RESEARCH BRIEF

OCTOBER 2025

Impacts of California Low Carbon Fuel Standard amendments on support for medium- and heavy-duty vehicle electrification

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SUMMARY

In November 2024, the California Air Resources Board adopted amendments to the Low Carbon Fuel Standard (LCFS) program that hold important implications for the state's transport sector. By proportionally incentivizing alternative fuels based on their greenhouse gas reductions, the amendments have the potential to offer sizeable support for medium- and heavy-duty vehicle (MHDV) electrification through three key mechanisms: charging infrastructure funding, charging cost reductions, and point-of-sale vehicle rebates. However, the ultimate impact of these support mechanisms is heavily dependent on LCFS credit prices, which can fluctuate substantially based on market dynamics.

This paper explores the revenue the LCFS amendments can direct to MHDV electrification in California through 2035. We define MDHVs as vehicles weighing greater than 14,000 pounds (Class 4 and above). We project that combined energy and infrastructure credits can generate approximately $8.4 billion in funding for charging infrastructure in our Central credit price scenario, and $3.8 and $15.3 billion in our Low and High scenarios, respectively, between 2025 and 2035. Credits directed toward point-of-sale MHDV rebates could provide an additional $0.41 billion ($0.22 in the Low and $0.88 billion in the High scenarios) in funding for MHDVs over the next decade. Together, this is much more than the approximately $1.4 billion in funding

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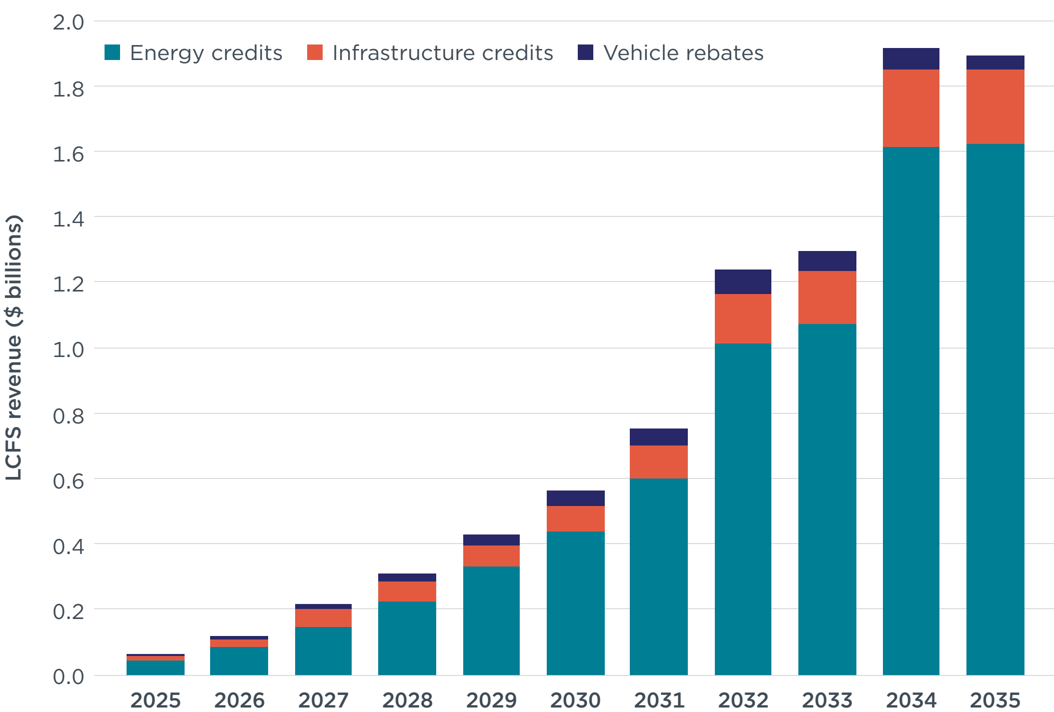
distributed to zero-emission trucks and buses since 2010 under California's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project.[1]

Within this total, we estimate that charge point operators can generate a cumulative $1.2 billion in infrastructure crediting under our Central credit price scenario with a cap in place. At high credit prices and low utilization rates, charge point operators generate substantial revenues from LCFS infrastructure credits. This support can help to balance the high breakeven costs of charger installation if utilization rates are low during early years of charger operation.

We present the estimated quantity of LCFS funding that can support MHDV electrification in Figure 1. We find that energy credits for charge point operators make up the greatest share of crediting, followed by infrastructure crediting and a dedicated pool of credits to fund point-of-sale rebates via the Clean Fuel Reward Program.

Figure 1
Total LCFS revenue to support MHDV electrification by year



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The LCFS has the potential to be an unprecedented funding stream for the electrification of MHDVs in California. Maintaining a high LCFS credit price is critical to offset the high breakeven costs of fast and ultra-fast chargers in the near term. Simultaneously, directing crediting revenue toward point-of-sale rebates via the Clean Fuel Reward Program can help lower the price premium of heavy weight-class battery electric vehicles.

1 "Impact," California HVIP, Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project, accessed September 22, 2025, https://californiahvip.org/impact/.

INTRODUCTION

Facilitating California's long-term ambition of decarbonizing its medium- and heavy-duty vehicle (MHDV) segment will take substantial investment in new zero-emission vehicles (ZEVs) and charging infrastructure. California Air Resources Board (CARB) analysis estimates that 510,000 new medium- and heavy-duty ZEVs will be registered in California by 2035, growing to 1,590,000 by 2050, driven by the state's Advanced Clean Trucks (ACT) and Advanced Clean Fleets regulations.[2] Despite the federal government's rescission of a Clean Air Act waiver granted to California, the state will continue to enforce the ACT regulation consistent with the voluntary agreement it struck with truck manufacturers in 2023.[3] To support rapid growth in the ZEV market, California will need to install nearly 100,000 overnight chargers and 5,000 fast and ultra-fast chargers to serve Class 4–8 MHDVs between 2025 and 2035.[4]

The November 2024 Low Carbon Fuel Standard (LCFS) amendments expand the program to offer credits for the deployment of charging infrastructure for MHDVs, supporting the state's broader goals for electrification. The amendments also establish a MHDV rebate program, which consolidates revenue from residential charging and distributes it to customers at the point of sale.[5] Newly adopted changes to other MHDV fuel pathways such as biomethane and biomass-based diesel are also expected to affect LCFS compliance and thus indirectly impact the rate of electrification.

To assess the revenue LCFS may direct towards the electrification of California's MHDV segment through 2035, this research brief projects the value and quantity of LCFS credits allocated to charging infrastructure and point-of-sale vehicle rebates. After this period, we expect that credit revenue will level off as average fast-charger utilization rates exceed the threshold to qualify for LCFS fast-charging infrastructure credits (FCI) and FCI crediting phases out of eligibility.

We begin by outlining the components of the LCFS amendments. Then, we summarize CARB's projections of the impact of the amendments on LCFS credit prices and fuel demand. We then project the number of deployed MHDV chargers through 2035, their modeled utilization rates, and their associated nameplate capacity and quantity of electricity dispensed. Based on those estimates, we project the annual revenue available to MHDV charging operators in Central, Low, and High credit price scenarios. We then assess the potential for the LCFS to support MHDV electrification through charging cost reductions and point-of-sale vehicle rebates. We conclude with a discussion of the impacts of the LCFS on MHDV electrification and policy considerations.

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2 CARB has withdrawn its federal waiver request for its Advanced Clean Fleets Regulation but plans to apply the rule to state and local fleets. "Advanced Clean Fleets," California Air Resources Board, accessed September 10, 2025, https://ww2.arb. ca.gov/our-work/programs/advanced-clean-fleets; California Air Resources Board, "Advanced Clean Trucks Regulation," accessed September 10, 2025, https://ww2.arb.ca.gov/rulemaking/2019/advancedcleantrucks.

3 State of California, "Executive Order N-27-25," June 12, 2025, https://www.gov.ca.gov/wp-content/uploads/2025/06/CRA-Response-EO-N-27-25_-ATTESTED.pdf.

4 Hamilton Steimer et al., *Mind the Gap: An Assessment of 2030 and 2035 Charging Infrastructure Needs for Zero-Emission Medium- and Heavy-Duty Vehicles in the United States* (International Council on Clean Transportation, 2025), https://theicct.org/publication/assessment-of-2030-and-2035-charging-infrastructure-needs-for-ze-mhdv-us-jul25/.

5 California Air Resources Board, "Final Regulation Order: Proposed Amendments to the Low Carbon Fuel Standard Regulation," July 1, 2025, https://ww2.arb.ca.gov/sites/default/files/2025-07/2025_lcfs_fro_oal-approved_unofficial_07162025.pdf.

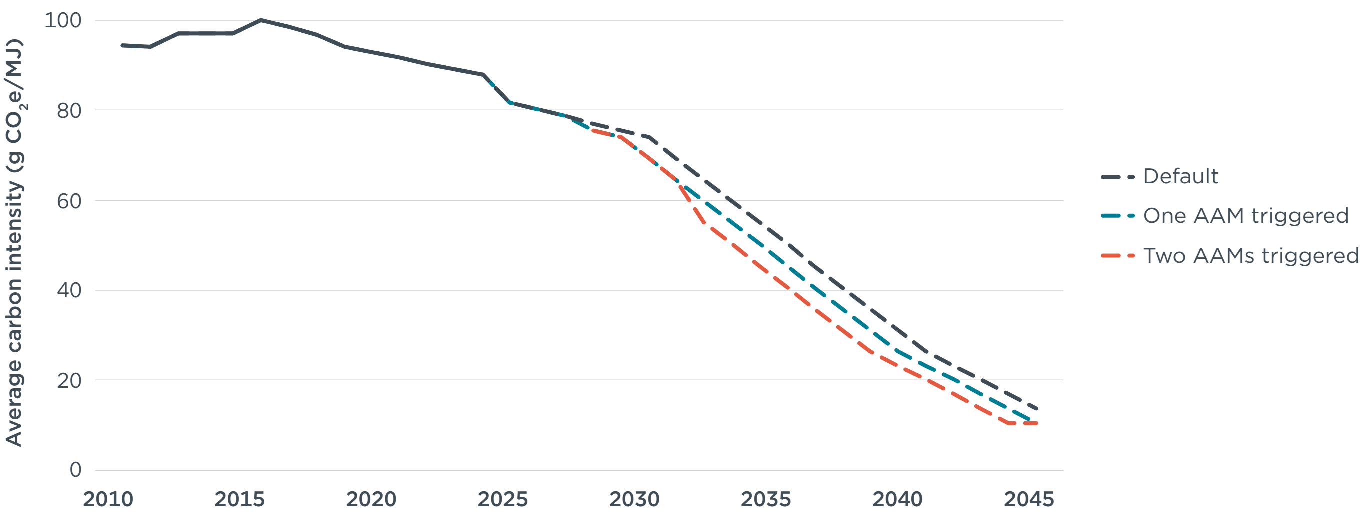
POLICY BACKGROUND

According to CARB's Initial Statement of Reasons, the LCFS amendments adopted by the board in November 2024 were designed to better align the program with the state's 2022 Scoping Plan for Achieving Carbon Neutrality, including rapidly moving toward zero-emission transportation.[6] The 2022 Scoping Plan is designed to set the California economy on a path to reach carbon neutrality by 2045 by reducing greenhouse gas (GHG) emissions by 85% from 1990 levels.[7] Accordingly, the adopted amendments set a target to reduce the carbon intensity (CI) of the transportation fuel pool by 30% below the fossil baseline by 2030, up from the former 20% target for that year. CARB also extended CI reduction targets through 2045 (targets previously plateaued in 2030) and set a 90% CI reduction target for that year.[8]

The amendments also pair the more ambitious CI reduction trajectory with an immediate 9% step-down in the annual CI benchmark in 2025. The annual CI reduction benchmark for the diesel fuel pool from the start of the LCFS program through 2045 is illustrated in Figure 2. The annual benchmark decreases at a steeper rate starting in 2031, continuing through later years. Beginning in 2028, the CI reduction trajectory may become dynamic due to the introduction of an automatic acceleration mechanism (AAM).[9] CARB introduced the AAM to help tighten the credit market and to draw down the program's current 38 million credit surplus.[10] We illustrate what the annual CI trajectory would look like if the AAM is triggered in 2027 (taking effect January 1 of the following year) and again in 2031.

Figure 2

Average carbon intensity reduction benchmark for the diesel fuel pool under adopted amendments and with one or two automatic acceleration mechanisms triggered



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6 California Air Resources Board. "Staff Report: Initial Statement of Reasons," December 19, 2023.

7 California Air Resources Board, "2022 Scoping Plan for Achieving Carbon Neutrality," December 2022, https://ww2.arb.ca.gov/sites/default/files/2023-04/2022-sp.pdf.

8 The framework of the LCFS program is explained more in detail in "Stillwater LCFS 101," Stillwater Associates LLC, September 10, 2025, https://stillwaterpublications.com/stillwater-lcfs-101/.

9 The AAM advances the CI trajectory by one year if certain requirements are met (specifically if the credit bank to deficit ration exceeds a value of 3) and can only be triggered once per year.

10 California Air Resources Board, "2024 LCFS Reporting Tool Quarterly Data Summary," April 30, 2025, https://ww2.arb.ca.gov/sites/default/files/2025-05/Q4%202024%20Data%20Summary.pdf.

The amendments introduce several new provisions to support MHDV electrification. The newly created FCI crediting pool establishes a mechanism for eligible parties (e.g., charge point operators) to generate credits from installed charging capacity. FCI credits are capped at 2.5% of total deficits from the previous quarter. Similar provisions apply for hydrogen refueling infrastructure crediting. Fast-charging installations must also adhere to specific criteria that prioritize high-capacity public charger deployment. We summarize the specification requirements for MHDV capacity crediting within the LCFS amendments in Table 1.[11] Charge point operators or designated third parties must submit applications for new chargers to CARB before December 31, 2035, to be eligible.

Table 1

Summary of criteria for MHDV capacity crediting within 2024 LCFS amendments

Criteria	Description
Minimum nameplate power rating	50 kW
Maximum power rating at a single address (kW)	40 MW
Minimum weight of serviced vehicles	14,001 lb
Period of applicability	2025–2045
Location restrictions	Public chargers must meet one of these criteria: • Be located in California • Be located within 5 miles of a Federal Highway Administration alternative fuel corridor • Situated on or adjacent to property used for overnight MHDV parking • Received capital funding from competitive governmental grant programs that incorporates location evaluation criteria
Other restrictions	• Chargers entered operation on or after January 1, 2022 • Chargers can generate FCI credits for a maximum of 10 years • Public chargers can service a single fleet for a maximum 12 hours per day • FCI credits from all approved heavy-duty FCI fueling supply equipment must not exceed 2.5% of deficits

The amendments also introduce a Clean Fuel Reward Program (CFRP) for point-of-sale MHDV rebates, restricted to vehicles with a minimum weight of 8,501 pounds. Battery electric motorcycles are also eligible for CFRP funding. The CFRP is administered by state electric distribution utilities and funded by proceeds from residential charging. Vehicles subject to California's High Priority and Federal Fleets requirements do not qualify for CFRP rebates. This includes vehicles owned and operated by an entity with a fleet size of at least 50 vehicles, entities that make $50 million or more in annual gross revenue, and vehicles operated by federal, state, and local government

11 California Air Resources Board, "Final Regulation Order."

agencies.[12] It remains unclear whether the suspension of the Advanced Clean Fleets rulemaking in mid-January will alter this definition of vehicle eligibility.[13]

The CFRP is administered by Southern California Edison on behalf of all participating utilities with oversight from the California Public Utilities Commission and CARB. The LCFS obligates all state investor-owned electric utilities, including Pacific Gas and Electric, San Diego Gas and Electric, and Southern California Edison, to participate in the program while other utilities may opt-in to the program and generate base credits.[14] All participating utilities must allocate a portion of base residential credits from home charging to fund the CFRP and another portion of credits to fund equity projects as described below.

The amendments indicate that base credits could be allocated to original equipment manufacturers if statewide zero-emission vehicle sales did not meet a minimum threshold. The subsequent board resolution directed CARB to implement a CFRP administered by state electric utilities. This change was implemented to provide a direct incentive to reduce the price of battery electric commercial rather than offsetting these costs for manufacturers by issuing base credits.[15] The share of base credits that electric utilities must contribute to the program varies by the size and ownership structure of the utility, as summarized in Table 2. These shares differ from the previous version of the CFRP, which applied to the light-duty vehicle segment. CARB retains the authority to review the CFRP and present recommendations to the board that may update the credit allocation structure by January 1, 2027.

Table 2
Contribution of electric utilities toward MHDV Clean Fuel Reward Program

Category	Base credit contribution
Large investor-owned utility	50%
Large publicly owned and medium investor-owned utility	25%
Medium publicly owned utilities	10%
Small publicly owned and investor-owned utilities	0%

We present a schematic in Figure 3 detailing how base credit revenue must be allocated and spent by utilities consistent with the November board resolution. In all cases, a portion of base credits from residential charging is allocated toward transport electrification projects while another share of the remaining credits, known as “holdback” credits, must be allocated toward point-of-sale vehicle rebates. Following this guidance, a large investor-owned electric utility that generates $1 million in base credits would allocate $500,000 to fund the CFRP, leaving approximately $375,000 remaining to fund a variety of equity projects that promote transport electrification as specified in Section 95483(c)5 of the regulation. Eligible CFRP transport electrification and equity projects are outlined in Table 3.

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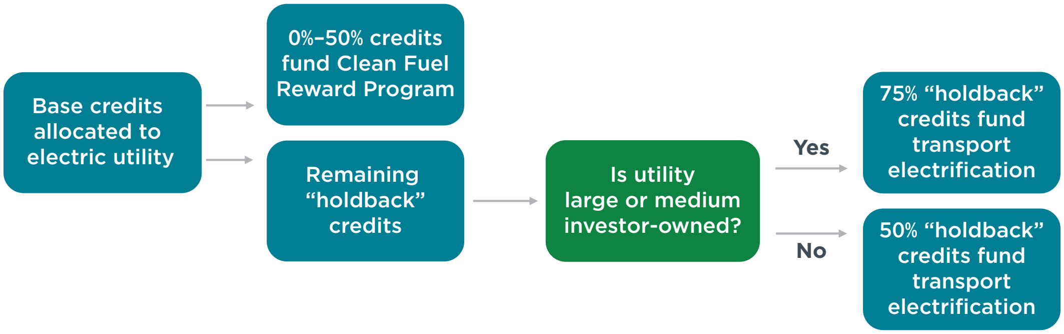
12 High Priority and Federal Fleets Applicability, Definitions, and General Requirements, Pub. L. No. 13 CCR § 2015 (2023). https://govt.westlaw.com/calregs/Document/I36E1B89061ED11EE978A8A2F3C3F0C90?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default).

13 Anish Sinha, *California's Advanced Clean Fleets Regulation* (International Council on Clean Transportation, 2025), https://theicct.org/publication/california-advanced-clean-fleets-regulation-apr25/.

14 California Air Resources Board, “LCFS Utility Rebate Programs,” accessed June 11, 2025, https://ww2.arb.ca.gov/resources/documents/lcfs-utility-rebate-programs.

15 California Air Resources Board, “Public Hearing to Consider Proposed Low Carbon Fuel Standard Amendments,” November 8, 2024, https://ww2.arb.ca.gov/sites/default/files/barcu/board/res/2024/res24-14.pdf.

Figure 3
Base credit allocation flowchart



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In Table 3, we summarize the flows of revenue from the LCFS that can be used to support MHDV electrification, including utility holdback credits as outlined above. Other credit categories include base credits from residential charging, incremental credits from low-carbon intensity or smart charging, non-residential charging credits for dispensed electricity, and fast FCI credits for installed charger capacity.

Table 3
Overview of LCFS funding streams for electric vehicles

Credit category	Description	Credit generator	Eligible projects
Base credits	Energy credits from residential charging (utility grid-average carbon intensity)	Electric distribution utilities	Point-of-sale rebates for MHDVs and battery electric motorcycles
Holdback credits	The portion of base credits not used to fund the CFRP	Electric distribution utilities	Equity projects including drayage truck electrification, charger installation in multi-family homes, electric vehicle sharing and ride-hailing programs, electric vehicle purchase and charging rebates for low-income households, incentives to promote public transit, and e-mobility
Incremental credits	Energy credits from low-carbon intensity or smart residential charging	Load serving entity, original equipment manufacturers, third-party	Smart charging, low-carbon intensity electricity
Non-residential charging credits	Energy credits from dispensed electricity at workplaces, depots, or public charging locations	Charge point operator or alternate party stipulated by contract	Electric vehicle charger installation, operation and maintenance
Fast charging infrastructure credits	Infrastructure credits for installed charger capacity proportional to utilization rate	Charge point operator or alternate party stipulated by contract	Electric vehicle charger installation, operation and maintenance

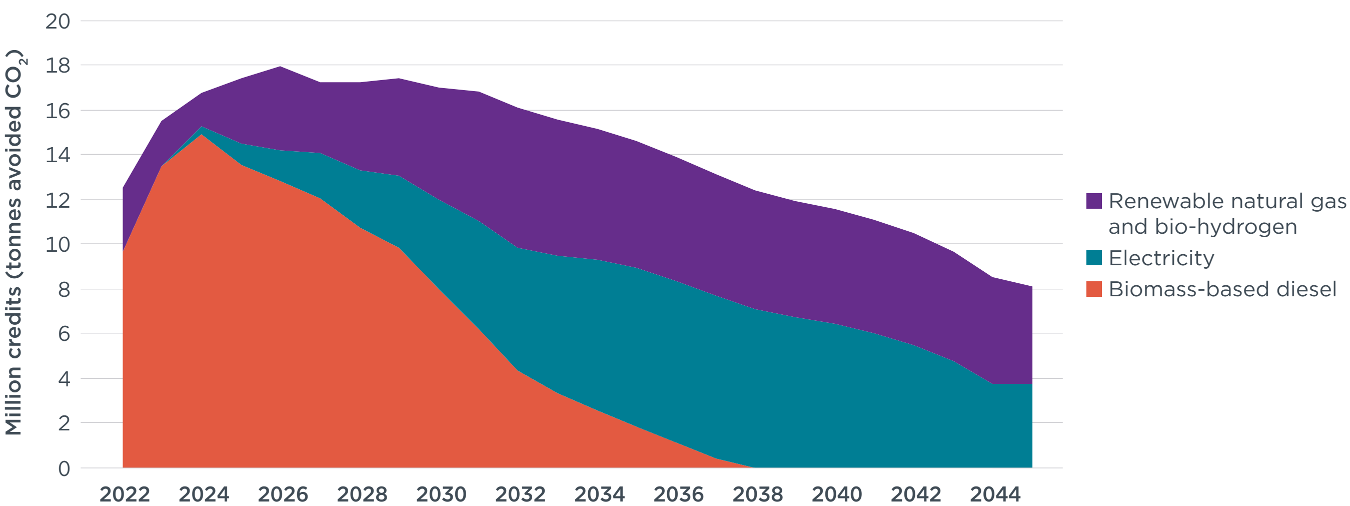
CURRENT AND FUTURE PROJECTIONS OF MEDIUM- AND HEAVY-DUTY FUEL MARKET IN CALIFORNIA

In this section, we assess credit prices and fuel demand projections developed by CARB for the 2024 LCFS rulemaking. In parallel with support for MHDV electrification, the LCFS also incentivizes alternative methods of decarbonizing the MHDV segment, such as the use of biofuels, natural gas, and hydrogen. For our assessment, we reference fuel consumption, credit generation, and credit price projections by major MHDV fuel pathway from the California Transport Supply (CATS) model. The CATS model is an optimization tool that projects the future fuel mix in California by solving for the lowest cost solution for a given compliance scenario.[16] Although the CATS model estimates electricity consumption by vehicle segment for each scenario, it does not present the quantity of electricity credits broken out by segment. In the below analysis, we adjust the total quantity of electricity credits estimated in CATS by the share of electricity consumed by MHDVs. We summarize credit generation for the three primary types of alternative fuels consumed in the MHDV segment: biomass-based diesel (BBD), comprising biodiesel and renewable diesel (i.e., hydrogenated vegetable oil); renewable natural gas (RNG) and hydrogen derived from biomethane; and electricity.

The CATS model estimates that in the near-term, the primary method of compliance with the increased LCFS targets will come from increased BBD blending, and that RNG and RNG-derived hydrogen will make up between 17% and 39% of MHDV credits over the next decade. Beginning in 2033, electricity will make up the greatest share of MHDV credits, peaking at 57% of this subset of credits in 2038. The model finds that BBD credits peaked at 89% of MHDV credits in 2024 and will phase out by 2038—though BBD blending will continue as a means of reducing deficit generation from fossil diesel (i.e., while BBD generates deficits, it will not generate as many as fossil diesel). The mix of MHDV credits for these three major fuel categories is illustrated in Figure 4. The total quantity of MHDV credits declines over time, consistent with an annual reduction in the CI benchmark.

Figure 4

Credit generation projections by MHDV fuel pathway under adopted amendments with automatic acceleration mechanism in place



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16 Michael Wara et al., "California's Low Carbon Fuel Standard: Simulating an EJ Scenario Using CARB's CATS Model" (Stanford Climate & Energy Policy Program Woods Institute for the Environment, 2023), https://woods.stanford.edu/publications/research-brief/californias-low-carbon-fuel-standard-simulating-ej-scenario-using-carbs.

The exact value of LCFS credits in the future is highly uncertain and challenging to model based on LCFS program design alone. The LCFS credit market is sensitive to a variety of assumptions, including the overall target, the cost of compliance across different technology pathways, and the value of complementary incentives such as tax credits and biofuel mandates. Federal tax credits such as the former 40A biodiesel producer tax credit and current 45Z Clean Fuel Production tax credit can further reduce compliance costs for using BBD.[17] In particular, there is a strong relationship between the federal Renewable Fuel Standard and the LCFS, as the federal biofuel blending mandates incentivize demand for BBD and generate high compliance values. These costs offset a portion of the cost of LCFS compliance for fossil fuel suppliers and make BBD blending an appealing near-term compliance option.[18] During the period of rapid growth in U.S. renewable diesel production from 2021 to 2023, a rise in Renewable Fuel Standard credit prices was correlated with a decline in LCFS prices. Both programs experienced further price declines when the quantity of BBD overshot the national-level advanced fuel mandate.[19] The threat of additional small refinery exemptions under the Renewable Fuel Standard may increase LCFS prices moving forward by reducing demand for BBD at the national level.[20]

Since the adoption of the amendments in early November, the LCFS credit price peaked near $80/tonne and fell to $45/tonne in early June 2025.[21] Assuming that the AAM is triggered, the CATS model estimates that credit prices will fluctuate between $100/tonne and $150/tonne through 2033, rising to $221/tonne in the late 2030s. Without an AAM in place, CARB estimates that credit prices will drop to zero due to credit oversupply (Figure 4), though credit prices will begin to rebound in the 2030s. The long-term increase in LCFS compliance costs is likely due to the more limited options for fuel suppliers as BBD blending approaches 100% of the diesel fuel pool. We note that there is substantial uncertainty in these projections due to the contribution of separate policies towards fuel demand and complementary credit values, such as the federal Renewable Fuel Standard and the 45Z tax credit; further, CARB's projections do not take into account limitations on crediting for virgin vegetable oils, deliverability requirements for biomethane, or a suspension of the Advanced Clean Fleets rulemaking.

Due to sustained market uncertainty, LCFS credit prices have traded at one-third the value that CARB estimated using the CATS model in the November 2024 rulemaking.[22] We therefore adjust credit prices downward between 2025 and 2030 from a starting price of $50/tonne and assume an exponential growth factor in interim years. We present the original and adjusted LCFS credit price projections from an August 2024 version of the CATS model with one AAM in place in Figure 5. We adopt the adjusted CATS prices shown in brown for our Central credit price scenario.

17 Inflation Reduction Act of 2022, Pub. L. No. 117-169 (2022). https://www.congress.gov/117/plaws/publ169/PLAW-117publ169.pdf.

18 Jarrett Whistance, Wyatt Thompson, and Seth Meyer, "Interactions between California's Low Carbon Fuel Standard and the National Renewable Fuel Standard," *Energy Policy* 101 (February 2017): 447–55, https://doi.org/10.1016/j.enpol.2016.10.040.

19 Maria Gerveni, Todd Hubbs, and Scott Irwin, "Is the U.S. Renewable Fuel Standard in Danger of Going over a RIN Cliff?" *Farmdoc Daily* 13, no. 99 (May 31, 2023), https://farmdocdaily.illinois.edu/2023/05/is-the-us-renewable-fuel-standard-in-danger-of-going-over-a-rin-cliff.html.

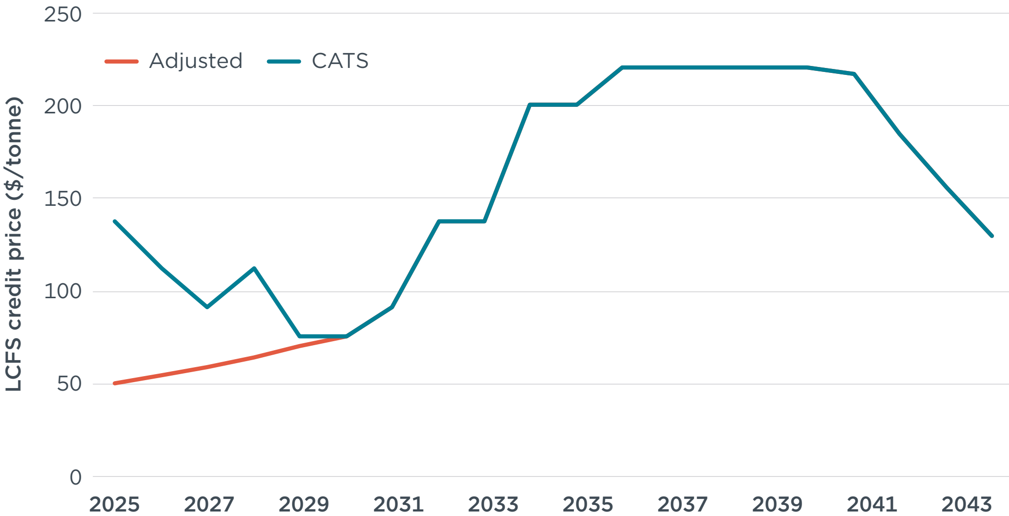
20 Scott Irwin, "Demand Destruction 2.0 for Biodiesel and Renewable Diesel?" *Farmdoc Daily* 15, no. 32 (February 19, 2025), https://farmdocdaily.illinois.edu/2025/02/demand-destruction-2-0-for-biodiesel-and-renewable-diesel.html.

21 Neste, *California Low Carbon Fuel Standard Credit Price*, accessed June 11, 2025, https://www.neste.com/investors/market-data/renewable-products.

22 "Renewable Products," Neste, accessed June 11, 2025, https://www.neste.com/investors/market-data/renewable-products.

Figure 5

Original and adjusted LCFS credit price with one automatic acceleration mechanism in place



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As illustrated above, the adopted amendments could have a substantial impact on the trajectory of MHDV fuel consumption in the coming two decades. Although increased program ambition, the introduction of an AAM, and higher stepdown are intended to tighten the LCFS market and raise credit prices in the near-term, these changes fail to return to high credit prices for the remainder of the decade. Maintaining high credit prices is critical to send a strong signal for electrification to meet program compliance and for complementary policies such as the ACT regulation. Credit revenue from vehicle charging and charging infrastructure deployment can be redirected towards ZEV rebates for high-cost battery electric MHDVs. It can also offset the costs of charging installation for fleet operators and other charge point operators. By offsetting these costs, charge point operators can offer more competitive charging rates to fleet operators, making electrification more attractive.

LCFS CREDIT POTENTIAL TO SUPPORT MHDV FAST CHARGING INFRASTRUCTURE

In this section, we model the cumulative in-state charger installations and specifications in California between 2025 and 2035. Applying these charger counts, capacities, and utilization rates, we then estimate the range of LCFS revenue potential from infrastructure and energy crediting. To estimate the annual quantity of credit generation, our analysis references the compliance trajectory of the adopted amendments with an AAM in place and average electricity grid CIs from an example set of inputs developed by CARB.[23] While the CATS model assumes that the average CI of electricity used by the MHDV segment falls to zero beginning in 2025, the example inputs assume the average CI is equal to 69 g CO_2e/MJ in 2025, decreasing to 42 g

23 "Public Workshop: Low Carbon Fuel Standard Modeling Updates," California Air Resources Board, August 16, 2023, https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/lcfs-meetings-and-workshops.

CO_2e/MJ in 2035. These CIs are more consistent with projections of the development of the grid in California over the next two decades.[24]

Our projections include Central, Low, and High credit price scenarios. The Central credit price scenario is sourced from the CATS model with prices adjusted downward between 2025 and 2030 (Figure 5). In the Low credit price scenario, prices are defined at $50/tonne in 2025, while in the High credit price scenario, prices are defined at $200/tonne. All scenarios are reported in 2025 U.S. dollars adjusted for a 2% annual inflation rate.[25]

We then compare these estimates to the breakeven cost of fast and ultra-fast charger installation to service MHDV segments and the cumulative cost of charger deployment for chargers installed between 2025 and 2035. We next evaluate the impact that base credits can have on funding a CFRP to lower the direct costs of MHDV sales via point-of-sale rebates. We consider recommendations from the automotive industry to improve the former CFRP, including streamlining credit auctions and prorating the value of rebates according to vehicle and battery performance parameters rather than assigning a fixed value to all eligible vehicles.

Our modeled charging demand is based on historic charging behavior wherein fleet operators have used longer dwell times and lower powered chargers to meet energy needs. In the future, fleet operators may rely on a smaller, high-capacity charging network to meet energy needs at faster charging rates.

Charger count

We estimate charger counts using HDV CHARGE, a charging infrastructure model developed by the ICCT that estimates energy and charging needs for zero-emission MHDVs.[26] HDV CHARGE calculates charging and energy needs based on input traffic data and zero-emission vehicle sales shares combined with charging characteristics such as utilization rate, capacity, and distribution across public and depot charging locations. We update the HDV CHARGE model with inputs specific to the California market and estimate that the state will need to install 46,287 chargers to service the MHDV segment by 2030, growing to 103,915 in 2035. Our modeled run assumes that the ACT remains in effect and that Inflation Reduction Act credits remain available in California. A full list of assumptions is provided in Steimer et al.[27]

As of August 2024, 152,256 public Level 2 (3–19 kW) and fast chargers servicing all vehicle segments had been installed in California, including nearly 140,000 Level 2 chargers and 15,000 fast chargers.[28] Approximately 1,500 public fast chargers service MHDVs, according to California Energy Commission data.[29]

24 California Air Resources Board, "Final Environmental Analysis for the 2022 Scoping Plan for Achieving Carbon Neutrality," December 13, 2022, https://ww2.arb.ca.gov/sites/default/files/2022-12/2022-sp-appendix-b-final-environmental-analysis.pdf.

25 "Economy at a Glance - Inflation (PCE)," Board of Governors of the Federal Reserve System, accessed June 11, 2025, https://www.federalreserve.gov/economy-at-a-glance-inflation-pce.htm.

26 Jakob Schmidt, *HDV CHARGE v1.2 Documentation*, computer software, International Council on Clean Transportation, 2025, https://theicct.github.io/HDVCHARGE-doc/versions/v1.2/#introduction.

27 Steimer et al., *Mind the Gap*.

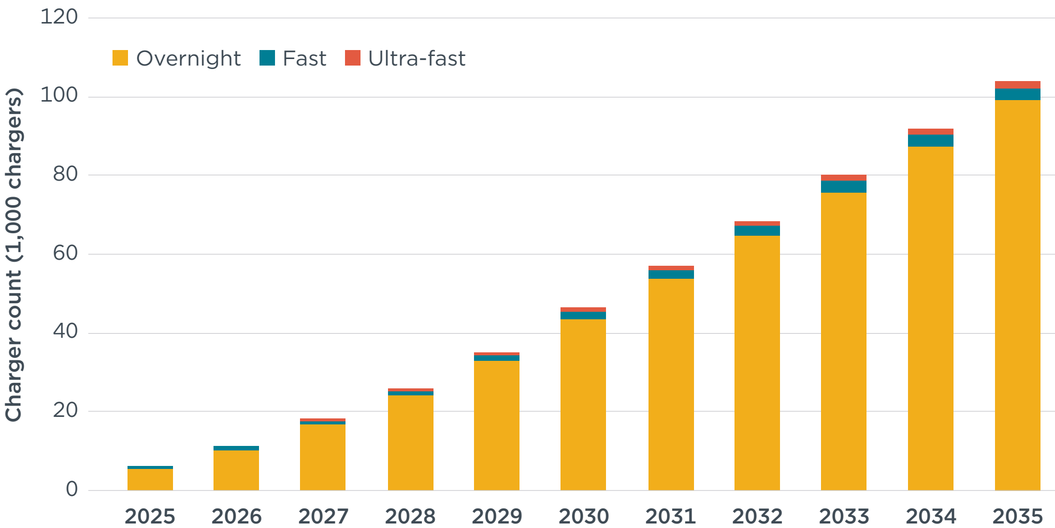
28 State of California, "California Surpasses 150,000 Electric Vehicle Chargers," *Governor of California* (blog), August 28, 2024, https://www.gov.ca.gov/2024/08/28/california-surpasses-150000-electric-vehicle-chargers/.

29 "Medium and Heavy Duty Infrastructure," December 16, 2024, https://cecgis-caenergy.opendata.arcgis.com/datasets/CAEnergy::medium-and-heavy-duty-infrastructure/explore?location=34.630050,-119.008232,6.00.

The HDV CHARGE model predicts that approximately 95% of chargers will be located at overnight charging lots in 2035 and the remainder along public highway corridors and at private fast charging depots. These findings are consistent with a recent ICCT study that estimated charging demand needs in the City of Seattle.[30] Overnight chargers have capacities that range between 19.2 and 200 kW, while fast chargers are rated at 350 kW and ultra-fast chargers are rated at a 1,000 kW power output. We present the cumulative number of chargers installed by year and type in California in Figure 6.

Figure 6

Installed MDHV charger count by year and charging type



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Charger counts also vary by location. In total, approximately 45% of chargers are projected to be installed at public charging locations, while the remaining 55% will be installed at private or semi-public depots. This split is primarily driven by differences in overnight versus fast charging behavior. The model predicts that approximately 98% of fast and ultra-fast chargers will be installed at public charging locations, while overnight chargers are more evenly split. Because fast charging is designed for short waiting times, these chargers are most suitable for en route highway locations for vehicles that need to charge away from their home depot or base. In contrast, overnight charging can occur at both public lots or private depots at lower power outputs and during longer charge times.

The charger counts estimated in this analysis are slightly lower than those ICCT modeled in a 2023 study and are derived using updated assumptions for charging session length, nameplate power capacity, and average utilization rates.[31] Consistent with the 2023 study, we exclude motor homes from our analysis and project charge counts through 2035. Charger counts by type and location are listed in Table 4. Charger counts are projected to more than double between 2030 and 2035, with overnight and public fast and ultra-fast chargers exhibiting the fastest growth.

30 Hamilton Steimer et al., *Powering Seattle Fleets: A Charging Infrastructure Strategy for Battery Eleectric Medium- and Heavy-Duty Vehicles* (International Council on Clean Transportation, 2024), https://theicct.org/publication/powering-seattle-fleets-charging-infrastructure-strategy-for-battery-electric-medium-and-heavy-duty-vehicles-may24/.

31 Pierre-Louis Ragon et al., *Near-Term Infrastructure Deployment to Support Zero-Emission Medium- and Heavy-Duty Vehicles in the United States* (International Council on Clean Transportation, 2023), https://theicct.org/publication/infrastructure-deployment-mhdv-may23/.

Table 4

Summary of cumulative charger counts in California servicing Class 4–8 vehicles

Charger type	Charger location	Charger count (2030)	Charger count (2035)
Overnight	Public	17,628	41,426
Overnight	Depot	25,912	57,542
Fast	Public	1,702	3,163
Fast	Depot	67	89
Ultra-fast	Public	973	1,689
Ultra-fast	Depot	5	6
Total		**46,287**	**103,915**

Comparatively, the California Energy Commission estimates that 256,294 depot chargers and 8,455 en route chargers will need to be deployed by 2035 to service the state's burgeoning MHDV market.[32] The commission similarly finds that 95% of charging needs will be met by depot chargers, although there are some key differences between the study assumptions that explain our study's lower charger count estimates. The commission classifies depot chargers as having a maximum rated capacity of 150 kW while our analysis assumes depot chargers have no maximum limits on charging capacity. The commission's study also includes Class 3 vehicle charging, which makes up approximately 17.4% of MHDV stock. Further, the commission's analysis finds that chargers will service 1.35 vehicles on average, while the vehicle to charger ratio in our analysis is 2.3 vehicles serviced per charger, contributing to our study's lower charge counts. Our modeling predicts that fleet operators will continue to meet their energy demand using long dwell times at low charging capacity; in the future, fleet operators may rely on a smaller, high-capacity charging network to meet their energy needs.

Charging costs

To estimate charging costs, we reference charger equipment, installation, and maintenance costs from the literature and linearly interpolate costs for chargers without a reference data point. We draw on cost data from an ICCT infrastructure cost study for fast chargers with power of 50, 150, and 350 kW and data from the National Renewable Energy Laboratory's (NREL) EVI-FAST calculator for 7.2 kW Level 2 chargers.[33] The EVI-FAST calculator is a financial model for electric vehicle charging infrastructure that allows users to input different charging specifications, costs, and utility rates to estimate financial indicators such as net present value, payback periods, and breakeven charging costs. Due to a lack of available data, we do not account for future reductions in equipment and installation costs. Our estimated charging costs are consistent with costs reported by NREL at higher capacities, though there is some variation.[34] For example, forecasting based on a linear trend line, we estimate

32 Adam Davis et al., "Assembly Bill 2127 Second Electric Vehicle Charging Infrastructure Assessment: Assessing Charging Needs to Support Zero-Emission Vehicles in 2030 and 2035" (California Energy Commission, March 6, 2024), https://www.energy.ca.gov/publications/2024/assembly-bill-2127-second-electric-vehicle-charging-infrastructure-assessment.

33 Michael Nicholas, *Estimating Electric Vehicle Charging Infrastructure Costs Across Major U.S. Metropolitan Areas* (International Council on Clean Transportation, 2019), https://theicct.org/publication/estimating-electric-vehicle-charging-infrastructure-costs-across-major-u-s-metropolitan-areas/; National Renewable Energy Laboratory, "EVI-FAST: Electric Vehicle Infrastructure – Financial Analysis Scenario Tool," accessed June 11, 2025, https://www.nrel.gov/transportation/evi-fast.

34 Jesse Bennett et al., *Estimating the Breakeven Cost of Delivered Electricity to Charge Class 8 Electric Tractors* (NREL, 2022), https://doi.org/10.2172/1894645.

that equipment costs for a 3 MW capacity charger would be $1.1 million, while NREL estimates that a charger with the same capacity costs $0.9 million. This corresponds to a 19% variation in equipment costs between our forecasted costs and NREL estimates. Applying the same linear relationship, we estimate that equipment costs for a 1 MW charger are approximately $380,000.

We summarize charger cost data by capacity in Table 5. We assume that all chargers have an annual maintenance fee of $500 regardless of capacity size, based on charger maintenance costs for Class 4–5 vehicles reported in CARB's Advanced Clean Trucks impact assessment.[35] This may underestimate total maintenance fees for ultra-fast chargers; however, this does not significantly impact our breakeven cost results. The installation costs cited in our literature review account for electrical grid upgrades that are necessary for charging sites to supply sufficient power to fast chargers; however, they may exclude other ancillary costs such as permitting fees.[36] Charger installation costs from other studies may exclude grid and site upgrading costs; therefore, cost estimates cannot always be directly compared. Further, although we present installation costs on a per charger basis, these costs are usually determined at the site level and decline on a per unit basis as the numbers of chargers per site increases.[37]

We estimate that the equipment and installation costs for fast chargers (defined as 50 kW and above) range between $73,907 and $490,939. Comparatively, Gamage et al. estimate that commissioning and installation costs range between $122,000 and $440,000, including wiring and electrical distribution grid upgrading costs.[38] We present a simplified cost summary for MHDV chargers installed between 2025 and 2035 in Table 5. Installation costs include the cost of utility upgrades and other site infrastructure.

Table 5
Total costs of charger deployment in California between 2025 and 2035

Capacity (kW)	19.2	50	100	150	200	350	1000
Number of chargers	33,673	40,893	19,926	20	4,476	3,233	1,694
Charger hardware cost	$9,333	$28,401	$50,693	$75,000	$87,222	$140,000	$379,448
Charger installation cost	$6,667	$45,506	$47,131	$47,781	$54,282	$65,984	$111,491
Total cost per charger	$16,000	$73,907	$97,825	$122,781	$141,504	$205,984	$490,939
Total cost (millions)	$539	$3,022	$1,949	$2	$633	$666	$832

In total, we estimate that MHDV charger deployment in California will cost approximately $7.6 billion based on the projected number of chargers installed between 2025 and 2035. Meeting 2030 charging needs will cost approximately $6.4 billion over their entire project lifetime. We present the cumulative charger count and estimated project costs by type and location in 2035 in Table 6.

35 California Air Resources Board, "Advanced Clean Trucks Regulation Standardized Regulatory Impact Assessment (SRIA)," August 8, 2019, https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2019/act2019/appc.pdf.

36 Tisura Gamage, Gil Tal, and Alan T. Jenn, "The Costs and Challenges of Installing Corridor DC Fast Chargers in California," *Case Studies on Transport Policy* 11 (March 1, 2023): 100969, https://doi.org/10.1016/j.cstp.2023.100969.

37 Nicholas, "Estimating."

38 Gamage, Tal, and Jenn, "Costs and Challenges."

Table 6
Summary of charger count and cumulative cost by type and location for chargers installed between 2025 and 2035

Charger type	Charger location	Nameplate capacity (kW)	Charger count	Cumulative charger cost (billions)
Overnight	Public	50	29,872	$2.21
Overnight	Public	100	7,078	$0.69
Overnight	Public	200	4,476	$0.63
Overnight	Depot	19.2	33,673	$0.54
Overnight	Depot	50	11,021	$0.81
Overnight	Depot	100	12,848	$1.26
Fast	Public	350	3,163	$0.65
Fast	Depot	150	20	$0.002
Fast	Depot	350	70	$0.01
Ultra-fast	Public	1000	1,689	$0.83
Ultra-fast	Depot	1000	5	$0.002
Total			**103,915**	**$7.64**

Charger utilization rate

Using the HDV CHARGE model, we also estimate the total kWh of delivered energy per charger type, from which we can infer average utilization rates as the ratio between the energy transferred and the maximum energy a charger could transfer when used at full load 24 hours a day. We calculate utilization at each charging location based on the charger's nameplate capacity and annual kWh of dispensed electricity. We find that annual utilization rates range between 2% and 36.9% across the 15-year lifetime of a charger that begins operation in 2025, after removing outlier datapoints. To infer hours charged from the utilization rate, we consider that chargers do not operate at full capacity continuously. A correction factor, the power delivery ratio assumed to be 85%, adjusts for the average capacity of power output; thus, a charger with a nameplate capacity of 1 MW would be expected to deliver a maximum 850 kWh of power over a 1 hour charging period.

The HDV CHARGE model estimates energy demand based on input traffic data and predicted charging behavior and allocates that demand across different charging capacities and vehicle segments. For this analysis, the model calculates charging needs at the county level. In some edge cases with low charger counts in certain counties, rounding effects can lead to overestimations of charger counts, resulting in low estimated utilization rates. This is due to how energy needs in our analysis are assigned at the county level, rounded to the nearest whole number, and then aggregated to calculate total statewide charging demand. For example, the model may assign 2,400 kWh of residual electricity to a 1 MW ultra-fast charger operating over an entire year, when instead these charging needs could be re-allocated to installed chargers that service another vehicle segment. This is a source of uncertainty within the model that is intended to avoid fractional charger outputs. We remove outliers from our dataset with utilization rates less than 2% in our credit calculation analysis. This reduces the cumulative charger count by 50 chargers in 2035.

Table 7 below provides an overview of the average utilization rates for chargers installed in 2025, broken out by vehicle segment, power, location, and charger type. The estimated utilization rates of between 2% and 36.9% are the equivalent of between 0.6 and 10.4 hours of charging per day. We present a complete list of utilization rates by vehicle segment, charger location, and charger type in the appendix.

Table 7
Summary of average utilization rates for chargers installed in 2025, broken out by vehicle segment and charger category

Charger type	Charger location	Average utilization rate, 2025–2039	Minimum utilization rate	Maximum utilization rate
Overnight	Public	22.8%	2%	36.9%
Overnight	Depot	19.2%	2%	33.6%
Fast	Public	8.8%	2%	15.7%
Fast	Depot	5.4%	2%	15.5%
Ultra-fast	Public	6.3%	2%	15.7%
Ultra-fast	Depot	3.6%	2%	5.1%

Projecting potential LCFS credit revenue from charging

Based on the estimated number of deployed chargers, their modeled utilization rates, and their quantity of electricity dispensed using HDV CHARGE, we can then estimate the annual revenue available to MHDV charging operators. This value is inclusive of the credits generated by charging as well as credits generated from infrastructure capacity. We input estimated charger counts and total dispensed electricity into the LCFS crediting formula for non-residential charging from Section § 95486.1(a) of the regulation. The crediting formula accounts for the quantity of electricity dispensed, utility-specific CI, and energy economy ratio of MHDVs (Equation 1). To determine overall revenue, we multiply this value by the annual LCFS credit price in our Central, High, and Low credit price scenarios.

Equation 1

$$\textit{LCFS energy credits } (\$) = \textit{Electricity dispensed } (kWh) \times \left(\frac{gCO_2e\,(CI_{benchmark} - CI_{utility})}{MJ} \times \frac{1}{EER} \right) \times \frac{3.6\ MJ}{kWh} \times EER \times \frac{ton}{10^6\ g} \times \textit{LCFS credit price} \left(\frac{\$}{tonne} \right)$$

Where:

EER (energy economy ratio) is set equal to 5, which represents the efficiency of battery electric MHDVs (Table 5 of regulation);

$CI_{benchmark}$ is set equal to the annual carbon intensity benchmark for diesel fuel (Table 2 of regulation);

$CI_{utility}$ is set equal to the carbon intensity of dispensed electricity. According to the regulation, this may be set equal to the “carbon intensity for California Average Grid Electricity, Zero-CI Electricity, or Smart Charging pathway from the Lookup Table in section 95488.5, or a carbon intensity value certified through the Tier 2 pathway application process”; and

LCFS credit price is variable in the Central price scenario, set equal to $50/tonne in the Low price scenario, $200/tonne in the High price scenario.

In total, we estimate that eligible parties (i.e., charge point operators or a third-party that entered into a contract agreement) can generate $3.2 billion in cumulative energy credit revenue between 2025 and 2035 under the Low credit price scenario and $12.9 billion in revenue under the High credit price scenario. Unlike infrastructure credits, all chargers that deliver electricity to the transport sector in California are eligible to generate energy credits regardless of nameplate capacity or utilization rate. In our Central credit price scenario, we estimate that charge point operators can generate $7.2 billion in cumulative energy credit revenue. Energy credits grow proportionally to the share of MHDVs on the market and the LCFS credit price. Our estimates of electricity dispensed to the MHDV segment from HDV CHARGE are very similar to total energy demand estimated by CARB in the CATS model.

In addition to energy credits from non-residential charging, charge point operators can also generate credits from owning and operating fast charging infrastructure. We calculate the value of infrastructure crediting for private and public charging following Equation 2 and Equation 3. The crediting formula is proportional to the nameplate capacity (P^{i}_{FCI}) of installed chargers (Equation 2). Capacities are corrected by an adjustment factor (F^{site}_{HD}) of 0.2 for publicly available chargers and 0.1 for private depot chargers. The crediting formula is designed to reward low-utilization chargers that are necessary to meet EV adoption targets but do not yet service a steady demand of electric MHDVs. In practice, this means that public chargers will no longer generate infrastructure credits once they exceed a 20% utilization rate (roughly 5 hours per day), while private chargers do not generate infrastructure credits beyond a 10% utilization rate (roughly 2.5 hours per day). Similarly, overnight chargers with a nameplate capacity below 50 kW do not generate infrastructure credits.

Equation 2

$$Cap^{i}_{FCI} = F^{site}_{HD} \times P^{i}_{FCI} \times 24$$

Where:

Cap^{i}_{FCI} is the charging capacity in kWh/day;

F^{site}_{HD} is the adjustment factor based on the type of charging site. This factor is set equal to 20% for public chargers and 10% for private chargers; and

P^{i}_{FCI} is the lesser of the charger's nameplate power rating or 2,000 kW.

The total credit generation for FCI credits is presented below in Equation 3. This formula accounts for the annual diesel carbon intensity benchmark, utility specific CI, and energy economy ratio of MHDVs.

Equation 3

$$Credits_{HD\text{-}FCI}(tonnes) = CI_{diesel\ standard} \times EER^{XD} - CI_{HD\text{-}FCI} \times C_{Elec} \times Cap^{i}_{HD\text{-}FCI} \times N \times UT - Elec_{disp} \times C$$

Where:

$CI_{diesel\ standard}$ is the carbon intensity benchmark for diesel for a given year as provided in section 95484 of the LCFS regulation;

EER^{XD} is the dimensionless Energy Economy Ratio for electricity relative to diesel;

$CI_{HD\text{-}FCI}$ is the California average grid electricity carbon intensity;

C_{elec} is the conversion factor for electricity (3.6 MJ per kWh);

$CAP^{i}_{HD\text{-}FCI}$ is the FCI charging capacity (kWh/day) for the HD charging site;

N is the number of days during the quarter;

UT is the uptime multiplier which is the fraction of time that the HD-FCI FSE is available for charging during the quarter;

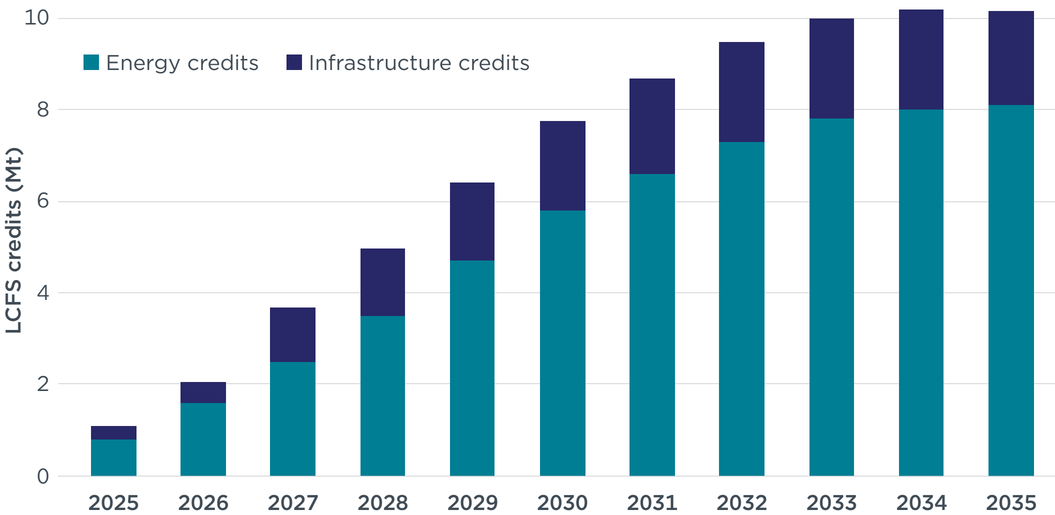
$Elec_{disp}$ is the quantity of electricity dispensed during the quarter (kWh); and

C is a factor used to convert credits to units of metric tonnes from grams of CO_2-equivalents.

Using the above equations, we estimate that the total theoretical quantity of LCFS credits from MHDV charging increases gradually over time, growing from 1.15 million in 2025 to 10.1 million in 2035, with the bulk of the credits generated via dispensed electricity. We note that the maximum quantity of infrastructure credits exceeds the cap on capacity credits established within the LCFS program, as we discuss in more detail below. We present the total theoretical quantity of energy and infrastructure credits attributed to MHDV electrification in million tonnes (Mt) in Figure 7. We find that infrastructure credit generation begins to level off in the mid-2030s due to higher charger utilization rates. At this time, charging infrastructure will begin to phase out of its 10-year crediting eligibility. By December 31, 2045, the infrastructure crediting provision will entirely phase out of the LCFS.

Figure 7

Theoretical quantity of LCFS credits generated from MHDV charging infrastructure between 2025 and 2035



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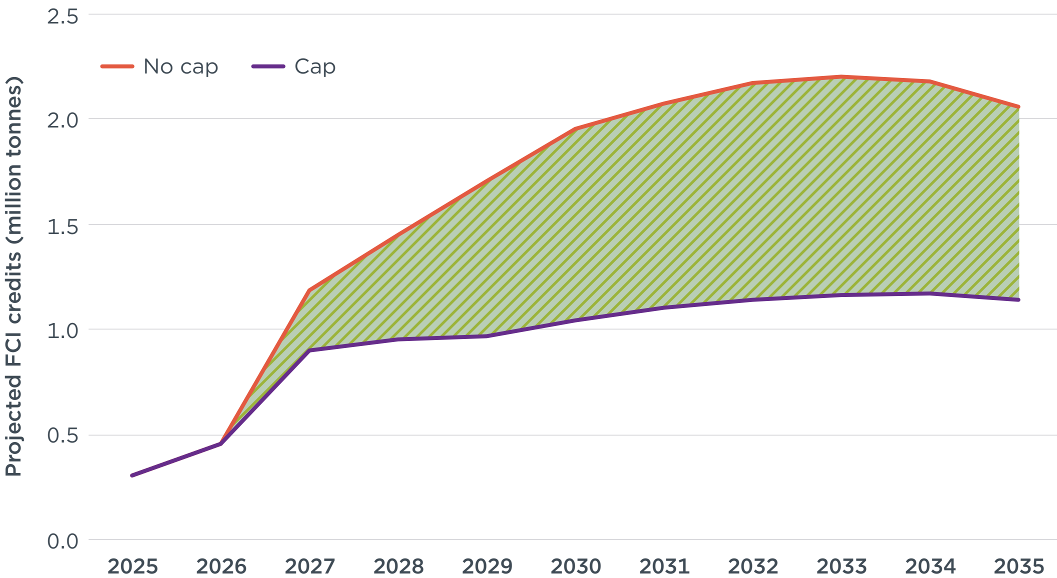
Though we calculate the theoretical total credit generation of MHDV infrastructure crediting in Figure 7, in practice, crediting will be limited by the cap on light-, medium-, and heavy-duty FCI credits established in LCFS regulation. The cap is applied to limit the quantity of credits coming from fueling infrastructure to 2.5% of program deficits within the most recent quarter of LCFS reporting. An equivalent cap is applied to the total quantity of credits generated from hydrogen refueling infrastructure.[39]

We estimate the annual cap on FCI credits based on CARB's modeling of program deficits from CATS. To estimate the cap, we draw upon the deficit count projected in the LCFS rulemaking, assuming one AAM is triggered in 2027. We set a limit on FCI credits equivalent to 2.5% of program deficits in the "Cap" line, while we illustrate the maximum quantity of credits based on our charger counts, capacities, and utilization rates from the HDV CHARGE model in the "No cap" line (Figure 8). We estimate a total of 7.4 Mt in excess credits over the period of our analysis (2025–2035).

39 California Air Resources Board, "Final Regulation Order."

Figure 8

Projected FCI credits with and without a 2.5% cap on deficits



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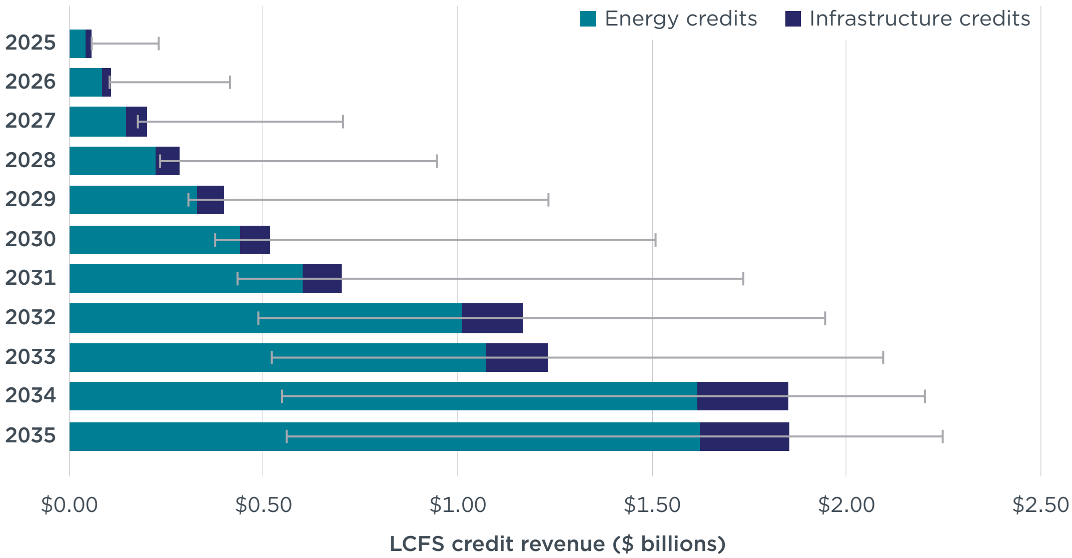
We project that the FCI crediting cap may begin to constrain the quantity of MHDV-FCI credits generated in the LCFS market beginning in 2027. With a cap on credits in place, the cumulative number of capacity credits reduce from 17.7 Mt to 10.3 Mt. In comparison, the CATS model assumes that FCI and hydrogen refueling infrastructure will only begin generating credits in 2031. Combined, the model assumes that these credits will only slightly exceed the 2.5% cap on FCI crediting. The CATS model does not respond to any changes in scenario inputs beyond the number of credit deficits, which leads to a discrepancy between CARB's infrastructure crediting projections and our own estimates.

We estimate that eligible parties (e.g., charge point operators) can generate a cumulative $1.2 billion in infrastructure crediting under our Central credit price scenario with a cap in place. Without a cap on infrastructure credits in place, total revenue could increase to more than $2.0 billion in our Central credit price scenario. Combined with energy credits, we estimate that eligible parties can generate up to $8.4 billion in LCFS revenue over the next decade, growing from $0.06 billion in 2025 to $1.85 in 2035. Under our Low credit price scenario, cumulative revenue from energy and infrastructure crediting decreases to $3.8 billion, while under our High credit price scenario, cumulative revenue increases to $15.3 billion. This represents a loss of between $0.42 and $1.7 in billion funding relative to a policy where no FCI credit cap was in place.

In all cases, we find that more than three-quarters of the potential policy support is attributed to dispensed energy crediting while the remainder is attributed to the newly established HD-FCI crediting provision. We present the combined value of energy and infrastructure LCFS revenue attributed to MHDV electrification in billion U.S. dollars (Figure 9). Stacked bars represent the LCFS credit revenue in our Central scenario while error bars represent the maximum and minimum value of revenue using our High and Low scenarios.

Figure 9

Estimated value of LCFS revenue generated from MHDV charging infrastructure



Note: Error bars represent credit revenue under High and Low credit price scenarios.

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IMPACT OF THE LCFS ON THE MDHV CHARGER COST GAP

As shown above, the LCFS can be a valuable mechanism to generate revenue for MHDV charging infrastructure. At the charger level, the ability of charge point operators to recoup costs is highly dependent on charger utilization rates. Utilization rates correspond to the quantity of electricity dispensed over a designated time period. We estimate the range in LCFS credit potential based on varying utilization rates for a private, 1 MW ultra-fast charger operating in 2030 as an illustrative example. We set low utilization rates (2%) based on 2023 ultra-fast charging data, medium utilization rates (4.4%) based on projected 2030 charging behavior from the HDV CHARGE model, and high utilization rates (7.0%) based on projected 2040 charging behavior from HDV CHARGE.[40]

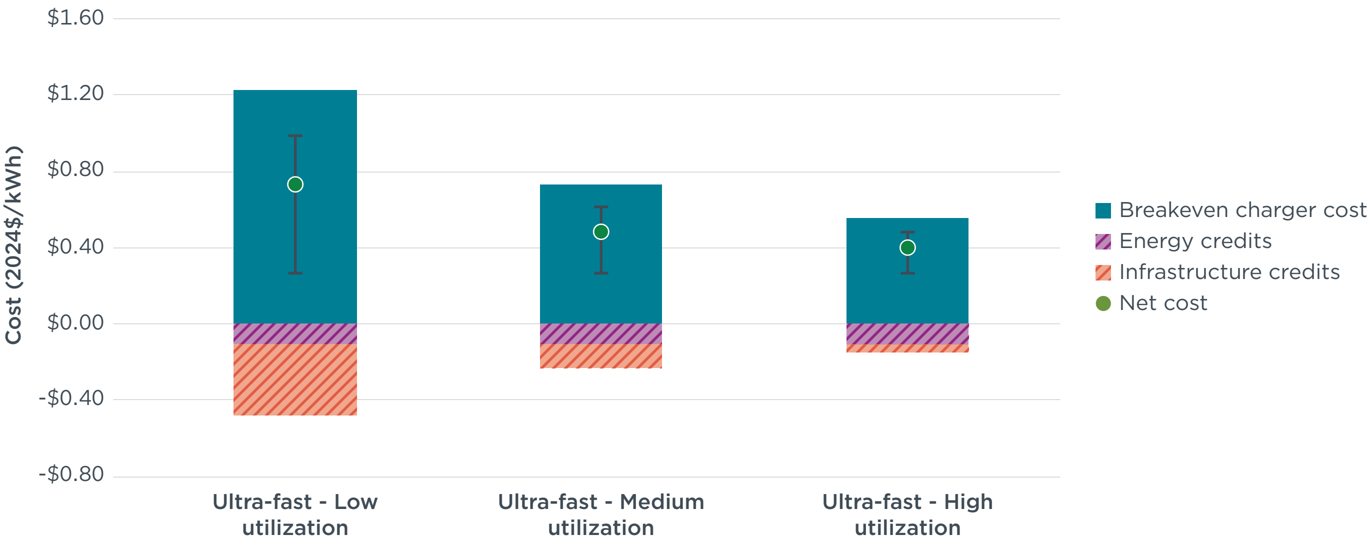
We calculate the breakeven cost of charging infrastructure from NREL's EVI-FAST calculator in 2024 U.S. dollars per kilowatt-hour. We update the EVI-FAST calculator with the utilization rates defined above, average price of commercial electricity in California, and projected cost data from the literature for 1,000 kW DC fast chargers.[41] We compare our estimated breakeven charging costs to the quantity of LCFS energy and infrastructure credits generated under the same conditions and set an average credit price of $100/tonne adjusted for inflation (Figure 10). We calculate net costs across a charger's 15-year project lifetime assuming that utilization rates remain constant over time. Error bars show the sensitivity of the net cost per kWh based on different LCFS credit price assumptions, with the upper whisker showing the impact of the LCFS on charging costs when credit prices approach $0/tonne and the lower impact illustrating the impact when the price reaches its cap around $200/tonne, adjusted for inflation.

40 Ragon et al., *Near-Term Infrastructure Deployment.*

41 U.S. Energy Information Administration, "Average Retail Price of Electricity, Annual," accessed June 11, 2025, https://www.eia.gov/electricity/data/browser/#/topic/7?agg=1,0&geo=vvvvvvvvvvvvo&endsec=4&linechart=ELEC.PRICE.US-COM.A&columnchart=ELEC.PRICE.US-COM.A&map=ELEC.PRICE.US-COM.A&freq=A&ctype=linechart&ltype=pin&rtype=s&pin=ELEC.PRICE.CA-COM.A&rse=0&maptype=0.

Figure 10

Total and net breakeven charger price for depot, ultra-fast chargers across varying utilization rates



Note: Error bars represent costs under a High and Low credit price scenario.

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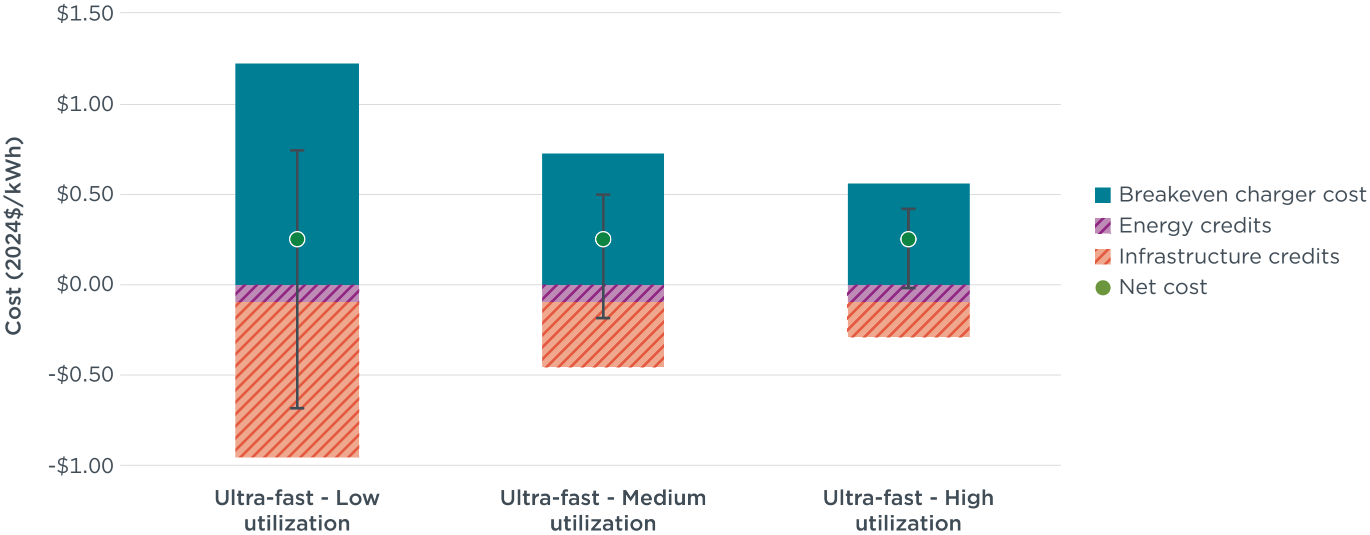
At private charging locations, we estimate that average net costs range between $0.41/kWh for high utilization chargers and $0.74/kWh for low utilization chargers. This corresponds to a 26%–39% cost reduction relative to a scenario where chargers do not receive any LCFS revenue.

Though not considered here, any depot chargers that exceed the 10% utilization threshold do not generate infrastructure credits. Energy credits are proportional to the quantity of kilowatt-hours dispensed and calculated at $0.10/kWh.

We also assess the net costs of ultra-fast charger installation at public charging locations operating in 2030. Charger rollout at these locations is a priority for CARB; therefore, public chargers remain eligible for infrastructure credits up to 20% utilization thresholds. We compare the net costs of ultra-fast public charger installation using the same utilization rate and credit price assumptions as above (Figure 11). Net costs are reduced relative to private charging locations due to the increased value of infrastructure credits. Across all three cases, the value of LCFS credits for dispensed electricity remain constant at $0.10/kWh. Considering our three utilization rates, we estimate that average net costs equal $0.27/kWh for public ultra-fast chargers operating between 2025 and 2039. This corresponds to a 52%–78% cost reduction relative to a scenario where chargers do not receive any LCFS revenue. At high credit prices and low utilization rates, charge point operators generate substantial revenues from LCFS infrastructure credits. Significant LCFS revenue potential at low utilization rates helps to balance the high breakeven costs of charger installation during early years of charger operation.

Figure 11

Total and net breakeven charger price for public, ultra-fast chargers across varying utilization rates



Note: Error bars represent costs under a High and Low credit price scenario.

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We extend this cost analysis to estimate the median breakeven costs of California's entire MHDV charging needs. Using the EVI-FAST model, we estimate that breakeven costs range between $0.37/kWh for 200 kW public overnight chargers and $0.94/kWh for 1 MW, ultra-fast depot chargers. These costs reflect the average cost of charging between 2025 and 2039 (i.e., a 15-year project lifetime) and do not include outliers with utilization rates below 2%. We summarize the average breakeven costs by charging capacity and location in 2030 in Table 8. Costs are reported in 2024 U.S. dollars.

Table 8

Average breakeven costs and LCFS credit revenue by charger type for chargers installed in 2025

Charger type	Nameplate capacity (kW)	Breakeven price ($/kWh)	Average LCFS credit revenue, 2025-2039 ($/kWh)	Net cost ($/kWh)	% cost coverage
Overnight – Depot	19.2	$0.42	$0.07	$0.34	19%
Fast – Depot	150	$0.71	$0.07	$0.62	13%
Fast – Depot	350	$0.64	$0.07	$0.55	14%
Overnight – Depot	50	$0.47	$0.07	$0.39	17%
Overnight – Depot	100	$0.45	$0.07	$0.37	18%
Ultra-fast – Depot	350	$0.76	$0.09	$0.66	12%
Ultra-fast – Depot	1000	$0.94	$0.09	$0.84	10%
Fast – Public	350	$0.48	$0.20	$0.23	51%
Overnight – Public	50	$0.44	$0.04	$0.40	11%
Overnight – Public	100	$0.40	$0.04	$0.35	12%
Overnight – Public	200	$0.37	$0.04	$0.32	13%
Ultra-fast – Public	1000	$0.63	$0.18	$0.44	30%

We estimate that the LCFS revenue can reduce breakeven charging costs by roughly 20% across all charger types. In some cases, costs may be entirely offset by credit revenue though there is significant uncertainty in credit prices and additional uncertainty in our modeled charging behavior.

In comparison, NREL estimates that breakeven charging costs for 3 MW ultra-fast chargers located in the United States range between $0.18/kWh and $0.38/kWh.[42] The NREL study assumes far lower energy charges for charge point operators than our analysis, leading to variation between our results. For example, while the NREL study assumes energy charges range from $0.030 to $0.065/kWh, we use an energy charge of $0.25/kWh based on the average commercial price of electricity in California. We note that the electricity costs used in our assessment may be an overestimate of energy rates that charge point operators must pay. Various state utilities offer seasonal and off-peak energy charge rates that may reduce the cost of electricity for operators while customers that enroll in subscription-based services can purchase electricity at a fixed fee to avoid additional demand charges.[43]

LCFS CREDIT POTENTIAL TO SUPPORT POINT-OF-SALE MHDV REBATES

The LCFS can also be leveraged to offset MHDV purchase costs when base and "holdback" credit revenue from residential charging are redirected toward point-of-sale rebates. More directly, the LCFS stipulates that up to 50% of base credits will fund a reinstated CFRP for commercial medium- and heavy-duty vehicles as well as battery electric motorcycles. CFRP funding can help cover the substantial cost differential of MHDV-ZEVs relative to internal combustion engine alternatives. For example, CARB estimates the cost differential between purchasing a battery electric and diesel Class 8 sleeper cab to be nearly $140,000 in 2025.[44] By 2035, CARB expects that this cost gap will decline to $18,713 per vehicle. Recent vehicle sales data indicates that this cost gap may be more significant. Xie finds that the average cost differential for MY2025 Class 8 vehicles was $250,247 in California based on historical vehicle sales trends.[45]

Based on CARB's August 2024 modeling of the proposed amendments, we estimate that $0.41 billion in LCFS revenue could be redirected to the CFRP between 2025 and 2035 under our Central price scenario, though with a high degree of uncertainty. We source annual energy demand projections from the CATS model and assume that 80% of light-duty vehicle energy demand is attributed to residential charging.[46] We reference the distribution of energy delivered by each public utility classification specified in the LCFS regulation to determine the weighted average contribution of utility base credits to the CFRP. This share is equivalent to 44% of base credits.

Applying the above assumptions, we find that annual funding for the program could grow from $5.4 million in 2025 to $37.9 million in 2035. The number of base credits generated peaks in 2032 and tapers off when the diesel CI benchmark converges with

42 Bennett et al., "Estimating the Breakeven Cost of Delivered Electricity to Charge Class 8 Electric Tractors."

43 California Public Utilities Commission, "Electricity Vehicles Rates and Cost of Fueling," accessed June 23, 2025, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/transportation-electrification/electricity-rates-and-cost-of-fueling.

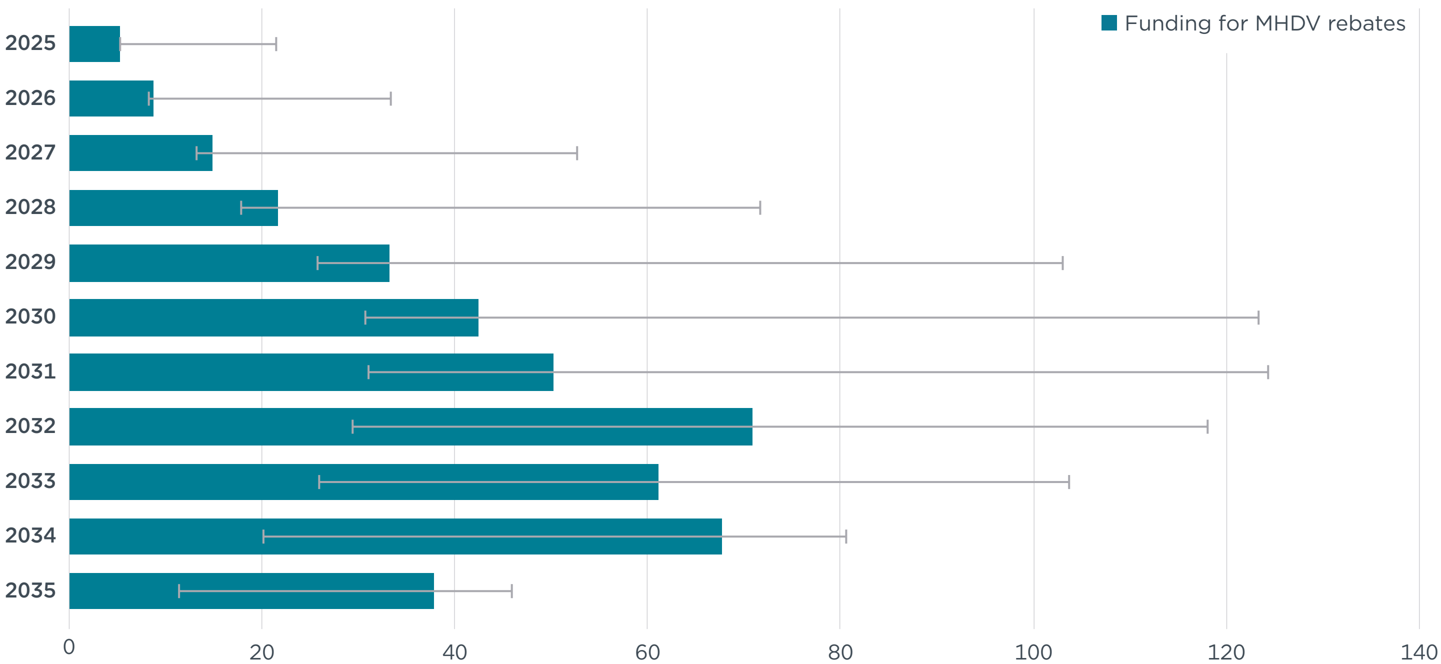
44 California Air Resources Board, "Proposed Advanced Clean Fleets Regulation Staff Report: Initial Statement of Reasons."

45 Yihao Xie, *The Cost of Energizing Medium- and Heavy-Duty Truck Charging Facilities in the United States* (International Council on Clean Transportation, in press).

46 International Energy Agency, *Global EV Outlook 2024* (2024), https://www.iea.org/reports/global-ev-outlook-2024.

the average CI of grid-supplied electricity. We present the annual estimated funding for point-of-sale MHDV rebates in Figure 12, assuming that 44% of utility base credits are allocated to the CFRP and all funding is directed to the MHDV sector. Credit prices are set equal to the August proposal with an AAM in place, with the upper and lower error bars designating High and Low credit price scenarios, respectively.

Figure 12
Projected base credit reinvestment for MHDV



Note: Error bars represent credit revenue under a High and Low credit price scenario.

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For the light-duty market, the former CFRP program offered between $750 and $1,000 in point-of-sale purchase rebates to more than 250,000 electric vehicle buyers in its 2 years of operation. The program was short-lived, however, and in September 2022 the value of rebates was dropped to zero due to a surplus of buyers in the market.[47] Stakeholders such as manufacturers have called for improvements to the program to maintain competitive rebate values and streamline the distribution of funds. For example, Tesla estimates that California utilities currently hold more than $420 million in CFRP funds that have not yet been disbursed to customers.[48]

Disbursement delays are in part due to reporting requirements. The public utilities responsible for administering the program, namely Southern California Edison, Pacific Gas and Electric, and San Diego Gas and Electric, have jurisdiction to set the rebate price and disburse funds to the program. However, utilities must first get approval from the California PUC to sell credits leading to transaction delays. Amending this

47 California Air Resources Board, "California Clean Fuel Reward Surpasses 250,000 Point-of-Sale Financial Incentives for EV Buyers," May 9, 2022, https://ww2.arb.ca.gov/news/california-clean-fuel-reward-surpasses-250000-point-sale-financial-incentives-ev-buyers.

48 Thad Kurowski, "Tesla Comments on CARB's Proposed Low Carbon Fuel Standard Amendments (Dec. 19, 2023)," February 20, 2024, https://www.arb.ca.gov/lists/com-attach/7042-lcfs2024-AjBdb1VkVjcLP1Rk.pdf.

reporting requirement could streamline the disbursement of funds and prioritize transactions when credit prices are high to maximize reinvestment.

Further, the LCFS regulation stipulates that large fleets cannot receive CFRP rebates despite them being critical first-movers for vehicle electrification. If large fleets remain ineligible for rebates, it is harder for these manufacturers to reduce production costs and demonstrate battery electric vehicle cost parity before smaller owner-operators begin to transition to battery electric vehicles.[49] In particular, bringing down the costs of Class 7 and 8 battery electric trucks, which accumulate the highest mileage of all vehicle segments, will have the greatest impact on reducing transport-wide GHG emissions.

DISCUSSION AND POLICY CONSIDERATIONS

This brief explored the impacts that the November 2024 LCFS amendments could have on the electrification of California's MHDV segment. We projected that the amendments have significant potential to support MHDV electrification through three key mechanisms: charging infrastructure funding, charging cost reductions, and point-of-sale vehicle rebates. Overall, we estimated that the newly adopted provisions of the LCFS could provide between $4.0 and $16.1 billion in support over the next decade, depending on credit prices. This includes combined energy and infrastructure crediting that can generate approximately $8.4 billion (or $3.8 and $15.3 billion under Low and High credit price scenarios, respectively) in funding for charging infrastructure. Credit revenue allocated toward point-of-sale MHDV rebates could provide an additional $0.41 billion ($0.22–$0.88 billion) in funding support.

This estimated level of funding is substantially more than the approximately $1.4 billion in funding distributed to zero-emission trucks and buses since 2010 under California's HVIP program. However, the actual impact of these support mechanisms is heavily dependent on LCFS credit prices, which can fluctuate substantially based on market dynamics.

The monetary contribution of the LCFS towards MHDV electrification is highly uncertain and depends on how outside factors affect the LCFS credit market. While the 2024 LCFS amendments expanded the potential for reinvestment and support for MHDV electrification in multiple ways, they also failed to address some of the causes for the recent decline in credit prices. CARB's modeling suggests that in the near term, absent safeguards, the LCFS will continue to drive demand for renewable diesel and book-and-claim dairy biomethane projects, which may depress credit prices until the 2030s. Limits or safeguards on these pathways, such as restrictions on virgin vegetable oil-derived BBD or deliverability restrictions on biomethane, could help to limit these pathways' contribution and tighten the LCFS credit market.

Energy and infrastructure capacity credits can greatly lower the cost of fast charging necessary for medium- and heavy-duty fleets. We estimate that total revenue from non-residential energy credits between 2025 and 2035 is $7.2 billion in our Central credit price scenario ($3.2 billion in the Low scenario and $12.9 billion in the High scenario) while total revenue from infrastructure crediting in our Central scenario is $1.2 billion ($0.6–$2.3 billion). We project that the sum of energy and infrastructure

49 Claire Sugihara, Scott Hardman, and Kenneth Kurani, "Social, Technological, and Economic Barriers to Heavy-Duty Truck Electrification," *Research in Transportation Business & Management* 51 (December 1, 2023): 101064, https://doi.org/10.1016/j.rtbm.2023.101064.

credits could provide enough funding to cover the estimated $7.6 billion required to purchase and install charging infrastructure for MHDV electrification through 2035.

We estimate that the average net costs of charging range between $0.37 and $0.94/kWh for MHDV chargers beginning operation in 2025. Energy and infrastructure credits offset up to 50% of the breakeven charging costs across various charging locations, capacities, and utilization rates. The LCFS provides the greatest support to high-capacity, public charging servicing numerous vehicle fleets. The value of LCFS revenue is proportional to the credit price and total energy dispensed, and inversely proportional to a charger's average utilization rate during its first 10 years of operation.

The LCFS infrastructure capacity crediting for fast charging could exceed the 2.5% cap before 2030. This analysis predicts that the FCI crediting cap may begin to constrain the quantity of MHDV-FCI credits generated in the LCFS market starting in 2027. With a cap on credits in place, cumulative credits reduce to 65.0 Mt while total, cumulative revenue declines by $0.9 billion in the Central scenario relative to a scenario where no FCI credit cap was in place. Increasing the FCI crediting cap to 5% of quarterly deficits could capture all FCI credit potential and increase policy support for MHDV charge point operators and other eligible parties to up to $9.3 billion in our Central scenario.

Reinvesting LCFS revenue into charging infrastructure and point-of-sale vehicle rebates can be an effective way to narrow the ZEV cost gap for Class 7 and 8 vehicles. We estimate a cumulative total of $0.41 billion would be available for the CFRP by 2035 in the Central credit price scenario, with a range of $0.22 billion to $0.88 billion in the Low and High scenarios. Further revisions to the CFRP such as streamlining reporting requirements for utilities and prorating the value of rebates based on performance parameters can help maximize financial incentives delivered to end-users.

APPENDIX

Table A1
Average utilization rates by charger type (complete)

Vehicle segment	Charger type	Charger location	Average utilization rate, 2025–2039 (%)
Combination long-haul truck	Overnight	Public	23%
Combination long-haul truck	Fast	Public	7%
Combination long-haul truck	Ultra-fast	Public	8%
Combination short-haul truck	Overnight	Public	21%
Combination short-haul truck	Overnight	Depot	14%
Combination short-haul truck	Fast	Public	9%
Combination short-haul truck	Ultra-fast	Public	7%
Refuse truck	Overnight	Depot	19%
Refuse truck	Fast	Depot	7%
Refuse truck	Ultra-fast	Depot	3%
School bus	Overnight	Depot	29%
School bus	Fast	Depot	5%
School bus	Ultra-fast	Depot	4%
Single unit long-haul truck (Class 6–8)	Overnight	Public	32%
Single unit long-haul truck (Class 6–8)	Fast	Public	10%
Single unit long-haul truck (Class 6–8)	Ultra-fast	Public	7%
Single unit long-haul truck (Class 4–5)	Overnight	Public	15%
Single unit long-haul truck (Class 4–5)	Fast	Public	10%
Single unit long-haul truck (Class 4–5)	Ultra-fast	Public	4%
Single unit short-haul truck (Class 6–8)	Overnight	Depot	18%
Single unit short-haul truck (Class 6–8)	Fast	Public	5%
Single unit short-haul truck (Class 6–8)	Fast	Depot	5%
Single unit short-haul truck (Class 4–5)	Overnight	Depot	22%
Single unit short-haul truck (Class 4–5)	Fast	Public	6%
Single unit short-haul truck (Class 4–5)	Fast	Depot	6%
Single unit short-haul truck (Class 4–5)	Ultra-fast	Public	2%
Single unit short-haul truck (Class 4–5)	Ultra-fast	Depot	2%
Transit bus	Overnight	Depot	11%
Other buses	Overnight	Depot	20%
Other buses	Fast	Public	2%

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