appendix A.

Figure 7. Annual Depot L2 Charging Port Deployments by Scenario and Power Level (2023 – 2030)



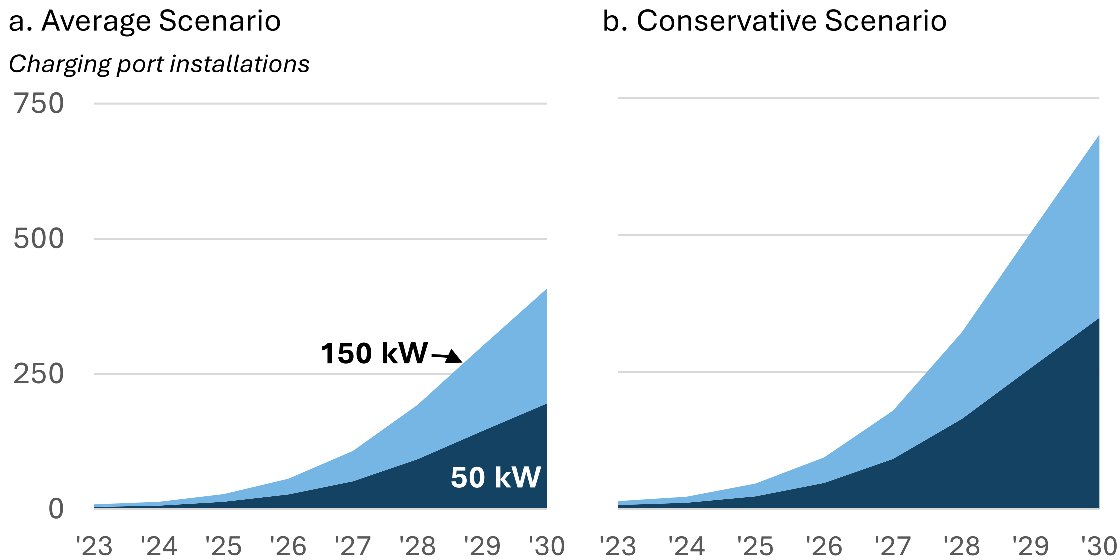

## Depot DC Chargers

Depot DC chargers support vehicles kept overnight at a depot with higher energy needs than can be supported by L2 chargers. Larger vehicles and those that travel longer distances between charging fall within this category. Only Class 4 through 8 vehicles fall into the DC depot charging category, including larger shuttle buses and regional trucks.

Overall, the annual need for DC charging at depots grows from near-zero in 2023 to between 400 and 700 DC depot charging stations by 2030. Far fewer DC depot chargers are needed than L2 depot chargers based on vehicle energy requirements. However, the high relative costs of DC depot chargers make the combined 50 kW and 150 kW DC depot charging category the highest cost overall in terms of total investment need in both cases. Cumulatively, Colorado will require between 1,100 and 1,900 depot DC chargers by 2030.

Figure 8 shows that between the two scenarios, the annual number of required depot DC chargers nearly doubles with the influx of vehicles that could formerly be charged with L2 chargers in the average scenario. However, the ratio of 50 kW to 150 kW depot DC charging ports remains similar across both scenarios despite the influx of vehicles formerly in L2 charging categories, indicating that a meaningful fraction of vehicles that could charge at 50 kW in the average case can still charge at 50 kW in the conservative scenario.

Figure 8. Annual Depot DC Charging Port Deployments by Scenario and Power Level (2023 – 2030)




## En-route Charging

En-route charging, separate from, but in some cases with overlap of corridor charging needs for long-haul electric trucks in certain geographic locations, is based on a fixed 10% of energy need the study assumes must be accounted for separate of home and depot charging during the early electric M/HD vehicle market. The en-route charging category is distinct from corridor charging[14] because it supports travel within a region rather than interregional and/or interstate corridor traffic.

En-route chargers are all assumed to be public / semi-public 350 kW DC charging ports necessary to quickly recharge M/HD vehicles at various times throughout a day. Since en-route charging will require refueling vehicles quickly at these high-power levels, many more vehicles will be able to share the same chargers. Therefore, the number of total chargers needed to satisfy en-route charging demand is based not only on energy recovery needs, but also on assumptions about charger utilization, and is much smaller in overall port count than other charging categories (see Appendix A for additional details).

Since Class 2b and 3 vehicle footprints are typically similar to those of light-duty vehicles[15], the en-route charging stations to address energy needs for Class 2b and 3 vehicles can be built incrementally alongside light-duty-focused public DC fast-charging.

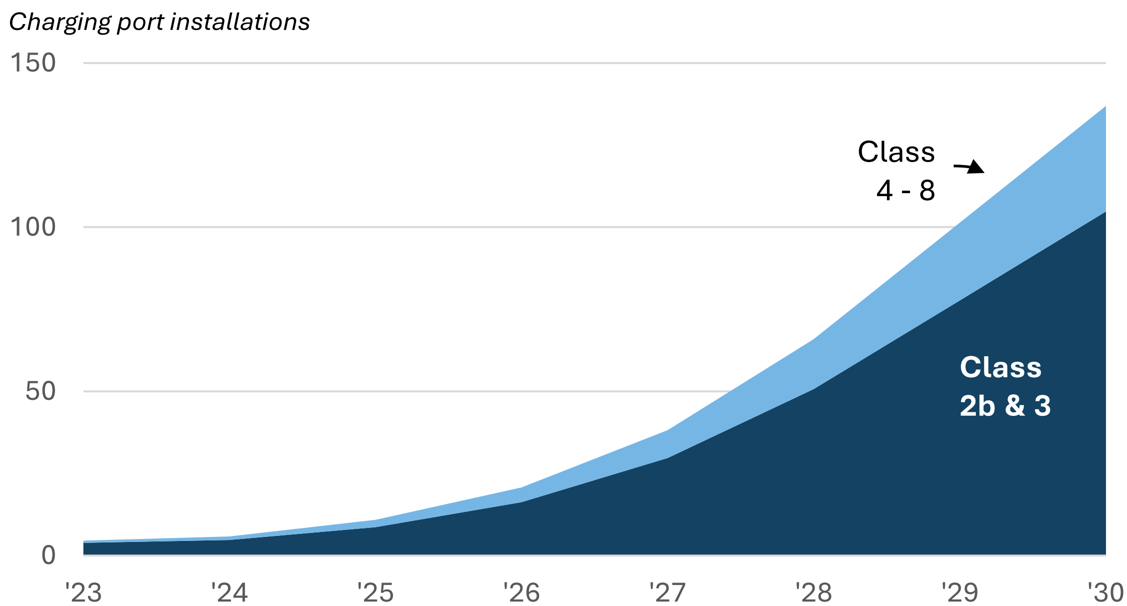
[14] Corridor charging needs are described later in this chapter.

[15] Note: Since Class 2b and 3 vehicles are often used for towing, some pull-through stations will be needed.

On the other hand, Class 4 through 8 vehicles have substantially larger footprints and will therefore require customized charging sites, likely with pull-through charging access, that can accommodate the additional space needed for these vehicles.

Figure 9 shows that annual need for public / semi-public en-route charging grows from near-zero in 2023 to 137 charging ports in 2030. Cumulatively, around 385 en-route 350 kW charging ports are estimated to be needed by 2030. Of these en-route charging ports, 88 would serve Class 4 through 8 vehicles and 297 would serve Class 2b and 3 vehicles.

Figure 9. En-route Charging Ports Needed by Vehicle Class (2023 – 2030)†




† Excludes corridor / long-haul charging sites

# Costs by Geography

The costs of deploying M/HD charging infrastructure will not be evenly distributed across Colorado. The INSITE tool provides estimates at the statewide fleet level; however, denser areas with more M/HD vehicle populations will require much more charging investment than the more sparsely populated parts of Colorado with less M/HD vehicle registrations. In this report, we have therefore downscaled these results to the Colorado county and utility territory level using M/HD vehicle registrations as a spatial proxy for charging station needs. For a full explanation of this downscaling method, see Appendix A.

At the county level, investment needs are substantially concentrated in the counties of the Denver Metropolitan Statistical Area, along with the cities of Boulder, Fort Collins, and Colorado Springs due to the density of M/HD vehicle registrations in these areas. The top 10 counties by investment need (shown in Table 6) account for almost 75% of the total investment needed across Colorado. While investment needs skew to highs as much as

$113 million in Denver County, the median Colorado county will need somewhere between $3.3 million and $4.6 million in M/HD charging investments by 2030.

Table 6. Cumulative 2030 Investment Need for Top 10 Counties in Colorado

| ***County*** | ***Average Case*** | ***Conservative Case*** |
|---|---|---|
| **1. Denver County** | $90,430,000 | $113,070,000 |
| **2. Weld County** | $86,090,000 | $109,740,000 |
| **3. Adams County** | $77,130,000 | $95,830,000 |
| **4. El Paso County** | $71,640,000 | $86,200,000 |
| **5. Arapahoe County** | $65,410,000 | $80,790,000 |
| **6. Jefferson County** | $53,560,000 | $64,010,000 |
| **7. Larimer County** | $50,680,000 | $63,450,000 |
| **8. Mesa County** | $30,070,000 | $37,710,000 |
| **9. Douglas County** | $28,580,000 | $36,100,000 |
| **10. Boulder County** | $28,040,000 | $35,840,000 |

When downscaled to utility territory, investment needs become considerably more concentrated. The top 10 utilities by investment need (shown in Table 7) account for approximately 95% of total investment needed in Colorado, while the top utility in terms of overall investment need, Xcel Energy, makes up about 58%.

Table 7. Cumulative 2030 Investment Need for Top 10 Utility Territories in Colorado

| ***Utility*** | ***Average Case*** | ***Conservative Case*** |
|---|---|---|
| **1. Xcel Energy** | $465,850,000 | $587,050,000 |
| **2. United Power** | $84,300,000 | $108,680,000 |
| **3. Black Hills Energy** | $68,050,000 | $84,570,000 |
| **4. City of Colorado Springs** | $41,260,000 | $51,060,000 |
| **5. Holy Cross Electric Assn** | $32,300,000 | $42,610,000 |
| **6. CORE Electric Cooperative** | $24,210,000 | $30,250,000 |
| **7. Highline Electric Assn** | $17,010,000 | $23,440,000 |
| **8. Delta Montrose Electric Assn** | $10,490,000 | $13,320,000 |
| **9. Empire Electric Assn** | $10,060,000 | $12,740,000 |
| **10. K C Electric Assn** | $6,020,000 | $8,710,000 |

Despite a substantial concentration of investment needed in Colorado's investor-owned utility territories, a full one-third of the $790 million to $1 billion in required investment will be needed in Colorado's cooperative and municipal utility territories. While the median cooperative or municipal utility territory will only require $2.1 to $3.3 million in investment, at least 7 of these utility territories will require overall investment in excess of $10 million.

# Electrifying Freight Corridors

To account for freight corridor charging, the study took a different approach than the home, depot, and en-route analysis to model the supplemental charging needs for long-haul electric trucks. Since long-haul trucks do not return to the same base overnight, long-haul electric truck uptake will be enabled by the strategic geographic buildout of DC fast-charging stations configured for M/HD electric trucks along key Colorado freight routes. Thus, for this freight corridor analysis, the study models the needed investment to provide minimum-coverage charging for long-haul electric trucks along the primary freight corridors in Colorado. This approach identifies the number and illustrative locations of needed corridor charging sites along Colorado freight routes based on the assumption that minimum-coverage requires 3.5 MW or larger sites with minimum 350 kW or higher-power charging ports built at approximately 100-mile intervals[16] along Colorado freight corridors with consideration for corridor intersections. Each corridor station is defined by a buffer within one (1) mile from the highway and five (5) miles from a corridor junction (node) or twenty (20) miles from a standalone corridor site on a roadway between intersections (edge). In certain instances, corridor charging locations may overlap with en-route charging sites where M/HD charging needs exist for both short- and regional-haul operations, as well as for long-haul trucks. For a full description of the study's freight corridor electrification analysis methods, see Appendix A.

As part of this study, three (3) Electric Freight Corridor Charging Phases have been developed spanning 2023 to 2035 to establish an initial plan for a Colorado Electric Freight Corridor Charging network. Corridor selection and sequencing was provided by the Colorado Energy Office in consultation with the Colorado Department of Transportation.

Table 8. Colorado Electric Freight Corridor Charging Phases

| Phase | Years | Location / Highway |
|---|---|---|
| **One** | 2027 | Denver Area *(Near-term short- & regional-haul)* |
| **Two** | 2027 – 2030 | I-25, I-70, I-76 |
| **Three** | 2035[17] | US-40, US-50, US-85, US-160, US-287, US-385 |

The minimum-coverage corridor charging sites modeled in this analysis are initially relatively small 3.5 MW installations (when considering long-haul electric truck charging) that could accommodate either exclusively 350 kW chargers sufficient for long-duration truck charging, or a combination with very high-power (MW+) charging stations sufficient for the rapid recharging of long-haul electric trucks without the need for multi-hour dwell times. The study utilizes costs from the West Coat Clean Transit Corridor Initiative (WCCTCI) report for a 3.5 MW charging site - approximately $3.8 million. As long-haul electric truck adoption expands, this market will likely require larger sites beyond this initial 3.5 MW minimum-buildout to avoid congestion and enable charging both during drivers' mandated 10 hour break and during shorter stops. The right combination of corridor site sizing and charging station power levels for long-haul electric trucks remains an open question for industry and researchers as this nascent market continues to develop.

[16] Minimum network requirements are based on the WCCTCI Interstate 5 Corridor Final Report with flexibility to site stations along corridor junctions. Sites are no more than 120 miles and no less than 60 miles apart [49].

[17] Due to multi-year lead times for multi-megawatt high-power freight corridor charging sites, investments for many of the charging stations in this phase must be committed by 2030.

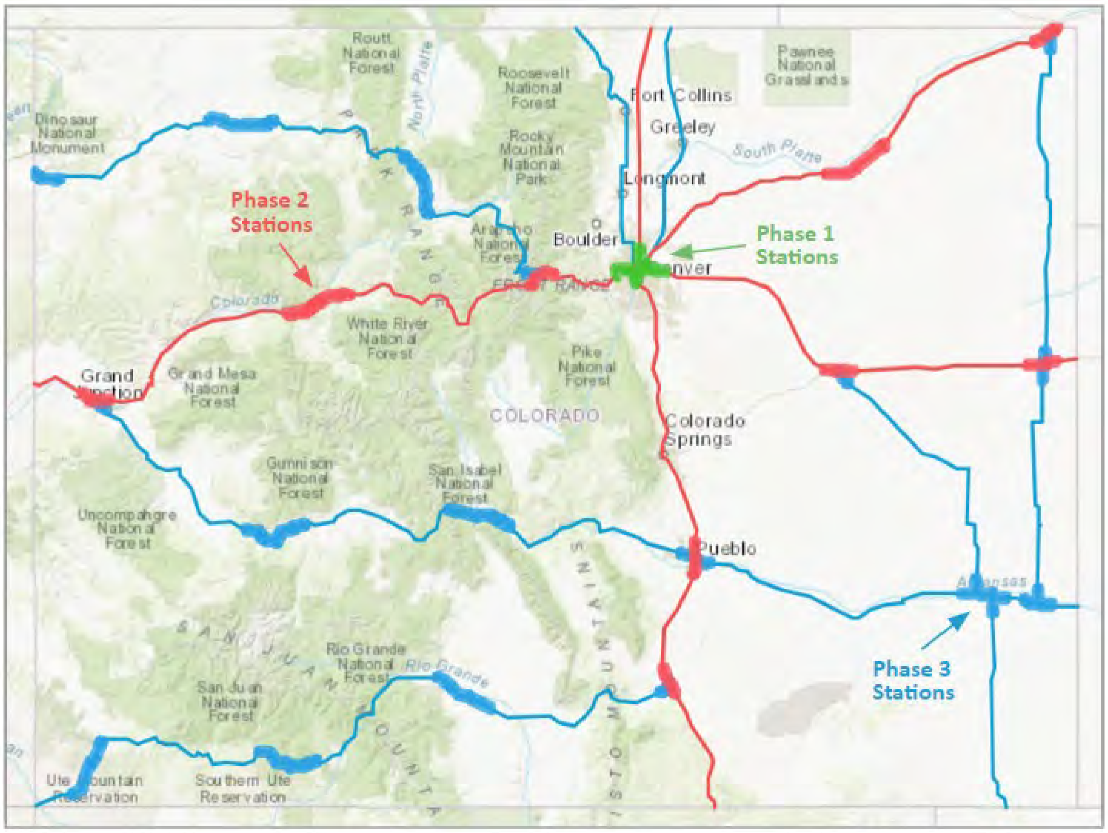
Phase one of the planned Colorado Electric Freight Corridor Charging Network consists of one (1) 3.5 MW deployment strategically distributed across one or multiple locations in the Denver area that in the near-term, will also serve as a M/HD charging hub(s) for short- and regional-haul electric truck charging needs. Phase two consists of nine (9) 3.5 MW charging sites along the I-25, I-70, and I-76 corridors. Phase three then fills out the remaining freight routes detailed in the Table above with ten (10) additional 3.5 MW corridor charging sites.

Figure 10. Installation Costs by Phase

A number of Colorado utilities can expect either one (1) or zero (0) of these M/HD corridor charging sites in their territories. However, as many as eight (8) of these sites may be located in Xcel Energy territory and four (4) other utilities may see two (2), including Highline Electric Association, Morgan County Rural Electric Association, Southeast Colorado Power Association, and United Power.

Accounting for the interstate nature of long-haul trucking, the projected locations of these freight corridor charging stations are interdependent on corridor segments that extend outside of Colorado to connect with out-of-state freight origins and destinations. See Figure 11 below for an initial map of the three (3) Electric Freight Corridor Charging Phases and Modeled Locations of Corridor Charging for Long-Haul Trucking in Colorado.

Figure 11. Modeled Locations of Corridor Charging for Long-Haul Trucking




# Current Funding Opportunities for M/HD Charging in Colorado

There are currently no funding sources dedicated exclusively to M/HD charging infrastructure development in Colorado – a funding gap the Colorado Energy Office is poised to fill with the development of its new M/HD charging infrastructure program with funding support from the state's Community Access Enterprise.

The Community Access Enterprise is estimated to have $310 million available to dedicate to clean transportation over the next 10 years with a portion of this funding specifically directed towards M/HD charging infrastructure. The state's Clean Fleet Enterprise will also have an estimated $289 million available over the next 10 years to incentivize zero-emission fleet vehicles, which although not directly for charging infrastructure, will provide complementary funding to further reduce the total cost of ownership of M/HD electric vehicle deployments in the state [11]. Colorado has also made $65 million available for electric school buses and associated charging infrastructure through *Senate Bill 22-193*, in addition to funding for electrification of the state's fleet through *SB 21-230* amongst other incentives to support zero-emission M/HD vehicle adoption [43] [44].

Xcel Energy, Colorado's largest investor-owned utility, has a remaining $48 of $110 million in funding available through its 2021-2023 Transportation Electrification Plan; however, it is uncertain how much of this funding will be used specifically for M/HD applications [45]. Xcel's 2024-2026 TEP however is likely to be larger and to have a higher degree of focus on M/HD charging. Black Hills Energy, Colorado's second IOU, is also proposing its next transportation electrification plan, although at a much smaller scale in terms of budget.

The reauthorized Section 30C federal tax credit for alternative fuel infrastructure can also fund up to 30% of charger deployment costs ($100,000 cap per charger), but this credit has a limited geographic scope to low-income and non-urban census tracts, meaning it will ultimately cover less than 30% of M/HD charging investment needs estimated by 2030 [46].

Other federal funding sources, such as VW settlement, Diesel Emission Reduction Act (DERA), and EPA Clean School Bus Program funds may also contribute to M/HD infrastructure costs for projects paired with vehicle deployments. And, additional federal funds may also be available through programs created or reauthorized by the recent Inflation Reduction Act (IRA) and Infrastructure Investment and Jobs Act (IIJA), such as the National Electric Vehicle Infrastructure (NEVI) Formula Program, Charging and Fueling Infrastructure (CFI) Discretionary Grant Program, Congestion Mitigation and Air Quality Improvement Program (CMAQ), Carbon Reduction Program, and National Highway Freight Program. At the same time, it is impossible to know how much of Colorado's needed M/HD charging infrastructure investment might be covered by funding from these programs, highlighting the importance of the state's Community Access Enterprise and the Colorado Energy Office's new M/HD charging infrastructure offering.

# Conclusion

The study's projections demonstrate that Colorado needs between $790 million and $1 billion in cumulative committed investment in M/HD charging by 2030 to meet the energy needs of M/HD electric vehicle adoption consistent with the state's Clean Truck Strategy goal of 35,000 zero-emission M/HD vehicles on the road by 2030. These amounts include a combination of state, federal, utility, private, and any other contributing funding sources. An additional $76 million in committed funding is required to build out a minimum network of long-haul focused corridor charging stations along Colorado's priority freight routes.

Notably, most of the overall costs required over the next seven years will accrue from depot-based charging installations, where the study projects most early-adopting fleets to charge their vehicles, since return-to-base operations are currently the most conducive to early market adoption due to project economics, range constraints, and charging availability. Additionally, the $210 million difference between the average and conservative scenarios illustrates how costs may increase if depot-based fleets choose to build with a more conservative operating margin, highlighting the importance of fleets right-sizing depot charging infrastructure. While a substantial fraction of this needed investment for M/HD charging should come from private sources over time, the M/HD charging market still requires policy support in the near-term to close the gap on project profitability, unlock funding from the private sector, and encourage long-term development of Colorado's M/HD electric vehicle sector, particularly while the market is still in its early stages.

# 4. Strategies for M/HD Charging Incentive Program Design

To achieve statewide climate goals and facilitate rapid adoption of zero-emission medium- and heavy-duty vehicles in Colorado, a M/HD charging incentive program must be well-designed, effectively bridge market and funding gaps, and successfully remove key hurdles to fleet electrification. In developing a M/HD vehicle infrastructure program, the Colorado Energy Office should pay close attention to a number of critical factors, such as project, applicant, and expense eligibility, funding amounts, as well as project and applicant requirements. In building on the foundation laid by California's M/HD state and utility incentive programs, Colorado has an opportunity to develop an effective incentive structure that applies best practices and lessons learned, while avoiding issues encountered by first movers. As only one of the first states in the U.S. to move into this space, Colorado too, will be setting precedent for others to follow as they design the state's M/HD infrastructure incentive program.

## Methods and Data

The analysis and conclusions presented in this chapter are informed by both findings from the prior two chapters on the *State of the Market* and Colorado's *Charging Needs Analysis*, as well as additional original qualitative analysis. Primary data collected for this chapter includes in-depth responses from a set of semi-structured interviews of funders and administrators of existing M/HD charging and vehicle incentive programs, as well as information sourced from M/HD charging program documentation.

Using this data, the study discusses alternative program designs and features, and identifies best practices. In addition, the study employs a criteria-alternative analysis that qualitatively examines the tradeoffs between competing program design features to provide CEO with a decision support tool that can inform program design decisions.

## Landscape of M/HD Charging Infrastructure Programs

Utility and government incentive programs are vital to scaling the adoption of electric M/HD vehicles and reducing charging infrastructure barriers. At the moment, only a few electric M/HD infrastructure incentive programs exist, nearly all of them managed by investor-owned utilities (IOUs) and funded by ratepayers. Several utilities noted in the table below support M/HD or fleet charging infrastructure deployment through targeted incentive programs, which complement existing public funding or fill gaps where government support does not currently exist. On the other hand, the majority of government funding for M/HD electrification so far has generally been allocated to vehicle vouchers through programs such as the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Program (HVIP) and Clean Off-Road Incentive Project (CORE) in California, New York Truck Voucher Incentive Program (NYTVIP), and New Jersey Zero-Emission Incentive Program (NJ ZIP), among a handful of others across the country. However, in 2022, California became the first state government in the United States to launch a program specifically designed to subsidize M/HD charging infrastructure, and in developing its own program, Colorado would join the small, but expanding list of leading states supporting the accelerated deployment of charging infrastructure for electric trucks.

The California Energy Commission (CEC)'s EnergIIZE (Energy Infrastructure Incentives for Zero-Emission Commercial Vehicles) program noted above is one of the only statewide offerings currently incentivizing M/HD electric vehicle charging infrastructure. EnergIIZE is therefore the most analogous program to that which CEO intends to establish and is the most pertinent in terms of direct lessons learned. Like CEO's prospective infrastructure program, EnergIIZE is funded through a state energy office and complements vehicle subsidies administered through an adjacent state agency - the California Air Resources Board (CARB)'s HVIP program. As a taxpayer-funded program, EnergIIZE must meet obligations laid out in legal statute and faces public funding constraints, akin to those likely to impact any CEO program. Similar to Colorado, the California government has robust clean energy, transportation, and environmental justice goals, and established EnergIIZE as a central means of achieving them. While the EnergIIZE program is very new, and not yet fully tested, it has already produced valuable lessons for CEO on how to structure a M/HD-focused charging infrastructure incentive program.

While California is one of the only states currently funding M/HD vehicle charging infrastructure in a standalone program, a number of utilities across the country as noted above currently manage similar initiatives. Most importantly for CEO, Xcel Energy currently administers a fleet electrification advisory program and an electric vehicle infrastructure offering across its Colorado service territory. Therefore, in designing its own state program, CEO should directly engage with Xcel (and any other CO utility that designs a similar program) to avoid duplication and to best complement existing incentives. Outside of Colorado, all major investor-owned utilities in California (Southern California Edison, Pacific Gas & Electric, and San Diego Gas & Electric) currently administer M/HD charging infrastructure programs, in addition to a small number of other utilities across the country, such as Portland General Electric (OR) and Consumers Energy (MI). Many of these utilities manage more established programs that predate EnergIIZE, which offer important lessons learned in terms of M/HD infrastructure program design. Unlike state agencies however, investor-owned utilities stand to earn a return from their investments in these programs.

Beyond the motivation of profit-seeking, state laws and regulatory bodies may compel investor-owned utilities to establish specific EV charging programs, including for M/HD vehicles. In Colorado, for example, both Xcel Energy and Black Hills Energy's electric vehicle offerings are guided by the companies' overarching transportation electrification plans, which were authorized by *SB 19-077 Electric Motor Vehicles Public Utility Services* and approved by the Colorado Public Utilities Commission (CPUC) [47].

A comprehensive table is included below highlighting the most relevant M/HD charging infrastructure programs currently active across the country as of the end of 2022. Program name, jurisdiction, year established, and a short description are provided. As depicted, nearly all existing M/HD infrastructure programs are managed through utilities and were established in just the past three years.

Table 9. M/HD Infrastructure Program Landscape

| Name | Description | Jurisdiction | Year |
|---|---|---|---|
| EnergIIZE | Supports both private and public installations of DCFC and L2 chargers to support Class 2-8 electric vehicles. Broad participant eligibility. | California Energy Commission (California) | 2022 |
| Electric Vehicle Supply Infrastructure (EVSI) | Turnkey fleet charging make-ready infrastructure (utility-owned); utility- or customer-owned electric vehicle charging equipment options. Minimum 4 charging ports or 50 kW of service. Technical advisory services as part of parallel Fleet Electrification Advisory Program. | Xcel Energy (Colorado Service Territory) | 2020 |
| Charge Ready Transport | Specific to M/HD fleets. Must acquire at least 2 M/HD EVs. No-cost, turnkey installation of utility- and customer-side make-ready up to the charger. Customer-side make-ready ownership option with rebate (80%). EV charging equipment rebates for schools / transit buses and sites in disadvantaged communities. | Southern California Edison (Southern CA, save San Diego) | 2020 |
| EV Fleet | Specific to M/HD fleets. Must acquire at least 2 M/HD EVs. No- | Pacific Gas & Electric (Northern CA) | 2019 |

| Name | Description | Jurisdiction | Year |
|---|---|---|---|
| | cost utility-side infrastructure from line to the meter. Customer responsible for panel and charger. EV charging equipment rebates for school / transit buses and sites in disadvantaged communities. | | |
| Power Your Drive for Fleets | Specific to M/HD fleets. Must acquire at least 2 M/HD EVs. No-cost, turnkey installation of utility- and customer-side make-ready up to the charger. Customer-side make-ready ownership option with rebate (80%). EV charging equipment rebates for school / transit buses and sites in disadvantaged communities. | San Diego Gas & Electric (San Diego, CA) | 2020 |
| Commercial EV Program | Subsidies for Class 1-8 commercial vehicles. Commercial EV charging equipment rebates for L2 ($4,500), public DCFC ($30K), and school bus DCFC ($15K). Incentives to support panel ($1K) and transformer upgrades ($5K). | Sacramento Municipal Utility District | 2020 |
| Fleet Partners Program | No-cost fleet advisory services. Turnkey charging infrastructure design / construction and up to $750K custom make-ready incentive. EV charging equipment rebates for L2 ($1K) and DCFC ($25K). To qualify, must take 70 kW or more of new load. | Portland General Electric (Greater Portland, OR) | 2021 |
| Commercial EV Charging Station Incentives | Fleet vehicle EV charging equipment rebates for L2 ($5K) or DCFC ($40K). Not specific to M/HD vehicles. Must install at least 2 L2 or 1 DCFC. | NV Energy (Majority of Nevada) | 2020 |
| Charging Forward eFleets | No-cost fleet advisory service. Fleet vehicle EV charging equipment rebates for L2 ($2,500) or DCFC ($70K). Not specific to | DTE Energy (Detroit & Eastern Michigan) | 2021 |

| Name | Description | Jurisdiction | Year |
|---|---|---|---|
| | M/HD vehicles. Customer will own EV charging equipment. | | |
| PowerMI Fleet | M/HD fleet eligibility. Fleet electrification assessment. No-cost, utility-owned make-ready upgrades to the meter. L2 ($5K) and DCFC EV charging equipment rebates ($35K). | Consumers Energy (Most of Michigan, outside of East Michigan and Detroit) | 2021 |

# Program Design Considerations

In developing a M/HD infrastructure incentive program, CEO will need to carefully weigh several program design considerations, such as eligibility, program requirements, vehicle purchase requirements, interagency engagement, and existing incentive coordination, among others. Existing programs, such as EnergIIZE and utility offerings, provide a valuable foundation on which to design a new program in a Colorado-specific context and on a more limited budget. This section evaluates the numerous design factors CEO must consider when developing its M/HD charging infrastructure program. This analysis will paint the landscape of possibilities, extract lessons learned from existing incentive programs, and provide a suggested course of action.

## Eligibility

Eligibility is a basic component of any incentive program, providing filters to allocate program funding in a targeted fashion. For the design of Colorado's M/HD infrastructure program, eligibility breaks down along three important dimensions: project eligibility, applicant eligibility, and expense eligibility, which define the who and what of potential funding recipients. Limiting eligibility allows the incentive administrator to channel finite funding towards applications that best suit program goals. However, if targeted too narrowly, eligibility criteria may inadvertently disqualify otherwise beneficial uses or applicant classes.

At the most basic level, eligibility requirements can strictly exclude one or more projects, applicants, or expense types from receiving program funding. However, more complex program designs subdivide funding into buckets, lanes, or carve-outs, which match to specific or set-aside budgets.

A funding lane or bucket creates subprograms for different project, applicant, or expense categories (or combinations thereof) within the parent program. This allows the program administrator to support a diversity of project types while reducing risk of a single project or applicant type dominating program subscriptions. Of course, this practice requires program administrators to determine their funding priorities (and to consider likely demand) and then to allocate funding to each lane or bucket accordingly.

Carve-outs or set-asides differ from funding lanes or buckets in that they *reserve* part of a program budget for a particular project, applicant, or expense type, rather than creating a separate funding amount. This means that a carve-out specifies a minimum funding amount for prioritized eligibility categories, and an effective maximum for those categories outside the set-aside funding. This practice allows the funder to ensure a minimum amount of funding goes to a prioritized applicant, project, or expense type without imposing a cap.

Carve-outs are most often used to ensure a project type or applicant class receives a share of the program funding that they might not otherwise be able to secure in open competition for grant funding. Typical examples include equity-based carve-outs for applicants or projects that meet specific equity qualifications. For example, M/HD make-ready infrastructure incentive programs managed across all three California investor-owned utilities require a specific minimum percentage of funds to be spent in designated *disadvantaged communities*.

### Project Eligibility

Project eligibility defines the types of M/HD charging projects that qualify for funding and ultimately shapes how the program performs with respect to its goals.

There are two fundamental types of M/HD charging projects:

- Private charging equipment and infrastructure that is reserved for single fleet or operator use
- Public or semi-public charging that is shared across multiple fleets or operators

Private charging projects are the most common type of M/HD charging project to-date. They typically involve installing chargers in areas where a single operator has access, such as at a truck depot or freight facility. These projects are usually associated with a specific vehicle or fleet of vehicles. Public or semi-public charging projects, on the other hand, include several subtypes, such as third-party charging depots, truck parking, en-route charging, as well as corridor-focused, high-power charging locations. These types of projects are not necessarily tied to the deployment of a specific vehicle or fleet and are typically led by a charging service provider rather than a fleet operator. Project eligibility for the M/HD program may be permissive and allow all project types. It also can restrict funding to a single type, or selectively exclude other projects. Alternatively, projects of different types might form the basis for funding buckets or set-asides.

The current M/HD charging market is primarily focused on deploying private charging projects. These projects match the return-to-base operations most conducive to early market adoption and are therefore likely to represent the majority of viable projects in the next several years. However, development of public and semi-public, high-power charging networks suitable to quickly recharge large vehicles en-route is advancing on the U.S. West Coast and in Europe. Early market entrants in this space indicate that available incentive funding is a major factor in their market expansion decisions.

Notably, lack of access to public charging accessible by M/HD vehicles serves as a primary market barrier for truck electrification. This is particularly true for those vehicles without return-to-base operations, or for fleets with difficult to navigate site ownership issues, such as those who lease their depots, but may otherwise have operations compatible with early market electric M/HD vehicle deployments. Additionally, access to offsite charging may be an enabling factor for some fleets that already have charging capabilities at a depot if this offsite charging can support occasional operations that exceed day-to-day vehicle ranges. The development of public or semi-public M/HD vehicle charging should therefore be perceived as a potential enabler for accelerating electric M/HD vehicle adoption.

In California, EnergIIZE provides funding opportunities for both private fleet charging (Class 2b and above), as well as for public M/HD charging installations across four different funding lanes.[18] California has committed to decarbonizing all M/HD vehicles by 2045 and adopted the Advanced Clean Trucks rule. To meet these goals, the state has therefore sought to support both private and public fleet charging projects to best shore up gaps where the private sector will be slow to act.

In contrast, utility funding programs have mainly focused on private charging models for dedicated customers. For example, Xcel Energy's EVSI incentive program and Fleet Electrification Advisory Program (FEAP) pair advisory services with turnkey infrastructure support for private fleet customers at their place of business. Meanwhile, Xcel has been approved to install and own just 12 public DCFC stations to-date and these installations are not specific to M/HD vehicles. Utility interviewees explain that they are hesitant to invest in public charging without certainty of usage and assurances that investments in public infrastructure will generate additional revenue and increase electricity sales. Exceptions to this trend include San Diego Gas & Electric and Portland General Electric, both of which are investing in public charging infrastructure for M/HD electric vehicles through their San Ysidro Port of Entry and Electric Island projects, respectively.

[18] The EnergIIZE funding lanes are as follows: 1) EV Fast Track Lane provides funding to those who have already purchased an electric M/HD vehicle or can furnish a purchase order, 2) EV Jump Start Funding Lane supports fleets operating in disadvantaged communities, or those who identify as a small business or an underrepresented demographic, 3) EV Public Charging Station Funding Lane, and 4) Hydrogen Funding Lane.

## Applicant Eligibility

Applicant eligibility defines the applicant classes who can secure funding through the program. Like project eligibility, the choice of which entities or organizations can participate is consequential to program outcomes and warrants specific attention. Important considerations for the M/HD charging program include:

- Whether the applicant owns or operates M/HD vehicles or is a third-party charging supplier
- Fleet size
- Financial capacity of the organization
- Whether the applicant organization is an underrepresented or small business
- Whether the fleet is domiciled or operates primarily in a disproportionately impacted community
- Whether the applicant is a privately or publicly owned organization

Whether or not third-parties are allowed to engage in the program will have a substantial impact on program outcomes. For instance, disallowing third-parties in effect excludes any public or semi-public charging projects, and also limits opportunities for private charger installations funded by charging-as-a-service providers or logistics facility owners.

Larger companies with high revenue and easy access to capital are most likely to be the first movers in private sector M/HD vehicle electrification and will therefore represent a large fraction of early M/HD charging market participants. However, these organizations are also least likely to be in a position where incentives are critical for M/HD electrification. Limiting funding for private sector eligibility through a maximum annual revenue limit can improve the efficiency and additionality of a program. In doing so, program designers can target funding at firms where additional financial support is more likely to be the deciding factor in whether they adopt electric M/HD vehicles and associated infrastructure. For example, Southern California Edison's (SCE) Charge Ready Transport program incorporates this feature in its M/HD EV charging station rebate structure, where only companies not on the Fortune® 1000 list are eligible for this rebate.

According to the *Colorado M/HD Vehicle Study*, public fleets make up about half of the vehicles in the 100 largest M/HD fleets in the state [15]. However, as a result of public commitments, government fleets are also more likely to electrify, so providing them access to funding may crowd out private fleet participation to the detriment of program outcomes.

California's EnergIIZE program supports a number of specified applicant categories, with a distinct focus on equity, project readiness, school buses, and public charging deployment. Any specific carve-out or decision surrounding applicant prioritization is made to best achieve goals or binding commitments enacted by state government. For project readiness specific to private fleet charging, the EnergIIZE Fast Track Lane targets commercial fleets and independent owner-operators who already own M/HD EVs or who have existing purchase orders. In doing so, the state intends to best align vehicle procurement and infrastructure deployment timelines, as well as move those most ready for electrification through the process as fast as possible. In prioritizing those fleets with acquired or ordered M/HD electric vehicles, the state will help to mitigate scenarios in which fleets are forced to sit vehicles in lots without access to onsite charging.

EnergIIZE also puts a significant emphasis on equity through prioritized deployments in disadvantaged communities and support for minority-owned fleets, dedicating an entire funding stream, the EV Jump Start Lane, just to these applicants. As part of the state's 2021-2022 Clean Transportation Investment Plan, the California Energy Commission committed to investing 50% of all clean transportation funds to support disadvantaged communities. In line with this objective, CEC has allocated 60% of EnergIIZE funds to equity-focused applicants or projects benefiting disadvantaged communities, as defined by the CalEnviroScreen Tool (geography-based).

For public charging, EnergIIZE remains relatively flexible, but is intended to support public charging developers and operators, including offsite "as-a-service providers," that can demonstrate project demand. According to interviewees, CEC is focused on ensuring these projects will see sufficient levels of utilization. In investing in public charging while soliciting information from applicants to substantiate proven demand, CEC seeks to de-risk these projects for private companies and to develop an emergent market.

Industry and stakeholder interviewees frequently mentioned the importance of specifically targeting funding to rural communities, low-income communities, and small fleet operators, especially those in territories served by rural electric cooperatives or municipal utilities. Equity in charger placement across the state, and therefore choice of applicants, was of critical importance to many interview participants. Moreover, interviewees called for expanding applicant eligibility beyond just entities with direct vehicle ownership, and to provide funding opportunities to the organization best positioned to manage and install charging infrastructure (to include "as-a-service" providers). This point was of particular importance when discussing public infrastructure funding.

### Expense Eligibility

Weighing what is eligible for cost coverage or reimbursement is a critical component of program design. This is a broad category of considerations that covers both the parameters for equipment eligibility, such as EV charging hardware type, power rating, certification, and warranties, in addition to the broad array of expenses that may be incurred by a M/HD charging project. These expenses may include:

- Electrical and construction costs necessary to install chargers
- Soft costs, such as site design, permitting, labor, and installation

- Other construction costs, such as supporting structures, site reconfiguration costs
- Distributed energy resources
- Energy management software and equipment
- Electrical capacity upgrades
- One-time software / networking fees
- Upfront warranty costs
- Future proofing costs

Expanding the scope of eligible costs can make more projects financially viable, but it will also raise the average cost per installed charger. Therefore, instituting a funding cap per charger is one way to limit otherwise uncontrolled funding outlays.

Some associated project expenses, such as the installation cost of the supporting electrical infrastructure and related soft costs should be expected for any charging program. However, these costs may vary widely depending on site-specific attributes and utility program offerings. Other expenses, such as construction costs to reconfigure space and/or accommodate chargers, or costs to augment electrical capacity, will not be necessary for all projects. While some utility-side capacity expansion will be required for most M/HD charging projects, investor-owned utility customers may have some or all of these costs covered, while customers of municipal or cooperative utilities will not.

Future proofing is another expense category for reimbursement consideration when it comes to program design. Unlike other cost categories that will impact immediate charger deployment, future proofing means sizing infrastructure to accommodate expected future needs rather than current needs. While such installations will be oversized and more costly in the near-term than what is needed to match current charging needs, consolidating construction enables economies of scale, spreads fixed costs across more chargers, and reduces site disruption, all of which will minimize costs and project timelines in the long run. At the same time, applying funding budgets to allow for future proofing requires care to ensure that money spent by the program eventually yields additional charger deployment.

EnergIIZE supports expenses related to demand mitigation software, make-ready infrastructure (switchgear, panel upgrades, wiring, meters), and EV charging hardware (L2 and DCFC) for private fleet charging. In providing funding for behind-the-fence charging, CEC can support needs-based charging infrastructure for individual fleets to cover a diverse range of use-cases, such as refuse trucks or last-mile delivery. To further ease the burden of electrification, equity-qualified applicants are also entitled to additional incentives (adders), increasing their maximum eligible cost coverage from the lesser of $500,000 or 50% of eligible project costs to $750,000 or 75% of eligible project costs. For public charging, CEC intends specifically to support corridor and en-route opportunity charging with future proofing in mind, requiring minimum installation of high-power 150 kW DCFC and encouraging developers to install at least one stub-out for a 350 kW DCFC.

Utilities across the country support a diverse array of cost coverage options related to EV charging, each with their own ownership models and service offerings based on internal goals, program budgets, business models, and regulatory requirements. In certain cases, utility programs cover some or most make-ready infrastructure costs for both L2 and DCFC, usually up to, but not including the charging hardware itself. Utilities may also offer no-cost fleet advisory services to help guide fleet owners and operators as they move through the electrification process, assigning a single point of contact to support projects with charging assessments, site designs, and even vendor identification. Interviewees noted that these services are especially valuable to smaller fleets, rural communities, and fleets in disadvantaged areas who have fewer resources and require more support; however, these customers are also less likely to have access to these types of programs if they are not located in an investor-owned utility territory, where most of these program offerings are concentrated. Interview data reveals that fleets in rural Colorado should therefore be primary targets of advisory, education, and incentive offerings, given that most will be unable to take advantage of Xcel Energy's EV charging services.

In certain cases, for instance with SCE and SDG&E, investor-owned utilities provide fully turnkey M/HD charging infrastructure where the company covers most or all of the cost of both utility- and customer-side make-ready. On the other hand, PG&E in California covers utility-side make-ready infrastructure from the line to the meter, with customers on the hook for the customer-side cost of the panel / switchgear and EV charging hardware. In cases where customer-side make-ready is considered a covered cost, the utility may offer a separate customer buildout option with a rebate to offset a certain percentage of these expenses, as are options provided by SCE and SDG&E. In these instances, the customer-side rebate option provides flexibility to the customer when it comes to site configuration and construction, as well as the opportunity to incorporate distributed energy resources. In addition to make-ready, some utilities also offer a rebate for charging equipment for eligible entities, such as for school and transit buses or sites in disadvantaged communities in California, or for low-income and high emission community customers in the case of Xcel Energy. In other scenarios, utilities like Portland General Electric will cover make-ready infrastructure up to the charger, while then also widely offering all program participants the option to apply for rebates for utility-qualified and networked L2 and DCFC. Beyond make-ready support, utilities like Black Hills Energy, NV Energy, and DTE Energy may strictly provide EV charging hardware rebates (L2 and/or DCFC) in the absence of direct infrastructure offerings. Generally, across utility programs, customers are responsible for purchasing, installing, operating, and maintaining their own EV charging hardware, though some utilities, like Xcel Energy, offer a separate option to install and maintain charging hardware for a monthly fee.

According to interview data, make-ready infrastructure levies the greatest cost burden and variability on fleets, so CEO should prioritize a program that offers eligibility for lower-cost installation and high-value incentives for infrastructure deployment. Interviewees further demonstrated interest in expanding cost coverage to include expenses beyond EV charging equipment and make-ready to additionally include labor, installation, and other soft costs, as well as any amenities associated with public charging. Interview participants also frequently mentioned the importance of distributed energy resources in mitigating electricity costs and improving resilience, and would therefore seek cost coverage (incentive adders) for the deployment of onsite solar and storage.

## Funding

Incentive design is an exercise in determining how to allocate funding in a way that best suits program goals. Eligibility considerations determine allocation on the macro-scale. Equally important are micro-scale decisions about how funding is allocated to projects and applicants. Funding amount considerations include relative and absolute maximum funding amounts per funded charger, per project or site, and per applicant.

Program funding is finite, which means there is a tradeoff between program generosity and the number of projects a program can fund. Determining an optimal amount of funding to be allocated to projects is challenging. In theory, the goal is to only include enough funding to make a project economically viable, as any additional support does not lead to incremental project adoption and any fewer funds will not lead to project investment at all. Complicating matters for private charging projects are that decisions to proceed with a charging project are dependent on the viability of not just the chargers, but also the entire cost of switching to electric vehicles. This means the funding for chargers will interact with any funding for vehicles applicants may receive, including for example, federal funding, like the tax credit for Qualified Commercial Clean Vehicles (known as 45W tax credits from the Inflation Reduction Act), as well as state tax credits, and funding from Colorado's Clean Fleet Enterprise.

Project costs also vary widely depending on the use-case. Lower-cost L2 AC charging is suitable for many M/HD applications despite its lower power rating, so long as the vehicle is stationary long enough each day to recover its daily energy needs. Higher-power DC chargers necessary for higher-energy-need depot applications and en-route and/or corridor public charging cost substantially more. Table 10 shows recent average cost ranges for installation of depot and public charging sites for M/HD vehicles. Costs are estimated on a per-port basis and do not include utility-side costs.

Table 10. Project Cost Ranges from INSITE Model

| Project Type | Charger (Hardware) Cost | Installation Cost |
|---|---|---|
| 48 – 80 amp AC Depot Charging | $2,000 – $6,000 | $4,000 – $20,000 |
| 50 – 150 kW DC Depot Charging | $40,000 – $110,000 | $32,000 – $54,000 |
| 150 – 350 kW DC Public Charging | $110,000 – $210,000 | $33,000 – $45,000 |
| 350 kW – 2 MW DC M/HD Corridor Charging | $210,000 – $600,000 | $85,000 – $130,000 |

The high costs for many M/HD charging projects will easily strain program budgets if cost coverage for a M/HD program mirrors the 80% maximums common among light-duty-focused incentive offerings. Moreover, depot charging projects may include many more charging stations of much higher power than a typical light-duty charging project, further pushing up potential overall project costs. One option to limit this risk is to institute a funding cap per charger, as is the case with CEO's Charge Ahead Colorado program, which establishes a maximum overall funding amount based on the number and type of chargers.

In California, the EnergIIZE program covers a baseline 50% of eligible costs and caps per active site project funding at $500,000, where a site is considered active until it is commissioned and fully operational. An applicant may then apply again for the same site once it is declared inactive. These project cost maximums are set against an estimated annual $50 million program budget and were designed with the intent that the state will substantially increase funding for M/HD charging infrastructure over the next several years.

On the utility side, most funding programs cover substantially more project costs, often paying for make-ready infrastructure in its entirety. For example, SoCal Edison's M/HD make-ready incentive program will cover all costs for utility-side infrastructure and either all, or up to 80% of customer-side infrastructure if the customer were to select the customer-built option. Interviewees relayed that these make-ready program allowances almost always cover all or the majority of non-EV charging hardware costs. Other utility programs, like those managed by NV Energy or DTE Energy, also offer a range of funding amounts for EV charging equipment rebates, rather than for make-ready infrastructure, spanning from $1,000 to $5,000 per port for L2 chargers, covering a maximum of 75% of hardware costs. For DCFC, these programs also offer between $25,000 and $75,000 per charger, generally covering up to 50% of hardware costs.

Investor-owned utilities generally earn a rate of return on every dollar they spend on charging programs, so they are not incentivized towards thrift, nor are their funding amounts meant to efficiently distribute limited funds in the same way a government program should. EnergIIZE supplies a better model for funding amounts and limits.

However, the sheer size of California's program allows it more flexibility to fund high-dollar projects. With a much smaller annual budget, Colorado's M/HD program funding would be swamped if just a few projects hit EnergIIZE's $500,000 per active site funding limit.

## Interaction with Other Funding Sources

Applicants are likely to have access to other charging infrastructure funding sources, such as federal offerings, including the section 30C Alternative Fuel Vehicle Refueling Property Credit, and utility program funding detailed above. Since more than one funding source may be available, it is important for CEO to consider a minimum applicant cost share for projects. It is equally important to carefully decide how the program might stack / combine with those other funding sources.

Minimum cost share requirements ensure that project applicants are contributing at least a bare minimum amount of their own capital to the project budget. By forcing the applicant to cover a minimum percentage of a project, minimum cost shares can enforce cost discipline and ensure that project applicants have a vested interest in the success of the deployment and usage of the funded chargers.

Cost share minimums are reasonably common across other incentive funding program designs (such as in the federal NEVI Formula Program). Notably, EnergIIZE does not enforce a cost share minimum and only stipulates that applicants cannot be reimbursed more funding than was spent on authorized expenditures. However, EnergIIZE does include a stipulation that it will not pay any make-ready infrastructure costs for applicants in IOU territories that have make-ready programs available, ensuring that EnergIIZE program funds are only spent on costs that the IOU programs do not cover.

## Equity Adders

In addition to considerations for appropriate funding amounts, funding parameters also provide another lever with which to achieve specific desired outcomes. Favored project types or applicant categories can receive a funding adder or might face relaxed cost share requirements. These levers are most valuable to support equity goals by providing additional funding (or ability to stack funding) for applicants or projects that may face steeper capital constraints than the typical applicant.

EnergIIZE equity-focused private fleet applicants receive a cost adder, increasing funding to up to $750,000, and covering up to 75% of total hardware, software, and other eligible soft costs in comparison to the standard offering of up to $500,000 and 50%. In offering additional cost coverage and a higher incentive cap for equity lane applicants, the government seeks to further de-risk these projects for those least likely to electrify without external support and to make good on their political commitments to support disadvantaged communities.

## Project Requirements

While funding and eligibility considerations are geared towards the targeted allocation of overall funding, project requirements are aimed at ensuring that funded projects will be successful and deliver benefits as expected once the funding has been disbursed.

Many best practices from light-duty infrastructure programs can be adopted directly for M/HD programs, including equipment warranty and certification requirements, network interoperability requirements, and other basic assurances that program funds will be spent on lasting investments. However, other requirements from light-duty programs may not translate as directly to M/HD projects.

For example, reliability requirements are becoming a common feature of light-duty charging infrastructure programs. However, trucking industry sources interviewed for this project were critical of reliability requirements for depot-based charging because the infrastructure users would also be responsible for ensuring reliability, and as a result, they are motivated to keep their chargers operating reliably. In this case, reporting on reliability metrics may incur costs on funding recipients without any meaningful improvements to charger reliability. Other requirements, such as accessible design and signage requirements may also not be germane to private charging installations for single fleets. However, public and shared M/HD charging is more similar to public light-duty projects and will still benefit from these requirements, though restricted fleet access may be desirable for some public M/HD charging to limit access by light-duty personal vehicles.

In addition, data sharing and reporting requirements are also common in light-duty charging programs. Trucking and charging service providers interviewed for this project expressed concerns about sharing certain data due to the sensitive nature of truck movement and operations. They cautioned that data requirements could be a potential obstacle for some projects. However, administrators of existing M/HD funding programs were confident the prospect of financial support outweighs concerns about competitive information when potential applicants consider incentive programs. Regardless, program administrators should be careful to only collect data that is necessary and useful and at an appropriate level of aggregation to limit reporting burdens and reduce privacy concerns.

Another common light-duty charging infrastructure program best practice that may require some adapting to M/HD applications is operating length requirements. Some industry members interviewed for this project indicated concern that long operation length requirements as implemented by some utility programs, such as the California IOU offerings and Xcel Energy's EVSI incentive (which are upwards of 10-year durations), do not work well with the typical 5- to 7-year commercial lease length.

Two requirements that are not necessarily common in light-duty program applications, but are good practice for M/HD programs are landowner authorization requirements and documented utility communication. Commercial fleet applicants are likely to lease their facilities, meaning that clearing potential landlord concerns early is an easy filter for project success. In addition, the high-power requirements of M/HD charging programs make utilities key players in charger deployment. Including requirements for potential applicants to speak to their utility first will prevent surprises later in the process. This will also ensure that funding is not tied up while dedicated to projects that are ultimately non-viable. California's EnergIIZE program includes these two requirements for its projects.

## Vehicle Purchase Requirements

While not a feature of light-duty charging programs, vehicle purchase requirements are common among M/HD infrastructure funding programs. Tying funding directly to the purchase of a specific M/HD vehicle is a blunt mechanism to ensure utilization of program-funded chargers. Additionally, requiring a purchase order up front gives reasonable assurance that an applicant will proceed to project completion. This mechanism is only pertinent to non-shared chargers, and if applied strictly, will exclude public and semi-public projects. Additionally, strict requirements may also exclude charging-as-a-service providers or other leasing arrangements. Provisions should be made to allow payment to third-party charging providers if they demonstrate that chargers will be used for specific customer vehicles. Several charging providers interviewed for this project indicated that utility programs were closed off to them due to vehicle purchase requirements.

Multiple program administrators and industry sources interviewed for this study indicated that problems arise with vehicle purchase requirements when timelines for vehicle purchases and infrastructure deployment do not align. This is most problematic when applicants take delivery of vehicles before infrastructure installation because that leaves vehicles stranded without an option to charge. Infrastructure builds and utility interconnection for private depots can take as long as two years to complete, meaning that if a signed vehicle purchase order is required at the beginning of the project, there is substantial risk that vehicle delivery will precede powered chargers onsite.

In the case of public chargers, other provisions are required to reasonably ensure use of funded chargers. It's practically difficult to project demand for public M/HD chargers that are not attached to a specific vehicle, particularly in the early market. While proximity to truck traffic is a basic requirement for charging demand, it does not necessarily lead to utilization. California's EnergIIZE program requires projects applying for public charging funding to demonstrate demand for charging power they propose to install, as well as documentation that the charging location serves corridor charging. In addition to EnergIIZE, both San Diego Gas and Electric and Portland General Electric have committed funding for public M/HD charging. Portland General Electric is pursuing a corridor-based approach to electrify freight routes in its service territory. Likewise, San Diego Gas and Electric has authorized funding to support a public M/HD charging project at a truck stop near the San Ysidro Port of Entry where truck traffic is high.

## Selecting Projects

The project selection process offers another opportunity to filter and fine-tune funding awards by assigning higher weights to projects with desirable attributes. Of course, relative to a first-come-first-served approach, a competitive selection process can also impose more administrative burden on both the administrator and grant applicant depending on how involved the selection process is. However, a competitive selection process can also weigh the cost-competitiveness of individual projects, which can encourage greater cost discipline on the part of applicants.

The competitive lanes of the EnergIIZE program subject applicants to a scoring process that weights geographic equity indicators (disadvantaged community, low-income community, and Tribal community) up to 50% of the project's overall score. For projects requesting funding of more than $150,000, applicants must also submit project narratives describing community support and benefits for the community. These narratives are assessed qualitatively and contribute to nearly one-third of the score. The remaining weight is assigned to having a complete program application.

A scored application process can replicate or enhance the effect of carve-outs or targeted funding for equity-focused investments by weighting projects or applicants higher (like how EnergIIZE is structured). The application process also provides opportunities for project level evaluation that would be too complicated or unwieldy to implement through the overall program design. A good example of this is project benefit estimation. While it would be challenging to incorporate a benefit requirement into the overall program design, the selection process can consider expected benefits (such as projected GHG emissions reductions) as a weighting factor in funding decisions. EnergIIZE adopts a loose benefit selection criterion, but stops short of asking applicants to quantify emissions benefits.

## Interagency Alignment and Other Best Practices

CEO's M/HD charging program will coincide with a vehicle and technology funding program from the Clean Fleet Enterprise administered by the Colorado Department of Public Health and the Environment (CDPHE). Many program participants will both need to purchase a vehicle and install charging infrastructure, and will therefore likely apply to both programs across the two agencies. This creates both an opportunity for efficiency and a coordination challenge. CEO's relationship to CDPHE mirrors closely the relationship in California between CEC's EnergIIZE program and CARB's HVIP. Staff from both government agencies and the implementer of both programs, CALSTART, noted that coordination was an administrative challenge. However, CALSTART also noted several best practices that emerged from this program collaboration, including:

- Frequent coordination meetings
- Sharing data and information
- Establishing or adopting common definitions for applicant categories, equity metrics, and other relevant criteria

California's experience is borne from integrating the new EnergIIZE M/HD charging infrastructure program into the long-standing HVIP vehicle incentive program. Because Colorado's programs are starting at a similar time, there may be more opportunities for upfront and ongoing collaboration, including the potential for streamlined applications, which can reduce application costs and streamline the process for prospective recipients.

# Program Recommendations

As demonstrated in sections above, there is both considerable nuance and variation in possible approaches to deploying a charging incentive program for electric M/HD vehicles in Colorado. While the main goal of this analysis is to provide CEO with an effective decision-making guide, in this section, we identify what we expect to be the most consequential decision points and provide high-level program recommendations.

## Evaluating Program Design Tradeoffs

There are substantial tradeoffs at play with so many design choices. Where there are substantial tradeoffs, we evaluate them across four criteria that assess: efficacy, efficiency, equity, and administrative feasibility. This evaluation provides high-level qualitative assessments of each program design decision on criteria, measured on a "very high" to "very low" scale.

Box 1: Evaluative Criteria

Efficacy Impact on program goals / performance metrics, such as: GHG / air quality emissions reductions, number of electric vehicles supported, number of chargers deployed, and charging capacity deployed. Low efficacy indicates program design is unlikely to spur deployment of charging infrastructure, whereas high efficacy indicates the opposite.

Efficiency Related to cost effectiveness, this criterion is concerned with expected economic efficiency of program designs. Higher efficiency indicates a program design that reduces free-riding from applicants that otherwise did not need funding to implement the project; and thus, wastes fewer resources on projects that would have occurred even without funding, whereas low efficiency indicates the opposite.

Equity Effect on distributional impact of the program across several dimensions: Environmental burdens, urban vs rural funding distribution, fleet (and company) size distribution. High equity scores indicate a design feature is equity improving (either through addressing historical inequities or ensuring more equitable access to M/HD infrastructure funding for all Colorado M/HD fleets). Low equity scores indicate higher likelihood of unequal access to funding and investment.

Administrative Impact This criterion evaluates the administrative burdens and costs (both on CEO and applicants) that are caused by program design specifics. High administrative feasibility indicates lower administrative burdens, lower application costs, lower use of CEO staff capacity, and fewer barriers to applicant participation.

## Applicant Eligibility

**We recommend a permissive stance on applicant eligibility to encourage innovation and allow for a broad range of potential applicants.** Due to the considerable uncertainty around how the market for M/HD charging will develop in the near- and longer-term, we cannot confidently evaluate tradeoffs between approaches. There appears to be substantial room for innovation across business models, which lends itself to broad applicability in the near-term. However, CEO should monitor program outcomes and awardees, and adjust as necessary if it becomes apparent that certain business models do not perform well or if a small number of applicant types dominate program uptake at the expense of supporting broader market adoption or advancing equity goals.

**We also recommend that CEO limit program funding opportunities to commercial or fleet-oriented applicants.** While technically medium-duty, many Class 2b and 3 vehicles are personal vehicles and so, they have use-cases much more similar to personal light-duty vehicles than their fleet-owned and commercial counterparts. While electrification of these vehicles is desirable, such efforts are best continued through existing light-duty focused funding programs.

## Public or Semi-Public M/HD Charging Eligibility

It is apparent from the trajectory of the early market that CEO's M/HD charging program should include funding for private charger deployment. Dedicated charging is the most mature model for deploying electric M/HD vehicles. The value of providing funding for public charging, particularly the expensive high-power charging necessary to rapidly charge heavy-duty vehicles, is much less certain.

Because private or otherwise dedicated charging projects are attached to the deployment of a vehicle, there is a more direct line between the deployment of a private charger project and program objectives for electric M/HD vehicle deployment. In addition, as private vehicle charging deployments are typically less expensive on a per-charger basis, limited funds can cover more charger deployments. With public charging projects, public charger utilization and its effect on M/HD vehicle deployment is neither as direct nor as certain, making public M/HD charging much riskier an investment from a program efficacy standpoint. Moreover, early-market cost efficacy is also likely much lower for public shared

M/HD charging. However, public charging will eventually be necessary to achieve the deep M/HD electrification envisioned by Colorado's policy goals, and early policy support for the sector may enable faster market development of that charging segment.

While limiting incentive funding to private fleet chargers is likely to mean the program will fund a greater number of chargers, it does not necessarily guarantee that funds will be spent more efficiently. Funding directed at private charging projects will certainly induce additional M/HD charger deployment, but because these projects are more likely to proceed regardless of funding in comparison to public charging projects, there is also a greater chance of funding deployments that would have occurred without incentives (or with less funding). This would signify some funding being spent without the benefit of incentivizing a new project that otherwise would not have occurred, although such funding may still result in a project being deployed earlier or in Colorado instead of in another state. At the same time, since public charging is riskier and utilization is more uncertain, it is also more dependent on incentives for viability, meaning that on average, funds spent on public M/HD charging will more likely be the deciding factor in determining project feasibility.

From an equity standpoint, public M/HD charging infrastructure has the advantage of enabling the electrification of fleets and independent owner-operators that do not have the resources or space to charge their vehicles where they are parked. Public (or semi-public offsite) charging may therefore enable greater electrification for underrepresented small businesses and independently owned commercial vehicles in low-income communities. Conversely, limiting incentive funding to private, dedicated fleet charging is more likely to concentrate the benefits of the funding program with better-resourced fleets, particularly if equity specific program designs and scoring mechanisms are not incorporated.

Administratively, it is much simpler to manage a program that only supports private, dedicated fleet charging, as it allows program staff to focus on only a single charging project mode, avoids complicated evaluation of project viability without guaranteed utilization, and reduces application complexity.

Table 11. Criteria-Alternative Matrix for Public Charging Eligibility

| | **Efficacy** | **Efficiency** | **Equity** | **Admin Feasibility** |
|---|---|---|---|---|
| Depot Charging Projects Only | Very High | Moderate | Moderate | Very High |
| Public Charging Eligible | High | Very High | High | Moderate |

**We suggest that CEO establish a limited funding pool for public and semi-public M/HD charging in Colorado to attract early investment.** While the high-level scoring for a depot-only charging program has advantages, the average difference between programs is small. In the near-term, ensuring that the majority of the funding granted through the program is targeted to depot projects is advisable, given their high efficacy on near-term electric M/HD vehicle adoption. However, allocating a smaller pot of the program funding also to public / semi-public projects could return important benefits in market development outcomes and equity that might otherwise be missed or delayed if the entire program budget is initially dedicated solely to private depot projects. Moreover, the early-market focus on depot charging will likely give way to a mid-market situation where the depot charging market has matured to the point where subsidies are less critical and where lack of public charging becomes the most significant barrier to continued electrification. At that point, market funding needs will invert, and public charging incentives will have the largest impact on furthering M/HD EV adoption goals. In the *Charging Needs Assessment*, the study identified a need for $223 million in public en-route charging investments by 2030, a figure not likely to be achieved without substantial seeding from public funds.

**We suggest that CEO limit eligibility for incentives for public or semi-public charging projects to 350 kW+ chargers.** High power levels are required to quickly recharge M/HD electric vehicles in public / semi-public charging scenarios. Where possible, CEO should even encourage the planned installation of these chargers at a 1 MW+ power level.

## Program Funding Amounts

Since Colorado's M/HD infrastructure incentive program will be on the cutting-edge of policymaking in this space, there is limited direct economic evidence on which to evaluate the effectiveness of any specific program funding amount. Though funding programs for public light-duty vehicle charging have been in place for a decade, the differences between the use-cases of personal light-duty vehicles and the commercial use of M/HD vehicles makes light-duty programs imperfect comparisons for determining funding amounts for this type of program. Additionally, because funding amounts are open-ended rather than discrete, they do not fit well into a criteria-alternative analysis framework. Therefore, we avoid making recommendations of specific dollar amounts for charger installations and do not directly compare tradeoffs. However, we do suggest the following high-level guidelines for structuring initial incentive amounts.

**We suggest that CEO follow California's lead in limiting incentives to no more than 50% of eligible project costs for private, behind-the-fence depot projects.** While private depot projects will generate public climate, local air quality, and market acceleration benefits, and so deserve subsidy, they will also provide assured benefits to the project applicant in the form of direct operational cost savings. This leads us to expect that private depot projects will require less subsidy to make feasible.

**We recommend that CEO follow the precedent of past light-duty public charging programs and offer up to 80% of eligible costs for public or semi-public charging.**

Public or semi-public charging projects are much riskier to the project developer and operator because there is no guaranteed utilization, especially in the near-term. Therefore, these projects are likely to require more subsidy to encourage investment. Additionally, because it is shared, public or semi-public charging may support the adoption of multiple M/HD electric vehicles in the medium- to long-term, which increases a single charger's public benefit relative to a private depot installation.

**We suggest that CEO limit per port incentives to a maximum percentage of average charging port costs that coincides with cost coverage maximums.** All else equal, this will generally limit public investment to at or below average costs, and account for stacking of other incentives, thus conserving limited program budgets.

**We suggest that CEO offer higher funding maximums for higher charger power levels.** This is a common strategy for charging incentive programs and will allow for fleets with operations that require higher-power charging to receive an appropriate subsidy. However, we do suggest that CEO limit the number of funding maximum categories to avoid overspecification. Applicants should be required to demonstrate need for (and compatibility with) the power level of chargers for which they are applying for by specifying the vehicles being electrified and/or submitting a brief fleet electrification plan. The program should encourage deployment of heavier utilization electric fleets, as these are the fleets likely to deliver the most emission and air quality benefits through electrification.

**We suggest that CEO impose some level of self-match requirements on program participants.** Given that applicants may have access to other forms of funding, such as incentives from utility programs or section 30C federal tax credits, this approach will conserve program funds to be applied to a wider array of projects and awardees. This recommendation is particularly important if CEO elects to allow for cost coverage in excess of 50% for its program.

**Relatedly, we recommend Colorado follow California's lead and disallow applicants that are customers of utilities that provide programs that cover costs of utility upgrades to use CEO funds for those utility eligible expenses.** Where possible, applicants should leverage available funding from utilities. This will preserve program funding, particularly for those applicants who will not have access to utility incentives.

**We recommend generally limited total project budgets while allowing for a small number of larger project awards.** Limiting overall project budgets to smaller total amounts will ensure that more projects can be funded, which should also lead to a more diverse set of projects. However, because there are important lessons to be learned from the deployment of larger charger installations, which require more power and more involved site work, CEO should consider offering a limited number of *large project awards* during each funding round.

**Most importantly, we recommend that CEO approach funding amounts with the intention to iterate across program funding rounds**. Information gleaned from program applications, project cost data, and overall program subscription rates should indicate whether program funding is either too generous or too limited. Moreover, as the market develops and the M/HD policy area attracts further research attention, CEO will gain access to more and better-quality evidence to base funding amounts on over time.

## Equity-Focused Program Design

While overall emissions reductions, electric vehicle deployment, and M/HD charging market development are critical outcomes of CEO's M/HD charging program, ensuring equitable distribution of both program funds and program benefits is also a key goal for CEO. Due to historical inequities in both resource allocation and the incidence of environmental harms from M/HD vehicle operations, equity improving mechanisms require the proactive targeting of program funds to projects in underserved areas or for underrepresented funding recipients. However, equity measures can often come at a tradeoff to absolute efficacy, efficiency, and administrative feasibility compared to a program without equity considerations. In this section, we evaluate the high-level tradeoffs of equity-focused design options for: equity carve-outs or funding buckets, equity funding adders and match reductions, and equity-focused application weights.

Relative to a program without equity-focused design, equity carve-outs may limit overall program uptake, and therefore total program benefits. This will be true if too few eligible applicants apply for program funding that is set-aside for equity-focused projects, and if non-earmarked funding is oversubscribed. The larger the set-aside, the greater that risk. Equity funding adders increase the per-project average cost, reducing the number of chargers that can be funded by the overall program budget. Larger adder amounts contribute to higher per-project costs. Relaxed applicant self-match requirements would not increase costs over an established maximum project cap, but can increase the overall amount of funding that a project will be eligible to receive. However, relaxed self-match requirements moderately reduce the incentive for the individual applicant to more carefully assess the value of their project due to less required applicant contribution, leading to the possibility of somewhat less effective projects overall. Comparatively, equity-focused application weights do not involve a set-aside or require additional funding, so their impact on efficacy will be limited to offsetting any efficacy-focused application scoring criteria.

In general, equity-focused projects are more likely to also be projects where program funding is critical to project viability, meaning that equity-focused program designs should also result in reduced free-ridership and improved program efficiency. However, offering additional funding to these projects would offset some of that effect.

In summary, impacts on equity are not equal. Both carve-outs and application weighting serve to make equity eligible projects more competitive with other projects, though the firm requirement of a carve-out is likely to have a stronger impact than an application weight. Funding adders have the strongest positive impact on equity because not only do they make eligible projects more competitive, they also increase the number of equity-focused projects that can be viable. Reduced self-match requirements have a similar effect, but their efficacy is blunted by the requirement that eligible projects still find other sources of project funding. All equity-focused designs increase administrative burdens because they require the program administrator to define and verify equity-based eligibility requirements.

Table 12. Criteria-Alternative Matrix for Equity-Focused Designs

| | **Efficacy** | **Efficiency** | **Equity** | **Admin Feasibility** |
|---|---|---|---|---|
| Carve-out | Moderate | High | High | Moderate |
| Funding Adder | Low to Moderate | Moderate | Very High | Moderate |
| Funding Match Reduction | High | High | Very High | Moderate |
| Application Weight | Very High | Moderate | Moderate | Moderate |
| No Equity Designs | Very High | Moderate | Low | High |

Table 12 shows the strong tradeoff between equity measures and program efficacy. All else equal, a program without equity-based designs is likely to deliver the largest absolute benefit in terms of overall emissions reductions, as well as vehicles and chargers deployed. However, a program without equity-based designs would also likely have a higher free-ridership rate, increasing the likelihood of funding projects that may have occurred anyway, and would not provide flexibility to concentrate emissions reductions and M/HD EV deployments in disproportionately impacted communities. This would therefore occur at a substantial loss to equity, as projects from better-resourced applicants crowd out those who would meet equity criteria and the communities most burdened by air pollution would not be specifically targeted for emissions reductions. The size of this tradeoff would depend on the magnitude of the carve-out, adder, match reduction, or application weight. Lower equity components (such as a smaller funding adder) would have less downward impact on efficacy, but also lower positive impact on equity.

**We suggest that CEO limit any equity adder to no more than 10% additional funding limit or cost share.** Given that CEO's likely allocated program budget is relatively limited compared to the overall investment needs required to support Colorado's zero-emission truck targets, substantially increasing funding for equity-qualified projects is not advisable. However, an equity adder of no more than 10% would likely have appreciable equity improving impacts without excessively straining program budgets, sufficiently rendering some equity-qualified projects economic that would not otherwise have been.

**We recommend that CEO relax self-match requirements for equity eligible projects.** Decreasing self-match funding requirements (assuming strict self-match requirements are in place) for these projects so they can gain additional funding by stacking incentives from different sources (such as the section 30C federal tax credit and utility programs) could substantially improve the economics of these projects without substantially detracting from project funding.

**We recommend that CEO include an equity-eligible project weight in their application scoring process.** While this measure will not guarantee equity improvement, it is a low-risk strategy to improve the equity of CEOs funding program.

# 5. Conclusion

With improving technology, expanding commercial offerings, more beneficial total cost of ownership, and new policy goals and incentives, electric M/HD vehicle deployment is quickly transitioning from ambition and aspiration to a present priority. Among the key practical considerations of a rapid transition of this market segment is the substantial amount of charging infrastructure necessary to support M/HD electric vehicles. The market for M/HD charging is currently in its infancy, but is already growing and showing signs of significant innovation. At the same time, the infrastructure investment required to meet Colorado's Clean Truck Strategy goal of 35,000 M/HD ZEVs on the road by 2030 is considerable. However, with dedicated incentive funding and the development of a strategically designed and administered M/HD EV charging infrastructure program, CEO is well positioned to accelerate the deployment of M/HD electric vehicles in Colorado.

## M/HD Charging Market

While the technology used to charge M/HD electric vehicles is the same or very similar to that which serves light-duty EVs, the needs of M/HD vehicle operators are often very different than those of light-duty vehicles. The supply side of the M/HD charging market is reacting to these differences with a number of emerging business models and products.

Much of the focus of these new business models is on establishing electric M/HD-focused turnkey solutions that relieve fleet owners and operators from needing to manage the complex transition to electric fueling, either at the customer's location or offsite. Additional pilot opportunities include alternative financing arrangements that provide customers with the ability to trade the capital-intensive process of charger deployment for an *as-a-service* or subscription model. These arrangements can provide charging equipment, shared or dedicated charging access, and even the M/HD electric vehicle itself, along with offering charging for a single ongoing fee. Such emerging business models show substantial promise, particularly to overcome electrification challenges for smaller fleets or M/HD operators with fewer resources. However, there is currently little in the way of evidence on the long-term effectiveness of these models, meaning that future research is warranted.

Regardless of new charging business models for M/HD electric vehicles, navigating split ownership issues between property owners and commercial fleet tenants will remain difficult for this market. While outside the scope of CEO's planned program, legislation to expand Colorado's "right to charge" rules to include commercial tenants would help to alleviate some of the concerns fleets that do not own their depots may encounter.

Most initial M/HD EV investment will occur in local or regional fleet applications where it is easiest to transition vehicles to electric fueling due to shorter operating distances and predictable charging opportunities. Long-haul freight trucking where vehicles drive much longer distances in a day and do not return to the same location each night will be much more difficult to electrify, particularly in the near-term. Electric M/HD vehicle range limitations and more expensive, public, high-power DC charging requirements present a substantial barrier to electrification of these trucking modes. However, as these challenges ease with continued technology evolution and cost reductions, Colorado will need a network of freight-focused en-route and long-haul corridor charging sites to support interregional and interstate electric trucking routes. Planning and early deployment of such public / semi-public fast-charging stations is already underway on the West Coast.

Additional considerations that are outside the scope of CEO's M/HD charging program, but that would be helpful to investigate to further advance the M/HD charging market in Colorado include: a) Identifying and implementing best practices to streamline permitting and zoning processes, b) expanding technical assistance offerings for fleets seeking to electrify their depots, c) engaging with and providing helpful educational resources to dealerships and market stakeholders, and d) coordinating with financing entities to expand the availability of low-cost financing for M/HD EV and charging infrastructure deployment.

# Utilities and M/HD Charging

Utilities are a key player in the M/HD charging market and can function as a primary enabler of M/HD vehicle electrification. However, M/HD charging deployment will require substantial upgrades to distribution grids, which will strain utility capacity that is already impacted by pandemic-related supply chain difficulties. Long timelines to power M/HD charging projects will be the norm for the foreseeable future, especially for high-power DC charging requirements. While much of this is outside of the control of CEO to change, it can still find a useful role in minimizing the impact of this barrier through careful planning, coordination, and utility engagement – both in relation to Xcel and Black Hills Energy's TEPs, as well as in connection with Colorado's many municipal and cooperative utilities.

An additional concern with utilities when it comes to M/HD charging is the high cost of utility upgrades that can accompany the already expensive cost of charging equipment, installation, and M/HD electric vehicle acquisition. Colorado's investor-owned utilities can defray much of this upfront cost for M/HD EV charging infrastructure through their own investment and cost recovery mechanisms, but this avenue is largely unavailable for customers of municipal and cooperative utilities that generally cannot fund such incentives to support utility upgrades. While CEO's incentive program may serve to offset some of these increased costs, it will remain a challenge for the deployment of high-power charging in many of Colorado's cooperative and municipal utility service areas. This problem is not confined to Colorado and requires substantial ongoing research attention.

While outside the scope of its planned M/HD charging infrastructure program, CEO should engage with, educate, and encourage utilities to adopt processes and capacity that are complementary to M/HD EV infrastructure deployment. These include:

- Developing internal electric vehicle knowledge and capacity among utility staff to help support customer electrification projects (this is particularly important for smaller municipal or cooperative utilities that will see substantial EV charging infrastructure development in their service territories).
- Developing transparent hosting capacity maps that easily and explicitly show the distribution capacity on three-phase feeder circuits[19] that can help fleets and charging infrastructure developers easily rule out project locations that are likely to run into near-term grid constraints.
- Including forecasts of EV load growth in integrated planning (and other similar infrastructure and system planning processes).

# Infrastructure Needs

By 2030, Colorado will need a combined $790 million to $1 billion in committed overall investment for around 30,000 installed charging ports to support M/HD EV adoption commensurate with achieving its Clean Truck Strategy goals. This investment includes funding allocated towards an additional approximately 12,000 depot and 560 en-route charging ports to be installed after 2030 (reflecting two-year depot and three-year en-route project completion timelines for charging installations post-investment). In addition, building a minimum network of M/HD corridor charging stations to support long-haul electric truck travel along Colorado's major freight routes will require as much as $76 million in supplemental committed funding by 2030 towards the deployment of 70 MW of 350 kW or higher-power charging ports distributed throughout twenty (20) 3.5 MW corridor charging sites to be commissioned between 2027 and 2035.[20] This total investment includes a combination of funding from fleets, the private sector, utilities, local, state, and federal entities, amongst all other market participants.

Excluding corridor charging, in the average scenario, where fleet managers adopt an optimized infrastructure strategy based on their average energy needs and dwell times, depot (private) charging accounts for about 64% of needed M/HD charging infrastructure investment by 2030 ($507 million). In the conservative scenario, where fleets size

[19] See Dominion Energy EV Capacity Map Tool for an example of an accessible EV-focused capacity map: https://www.dominionenergy.com/projects-and-facilities/electric-projects/ev-capacity-map.
[20] Corridor charging sites are modeled based on WCCTCI recommendations to locate at least one (1) 3.5 MW charging site per 100 miles, with flexibility allocated to account for freight corridor junctions.

infrastructure to have a 30% capacity reserve, accounting for charging being upsized to consider fleets' longest routes and shortest dwell times, costs increase by about $218 million, inflating depot charging cost share to 72% of investment needs by 2030 ($725 million). This cost differential between scenarios, although accounting for essentially the same number of cumulative depot charging ports invested in (around 24,800) and commissioned (12,900) by 2030, illustrates the substantial impact that overbuilding DC charging versus right-sizing charging infrastructure and encouraging L2 charging where sufficient could have on needed investment and highlights the importance of balancing these two scenarios through market education and CEO's application evaluation process.

The total overall investment needs further account for $223 million in public / semi-public en-route (non-long-haul corridor) charging representing 385 350 kW or higher-power charging ports commissioned by 2030, plus an additional 560 installed by 2033. This en-route charging will be necessary to support the incremental fueling needs for vehicles that occasionally exceed the capacity of their depot-based private charging, as well as a limited number of M/HD vehicles that do not have access to depot or home charging. Finally, the costs also include $59 million for over 17,000 home L2 charging ports built by 2030 primarily to support Class 2b and 3 vehicles that are personally registered to individuals.

Geographically, the median Colorado county will require between $3.3 and $4.6 million in cumulative investment for M/HD charging through 2030. However, total overall investment needs are highly concentrated in the heavily populated areas around the Denver Metro region, Fort Collins, and Colorado Springs due to the density of M/HD vehicle registrations in these locations. About two-thirds of needed investment through 2030 occurs in Xcel Energy and Black Hills Energy territories, Colorado's two investor-owned utilities, leaving about one-third of the required investment in municipal and cooperative utility territories.

There is currently no funding dedicated exclusively to M/HD EV charging infrastructure in Colorado. However, a significant amount of the estimated investment needed through 2030 will be covered through funding from private and public market participants, tax incentives, federal funds, and utility programs, amongst other investments. CEO's incentive funding through the upcoming M/HD infrastructure program (and the required applicant match, if enforced) will further help to close this gap between available funding and expected needs and will kickstart the M/HD electric vehicle market in the state, though a substantial portion of this investment will need to be made by private enterprise.

# Program Design Strategy

There are limited examples of M/HD charging infrastructure incentive programs with the most direct predecessor being the California Energy Commission's EnergIIZE program, which launched in 2022. Other examples are primarily confined to utility offerings, which provide programmatic lessons for CEO, but are imperfect models given the difference in structure, incentives, and governance of utility programs. Many examples of light-duty-focused EV initiatives also exist, but the applicability in learning from these programs is limited due to the differences between personal and commercial vehicle operations.

The variable nature of M/HD vehicles, their use-cases, and charging needs makes incentive design for them more nuanced than charging programs directed at light-duty charger deployment. Key design decisions include: a) Whether to make funding available to depot-based (private) charging, public (or semi-public) charging, or both and the extent to which funding should be allocated to either, b) how to best ensure the equitable distribution of funds to historically underinvested and disproportionately impacted communities and businesses, and c) how to structure funding and define funding limits and cost share.

The large early investment needs required to support the most applicable near-term use-case and guaranteed utilization of private depot charging necessitates substantial early investment in that sector. However, the long-term development of the M/HD EV market will also rely on a robust network of public / semi-public fast-charging locations, while private depot charging will require less incentive funding over time. Therefore, we recommend CEO initiate their program by focusing primarily on depot charging projects, while also allocating a small portion of program funding to public / semi-public charging in early incentive rounds with the expectation that this distribution share will need to be adjusted over time.

Creating an equitable program is an important objective for CEO and the State of Colorado. However, with a limited program budget, large equity adders could quickly strain funding resources. Therefore, we recommend either a small equity adder and/or relaxed self-match funding requirements for equity-qualified applicants. In addition, we recommend that equity-qualified applicants and projects receive priority in the selection process. This will help to ensure that as many awards go to viable projects by equity-qualified applicants and in the highest need communities as possible.

Since Colorado is on the leading edge of M/HD charging infrastructure incentive program development, there is little in the way of evidence to strongly support any specific funding levels as the most economically effective or efficient amounts to maximize program cost-benefit ratios or cost effectiveness. However, CEO should consider awarding smaller amounts (on a per charger basis) to private depot charging projects, since these projects - although representing a higher percentage of the overall program budget in the near-term - will likely require less support on an individual project level to render economically viable. Comparatively, higher funding amounts (on a per charger basis) should be considered for public / semi-public charging projects because they lack the certainty of utilization and return on investment that private depot charging projects enjoy, even though the overall budget for public / semi-public charging projects should be more limited in the near-term and then increase over time. Most importantly, CEO should be prepared to continually evaluate program data, new research, and market trends, and to adjust incentive amounts and cost share limits between funding rounds as more information becomes available.

Developing an understanding of the impact of incentive levels on uptake, the prevalence of free-riding amongst the program, and the effectiveness of M/HD charging infrastructure incentives as compared to other policy interventions, is a rich research area that deserves ongoing study. This is not only the case in Colorado, but globally, as other jurisdictions inevitably seek to identify and implement the most effective ways to encourage the accelerated adoption of M/HD electric vehicles.

# Appendix A: Modeling Appendix

As described in *Chapter 3: Charging Needs Analysis*, Atlas used the INSITE tool to perform analyses of M/HD charging infrastructure needs in Colorado consistent with achieving the 2030 M/HD zero-emission vehicle deployment goals of the Colorado Clean Truck Strategy.

This Appendix provides additional modeling details for the use of the INSITE tool, along with methods explanations for the M/HD freight corridor electrification analysis, and the study's downscaling techniques.

## Electric Vehicle Adoption

Atlas modeled a M/HD electric vehicle adoption curve provided by the Colorado Energy Office reflecting the Colorado Clean Truck Strategy goal of 35,000 zero-emission M/HD vehicles on the road by 2030. This adoption curve was provided by gross vehicle weight rating (GVWR) Class: Class 2b – 3, Class 4 – 5, Class 6 – 7, and Class 8 (See Table 13).

Table 13. Cumulative M/HD Electric Vehicle Stock Consistent with Colorado's Clean Truck Strategy

| GVWR | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|
| **Class 2b-3** | 390 | 868 | 1,738 | 3,365 | 6,337 | 11,410 | 19,182 | 29,661 |
| **Class 4-5** | 15 | 38 | 82 | 166 | 320 | 583 | 983 | 1,520 |
| **Class 6-7** | 23 | 56 | 119 | 244 | 482 | 899 | 1,555 | 2,461 |
| **Class 8** | 4 | 13 | 37 | 95 | 222 | 469 | 869 | 1,408 |
| **Total** | 431 | 974 | 1,976 | 3,870 | 7,360 | 13,361 | 22,590 | 35,050 |

Source: State of Colorado

## Energy Recovery

The INSITE tool calculates, for each vehicle use-case (see Table 3) and GVWR Class, the daily energy recovery needed per vehicle. This calculation is the product of five factors:

1) **Vehicle efficiency:** The study uses forward-looking vehicle efficiencies from Argonne National Laboratory's Autonomie model [48]. See Figure 12 for a description of this process.
2) **Daily charging window:** The study uses the California Air Resources Board's Advanced Clean Trucks rule documentation assumption of a 9 hour average daily charging window [2]. Refuse trucks are assigned a 13 hour charging window due to documented longer average dwell times.
3) **Daily vehicle miles traveled (VMT):**

- The study presents two VMT scenarios:
    - An ‘Average’ Case: For the Average case, for most vehicle use-cases and Classes, the study uses national average daily miles traveled from the WCCTCI report [49]. See Figure 13. However, it uses 141 miles per day for Class 7 and 8 regional-haul trucks. This figure is based on the Colorado case in the U.S. Environmental Protection Agency’s Motor Vehicle Emission Simulator (MOVES) Model and assumes 250 workdays per year (on advice from the North American Council for Freight Efficiency (NACFE)) [50].
    - A ‘Conservative’ Case: The Conservative case is equal to 1.3 times the VMT used in the Average case, since the Average case is based on a fleet’s average daily VMT and average overnight dwell time, which would not account for real-world operation scenarios where charging will likely be sized to a fleet's longest daily VMT and shortest overnight dwell time.

4) **Assumed slowdown in charge rate above 80% state of charge**: Based on existing research and advice received from industry interviews, the study assumes depot charging slows down beyond 80% state of charge such that it takes as long for vehicles to charge from 0 to 80% as it does for them to charge from 80 to 100% state of charge. Given the economics of commercial driving, for en-route charging, the study assumes drivers do not stay and wait for this final 20% of charging to complete. Instead, they choose to oversize their battery relative to daily energy needs or stop multiple times to avoid the slow down when charging en-route.
5) **Assumed electricity losses in charging equipment**: Electricity losses when charging are assumed to increase energy recovery by 15% relative to the amount demanded by the vehicles themselves based on the daily energy recovery needed.

Figure 12. Process to Estimate Vehicle Efficiency by INSITE Vehicle Type

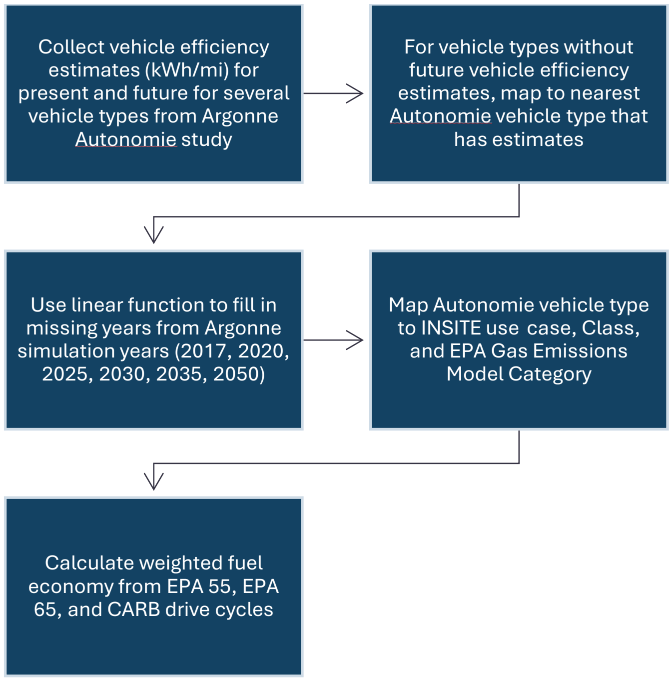


Figure 13. U.S. Daily Average VMT Per Vehicle Segment and Class

| Segment | Class 3 | Class 4 | Class 5 | Class 6 | Class 7 | Class 8 |
|---|---|---|---|---|---|---|
| Construction Truck | 48 | 34 | 48 | 38 | 38 | 38 |
| Regional Truck | 29 | 48 | 74 | 74 | 74 | 208 |
| Motor Home | 32 | 64 | 112 | 112 | 112 | 112 |
| Pickup | 77 | | | | | |
| Long-Haul Truck | | | | | 545 | 545 |
| Drayage | | | | | 32 | 32 |
| Bus | | 40 | 48 | 112 | 96 | |
| Step Van | 53 | 53 | 53 | 53 | | |
| Refuse | | | | 75 | 75 | 75 |
| School Bus | | | | 48 | 48 | 48 |
| Van Cargo | 87 | | | | | |
| City Bus | | | | 112 | 112 | 112 |
| Shuttle Bus | 48 | 48 | 96 | 112 | | |
| Coach | | | | | | 112 |
| Fire Truck | | | | | | 21 |
| SUV | 42 | | | | | |
| Terminal Tractor | | | | | | 112 |
| Emergency Truck | | | 243 | 243 | | |

Source: West Coast Clean Transit Corridor Initiative (WCCTCI) Report [49]

# Charging Location

Since the analysis is focused on the next eight (8) years through 2030, during which time electric M/HD vehicle markets are still expected to be in the growth stages, it modeled a home- and depot-focused charging ecosystem. Just like for light-duty vehicles, electric M/HD vehicles that can charge at home or at a depot face lower costs to fuel and are not completely reliant on the buildout of a full geographic network of en-route vehicle chargers, making home and depot charging for M/HD EVs more viable to electrify in the short-term.

The study assumes:

- All school bus and shuttle bus charging takes place at depots

- 90% of electric non-long-haul Class 2b – 8 charging takes place at depots (all vehicles registered for commercial use) or homes (vehicles registered for personal use). The remaining 10% of energy for these trucks is from en-route charging
- Class 2b and 3 vehicles that are registered for personal use charge at homes (59%), but individually registered Class 4 – 8 vehicles charge at a depot or en-route
- All long-haul truck charging takes place along freight corridors (at truck stops, truck parking, gas stations, or other M/HD charging sites)

# Charger Power Level and Utilization

For every vehicle use-case, weight Class, and VMT case, the study assigns depot charging vehicles to a charging power level that covers their daily energy recovery needs (including the assumed slowdown above 80% state of charge) in a 9 hour charging window. This charging window is taken from CARB's Advanced Clean Trucks rule documentation [2].

The analysis combines: a) This charging power and location information with b) the M/HD EV adoption curve discussed previously and c) the share of each use-case within each vehicle weight Class from 2019 S&P Global registration data[21] (the latest data that Atlas had available). In doing so, the study allocates the M/HD electric vehicle stock provided by Colorado (Table 13) to charging location and power level. These results are shown in Table 14 (Average Case) and Table 15 (Conservative Case). Note that the study uses these adoption figures to implement the modeled split of energy recovery between homes / depots versus en-route charging (90% versus 10% of non-bus, non-long-haul charging - see prior section). In reality, it is possible that rather than 90% of vehicles charging solely at homes / depots, and the remaining 10% charging solely en-route, individual vehicles could instead take 90% of their energy demand from homes / depots and 10% from en-route chargers. This would lead to all the same outcomes in the modeling, i.e. the INSITE tool is agnostic as to which specific vehicles are charging where, and rather, captures the total energy demanded at each location type.

Long-haul trucks are assumed to electrify slower than other Class 8 vehicles due to their greater range needs and lack of return-to-base operations. The analysis assumes that none of the Class 8 EV stock is made up of long-haul electric trucks until 2027, when it models 5% of Class 8 EVs as long-haul. The analysis increases this by 1 percentage point each following year, i.e., in 2030, 8% of Class 8 EVs are long-haul. As mentioned in *Chapter 3: Charging Needs Analysis*, the study models charging needs for long-haul electric trucks differently than all other M/HD vehicles. The long-haul EV stock shown below is therefore not used directly in the INSITE analysis because the study assumes these vehicles' charging needs are instead met by the minimum-build corridor charging locations covered

[21] 2019 data was purchased from S&P Global Mobility, an automotive data provider.

in the corridor charging analysis. However, these vehicles are allocated and shown in Table 14 to display the full set of EVs that sum to the total EV stock figures provided by Colorado (see section on EV Adoption).

Within the Level 2 (L2) depot charging M/HD vehicle categories, the study assumes:

In the 'Average' Case (where energy demand is lower):

- For Class 2b – 3 vehicles: 97% use 48 amp and 3% use 80 amp chargers
- For Class 4 – 8 vehicles: 30% use 48 amp and 70% use 80 amp chargers

In the 'Conservative' Case (where energy demand is higher):

- For Class 2b – 3 vehicles: 4% use 48 amp and 96% use 80 amp chargers
- For Class 4 – 8 vehicles: 35% use 48 amp and 65% use 80 amp chargers, though a number of Class 4 – 8 vehicles transition to requiring DC depot charging

These assumptions are based on the share of M/HD electric vehicles assigned to each charging power level using the 2019 S&P Global registration data for Colorado.

Table 14. Allocation of EV Stock to INSITE Vehicle / Charging Types: Average Case

| Allocation | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|
| **Class 2b-3<br>L2 Home Charging** | 228 | 508 | 1,017 | 1,969 | 3,707 | 6,675 | 11,221 | 17,352 |
| **Class 2b-3<br>L2 Depot Charging** | 123 | 273 | 547 | 1,060 | 1,996 | 3,594 | 6,042 | 9,343 |
| **Class 2b-3<br>En-Route Charging** | 39 | 87 | 174 | 337 | 634 | 1,141 | 1,918 | 2,966 |
| **Class 4-8<br>L2 Depot Charging** | 19 | 49 | 110 | 233 | 467 | 886 | 1,542 | 2,431 |
| **Class 4-8<br>50 kW DC<br>Depot Charging** | 9 | 22 | 50 | 105 | 211 | 400 | 697 | 1,098 |
| **Class 7-8<br>150 kW DC<br>Depot Charging** | 10 | 25 | 55 | 117 | 234 | 444 | 773 | 1,219 |
| **Class 4-8<br>En-Route Charging<br>(Non-Long-Haul)** | 4 | 11 | 24 | 50 | 101 | 192 | 335 | 528 |
| **Long-Haul Truck<br>Corridor Charging** | - | - | - | - | 11 | 28 | 61 | 113 |
| **TOTAL** | **431** | **974** | **1,976** | **3,870** | **7,360** | **13,361** | **22,590** | **35,050** |

Table 15. Allocation of EV Stock to INSITE Vehicle / Charging Types: Conservative Case

| Allocation | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|
| **Class 2b-3 L2 Home Charging** | 228 | 508 | 1,017 | 1,969 | 3,707 | 6,675 | 11,221 | 17,352 |
| **Class 2b-3 L2 Depot Charging** | 123 | 273 | 547 | 1,060 | 1,996 | 3,594 | 6,042 | 9,343 |
| **Class 2b-3 En-Route Charging** | 39 | 87 | 174 | 337 | 634 | 1,141 | 1,918 | 2,966 |
| **Class 4-8 L2 Depot Charging** | 13 | 34 | 76 | 160 | 322 | 611 | 1,064 | 1,677 |
| **Class 4-8 50 kW DC Depot Charging** | 13 | 32 | 72 | 153 | 306 | 582 | 1,012 | 1,596 |
| **Class 7-8 150 kW DC Depot Charging** | 12 | 30 | 67 | 141 | 283 | 538 | 936 | 1,476 |
| **Class 4-8 En-Route Charging (Non-Long-Haul)** | 4 | 11 | 24 | 50 | 101 | 192 | 335 | 528 |
| **Long-Haul Truck Corridor Charging** | - | - | - | - | 11 | 28 | 61 | 113 |
| **TOTAL** | **431** | **974** | **1,976** | **3,870** | **7,360** | **13,361** | **22,590** | **35,050** |

The analysis assumes each Level 2 charging port serves only one (1) vehicle. It also assumes that depot DC fast-charging ports are shared between vehicles up to 80% utilization of the charger during the 9 hour charging window [2]. Implementing this sharing feature results in a maximum of two (2) vehicles sharing each depot DC fast-charging port.

For en-route charging ports, the study assumes the following utilization:

- Ten (10) vehicles per day, per 350 kW en-route charging port for Class 2b – 3 vehicles. These vehicles are assumed to be able to charge at the same public charging stations as light-duty EVs, so this relatively high utilization assumption assumes that charging built for Class 2b – 3 vehicles is incremental to light-duty charging buildout at high-utilization locations where additional charging is needed to reduce congestion / support energy recovery for these additional vehicles.
- Six (6) vehicles per day, per 350 kW en-route charging port for Class 4 – 8 non-long-haul electric M/HD vehicles. In 2030, these vehicles are expected to take a weighted average of approximately 30 minutes to charge their daily energy needs at this power level (assuming they avoid waiting to charge more slowly above 80% state of charge). This therefore assumes an approximately 20% utilization rate

during a 6am – 9pm charging window (or a 13% utilization rate across the entire 24 hour day). This also assumes that the initial buildout of en-route charging for Class 4 – 8 vehicles over the next eight years is along select, higher-demand routes.

# Cost Per Charging Port

Table 16 displays the cost per charging port assumptions used and their sources. These costs incorporate charging hardware, design, labor, construction, permitting, project management, and electrical upgrades not expected to be covered by utilities (e.g. front-of-meter costs for DC charging and make-ready infrastructure). The costs for DC fast-charging hardware listed below are reduced 3% per year through the end of the study period, in line with conversations with private sector electric vehicle service providers (EVSPs). No further cost declines are assumed after 2030, and costs for labor, construction, materials, or L2 charging hardware are not reduced over time.

Table 16. Modeled Costs Per Charging Port ($2022)

| EV Charging Station Type | EV Charging Hardware Cost | Other Costs | Total Cost Per Port | Notes & Sources |
|---|---|---|---|---|
| **Home L2 Single-Family Detached** | $759 | $1,841 | $2,600 | Other costs include ICCT home charging installation costs [51], inflated to 2022 dollars. Assume 100% need an outlet upgrade. Add $1,230 installation cost for panel upgrade to 200 amps for 50% of homes [52]. EV charging station cost is average of JuiceNet ($679) [53], Clipper Creek ($899) [54], and ChargePoint ($699) models [55]. |
| **Home L2 Single-Family Attached** | $759 | $3,641 | $4,400 | |
| **Home L2 Multifamily Building** | $759 | $5,541 | $6,300 | |
| **Depot L2 48 amp Class 2b-3** | $2,255 | $4,320 | $6,600 | EV charging station cost is average 11 kW EV charging station cost from 2021 - 2022 Charge Ahead Colorado (CAC) installs; other costs are CAC labor costs for 2021 - 2022 9.6 – 11 kW installs (due to smaller size of vehicles), ICCT "outside CA" materials costs for workplace charging assuming 6+ charging ports per site, and for site design / project management applying the same cost percent as Class 4-8 trucks from U.S. Postal Service (USPS) installs. |
| **Depot L2 80 amp Class 2b-3** | $5,816 | $4,320 | $10,100 | EV charging station cost is average 19 kW equipment cost from high-powered L2 Colorado-provided data for 2022; Other costs are CAC |

| EV Charging Station Type | EV Charging Hardware Cost | Other Costs | Total Cost Per Port | Notes & Sources |
|---|---|---|---|---|
| | | | | labor costs for 2021 - 2022 9.6 - 11 kW installs (due to smaller size of vehicles), ICCT "outside CA" materials costs for workplace charging assuming 6+ charging ports per site, and for site design / project management applying the same cost percent as Class 4-8 trucks from USPS installs. |
| **Depot L2 48 amp Class 4-8** | $2,255 | $19,225 | $21,500 | EV charging station cost is average 11 kW EV charging station cost from 2021 - 2022 CAC installs; Other costs are labor cost from high-powered L2 Colorado-provided data for 4-port installs (due to larger vehicles) and site design / project management based on average per site costs from USPS sites. |
| **Depot L2 80 amp Class 4-8** | $5,816 | $19,225 | $25,000 | EV charging station cost is average 19 kW equipment cost from high-powered L2 Colorado-provided data for 2022; Other costs are labor cost from high-powered L2 Colorado-provided data for 4-port installs (due to larger vehicles) and site design / project management based on average per site costs from USPS sites. |
| **Depot DC 50-62 kW Class 4-8** | $39,152 | $47,721 | $86,900 | EV charging station cost is average 2021 - 2022 CAC EV charging station cost for 50 - 62 kW equipment. Labor, customer make-ready (scaled down from 150 kW), and site design / project management costs are from GNA EDF report [56]. Plus, an additional $144 per kW for front-of-the-meter costs due to anticipated utility upgrades (average from data provided by the Los Angeles Cleantech Incubator (LACI)). |
| **Depot DC 150 kW Class 7-8** | $108,500 | $84,837 | $193,300 | EV charging station, labor, customer make-ready, and site design / project management costs are from GNA EDF report. Plus, an additional $144 per kW for |

| EV Charging Station Type | EV Charging Hardware Cost | Other Costs | Total Cost Per Port | Notes & Sources |
|---|---|---|---|---|
| | | | | front-of-the-meter costs (average from data provided by LACI). |
| **En-Route 350 kW Class 2b-3** | $210,000 | $44,915 | $254,900 | EV charging station cost is from WCCTCI; Labor, and other site costs are from ICCT (inflated to 2022 dollars, assume 6+ charging ports per site). |
| **En-Route 350 kW Class 4-6** | $210,000 | $126,000 | $336,000 | Costs from WCCTCI. Includes permits, design, materials, construction costs for medium-duty vehicle site. Also includes utility upgrade costs for a 3.5 MW site. |
| **En-Route 350 kW Class 7-8** | $210,000 | $171,000 | $381,000 | Costs from WCCTCI. Includes permits, design, materials, construction costs for heavy-duty vehicle site. Also includes utility upgrade costs for a 3.5 MW site. |

*Sources:*

*GNA Report: "California Heavy-Duty Fleet Electrification Summary Report"* [56]

*ICCT Report: "Estimating Electric Vehicle Charging Infrastructure Costs Across Major U.S. Metropolitan Areas"* [51]

*"West Coast Clean Transit Corridor Initiative Summary Report 2020"* [49]

*Energetics Incorporated Report: "California Investor-Owned Utility Transportation Electrification Priority Review Projects"* [57]

# Total Costs

Total costs are calculated by multiplying the infrastructure needed in each year (number of charging ports per charging station type), by the infrastructure cost in each year (total cost per port by charging station type). Infrastructure investments reflect station deployments in the same-year for home charging, with two-year lead times for depot charging, and three-year lead times for en-route charging. Charging costs for home and depot L2 charging modes are combined based on underlying percentages of home type and depot charging station type. All costs reported are in undiscounted 2022 dollars. To calculate forward-looking budgets in nominal dollars for a given future year, users should inflate these results to the dollar year of interest. To do so, it is suggested to use the Producer Price Index.

# Costs by Geography

Due to inherent uncertainty around the geographic distribution of electric vehicle adoption, the INSITE model is designed to produce aggregate results for large geographies. However, for planning purposes, results at the county and utility territory level are desirable. For this analysis, an ad hoc downscaling analysis was employed that took the aggregate results at the state level and allocated them to utility and county level using vehicle registrations by zip code as a spatial surrogate.

A spatial surrogate is a geographic indicator that can be used as a proxy to predict how aggregate results would split up at a more granular spatial and geographic resolution. In this case, the study uses historical vehicle registration data (a measure of where M/HD vehicles are currently located) as a pattern for the likely deployment of future M/HD electric vehicles. Statewide INSITE results are then allocated to county and utility territories in Colorado based on the proportion of M/HD vehicles that are registered in that county relative to the statewide total. Equation 1 below shows the mathematical operation used to allocate results for charging port counts.

### Equation 1. Port Downscaling Equation

$$PortsGEO_{i,x} = PortsINSITE_x \times \frac{RegGEO_{i,v}}{\sum_{i,v}^{n} RegGEO}$$

Where:

- $PortsGEO$ is the needed M/HD charging ports in a geography (utility or county)
- $PortsINSITE$ is the estimated statewide needed M/HD charging ports
- $RegGEO$ is the number of M/HD vehicles registered in each geography (utility or county)
- $i$ is a specific geography (out of $n$ Colorado geographies)
- $x$ is a specific charger type
- $v$ is the M/HD vehicle category or categories that correspond to charger type $x$

To illustrate how the downscaling method functions, the following is a hypothetical example: If the INSITE tool estimates that Colorado needs one hundred (100) 150 kW depot chargers (x), and if there are 10,000 M/HD vehicles (v) across all Colorado counties ($\mathrm{RegGEO}_{i\text{-}n}$), where 1,000 of those vehicles are in Denver County ($\mathrm{RegGEO}_{i}$), then the expected number of needed 150 kW depot charging ports in Denver County ($\mathrm{PortsGEO}_{i,x}$) can be expressed as shown in Equation 2.

### Equation 2. Downscaling Example Equation

$$PortsGEO_{Denver,150\ kW\ Depot} = 100 \times \frac{1{,}000}{10{,}000} = 10$$

Since this allocation method can result in irrational estimates of fractional charging ports within a specific geography, the analysis implements a de minimis of at least one (1) charging port per geography for home- and depot-based charging ports, and at least four (4) charging ports for 350 kW en-route charging. Any remaining charging ports (or fractions of charging ports) left after this operation are aggregated and reallocated to the geographies that had above-de minimis charging ports in the first allocation round.

The downscaling for estimated costs (or $CostsGEO_{i,x}$) follows the same method as charging ports, but replaces $PortsINSITE_x$ with $CostsINSITE_x$ as the value allocated to geographies.

# Electrifying Freight Corridors

The INSITE model is not equipped to estimate charging needs for long-haul electric trucks within a confined geography because long-haul traffic on in-geography corridors originates, terminates, or both, at locations outside of the modeled geographic bounds. Since INSITE modeling is predicated on estimating energy use of vehicles expected to be deployed in-geography, it cannot adequately model long-haul electric trucks for a limited region.

Therefore, to address planning for long-haul electric truck deployment in Colorado, the study takes a minimum-build approach, where it estimates the minimum needed charging infrastructure to electrify the primary freight corridors in Colorado. Corridors were selected by the Colorado Energy Office in consultation with the Colorado Department of Transportation. CEO assigned charging corridors into three (3) distinct phases based on target completion dates and expected electric truck rollout timelines. The three (3) Electric Freight Corridor Charging Phases are identified below in Table 17.

Table 17. Electric Freight Corridor Charging Phases Specified by CEO

| Phase | Years | Location / Highway |
|---|---|---|
| **One** | 2027 | Denver Area *(Near-term short- & regional-haul)* |
| **Two** | 2027 – 2030 | I-25, I-70, I-76 |
| **Three** | 2035 | US-40, US-50, US-85, US-160, US-287, US-385 |

To establish the minimum long-haul charging corridor buildout scenario, the study borrows the *West Coast Clean Transit Corridor Initiative Summary Report (2020)* assumption that effective M/HD corridor electrification requires at least one (1) minimum 3.5 MW charging site configured for M/HD electric truck utilization every 100 miles to support through-traffic along that corridor [49]. The study employs a geospatial analysis methodology that produces an approximation of M/HD corridor charging station density, while also respecting the network structure of Colorado's freight corridors.

For the purposes of this study, Atlas developed a simple, graph-based model of the freight corridors selected by CEO using the U.S. Department of Transportation Freight Analysis Framework national network dataset [58]. In the corridor charging model, intersections of corridors are represented as nodes and the roadways between intersections are represented as edges. Boundary nodes for corridors that extend beyond Colorado's borders are defined as the nearest intersection with another major freight corridor.

Nodes represent highway interchanges that are already common locations for fueling sites because they serve multiple directions of traffic. These are natural corridor charging site locations, and so the study assigns a single 3.5 MW charging site to each network node to form the backbone of the Colorado Electric Freight Corridor Charging Network. To ensure the average distance between charging sites remains about 100 miles on average, some flexibility is allocated to site stations along network edges at approximately (rather than exact) 100 mile intervals. For example, if an edge (highway segment) between nodes is less than 120 miles, it is not subdivided. This means that sites are no more than 120 miles apart and no less than 60 miles apart. Where multiple intersections (nodes) between corridors fall within 5 miles of each other, they are combined into a single charging site that will serve both intersections. Lastly, an approximate expected location for each corridor charging site is defined by creating spatial buffers within 1 mile from the highway and within a 5 mile radius from a node / intersection or a 20 mile radius from an edge-based site.

It is expected that long-haul electric truck charging eventually takes place at a combination of 350 kW chargers during driver's mandated breaks and/or overnight, and at 1 to 2 MW chargers during shorter stops, though guessing at the charging mix the market will demand in the future is challenging. In either scenario, both cases are estimated to cost a similar amount, about $3.8M per site (utilizing costs from the WCCTCI), since the modeled corridor charging locations are each based on 3.5 MW of total power deployed. It is assumed these initial 3.5 MW minimum-build corridor charging sites will be located at "low-hanging fruit" sites that do not require new substations to handle the load. As a result, investments for deploying the M/HD corridor charging sites are anticipated to be needed three-years in advance of station availability. Research however shows that timelines for the buildout of M/HD corridor charging sites could increase to up to 5 years if new or significant substation upgrades are required, highlighting the importance of state and utility coordination in planning for anticipated M/HD electric truck charging needs.

# Appendix B: Results Appendix

Table 18. M/HD Charging Ports Per Colorado County By 2030 – Average Case

| County | Home L2: Class 2b 3 | Depot 48a L2: Class 2b 3 | Depot 48a L2: Class 4 8 | Depot 80a L2: Class 2b 3 | Depot 80a L2: Class 4 8 | Depot 50 62 kW: Class 4 8 | Depot 150 kW: Class 7 8 | En route 350 kW: Class 2b 3 | En route 350 kW: Class 4 8 | Total (Excluding Home Charging) |
|---|---|---|---|---|---|---|---|---|---|---|
| Adams County | 1,221 | 739 | 85 | 13 | 155 | 63 | 48 | 26 | 14 | **1,143** |
| Alamosa County | 78 | 34 | 3 | 2 | 9 | 3 | 6 | 0 | 0 | **57** |
| Arapahoe County | 863 | 679 | 78 | 29 | 160 | 56 | 35 | 21 | 12 | **1,070** |
| Archuleta County | 140 | 28 | 2 | 0 | 6 | 1 | 2 | 0 | 0 | **39** |
| Baca County | 38 | 10 | 0 | 0 | 1 | 1 | 4 | 0 | 0 | **16** |
| Bent County | 32 | 3 | 0 | 1 | 2 | 0 | 1 | 0 | 0 | **7** |
| Boulder County | 515 | 387 | 33 | 10 | 77 | 23 | 17 | 12 | 0 | **559** |
| Broomfield County | 119 | 43 | 5 | 2 | 7 | 1 | 1 | 0 | 0 | **59** |
| Chaffee County | 132 | 45 | 4 | 1 | 15 | 4 | 3 | 0 | 0 | **72** |
| Cheyenne County | 25 | 11 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | **14** |
| Clear Creek County | 25 | 13 | 2 | 0 | 6 | 0 | 0 | 0 | 0 | **21** |
| Conejos County | 73 | 18 | 0 | 0 | 3 | 2 | 3 | 0 | 0 | **26** |
| Costilla County | 24 | 4 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | **7** |
| Crowley County | 25 | 8 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | **12** |
| Custer County | 76 | 11 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | **14** |
| Delta County | 298 | 74 | 4 | 0 | 12 | 4 | 6 | 5 | 0 | **105** |
| Denver County | 507 | 793 | 113 | 43 | 273 | 91 | 56 | 17 | 21 | **1,407** |
| Dolores County | 33 | 9 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | **10** |
| Douglas County | 809 | 399 | 21 | 8 | 54 | 14 | 17 | 16 | 0 | **529** |
| Eagle County | 183 | 243 | 13 | 8 | 24 | 6 | 6 | 5 | 0 | **305** |
| El Paso County | 1,640 | 675 | 83 | 27 | 182 | 42 | 35 | 32 | 11 | **1,087** |

| County | Home L2: Class 2b 3 | Depot 48a L2: Class 2b 3 | Depot 48a L2: Class 4 8 | Depot 80a L2: Class 2b 3 | Depot 80a L2: Class 4 8 | Depot 50 62 kW: Class 4 8 | Depot 150 kW: Class 7 8 | En route 350 kW: Class 2b 3 | En route 350 kW: Class 4 8 | Total (Excluding Home Charging) |
|---|---|---|---|---|---|---|---|---|---|---|
| Elbert County | 335 | 87 | 4 | 0 | 6 | 3 | 4 | 5 | 0 | **109** |
| Fremont County | 299 | 57 | 5 | 4 | 17 | 5 | 6 | 5 | 0 | **99** |
| Garfield County | 418 | 340 | 10 | 8 | 31 | 7 | 13 | 10 | 0 | **419** |
| Gilpin County | 53 | 15 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | **18** |
| Grand County | 147 | 73 | 2 | 1 | 9 | 3 | 3 | 0 | 0 | **91** |
| Gunnison County | 94 | 50 | 2 | 3 | 8 | 2 | 2 | 0 | 0 | **67** |
| Hinsdale County | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **3** |
| Huerfano County | 67 | 12 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | **16** |
| Jackson County | 24 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **16** |
| Jefferson County | 1,386 | 556 | 55 | 27 | 128 | 30 | 21 | 26 | 8 | **851** |
| Kiowa County | 25 | 6 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | **9** |
| Kit Carson County | 71 | 44 | 3 | 1 | 6 | 2 | 9 | 0 | 0 | **65** |
| La Plata County | 288 | 151 | 9 | 3 | 19 | 6 | 7 | 6 | 0 | **201** |
| Lake County | 41 | 22 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | **26** |
| Larimer County | 988 | 551 | 43 | 12 | 86 | 27 | 36 | 20 | 8 | **783** |
| Las Animas County | 103 | 41 | 3 | 1 | 6 | 2 | 3 | 0 | 0 | **56** |
| Lincoln County | 51 | 26 | 1 | 0 | 2 | 1 | 3 | 0 | 0 | **33** |
| Logan County | 119 | 61 | 5 | 2 | 8 | 4 | 8 | 0 | 0 | **88** |
| Mesa County | 867 | 377 | 25 | 10 | 59 | 18 | 18 | 17 | 0 | **524** |
| Mineral County | 9 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **3** |
| Moffat County | 168 | 71 | 0 | 2 | 6 | 1 | 4 | 0 | 0 | **84** |
| Montezuma County | 281 | 79 | 4 | 1 | 9 | 3 | 5 | 4 | 0 | **105** |
| Montrose County | 332 | 121 | 5 | 3 | 21 | 4 | 8 | 6 | 0 | **168** |
| Morgan County | 259 | 133 | 5 | 1 | 16 | 5 | 14 | 5 | 0 | **179** |
| Otero County | 95 | 29 | 3 | 1 | 10 | 3 | 5 | 0 | 0 | **51** |
| Ouray County | 28 | 17 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | **18** |

| County | Home L2: Class 2b 3 | Depot 48a L2: Class 2b 3 | Depot 48a L2: Class 4 8 | Depot 80a L2: Class 2b 3 | Depot 80a L2: Class 4 8 | Depot 50 62 kW: Class 4 8 | Depot 150 kW: Class 7 8 | En route 350 kW: Class 2b 3 | En route 350 kW: Class 4 8 | Total (Excluding Home Charging) |
|---|---|---|---|---|---|---|---|---|---|---|
| Park County | 180 | 36 | 2 | 0 | 5 | 2 | 3 | 0 | 0 | **48** |
| Phillips County | 47 | 19 | 1 | 0 | 3 | 1 | 4 | 0 | 0 | **28** |
| Pitkin County | 27 | 54 | 2 | 2 | 8 | 2 | 1 | 0 | 0 | **69** |
| Prowers County | 90 | 31 | 3 | 1 | 7 | 2 | 6 | 0 | 0 | **50** |
| Pueblo County | 585 | 210 | 18 | 5 | 39 | 12 | 15 | 10 | 0 | **309** |
| Rio Blanco County | 100 | 62 | 0 | 0 | 3 | 0 | 2 | 0 | 0 | **67** |
| Rio Grande County | 82 | 30 | 1 | 0 | 6 | 3 | 7 | 0 | 0 | **47** |
| Routt County | 181 | 87 | 3 | 2 | 16 | 3 | 4 | 0 | 0 | **115** |
| Saguache County | 51 | 24 | 1 | 0 | 3 | 2 | 6 | 0 | 0 | **36** |
| San Juan County | 91 | 20 | 0 | 0 | 5 | 0 | 1 | 0 | 0 | **26** |
| San Miguel County | 35 | 34 | 0 | 0 | 4 | 0 | 1 | 0 | 0 | **39** |
| Sedgwick County | 20 | 8 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | **10** |
| Summit County | 119 | 119 | 4 | 8 | 14 | 3 | 2 | 0 | 0 | **150** |
| Teller County | 195 | 43 | 2 | 2 | 10 | 2 | 3 | 0 | 0 | **62** |
| Washington County | 49 | 25 | 2 | 0 | 4 | 1 | 4 | 0 | 0 | **36** |
| Weld County | 1,943 | 999 | 35 | 16 | 92 | 35 | 72 | 40 | 12 | **1,301** |
| Yuma County | 115 | 63 | 2 | 0 | 7 | 3 | 8 | 0 | 0 | **83** |

Table 19. M/HD Charging Ports Per Colorado County By 2030 – Conservative Case

| County | Home L2: Class 2b 3 | Depot 48a L2: Class 2b 3 | Depot 48a L2: Class 4 8 | Depot 80a L2: Class 2b 3 | Depot 80a L2: Class 4 8 | Depot 50 62 kW: Class 4 8 | Depot 150 kW: Class 7 8 | En route 350 kW: Class 2b 3 | En route 350 kW: Class 4 8 | Total (Excluding Home Charging) |
|---|---|---|---|---|---|---|---|---|---|---|
| Adams County | 1,221 | 20 | 100 | 731 | 105 | 105 | 76 | 26 | 14 | **1,177** |
| Alamosa County | 78 | 4 | 3 | 32 | 6 | 5 | 9 | 0 | 0 | **59** |
| Arapahoe County | 863 | 36 | 55 | 673 | 115 | 94 | 55 | 21 | 12 | **1,061** |
| Archuleta County | 140 | 0 | 3 | 28 | 3 | 3 | 3 | 0 | 0 | **40** |
| Baca County | 38 | 0 | 0 | 10 | 0 | 2 | 6 | 0 | 0 | **18** |
| Bent County | 32 | 1 | 0 | 3 | 1 | 1 | 2 | 0 | 0 | **8** |
| Boulder County | 515 | 18 | 19 | 378 | 55 | 38 | 27 | 12 | 0 | **547** |
| Broomfield County | 119 | 2 | 5 | 43 | 4 | 3 | 3 | 0 | 0 | **60** |
| Chaffee County | 132 | 3 | 5 | 43 | 9 | 7 | 5 | 0 | 0 | **72** |
| Cheyenne County | 25 | 0 | 0 | 11 | 0 | 1 | 4 | 0 | 0 | **16** |
| Clear Creek County | 25 | 1 | 4 | 13 | 3 | 1 | 1 | 0 | 0 | **23** |
| Conejos County | 73 | 0 | 0 | 17 | 1 | 3 | 4 | 0 | 0 | **25** |
| Costilla County | 24 | 0 | 2 | 4 | 1 | 1 | 2 | 0 | 0 | **10** |
| Crowley County | 25 | 0 | 0 | 8 | 1 | 1 | 2 | 0 | 0 | **12** |
| Custer County | 76 | 0 | 0 | 11 | 1 | 1 | 1 | 0 | 0 | **14** |
| Delta County | 298 | 0 | 4 | 73 | 7 | 7 | 10 | 5 | 0 | **106** |
| Denver County | 507 | 58 | 54 | 779 | 164 | 165 | 89 | 17 | 21 | **1,347** |
| Dolores County | 33 | 0 | 0 | 8 | 0 | 1 | 1 | 0 | 0 | **10** |
| Douglas County | 809 | 9 | 10 | 397 | 31 | 28 | 27 | 16 | 0 | **518** |
| Eagle County | 183 | 9 | 4 | 243 | 15 | 12 | 9 | 5 | 0 | **297** |
| El Paso County | 1,640 | 40 | 79 | 662 | 116 | 82 | 55 | 32 | 11 | **1,077** |
| Elbert County | 335 | 1 | 4 | 87 | 4 | 4 | 7 | 5 | 0 | **112** |
| Fremont County | 299 | 6 | 9 | 56 | 9 | 10 | 10 | 5 | 0 | **105** |
| Garfield County | 418 | 8 | 9 | 339 | 20 | 14 | 20 | 10 | 0 | **420** |

| County | Home L2: Class 2b 3 | Depot 48a L2: Class 2b 3 | Depot 48a L2: Class 4 8 | Depot 80a L2: Class 2b 3 | Depot 80a L2: Class 4 8 | Depot 50 62 kW: Class 4 8 | Depot 150 kW: Class 7 8 | En route 350 kW: Class 2b 3 | En route 350 kW: Class 4 8 | Total (Excluding Home Charging) |
|---|---|---|---|---|---|---|---|---|---|---|
| Gilpin County | 53 | 0 | 2 | 15 | 1 | 1 | 1 | 0 | 0 | **20** |
| Grand County | 147 | 1 | 0 | 73 | 4 | 6 | 4 | 0 | 0 | **88** |
| Gunnison County | 94 | 4 | 5 | 49 | 5 | 3 | 3 | 0 | 0 | **69** |
| Hinsdale County | 5 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | **3** |
| Huerfano County | 67 | 0 | 0 | 11 | 1 | 1 | 2 | 0 | 0 | **15** |
| Jackson County | 24 | 0 | 0 | 16 | 0 | 0 | 1 | 0 | 0 | **17** |
| Jefferson County | 1,386 | 30 | 35 | 554 | 83 | 58 | 33 | 26 | 8 | **827** |
| Kiowa County | 25 | 0 | 0 | 5 | 0 | 1 | 3 | 0 | 0 | **9** |
| Kit Carson County | 71 | 4 | 0 | 41 | 5 | 3 | 14 | 0 | 0 | **67** |
| La Plata County | 288 | 3 | 8 | 150 | 13 | 10 | 11 | 6 | 0 | **201** |
| Lake County | 41 | 0 | 2 | 22 | 1 | 1 | 1 | 0 | 0 | **27** |
| Larimer County | 988 | 20 | 39 | 542 | 62 | 45 | 56 | 20 | 8 | **792** |
| Las Animas County | 103 | 2 | 3 | 40 | 4 | 4 | 4 | 0 | 0 | **57** |
| Lincoln County | 51 | 0 | 1 | 26 | 1 | 2 | 5 | 0 | 0 | **35** |
| Logan County | 119 | 3 | 6 | 60 | 5 | 7 | 12 | 0 | 0 | **93** |
| Mesa County | 867 | 13 | 19 | 374 | 39 | 32 | 29 | 17 | 0 | **523** |
| Mineral County | 9 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | **3** |
| Moffat County | 168 | 2 | 0 | 71 | 4 | 2 | 6 | 0 | 0 | **85** |
| Montezuma County | 281 | 1 | 2 | 79 | 6 | 5 | 8 | 4 | 0 | **105** |
| Montrose County | 332 | 7 | 5 | 118 | 13 | 8 | 13 | 6 | 0 | **170** |
| Morgan County | 259 | 1 | 5 | 133 | 9 | 9 | 22 | 5 | 0 | **184** |
| Otero County | 95 | 2 | 3 | 28 | 5 | 5 | 7 | 0 | 0 | **50** |
| Ouray County | 28 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | **17** |
| Park County | 180 | 1 | 2 | 35 | 3 | 3 | 5 | 0 | 0 | **49** |
| Phillips County | 47 | 0 | 0 | 19 | 2 | 2 | 7 | 0 | 0 | **30** |
| Pitkin County | 27 | 2 | 0 | 54 | 2 | 5 | 1 | 0 | 0 | **64** |

| County | Home L2: Class 2b 3 | Depot 48a L2: Class 2b 3 | Depot 48a L2: Class 4 8 | Depot 80a L2: Class 2b 3 | Depot 80a L2: Class 4 8 | Depot 50 62 kW: Class 4 8 | Depot 150 kW: Class 7 8 | En route 350 kW: Class 2b 3 | En route 350 kW: Class 4 8 | Total (Excluding Home Charging) |
|---|---|---|---|---|---|---|---|---|---|---|
| Prowers County | 90 | 1 | 1 | 31 | 4 | 4 | 9 | 0 | 0 | **50** |
| Pueblo County | 585 | 6 | 23 | 209 | 22 | 23 | 24 | 10 | 0 | **317** |
| Rio Blanco County | 100 | 0 | 1 | 62 | 2 | 0 | 3 | 0 | 0 | **68** |
| Rio Grande County | 82 | 0 | 2 | 29 | 3 | 5 | 11 | 0 | 0 | **50** |
| Routt County | 181 | 4 | 4 | 85 | 7 | 7 | 6 | 0 | 0 | **113** |
| Saguache County | 51 | 0 | 3 | 23 | 2 | 3 | 10 | 0 | 0 | **41** |
| San Juan County | 91 | 1 | 0 | 20 | 2 | 1 | 2 | 0 | 0 | **26** |
| San Miguel County | 35 | 0 | 0 | 34 | 1 | 2 | 1 | 0 | 0 | **38** |
| Sedgwick County | 20 | 0 | 0 | 8 | 0 | 1 | 2 | 0 | 0 | **11** |
| Summit County | 119 | 9 | 2 | 119 | 9 | 6 | 3 | 0 | 0 | **148** |
| Teller County | 195 | 3 | 6 | 43 | 5 | 4 | 5 | 0 | 0 | **66** |
| Washington County | 49 | 1 | 2 | 25 | 3 | 3 | 7 | 0 | 0 | **41** |
| Weld County | 1,943 | 17 | 25 | 996 | 60 | 59 | 112 | 40 | 12 | **1,321** |
| Yuma County | 115 | 1 | 0 | 63 | 3 | 6 | 13 | 0 | 0 | **86** |

Table 20. M/HD Charging Ports Per Utility Territory By 2030 – Average Case

| Utility Name | Home L2: Class 2b 3 | Depot 48a L2: Class 2b 3 | Depot 48a L2: Class 4 8 | Depot 80a L2: Class 2b 3 | Depot 80a L2: Class 4 8 | Depot 50 62 kW: Class 4 8 | Depot 150 kW: Class 7 8 | En route 350 kW: Class 2b 3 | En route 350 kW: Class 4 8 | Total (Excluding Home Charging) |
|---|---|---|---|---|---|---|---|---|---|---|
| Black Hills Energy | 1,837 | 546 | 56 | 25 | 145 | 39 | 50 | 29 | 8 | **898** |
| City of Burlington | 35 | 27 | 1 | 1 | 2 | 0 | 4 | 0 | 0 | **35** |
| City of Colorado Springs | 863 | 481 | 56 | 18 | 107 | 26 | 22 | 16 | 5 | **731** |
| City of Fort Morgan | 117 | 83 | 2 | 0 | 9 | 2 | 8 | 0 | 0 | **104** |
| City of Loveland | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **17** |
| CORE Electric Cooperative | 849 | 239 | 13 | 4 | 60 | 12 | 17 | 13 | 0 | **358** |
| Delta Montrose Electric Assn | 341 | 134 | 6 | 3 | 20 | 5 | 7 | 5 | 0 | **180** |
| Empire Electric Assn | 366 | 116 | 5 | 2 | 15 | 5 | 7 | 5 | 0 | **155** |
| Grand Valley Power | 15 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **2** |
| Gunnison County Electric Assn | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **3** |
| High West Energy | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **2** |
| Highline Electric Assn | 303 | 157 | 9 | 4 | 20 | 11 | 23 | 5 | 0 | **229** |
| Holy Cross Electric Assn | 647 | 639 | 25 | 18 | 65 | 16 | 20 | 15 | 0 | **798** |
| K C Electric Assn | 117 | 45 | 4 | 0 | 8 | 4 | 13 | 0 | 0 | **74** |
| La Plata Electric Assn | 165 | 75 | 5 | 2 | 8 | 3 | 3 | 0 | 0 | **96** |
| Moon Lake Electric Assn | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **1** |
| Morgan County Rural Electric Assn | 151 | 52 | 2 | 0 | 7 | 2 | 6 | 0 | 0 | **69** |
| Mountain Parks Electric | 163 | 90 | 3 | 3 | 15 | 3 | 4 | 0 | 0 | **118** |

| Utility Name | Home L2: Class 2b 3 | Depot 48a L2: Class 2b 3 | Depot 48a L2: Class 4 8 | Depot 80a L2: Class 2b 3 | Depot 80a L2: Class 4 8 | Depot 50 62 kW: Class 4 8 | Depot 150 kW: Class 7 8 | En route 350 kW: Class 2b 3 | En route 350 kW: Class 4 8 | Total (Excluding Home Charging) |
|---|---|---|---|---|---|---|---|---|---|---|
| Mountain View Electric Assn | 121 | 33 | 2 | 0 | 6 | 1 | 3 | 0 | 0 | **45** |
| Poudre Valley Rural Electric Assn | 25 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **3** |
| San Isabel Electric Assn | 79 | 37 | 3 | 1 | 5 | 2 | 2 | 0 | 0 | **50** |
| San Miguel Power Assn | 37 | 15 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | **17** |
| Southeast Colorado Power Assn | 32 | 7 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | **11** |
| Town of Fleming | 8 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **2** |
| Town of Frederick | 10 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **1** |
| Town of Granada | 23 | 3 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | **5** |
| Town of Haxtun | 14 | 9 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | **11** |
| United Power | 1,671 | 982 | 74 | 16 | 113 | 60 | 66 | 31 | 11 | **1,353** |
| White River Electric Assn | 151 | 69 | 0 | 1 | 6 | 1 | 3 | 0 | 0 | **80** |
| Xcel Energy | 9,149 | 5,167 | 455 | 175 | 1,077 | 334 | 306 | 173 | 63 | **7,750** |
| Yampa Valley Electric Assn | 19 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **4** |
| Y-W Electric Assn | 17 | 6 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | **8** |

Table 21. M/HD Charging Ports Per Utility Territory By 2030 – Conservative Case

| Utility Name | Home L2: Class 2b 3 | Depot 48a L2: Class 2b 3 | Depot 48a L2: Class 4 8 | Depot 80a L2: Class 2b 3 | Depot 80a L2: Class 4 8 | Depot 50 62 kW: Class 4 8 | Depot 150 kW: Class 7 8 | En route 350 kW: Class 2b 3 | En route 350 kW: Class 4 8 | Total (Excluding Home Charging) |
|---|---|---|---|---|---|---|---|---|---|---|
| Black Hills Energy | 1,837 | 31 | 63 | 542 | 83 | 75 | 79 | 29 | 8 | **910** |
| City of Burlington | 35 | 4 | 0 | 24 | 2 | 1 | 6 | 0 | 0 | **37** |
| City of Colorado Springs | 863 | 29 | 52 | 470 | 70 | 51 | 34 | 16 | 5 | **727** |
| City of Fort Morgan | 117 | 1 | 0 | 83 | 5 | 5 | 12 | 0 | 0 | **106** |
| City of Loveland | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | **17** |
| CORE Electric Cooperative | 849 | 5 | 7 | 238 | 36 | 22 | 28 | 13 | 0 | **349** |
| Delta Montrose Electric Assn | 341 | 6 | 7 | 130 | 13 | 9 | 11 | 5 | 0 | **181** |
| Empire Electric Assn | 366 | 2 | 2 | 116 | 8 | 9 | 11 | 5 | 0 | **153** |
| Grand Valley Power | 15 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | **2** |
| Gunnison County Electric Assn | 2 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | **3** |
| High West Energy | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | **2** |
| Highline Electric Assn | 303 | 5 | 7 | 156 | 13 | 18 | 37 | 5 | 0 | **241** |
| Holy Cross Electric Assn | 647 | 20 | 13 | 637 | 39 | 32 | 32 | 15 | 0 | **788** |
| K C Electric Assn | 117 | 0 | 1 | 45 | 6 | 6 | 20 | 0 | 0 | **78** |
| La Plata Electric Assn | 165 | 2 | 3 | 75 | 7 | 4 | 5 | 0 | 0 | **96** |
| Moon Lake Electric Assn | 8 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | **1** |
| Morgan County Rural Electric Assn | 151 | 0 | 3 | 52 | 4 | 4 | 10 | 0 | 0 | **73** |
| Mountain Parks Electric | 163 | 4 | 4 | 88 | 5 | 8 | 6 | 0 | 0 | **115** |

| Utility Name | Home L2: Class 2b 3 | Depot 48a L2: Class 2b 3 | Depot 48a L2: Class 4 8 | Depot 80a L2: Class 2b 3 | Depot 80a L2: Class 4 8 | Depot 50 62 kW: Class 4 8 | Depot 150 kW: Class 7 8 | En route 350 kW: Class 2b 3 | En route 350 kW: Class 4 8 | Total (Excluding Home Charging) |
|---|---|---|---|---|---|---|---|---|---|---|
| Mountain View Electric Assn | 121 | 1 | 3 | 33 | 4 | 2 | 4 | 0 | 0 | **47** |
| Poudre Valley Rural Electric Assn | 25 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | **3** |
| San Isabel Electric Assn | 79 | 2 | 3 | 36 | 4 | 4 | 3 | 0 | 0 | **52** |
| San Miguel Power Assn | 37 | 0 | 0 | 15 | 0 | 0 | 2 | 0 | 0 | **17** |
| Southeast Colorado Power Assn | 32 | 0 | 0 | 7 | 1 | 1 | 3 | 0 | 0 | **12** |
| Town of Fleming | 8 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | **2** |
| Town of Frederick | 10 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | **1** |
| Town of Granada | 23 | 0 | 0 | 3 | 0 | 1 | 2 | 0 | 0 | **6** |
| Town of Haxtun | 14 | 0 | 0 | 9 | 0 | 1 | 2 | 0 | 0 | **12** |
| United Power | 1,671 | 23 | 93 | 973 | 81 | 97 | 105 | 31 | 11 | **1,414** |
| White River Electric Assn | 151 | 2 | 0 | 68 | 3 | 2 | 6 | 0 | 0 | **81** |
| Xcel Energy | 9,149 | 230 | 316 | 5,112 | 698 | 594 | 483 | 173 | 63 | **7,669** |
| Yampa Valley Electric Assn | 19 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | **4** |
| Y-W Electric Assn | 17 | 0 | 0 | 5 | 0 | 0 | 2 | 0 | 0 | **7** |

# References

[1] Northeast States for Coordinated Air Use Management, "Multi-State Medium- and Heavy-Duty Zero Emission Vehicle Memorandum of Understanding," Northeast States for Coordinated Air Use Management, 2020.

[2] California Air Resources Board, "Advanced Clean Trucks Regulation," 15 March 2021. [Online]. Available: https://ww2.arb.ca.gov/rulemaking/2019/advancedcleantrucks. [Accessed 3 March 2023].

[3] Colorado Energy Office, Colorado Air Pollution Control Division, and Colorado Department of Transportation, "2022 Colorado Clean Truck Strategy," Denver, 2022.

[4] U.S. Environmental Protection Agency, "Sources of Greenhouse Gas Emissions," 5 August 2022. [Online]. Available: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions. [Accessed 26 January 2023].

[5] United States Envrionmental Protection Agency, "Colorado Nonattainment/Maintenance Status for Each County by Year for All Criteria Pollutants," [Online]. Available: https://www3.epa.gov/airquality/greenbook/anayo_co.html. [Accessed 3 March 2023].

[6] Colorado General Assembly, "HB19-1261: Climate Action Plan to Reduce Pollution," Colorado General Assembly, Denver, 2019.

[7] Colorado General Assembly, "SB23-016: Greenhouse Gas Emission Reduction Measures," Colorado General Assembly, Denver, 2023.

[8] State of Colorado, "Colorado Greenhouse Gas Pollution Reduction Roadmap," Denver, 2021.

[9] Office of Governor Jared Polis, "Executive Order B 2019 002," Office of Governor Jared Polis, Denver, 2019.

[10] Northeast States for Coordinated Air Use Management, "15 States and the District of Columbia Join Forces to Accelerate Bus and Truck Electrification," Northeast States for Coordinated Air Use Management, 2020.

[11] Colorado State Legislature, "Senate Bill 21-260," Colorado State Legislature, Denver, 2021.

[12] Colorado Department of Public Health and Environment, "Colorado adopts new measures to increase availability of zero-emission trucks that offer lower operating and fuel costs," Denver, 2023.

[13] Colorado Department of Public Health and Environment , "Fact Sheet: Colorado Clean Truck Rules," Denver, 2022.

[14] Colorado State Legislature, "House Bill 23-1272," Colorado State Legislature, Denver, 2023.

[15] Paul Moynihan et al., "Colorado Medium- and Heavy-Duty (M/HD) Vehicle Study," MJ Bradley & Associates, 2021.

[16] Colorado Energy Office, "Opportunities for Low-Carbon Hydrogen in Colorado: A Roadmap," Colorado Energy Office, Denver, 2021.

[17] Marissa Moultak, Nic Lutsey, and Dale Hall, "Transitioning to Zero-Emission Heavy-Duty Freight Vehicles," International Council on Clean Transportation, Washington, DC, 2017.

[18] Rick Mihelic, Mike Roeth, Denise Rondini, and Laurie Guevara-Stone, "Electric Trucks—Where They Make Sense," North American Council for Freight Efficiency, 2018.

[19] Angie Farrag-Thibault, et al., "Making Zero-Emissions Trucks Possible: An Industry-Backed, 1.5°C-Aligned Transition Strategy," Mission Possible Partners, 2022.

[20] Mike Roeth et al., "Electric Trucks Have Arrived: The Use Case for Medium-Duty Box Trucks," North American Council for Freight Efficiency, 2022.

[21] Mike Roeth et al., "Electrick Trucks Have Arrived: The Use Case for Terminal Tractors," North American Council For Freight Efficiency, 2022.

[22] Mike Roeth et al., "Electric Trucks Have Arrived: The Use Case for Vans and Step Vans," North American Council For Freight Efficiency, 2022.

[23] Mike Roeth et al., "Electric Trucks Have Arrived: The Use Case for Heavy-Duty Regional Haul Tractors," North American Council for Freight Efficiency, 2022.

[24] Jessie Lund, John Schroeder, Emily Porter, and Dave Mullaney, "Charting the Course for Early Truck Electrification," RMI, 2022.

[25] Amol Phadke et al., "Why Regional and Long-Haul Trucks are Primed For Electrification Now," Lawrence Berkeley National Laboratory, Berkeley , 2021.

[26] Jessie Lund, Rick Mihelic, and Mike Roeth, "Amping Up: Charging Infrastructure for Electric Trucks," North American Council For Freight Efficiency, 2019.

[27] Kevin Walkowicz, Andrew Meintz, and John Farrell, "R&D Insights for Extreme Fast Charging of Medium- and Heavy-Duty Vehicles: Insights from the NREL Commercial

Vehicles and Extreme Fast Charging Research Needs Workshop," National Renewable Energy Laboratory, Golden, Colorado, 2019.

[28] Brennan Bourlaugh et al., "Charging Needs for Electric Semi-Trailer Trucks," *Renewable and Sustainable Energy Transition,* vol. 2, 2022.

[29] World Economic Forum, "Road Freight Zero: Pathways to Faster Adoption of Zero-Emissions Trucks," World Economic Forum , Geneva, 2021.

[30] Leilani Gonzalez, Sofya Olenicheva, Eva Brungard, and Rianna LeHane, "Medium- and Heavy-Duty Electrification: Weighing the Opportunities and Barriers to Zero Emission Fleets," Zero Emission Transportation Association (ZETA), 2022.

[31] Lucy McKenzie, James Di Filippo, Josh Rosenberg, and Nick Nigro, "U.S. Vehicle Electrification Infrastructure Assessment: Medium- and Heavy-Duty Truck Charging," Atlas Public Policy, Washington, DC, 2021.

[32] Chih-Wei Hsu, Peter Slowik, and Nic Lutsey, "Colorado Charging Infrastructure Needs to Reach Electric Vehicle Goals," International Council on Clean Transportation, 2021.

[33] California Energy Commission, "Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment: Analyzing Charging Needs to Support Zero Emission Vehicles in 2030," California Energy Commission, Sacramento, 2021.

[34] Tom Taylor, "The Advance of the Advanced Clean Truck Rule," Atlas Public Policy, Washington, DC, 2021.

[35] CharIN, "Megawatt Charging System (MCS)," CharIN, [Online]. Available: https://www.charin.global/technology/mcs/. [Accessed 5 March 2023].

[36] Nicole Lepre, Spencer Burget, and Lucy McKenzie, "Deploying Charging Infrastructure For Electric Transit Buses," Atlas Public Policy, Washington D.C., 2022.

[37] Cassandra Profita, "PGE, Daimler team up to build charging hub for electric trucks in Portland," Oregon Public Broadcasting, Portland, 2020.

[38] Southwest Energy Efficiency Partnership, "Colorado Utility Energy Efficiency Programs," 2018. [Online]. Available: https://www.swenergy.org/utilities/states/colorado. [Accessed 10 February 2023].

[39] California State Legislature, "Senate Bill 944," California State Legislature, Sacramento, 2017.

[40] Colorado State Legislature, "House Bill 23-1233," Colorado State Legislature, Denver, 2023.

[41] Elaine O'Grady and Jesse Way, "Prepaing Our Communities for Electric Vehicles: Facilitating Deployment of DC Fast Chargers," Northeast States for Coordinated Air Use Management, 2019.

[42] New York State Energy Research Development Authority, "DC Fast Charger Streamlined Permitting Guidbook for Local Governments," New York State Energy Research Development Authority, Albany, 2020.

[43] Colorado State Legislature, "Senate Bill 22-193," Colorado State Legislature, Denver, 2022.

[44] Colorado State Legislature, "Senate Bill 21-230," Colorado State Legislature, Denver, 2021.

[45] Public Service Company of Colorado, "Transportation Electrification Plan 2021-2023," Public Service Company of Colorado, 2020.

[46] U.S. Department of Energy, "Alternative Fuels Data Center," [Online]. Available: https://afdc.energy.gov/laws/10513. [Accessed 3 March 2023].

[47] Colorado State Legislature, "Senate Bill 19-077," Colorado State Legislature, Denver, 2019.

[48] Ehsan Sabri Islam, Ram Vijayagopal, and Aymeric Rousseau, "A Comprehensive Simulation Study to Evaluate Future Vehicle Energy and Cost Reduction Potential," Argonne National Laboratory , Lemont, IL, 2022.

[49] HDR, CALSTART, S Curve Strategies, Ross Strategic, "West Coast Clean Transit Corridor Initiative: Interstate 5 Corridor (CA, OR, WA) Final Report," June 2020.

[50] U.S. Environmental Protection Agency , "Latest Version of MOtor Vehicle Emission Simulator (MOVES)," 9 December 2022. [Online]. Available: https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves. [Accessed 3 March 2023].

[51] M. Nicholas, "Estimating Electric Vehicle Charging Infrastructure Costs Across Major U.S. Metropolitan Areas," International Council on Clean Transportation, Washington, DC, August 2019.

[52] Home Advisor, "How Much Does It Cost to Upgrade or Replace an Electrical Panel," 6 July 2022. [Online]. Available: https://www.homeadvisor.com/cost/electrical/upgrade-an-electrical-panel/#200. [Accessed 3 March 2023].

[53] ZEVS Society, "JuiceBox 48 Hardwire," [Online]. Available: https://shop.zevsociety.com/products/juicebox-48-hardwire. [Accessed 3 March 2023].

[54] ClipperCreek, "HCS-60, 48 Amp, Level 2 EVSE, 240V, with 25 ft cable," [Online]. Available: https://store.clippercreek.com/level2/level2-40-to-80/hcs-60-48-amp-ev-charging-station. [Accessed 3 March 2023].

[55] ChargePoint, "ChargePoint Home Flex, NEMA 6-50 Plug," 2023. [Online]. Available: https://www.chargepoint.com/drivers/home/chargepoint-home-flex/. [Accessed 3 March 2023].

[56] Gladstein, Neandross & Associates and Environmental Defense Fund, "California Heavy-Duty Fleet Electrification: Summary Report," Gladstein, Neandross & Associates , March 2021.

[57] Energetics Incorporated, "California Investor-Owned Utility Transportation Electrification Priority Review Projects: Final Evaluation Report," April 2021.

[58] Bureau of Transportation Statistics, *Freight Analysis Framework Highway Network Assignments,* 2022.

[59] Colorado Department of Public Health and Environment , "Clean Trucking," Updated 2023. [Online]. Available: https://cdphe.colorado.gov/cleantrucking. [Accessed 8 February 2023].

[60] U.S. Environmental Protection Agency, [Online].

[61] Ehsan Sabri Islam et al., "A Detailed Vehicle Modeling & Simulation Study Quantifying Energy Consumption and Cost Reduction of Advanced Vehicle Technologies Through 2050," Argonne National Laboratory , Lemont, IL, 2021.

[62] Volvo Lights, "About Volvo Lights," 2020 February . [Online]. Available: https://www.lightsproject.com/about/. [Accessed 9 February 2023].

[63] California Energy Commission , "Electric Vehicle Charging Infrastructure Assessment: Analyzing Charging Needs to Support Zero-Emission Vehicles in 2030," California Energy Commission, Sacramento, 2021.

ATLAS
PUBLIC POLICY
WWW.ATLASPOLICY.COM